OM-01 OPERATIONS MODEL STUDY
INTERIM REPORT

SKAGIT RIVER HYDROELECTRIC PROJECT
FERC NO. 553

Seattle City Light

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Initial Study Report

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List of Acronyms and Abbreviations

cfs .... cubic feet per second
CHEOPS™ .... Computerized Hydro Electric Operations and Planning Software
City Light .... Seattle City Light
FERC .... Federal Energy Regulatory Commission
FSA .... Fisheries Settlement Agreement
ISR .... Initial Study Report
LP .... licensing participant
MW .... megawatt
MWh .... megawatt hour
POR .... period of record
Project .... Skagit River Hydroelectric Project
RSP .... Revised Study Plan
SPD .... Study Plan Determination
USGS .... U.S. Geological Survey
USR .... Updated Study Report

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1.0 INTRODUCTION

The OM-01 Operations Model Study is being conducted in support of the relicensing of the Skagit River Hydroelectric Project (Project), Federal Energy Regulatory Commission (FERC) No. 553, as identified in the Revised Study Plan (RSP) submitted by Seattle City Light (City Light) on April 7, 2021 (City Light 2021). On June 9, 2021, City Light filed a "Notice of Certain Agreements on Study Plans for the Skagit Relicensing" (June 9, 2021 Notice)[1] that detailed additional modifications to the RSP agreed to between City Light and supporting licensing participants (LP) (which include the Swinomish Indian Tribal Community, Upper Skagit Indian Tribe, National Marine Fisheries Service, National Park Service, U.S. Fish and Wildlife Service, Washington State Department of Ecology, and Washington Department of Fish and Wildlife). The June 9, 2021 Notice proposed no changes to the Operations Model Study as described in the RSP.

In its July 16, 2021 Study Plan Determination (SPD), FERC approved the Operations Model Study with modification. Specifically, FERC required that the Initial Study Report (ISR) include details about inflow datasets used to develop the Operations Model.

This interim report on the 2021 study efforts is being filed with FERC as part of City Light's ISR. City Light will perform additional work for this study in 2022 and include a report in the Updated Study Report (USR) in March 2023.

1 Referred to by FERC in its July 16, 2021 Study Plan Determination as the "updated RSP."

2.0 STUDY GOALS AND OBJECTIVES

The goal of the Operations Model Study is to develop a Base Case. The Base Case scenario is the Baseline representation of Project operations. For purposes of Operations Model development, the Baseline (or Base Case) represents the Project's operations under the current FERC license. The objective of this study is to develop an Operations Model that describes and simulates existing Project operations for purposes of relicensing, and which can be used to simulate potential future operations under a variety of operating scenarios. Simulation of various potential Project operation scenarios considered during the relicensing process will aid in decision-making regarding the effects of those various operating scenarios on water allocation, flood control, fish and wildlife habitat, instream flows, reservoir levels, wetland and floodplain connectivity, recreation, hydropower generation, and other matters affected by flow releases from the Project. The Current Operations Baseline has specific relevance in FERC relicensing proceedings as it represents the baseline conditions to which other scenarios of potential future operations are compared.[2]

City Light's goal for the study is to develop a tool to simulate Project operations to evaluate the effects of numerous, and potentially competing, alternative future operating scenarios for and with consultation by LPs. The Operations Model will be capable of providing direct or supporting analysis to inform decision-making related to the following potential issues:

- Reservoir storage/refill/outflows/flood control;
- Reservoir water surface level fluctuations (affecting, for example, aquatic and wildlife habitat, riparian vegetation, recreation, navigation, cultural site protection);
- Seasonal targets for reservoir levels under a range of hydrologic conditions;
- Instream flows in the Skagit River downstream of the Project and within the Gorge bypass reach;
- Connectivity of wetlands, floodplains, and tributaries to river and reservoirs;
- Power generation and its timing; and
- Aquatic habitat particularly with salmonid spawning, incubating, and rearing flows.

[2] City Light originally envisioned simulating both a Base Case scenario (defined by current FERC license requirements) and a Current Operations Baseline scenario (defined to include the current fisheries adaptive management by City Light). However, after a review of operations and operational requirements it was apparent that the Current Operations Baseline effectively captures the current FERC license requirements.

3.0 STUDY AREA

The scope of the Operations Model Study is the geographic region of the Skagit River from the upper end of Ross Lake to the Gorge Powerhouse tailrace. The Operations Model will include Ross Lake, Ross Dam and Powerhouse, Diablo Lake, Diablo Dam and Powerhouse, Gorge Lake, Gorge Dam, Gorge bypass reach, Gorge Powerhouse, and tailrace.

4.0 METHODS

City Light is developing an Operations Model using the Computerized Hydro Electric Operations and Planning Software (CHEOPS™) model. CHEOPS™ is a flexible, reliable, and easy-to-use tool created more than two decades ago specifically to evaluate a wide range of factors considered during FERC relicensing that may affect natural resources and Project operations, including reservoir levels, water uses, and generation. One of the many capabilities of the CHEOPS™ modeling platform is the degree to which the Operations Model architecture provides a customized platform to investigate river- and Project-specific characteristics, water demands, and constraints of the particular plant and river system being evaluated. Additionally, CHEOPS™ is designed to be user-friendly—it can be run from a PC or personal laptop through an easy-to-use graphical interface and utilizes Microsoft Excel as the output data analysis platform, which allows the Operations Model to be used by LPs with a minimal amount of training or computer know-how.

Utilizing a daily average inflow dataset as primary input, CHEOPS™ simulates operations to allocate water between reservoir storage and required outflow constraints (physical, environmental, and operational) while permitting generation. This report characterizes the development and verification of the customized Skagit River Hydroelectric Project CHEOPS™ Model (Skagit Operations Model). The Skagit Operations Model is intended to be used as a tool to assist in evaluating water quantity distribution between the available water conveyances due to changes in model inputs, including various operational modifications and physical plant modifications. This is performed by reviewing relative changes between scenarios proposing modifications within the system. The Skagit Operations Model is capable of determining reservoir elevation, headlosses, net head, turbine discharge and spill, power generation, and other user-specified variables in hourly (or higher resolution) increments.

The Skagit Operations Model encompasses an inflow dataset, including streamflows into Ross Lake, incremental inflows to Diablo and Gorge lakes, as well as incremental flows to nodes along the Skagit River downstream of the Gorge Development. The Gorge Development includes Gorge Powerhouse as well as the Gorge spillway, so the analysis is inclusive of flows through both Gorge Powerhouse and Gorge spillway. The Skagit Operations Model includes characteristics of the three Project reservoirs' powerhouses and water conveyance structures, as well as incremental tributary flows and hydraulic relationships at select nodes along the Skagit River. As an example of integration of between studies, going forward the Skagit Operations and Instream Flow Models (being developed as part of FA-02 Instream Flow Model Development Study and FA-05 Skagit River Gorge Bypass Reach Hydraulic and Instream Flow Model Development Study; City Light 2022a and 2022b, respectively) will be utilized in tandem, where the Skagit Operations Model simulates Project operations, and the Instream Flow Models simulate the riverine flow hydraulics (depth, velocity, water surface elevation, etc.) downstream of the Gorge Development, either downstream of the Gorge Powerhouse or through the Gorge bypass reach. The Instream Flow Models will define stage discharge rating curve relationships at key node locations (to be defined as part of the Instream Flow Models) along the Skagit River downstream of the Gorge Development. Once developed, these stage discharge relationships can be incorporated into the Skagit Operations Model, enabling the Skagit Operations Model to simulate Project operations in support of specific stage or flow objectives at these key node locations. Figure 4.0-1 shows a conceptual schematic of the linkages between the Skagit Operations Model and the Instream Flow

Model. Similar linkages will be made to other models under development in the relicensing process.

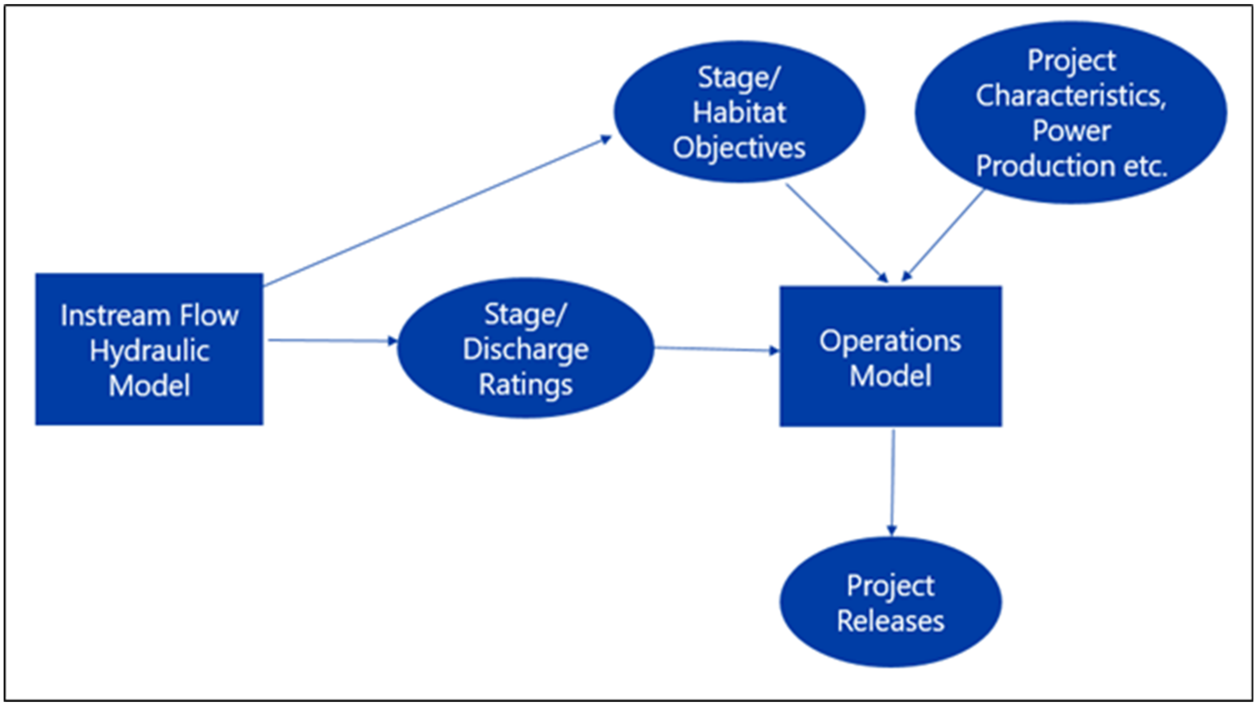

Figure 4.0-1. Linkage between Skagit Operations Model and Instream Flow Models.

The Skagit Operations Model will be utilized to perform simulations (Model runs), comparing outputs/effects relative to the Current Operations Baseline scenario. This alternatives analysis process will then show the direct effect of proposed operating protocols on Project operations and other endpoints of interest as compared to the Baseline scenario.

4.1 Model Development

Primary Skagit Operations Model development activities include:

- Assembly and compilation of historical operational data;
- Assembly of system information pertaining to the physical and operational characteristics of the Ross, Diablo, and Gorge developments;
- Development or identification of a historical inflow dataset including a summary of the inflow analysis per FERC's SPD to include: (1) a specific description of the reservoir tributaries included in the inflow analysis; (2) the period of record (POR) used for each; and (3) the source of the flow data for each (e.g., U.S. Geological Survey [USGS] gage flow record or synthetic flow record). This historical inflow dataset summary is provided in Appendix 1 of the attached Skagit Operations Model Logic and Validation Report (Attachment A);
- Initial Skagit Operations Model development using physical data such as reservoir storage curves, dam spillway capacity, headwater curves, tailwater curves, turbine performance curves,

generator performance curves, as well as operational data, including minimum flows, operation/dispatch routines, and operating/elevation limits; and

- Model validation and establishment of the Current Operations Baseline scenario.

Skagit Operations Model validation (i.e., determining that the Skagit Operations Model is well-founded and fulfills the purpose for which it was constructed) occurred in two steps. In the first step, the Skagit Operations Model was evaluated for the POR from January 1, 1997 through December 31, 2020 by comparing the Skagit Operations Model output to the historical operations records and outflow from Gorge Development calculated from USGS flow records. This POR represents the period of available hourly historical operations records specifically, average daily flows, reservoir elevations or storage, and generation. Additionally, this POR is also representative of current Project operations. Differences between the Skagit Operations Model output and the historical record are expected in this process as changes in operating strategy can happen over time, changes in equipment performance occur with age, and minor and major unplanned outages occur. More importantly, it must be recognized that all input data contain measurement errors.

The second step verified that the Skagit Operations Model describes and simulates the Project's operating rules by comparing the Current Operations Baseline scenario to historical operations records. The purpose of the Current Operations Baseline scenario is to simulate the current operating system configuration for the selected POR to serve as the reference point for relative comparison as alternate scenarios are developed and run.

Model development, including the hydrologic dataset, verification, and the Current Operations Baseline scenario are outlined in the Skagit Operations Model and Logic and Validation Report (Attachment A).

4.1.1 Verification Scenarios

Verification scenarios were established in the Skagit Operations Model following the historical operating requirements of the system by simulating daily changing target elevations to match historic elevations, historical reported spillway flows, and unit outages to simulate historical daily turbine operations. The intent of the Verification scenarios was to demonstrate the ability of the Skagit Operations Model to perform its intended functions and simulate actual recorded historical operations of the developments.

To represent historical operations, the Verification scenarios presented in this report are based on the Current Operations Baseline scenario, with the additions or modifications outlined below:

- Gorge Development minimum instantaneous outflow of 1,800 cubic feet per second (cfs) to simulate historical Gorge outflow;
- Daily changing target reservoir elevations to simulate historical operations;
- Daily spillway flow to simulate historical operations at each development;
- Varying Ross Powerhouse unit dispatching;
- Daily changing turbine outages at each development. If a unit was not operated historically, then it was also not operated for the same day in the Verification scenarios; and

- Unit 24 at Gorge Powerhouse was upgraded in 2006, so Verification scenarios were developed to represent pre- and post-upgrade performance for Gorge Powerhouse Unit 24. Pre-upgrade performance simulated 1997 through 2006 and post-upgrade 2007 through 2020.

4.1.2 Develop Current Operations Baseline

The intent of the Current Operations Baseline scenario is to provide a representation of current Project operations and serve as the basis for comparison of all subsequent Skagit Operations Model runs (scenarios or simulations). Where the Verification scenarios were developed to reflect daily historical operations, the Current Operations Baseline scenario was developed to represent current operations based on a discrete or fixed set of model rules and logic which are uniformly applied over the POR absent influence of the randomized historical operational factors such as forced/unforced outages, maintenance activities, power demands, and other factors which may have necessitated human intervention in proactive or reactive response to real-time conditions. Simulation of the Current Operations Baseline scenario with such a set of discrete or fixed model rules and logic is necessary to provide the basis for comparison to subsequent Skagit Operations Model runs, which will also be simulated with the same set of discrete rules and logic, but which are built upon or augmented through the alternate scenario development process which will occur.

4.1.3 Consultation Process with Licensing Participants

City Light has and will continue to engage LPs through a series of study workshops at key milestones through both the development and execution of the Skagit Operations Model.[3] In 2021 and 2022, several study workshops were conducted, including:

(1) **Workshop 1 (June 2021)** – General Model Introduction
   - a. Skagit Operations Model Methodology/Overview
      - i. General overview of Skagit Operations Modeling
      - ii. Skagit Operations Model functionality
         1. General overview
         2. Custom functionality specific to the Project
      - iii. Skagit Operations Model development outline and next steps
   - b. Hydrology
      - i. Review of available data
      - ii. Climate change

(2) **Workshop 2 (June 2021)** – Scenario Discussion
   - a. Overview of scenario development and execution process
   - b. Review and modify example scenario request form

[3] The issuance of FERC's SPD on July 16, 2021 reduced the time available to conduct the consultation workshops as described in the RSP. As a result, the consultation workshop topics and scheduled were modified to better address study needs and agenda topics were identified in consultation with LPs.

c. Document potential operational scenarios of interest identified by LPs

(3) **Workshop 3 (December 2021)** – Skagit Operations Model Development

a. Recap of historical hydrology

b. Skagit Operations Model updates

c. Current Operations Baseline

(4) **Workshop 3.5 (January 2022)** – Skagit Operations Model Development

a. Review model development and ISR preview for OM-01 Operations Model Study

b. Follow-up discussion on information presented and topics raised at the December 16, 2021 Operations Model Work Group Meeting

(5) **Workshop 4 (February 2022)** – Operations Model LP training

4.1.4 Evaluate Alternative Project Operation Scenarios

Going forward, the Skagit Operations Model will be used to analyze and assess various proposed operating scenarios. This is further discussed in Section 6.1 of this study report. After the scenario modeling is completed, City Light will prepare a Scenario Documentation Report and include it in the USR, with addendum reports as necessary if modeling continues beyond the USR.

5.0 PRELIMINARY RESULTS

Attachment A, Skagit Operations Model Logic and Validation Report, characterizes the development and verification of the customized Skagit Operations Model. The Skagit Operations Model is intended to be used as a tool to assist in evaluating water quantity distribution between the available water conveyances due to changes in model inputs, including various operational modifications and physical plant modifications. This is performed by reviewing relative changes between the Base Case and scenarios proposing modifications within the system.

Attachment A documents inputs and assumptions used to develop the Skagit Operations Model, demonstrates that the Skagit Operations Model characterizes operations of the system, and demonstrates that the Skagit Operations Model is appropriate for use in evaluating the effects of alternative operating scenarios on generation, reservoir levels, and outflows from the Project.

5.1 Hydrology

A hydrologic dataset of average daily flows was developed for the period January 1, 1988 through December 31, 2020, utilizing available hydrologic data as compiled from USGS gages in the vicinity and Project operations records. The 33-year POR was identified based on available historical data to provide hydrologic data for simulation of the Skagit Operations Model, including the Current Operations Baseline. A sub-set of this 33-year POR, a 24-year period of January 1, 1997 through December 31, 2020, was utilized for simulation of the Skagit Operations Model Verification scenarios. This 24-year period represents the period of available historical operations data, where City Light's Oracle data collection system was in place. The Oracle data collection system contains historical reservoir and powerhouse operations records on an hourly basis. In this report, the Current Operations Baseline is also compared to historical data for the period January 1, 2012 through December 31, 2020, which represents the period since the execution of the most recent operational agreements. As previously noted, FERC's SPD specifies the report must include: (1) a specific description of the reservoir tributaries included in the inflow analysis; (2) the POR used for each; and (3) the source of the flow data for each (e.g., USGS gage flow record or synthetic flow record); this historical inflow dataset is summarized in Appendix 1 of the attached Skagit Operations Model Logic and Validation Report (Attachment A).

5.2 Model Development Summary

Development of the Skagit Operations Model (for both Verification scenarios and the Current Operations Baseline scenario) included a review of the historical Project operations down to a unit-by-unit basis. This operations review showed significant variation in unit dispatching, or combination of units within a powerhouse for any given flow. The allocation of flow between units is important to the Skagit Operations Model as it impacts the efficiency of the units to generate. City Light operators noted that given the remote nature of the Project, the Ross Development especially, there are times that the units have been operated to limit unit shutdowns. This type of operation can result in a significant impact to the unit operational efficiency. For example, if a flow of 2,500 cfs is passed through a single Ross Powerhouse unit the turbine efficiency is greater than 90 percent, but if that same 2,500 cfs is distributed evenly across all four Ross Powerhouse units the efficiency drops by approximately 20 percent, which significantly impacts the resulting generation for any given flow. The review of historical unit dispatching did not indicate a clearly defined pattern or repetition of operation, rather it varied greatly, even from day to day. As such, part of the analysis outlined in this report includes varying the type of dispatching of the Ross Powerhouse units to simulate the potential efficient operation versus evenly dispatching of the units. By default, the Skagit Operations Model simulates the efficient combination of unit operation—this is referred to throughout this report as default unit dispatch. However, as noted, the actual historical operations of the units across the Project vary greatly, most significantly at the Ross Powerhouse, therefore an even unit dispatch functionality was also simulated for the Ross Powerhouse as part of the Skagit Operations Model Verification scenarios. The CHEOPS™ even unit dispatch logic (as referred to throughout this report) requires the plant to operate a daily average flow with no flow fluctuation within the day.

As outlined in Section 4.1.1 of this study report, to represent historical operations, the Verification scenarios presented in this report are based on the Current Operations Baseline scenario, with the additions or modifications outlined below:

- Gorge Development minimum instantaneous outflow of 1,800 cfs to simulate historical Gorge Powerhouse output;
- Daily changing target reservoir elevations to simulate historical operations;
- Daily spillway flow to simulate historical operations at each development;
- Varying Ross Powerhouse unit dispatching;
- Daily changing turbine outages at each development. If a unit was not operated historically, then it was also not operated for the same day in the Verification scenarios; and
- Unit 24 at Gorge Powerhouse was upgraded in 2006, so Verification scenarios were developed to represent pre- and post-upgrade performance for Gorge Powerhouse Unit 24. Pre-upgrade performance simulated 1997 through 2006 and post-upgrade 2007 through 2020.

Table 5.2-1 summarizes the Skagit Operations Model input differences by Verification and Current Operations Baseline scenarios.

Table 5.2-1. Skagit Operations Model input assumptions.

	Scenarios	
	Verification	**Current Operations Baseline**
Hydrology Period for comparison to historical operations	January 1, 1997 through December 31, 2020	January 1, 2012 through December 31, 2020
Dispatch Regime	Two options: (1) Default; and (2) Even at Ross Powerhouse, Default elsewhere	Default
Unit Outages	Historical	None
Target Elevations	Historical end of day	Median historical first of month (Ross Lake), Constant target elevation elsewhere, based on median historical
Flow Rules	1,800 cfs minimum instantaneous from Gorge Development only	Flow requirements per Fisheries Settlement Agreement (FSA)
Spillway Flows	Historical daily average	Only when needed based on simulated reservoir elevation
Gorge Powerhouse Unit 24	Pre- and Post-upgrade performance	Post-upgrade performance

As previously noted, the Skagit Operations Model verification was performed using historical operations data provided by City Light and were developed to test the simulated input data sets and operation rules. The Verification scenarios were developed to simulate operations for all three developments for the calendar years 1997-2020 with the varying unit dispatching at Ross Powerhouse, and 1997-2006 representing pre–Gorge Powerhouse Unit 24 upgrade and 2007-2020 representing post Gorge Powerhouse Unit 24 upgrade. The Skagit Operations Model generation results for the Skagit River powerhouses are shown in Table 5.2-2 for the Verification scenarios.

In addition to verifying that the Skagit Operations Model represents reservoir operations by comparing generation, the total Skagit River flow over the period of the Verification scenarios was also evaluated. The modeled total Skagit River flow at the tailrace of the Gorge Development closely represents the outflow from the Gorge Development calculated from USGS reported flows, within 1.6 percent on an annual basis and 0.0 percent on average for the full period January 1, 1997 through December 31, 2020.

Table 5.2-2. Verification scenarios generation comparison.

Annual Average (1997-2020)	Historical Generation (MWh)[1]	Default Dispatch[2]		Even Dispatch[3]	
		Simulated Generation (MWh)	Percent Difference from Historical (%)	Simulated Generation (MWh)	Percent Difference from Historical (%)
Ross Powerhouse	726,841	801,585	10.3%	708,315	-2.5%
Diablo Powerhouse	781,110	805,540	3.1%	808,833	3.5%
Gorge Powerhouse	955,523	982,520	2.8%	982,144	2.8%
System Total	**2,463,474**	**2,589,645**	**5.1%**	**2,499,292**	**1.5%**

1 MWh = megawatt hours.
2 Scenario simulated with Ross, Diablo, and Gorge powerhouse units dispatched using default dispatch logic.
3 Scenario simulated with Ross Powerhouse units dispatched using even dispatch logic; Diablo and Gorge powerhouse units dispatched using default dispatch logic.

The Current Operations Baseline scenario was also compared against historical operations data provided by City Light as well as the modeled total Skagit River flow from the Gorge Development to the outflow from Gorge Development calculated from USGS reported flows for the period January 1, 2012 through December 31, 2020. The Current Operations Baseline scenario, which will be the basis for comparison of all subsequent Skagit Operations Model scenarios, was expected to vary more from historical generation than the Verification scenarios, as this Baseline scenario assumes default unit dispatching and does not include historical unit outages. Similar to the Verification scenarios, in addition to verifying that the Skagit Operations Model represents reservoir operations by comparing generation, the modeled total Skagit River flow from the Gorge Development was compared to the outflow from Gorge Development calculated from USGS reported flows. This comparison shows a maximum variation of 8.5 percent on an annual basis, and an average of 0.1 percent for the period January 1, 2012 through December 31, 2020. The annual variation in total Skagit River flow is discussed in Appendix A. The Skagit Operations Model generation results for the Skagit River powerhouses are shown in Table 5.2-3 for the Current Operations Baseline scenario.

Table 5.2-3. Current Operations Baseline scenario generation comparison.

Annual Average (1997-2020)	Historical Generation (MWh)	Simulated Generation[1] (MWh)	Percent Difference from Historical (%)
Ross Powerhouse	727,850	896,512	23.2%
Diablo Powerhouse	766,943	857,118	11.8%
Gorge Powerhouse	980,149	1,044,692	6.6%
System Total	**2,474,942**	**2,798,322**	**13.1%**

1 Scenario simulated with Ross, Diablo, and Gorge powerhouse units dispatched using default dispatch logic.

6.0 SUMMARY

This report and its Attachment A document inputs and assumptions used in Skagit Operations Model development to demonstrate that the Skagit Operations Model characterizes operations of the system and is appropriate for use in evaluating the effects of alternative operating scenarios on generation, reservoir levels, and outflows from the Project. When applying the Skagit Operations Model for evaluating the effects of alternative operating scenarios on generation, it is important to consider the Skagit Operations Model was developed for application in an alternative operating scenario incremental analysis. Historically, unit dispatching operations have varied significantly, but the alternative operating scenarios will be simulated with a discrete rule set.

CHEOPS™ software and the Skagit Operations Model are tools to evaluate relative sensitivity and response of the system to changing operational constraints. The Skagit Operations Model is a tool and does not predict future conditions or outcomes. Skagit Operations Model results must be analyzed and interpreted based on knowledge of hydrologic and hydraulic principles and understanding of results viewed in a relative, rather than an absolute, context.

The Skagit Operations Model verification process includes comparisons between modeled output and historical data. The modeled release from the Gorge Development was compared to historical data to show the Skagit Operations Model describes and simulates Project operations throughout the year (e.g., the timing, magnitude, and duration of operations).

As shown, the Skagit Operations Model can be configured to closely simulate long-term generation at the Skagit developments and is representative of historical operations. However, there are many factors inherent in the Skagit Operations Model data and setups that can contribute to output discrepancies (i.e., deviations) when compared to historical data. In many cases, several of these factors may be involved simultaneously, which makes it difficult to isolate individual sources of difference. Potential sources for deviations from historical data include actual discretionary reservoir operations versus simulated generic operations, including spillway discharges, estimated unit performance curves, unit dispatch, historical unit outages, hydrology, minimum flow requirements, and leakage:

- **Unit Performance** – The Skagit Operations Model was set up with available unit performance information, some of which data dated back to the 1950s.
- **Unit Dispatch –** Significant variations in the dispatching of units has occurred historically, with the most significant variations occurring at Ross Powerhouse due to the remote nature of the powerhouse. However, the historical unit dispatching at both Diablo and Gorge powerhouses have been less than peak flow efficiency at times, which accounts for some of the deviations in the calculation of generation as compared to historical data.
- **Historical Unit Outages –** The Verification scenarios did take into account historical unit outage information. If a unit was not operated historically, then it was also not operated for the same day in the Verification scenarios, but the Skagit Operations Model keeps units out of service for an entire day. Actual power demand and generation likely varied from the entire-day rule set that the Skagit Operations Model follows, and the historical data indicated many days with unit operation for a couple of hours, or less.

- **Hydrology –** The Skagit Operations Model utilizes data from USGS gages as reference gages for calculation of inflow to the Project sub-basins. The overall hydrologic data set appears to represent inflow to the Project and is acceptable for use in alternative analyses. Although similar over a longer period, when viewed on a daily basis, the timing and extent of runoff events can vary between the sub-basins and lead to short-term variations in generation when compared to historical data.
- **Leakage –** Unit leakage was estimated for the Verification and Current Operations Baseline Skagit Operations Model scenarios.

In interpreting the information provided in this report, it is important to reflect on the purpose of the Skagit Operations Model: to characterize system operations and evaluate the effects of alternative operating scenarios on generation, reservoir levels, and outflows from the Project. Comparing Skagit Operations Model results with historical data confirms use of the Skagit Operations Model as a tool for simulating "real" operations.

Small changes in input data or Skagit Operations Model logic can often result in large swings in output. This is due to a number of reasons including (but not limited to) runoff characteristics, reliance on coordinated operations, and numerous/variable flow requirements. Each of these elements individually contributes to the sensitivity of the system. Combined, they multiply that sensitivity exponentially. The input data and logic in the historical base scenario is an attempt to consolidate the effects of these variables to achieve an approximation of "characteristic operations."

The sensitivity described above also means that those factors that are unable to be accounted for in the Skagit Operations Model (short-term operations decisions based on pricing, demand, forecasts, etc.) as well as data that is impossible to replicate exactly (synthesized hydrology data, outages, etc.), can result in relatively large discrepancies between modeled output and historical data on a per-month/per-development basis. The factors and sensitivity warrant careful Skagit Operations Model review with awareness of the potential for outliers. The ultimate acceptance of the results should not hinge on the extremes, but rather on the overall impression of consistency between modeled and historical operations. Particularly, it must always be foremost in model discussions that the Skagit Operations Model should be used to assess the relative differences between scenarios. What this means is model verification is the only time it is appropriate to compare Skagit Operations Model results with historical data.

6.1 Next Steps

City Light has and will continue to engage LPs through a series of study workshops at key milestones through both the development and execution of the Skagit Operations Model.[4] The Skagit Operations Model is capable of evaluating alternative Project operation scenarios developed by City Light and/or LPs. The Skagit Operations Model was developed based on information available at the time of this report. Refinements to the model may be implemented if additional information becomes available. Going forward, the Skagit Operations Model will be used to

[4] The issuance of FERC's SPD on July 16, 2021 reduced the time available to conduct the consultation workshops as described in the RSP. As a result, the consultation workshop topics and schedules were modified to better address study needs and agenda topics were identified in consultation with LPs.

analyze and assess various proposed operating scenarios. Modeling scenarios will be consistent with City Light's non-consumptive and storage water rights.

A scenario request form, similar to the example attached to the RSP, will be used to develop model scenarios in consultation with LPs. To help facilitate the consultation with LPs, a reoccurring monthly Operations Model Work Group Meeting is scheduled for every third Thursday of the month. Evaluation of operating scenarios and potential resource impacts will be done in coordination with other Project models and resource study information. It is anticipated that a model output template will be developed to provide consistent information on modeling results for each of the scenarios evaluated.

City Light will maintain the input model runs and a record of results of operational scenarios evaluated. The model output will be summarized to track the key interest areas and to compare the system response to changes in operation from the Current Operations Baseline scenario.

The following are examples of LP-requested alternative operations scenario topics:

- Alternative flood operation procedures;
- Alternative seasonal drawdown extents;
- Alternative basin inflows; and
- Structured flows into the Gorge bypass reach.

The simulation models are decision support tools and are not intended to simulate or predict exact future conditions on a daily or annual basis. The models are tools for comparing different scenarios. The Skagit Operations Model will use historical inflows to simulate likely future conditions, as if the inflow will occur in the same pattern in the future as occurred in the past. Additional model sensitivities relative to changes in inflow hydrology due to potential climatic conditions can be employed in the modeling process as needed.

After the scenario modeling is completed, City Light will prepare a Scenario Documentation Report and include it in the USR, with addendum reports as necessary if modeling continues beyond the USR. This report will incorporate results from other applicable models to provide a comprehensive report out on each scenario that is analyzed. This report will include the following elements:

- Scenario inputs incorporated into each of the analyzed scenarios;
- Modeled results provided in graphical and tabular format;
- Modeled results from other models applicable to the scenario (e.g., Instream Flow Models); and,
- A comparison of results as relative differences between scenarios and the baseline scenarios.

7.0 VARIANCES FROM FERC-APPROVED STUDY PLAN AND PROPOSED MODIFICATIONS

City Light originally envisioned simulating both a Base Case scenario (defined by current FERC license requirements) and a Current Operations Baseline scenario (defined to include the current fisheries adaptive management by City Light). However, after a review of operations and operational requirements, it was apparent that the Current Operations Baseline effectively captures current FERC license requirements. Therefore, simulation of separate Base Case and Current Operations Baseline scenarios is not necessary to meet the objective of this study, which is to develop an Operations Model that describes and simulates existing Project operations for purposes of relicensing.

The issuance of FERC's SPD on July 16, 2021 reduced the time available to conduct the consultation workshops as described in the RSP. As a result, the consultation workshop topics and schedules were modified to better address study needs and agenda topics were identified in consultation with LPs.

8.0 REFERENCES

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OPERATIONS MODEL STUDY INTERIM REPORT

ATTACHMENT A

SKAGIT OPERATIONS MODEL LOGIC AND VALIDATION REPORT

SKAGIT OPERATIONS MODEL LOGIC AND VALIDATION REPORT

SKAGIT RIVER HYDROELECTRIC PROJECT FERC NO. 553

Seattle City Light

Prepared by:
HDR Engineering, Inc.

March 2022

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List of Acronyms and Abbreviations

cfs .... cubic feet per second
CHEOPS™ .... Computerized Hydro Electric Operations and Planning Software
City Light .... Seattle City Light
CoSD .... City of Seattle datum
ELC .... Environmental Learning Center
FERC .... Federal Energy Regulatory Commission
FSA .... Fisheries Settlement Agreement
HDR .... HDR Engineering, Inc.
MW .... megawatt
MWh .... megawatt hour
NAVD 88 .... North American Vertical Datum of 1988
PAD .... Pre-Application Document
POR .... period of record
PRM .... Project River Mile
Project .... Skagit River Hydroelectric Project
RM .... river mile
SPD .... Study Plan Determination
SR .... State Route
USGS .... U.S. Geological Survey

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1.0 EXECUTIVE SUMMARY

The Skagit River Hydroelectric Project (Project), licensed to The City of Seattle, Washington, and operated through its publicly-owned electric power utility Seattle City Light (City Light), is located in northern Washington State, and consists of three power generating developments on the Skagit River—Ross, Diablo, and Gorge—and associated lands and facilities. The Project generating developments are in the Cascade Mountains of the upper Skagit River watershed, between Project River Miles (PRM) 94.7 and 127.9 (U.S. Geological Survey [USGS] river miles [RM] 94 and 127). Power from the Project is transmitted via two 230-kilovolt powerlines that span over 100 miles and end just north of Seattle at the Bothell Substation. The Project also includes two City Light-owned towns, an Environmental Learning Center (ELC), several recreation facilities, and several parcels of fish and wildlife mitigation lands.

The Project developments are all located in Whatcom County, although Ross Lake, the most upstream reservoir, crosses the U.S.-Canada border and extends for about one mile into British Columbia at normal maximum water surface elevation. Gorge Development, the most downstream of the three Project developments, is approximately 120 miles northeast of Seattle and 60 miles east of Sedro-Woolley, the nearest large town. The closest town is Newhalem, which is part of the Project and just downstream of the Gorge Development.

City Light engaged with HDR Engineering, Inc. (HDR) to develop an operations model for the Project as part of the on-going Federal Energy Regulatory Commission (FERC) relicensing of the Project. Consistent with FERC's Study Plan Determination (SPD) issued on July 16, 2021, the operations model for the Project has been developed using HDR's Computerized Hydro Electric Operations and Planning Software (CHEOPS™) software platform. CHEOPS™ is specifically designed to evaluate the effects of operational changes and physical modifications at hydroelectric projects and has been used to evaluate the physical and operational changes considered during the FERC relicensing of more than 27 hydropower projects. One of the many strengths of the CHEOPS™ is the degree of customization each individual model contains. CHEOPS™ models are tailored to meet the demands of the particular system being modeled. CHEOPS™ models are also custom configured based on specific system constraints such as flow requirements, target reservoir elevations, and powerhouse equipment constraints. Utilizing a daily average inflow dataset as primary input, CHEOPS™ simulates operations to allocate water between reservoir storage and required outflow constraints (physical, environmental, and operational) while permitting generation.

The purpose of this report is to document inputs and assumptions used to develop the Skagit River Hydroelectric Project CHEOPS™ Model (Skagit Operations Model), to demonstrate the Skagit Operations Model characterizes operations of the system, and to demonstrate that the Skagit Operations Model is appropriate for use in evaluating the effects of alternative operating scenarios on generation, reservoir levels, and outflows from the Project.

Skagit Operations Model validation (i.e., determining that the Skagit Operations Model is well-founded and fulfills the purpose for which it was constructed) occurred in two steps. In the first step, the Skagit Operations Model was evaluated by comparing the Skagit Operations Model output from Verification scenarios to the historical operations records and outflow from Gorge Development calculated from USGS reported flows. The second step verified that the Skagit

Operations Model describes and simulates the Project's operating rules by comparing the Current Operations Baseline scenario (as described below) to historical operations records.

The overall intent is that this Current Operations Baseline scenario is a representation of current Project operations and serves as the basis for comparison of all subsequent Skagit Operations Model runs. Where the Verification scenarios were developed to reflect daily historical operations, the Current Operations Baseline scenario was developed to represent current operations based on a discrete or fixed set of model rules and logic which are uniformly applied over the period of record (POR) absent influence of the randomized historical operational factors such as forced/unforced outages, maintenance activities, power demands, and other factors which may have necessitated human intervention in proactive or reactive response to real-time conditions. Simulation of the Current Operations Baseline scenario with such a set of discrete or fixed model rules and logic is necessary to provide the basis for comparison to subsequent Skagit Operations Model runs, which will also be simulated with the same set of discrete rules and logic, but which are built-upon or augmented through the alternate scenario development process.

A hydrologic dataset of average daily flows was developed for the period January 1, 1988 through December 31, 2020, utilizing available hydrologic data as compiled from USGS gages in the vicinity and Project operations records. This 33-year POR was identified based on available historical data to provide hydrologic data for scenario simulation, including the Current Operations Baseline. A sub-set of this 33-year POR, a 24-year period of January 1, 1997 through December 31, 2020, was utilized for simulation of the Skagit Operations Model Verification scenarios. This 24-year period represents the period of available historical operations data, during which City Light's Oracle data collection system was in place. The Oracle data collection system contains historical reservoir and powerhouse operations records on an hourly basis. In this report, the Current Operations Baseline is also compared to historical data for the period January 1, 2012 through December 31, 2020, which represents the period since the execution of the most recent operational agreements.

Development of the Skagit Operations Model (for both Verification scenarios and the Current Operations Baseline scenario) included a review of the historical Project operations down to a unit-by-unit basis. This operations review showed significant variation in unit dispatching, or combination of units within a powerhouse for any given flow. The allocation of flow between units is important to the Skagit Operations Model as it impacts the efficiency of the units to generate. City Light operators noted that given the remote nature of the Project, and the Ross Development especially, there are times that the units have been operated to limit unit shutdowns. This type of operation can result in a significant impact to the unit operational efficiency. For example, if a flow of 2,500 cubic feet per second (cfs) is passed through a single Ross Powerhouse unit, the turbine efficiency is greater than 90 percent, but if that same 2,500 cfs is distributed evenly across all four Ross Powerhouse units, the efficiency drops by approximately 20 percent, which significantly impacts the resulting generation for any given flow. The review of historical unit dispatching did not indicate a clearly defined pattern or repetition of operation, rather it varied greatly, even from day to day. As such, part of the analysis outlined in this report includes varying the type of dispatching of the Ross Powerhouse units to simulate the potential efficient operation versus evenly dispatching of the units. By default, the Skagit Operations Model simulates the efficient combination of unit operation. This is referred to throughout this report as default unit dispatch. However, as noted, the actual historical operations of the units across the Project vary greatly, most significantly at the Ross Powerhouse, therefore an even unit dispatch functionality was also simulated for the Ross Powerhouse as part of the Skagit Operations Model Verification scenarios. The CHEOPS™ even unit dispatch logic (as referred to throughout this report) requires the plant to operate a daily average flow with no flow fluctuation within the day.

To represent historical operations, the Verification scenarios presented in this report are based on the Current Operations Baseline scenario, with the additions or modifications outlined below:

- Gorge Development minimum instantaneous outflow of 1,800 cfs to simulate historical Gorge Powerhouse output;
- Daily changing target reservoir elevations to simulate historical operations;
- Daily spillway flow to simulate historical operations at each development;
- Varying Ross Powerhouse unit dispatching;
- Daily changing turbine outages at each development. If a unit was not operated historically, then it was also not operated for the same day in the Verification scenarios; and
- Unit 24 at Gorge Powerhouse was upgraded in 2006, so Verification scenarios were developed to represent pre- and post-upgrade performance for Gorge Powerhouse Unit 24. Pre-upgrade performance simulated 1997 through 2006 and post-upgrade 2007 through 2020.

Table 1.0-1 summarizes the Skagit Operations Model input differences by Verification and Current Operations Baseline scenarios.

Table 1.0-1. Skagit Operations Model input assumptions.

	Scenarios	
	Verification	**Current Operations Baseline**
Hydrology Period for comparison to historical operations	January 1, 1997 through December 31, 2020	January 1, 2012 through December 31, 2020
Dispatch Regime	Two options: (1) Default; and (2) Even at Ross Powerhouse, Default elsewhere	Default
Unit Outages	Historical	None
Target Elevations	Historical end of day	Median historical first of month (Ross Lake), Constant target elevation elsewhere, based on median historical
Flow Rules	1,800 cfs minimum instantaneous from Gorge Development only	Flow requirements per Fisheries Settlement Agreement (FSA)
Spillway Flows	Historical daily average	Only when needed based on simulated reservoir elevation
Gorge Powerhouse Unit 24	Pre- and Post-upgrade performance	Post-upgrade performance

As previously noted, the Skagit Operations Model verification was performed using historical operations data provided by City Light and were developed to test the simulated input data sets and operation rules. The Verification scenarios were developed to simulate operations for all three developments for the calendar years 1997 through 2020 with the varying unit dispatching at Ross Powerhouse, 1997 – 2006 representing pre–Gorge Powerhouse Unit 24 upgrade, and 2007 – 2020 representing post Gorge Powerhouse Unit 24 upgrade. The Skagit Operations Model generation results for the Skagit River powerhouses are shown in Table 1.0-2 for the Verification scenarios. In addition to verifying that the Skagit Operations Model represents reservoir operations by comparing generation, the total Skagit River flow over the period of the Verification scenarios was also evaluated. The modeled total Skagit River flow at the tailrace of the Gorge Development closely represents the outflow from the Gorge Development calculated from USGS reported flows, within 1.6 percent on an annual basis and 0.0 percent on average for the period January 1, 1997 through December 31, 2020.

Table 1.0-2. Verification scenarios generation comparison.

Annual Average (1997-2020)	Historical Generation (MWh)[1]	Default Dispatch[2]		Even Dispatch[3]	
		Simulated Generation (MWh)	Percent Difference from Historical (%)	Simulated Generation (MWh)	Percent Difference from Historical (%)
Ross Powerhouse	726,841	801,585	10.3%	708,315	-2.5%
Diablo Powerhouse	781,110	805,540	3.1%	808,833	3.5%
Gorge Powerhouse	955,523	982,520	2.8%	982,144	2.8%
System Total	**2,463,474**	**2,589,645**	**5.1%**	**2,499,292**	**1.5%**

1 MWh = megawatt hours.
2 Scenario simulated with Ross, Diablo, and Gorge powerhouse units dispatched using default dispatch logic.
3 Scenario simulated with Ross Powerhouse units dispatched using even dispatch logic, Diablo and Gorge powerhouse units dispatched using default dispatch logic.

The Current Operations Baseline scenario was also compared against historical operations data provided by City Light as well as the modeled total Skagit River flow from the Gorge Development to the outflow from Gorge Development calculated from USGS reported flows for the period January 1, 2012 through December 31, 2020. The Current Operations Baseline scenario, which will be the basis for comparison of all subsequent Skagit Operations Model scenarios, was expected to vary more significantly from historical generation as this Baseline scenario assumes default unit dispatching and does not include historical unit outages. Similar to the Verification scenarios, in addition to verifying that the Skagit Operations Model represents reservoir operations by comparing generation, the modeled total Skagit River flow from the Gorge Development was compared to the outflow from Gorge Development calculated from USGS reported flows. This comparison shows a maximum variation of 8.5 percent on an annual basis with an average of 0.1 percent on average for the period January 1, 2012 through December 31, 2020. The annual variation in total Skagit River flow is discussed within the body of this report. The Skagit Operations Model generation results for the Skagit River powerhouses are shown in Table 1.0-3 for the Current Operations Baseline scenario.

Table 1.0-3. Current Operations Baseline scenario generation comparison.

Annual Average (1997-2020)	Historical Generation (MWh)	Simulated Generation[1] (MWh)	Percent Difference from Historical (%)
Ross Powerhouse	727,850	896,512	23.2%
Diablo Powerhouse	766,943	857,118	11.8%
Gorge Powerhouse	980,149	1,044,692	6.6%
System Total	**2,474,942**	**2,798,322**	**13.1%**

1 Scenario simulated with Ross, Diablo, and Gorge powerhouse units dispatched using default dispatch logic.

When considering the impact of significant variation in historical unit dispatching on generation, the Verification and Current Operations Baseline scenario results show the Skagit Operations Model compares well to historical data, characterizes system operations, and is appropriate for use in evaluating the effects of alternative operating scenarios on reservoir levels, outflows, and generation from the Project. The CHEOPS™ software and the Skagit Operations Model are tools that, as this report demonstrates, can be successfully used to evaluate the relative sensitivity and response of the system to changing operational constraints. As with any model, accuracy is highly dependent on input data; consequently, Skagit Operations Model results should be viewed in a relative, rather than an absolute, context. The Skagit Operations Model was developed based on information available at the time of this report. Refinements to the model may be implemented if additional information becomes available.

2.0 INTRODUCTION

The Skagit River Hydroelectric Project (Project), licensed to The City of Seattle, Washington, and operated through its publicly-owned electric power utility Seattle City Light (City Light), is located in northern Washington State, and consists of three power generating developments on the Skagit River—Ross, Diablo, and Gorge—and associated lands and facilities. The Project generating developments are in the Cascade Mountains of the upper Skagit River watershed, between Project River Miles (PRM) 94.7 and 127.9 (U.S. Geological Survey [USGS] river miles [RM] 94 and 127). Power from the Project is transmitted via two 230-kilovolt powerlines that span over 100 miles and end just north of Seattle at the Bothell Substation. The Project also includes two City Light-owned towns, an Environmental Learning Center (ELC), several recreation facilities, and several parcels of fish and wildlife mitigation lands.

The Project developments are all located in Whatcom County, although Ross Lake, the most upstream reservoir, crosses the U.S.-Canada border and extends for about one mile into British Columbia at normal maximum water surface elevation. The Gorge Development, the most downstream of the three Project developments, is approximately 120 miles northeast of Seattle and 60 miles east of Sedro-Woolley, the nearest large town. The closest town is Newhalem, which is part of the Project and just downstream of the Gorge Development.

City Light engaged with HDR Engineering, Inc. (HDR) to develop an operations model for the Project as part of the on-going Federal Energy Regulatory Commission (FERC) relicensing of the Project. Consistent with FERC's Study Plan Determination (SPD) issued on July 16, 2021, the operations model has been developed using HDR's Computerized Hydro Electric Operations and Planning Software (CHEOPS™) software platform. CHEOPS™ is specifically designed to evaluate the effects of operational changes and physical modifications at hydroelectric projects and has been used to evaluate the physical and operational changes considered during the FERC relicensing of more than 27 hydropower projects. One of the many strengths of CHEOPS™ is the degree of customization each individual model contains. CHEOPS™ models are tailored to meet the demands of the particular system being modeled. CHEOPS™ models are also custom configured based on specific system constraints such as flow requirements, target reservoir elevations, and powerhouse equipment constraints. Utilizing a daily average inflow dataset as primary input, CHEOPS™ simulates operations to allocate water between reservoir storage and required outflow constraints (physical, environmental, and operational) while permitting generation.

The study area for the Operations Model Study is the geographic region of the Skagit River from the upper end of Ross Lake to the Gorge Powerhouse tailrace (Figure 2.0-1). The Operations Model will include Ross Lake, Ross Dam and Powerhouse, Diablo Lake, Diablo Dam and Powerhouse, Gorge Lake, Gorge Dam, Gorge bypass reach, Gorge Powerhouse, and tailrace. Additionally, the Operations Model will integrate with models being developed as part of other relicensing studies.

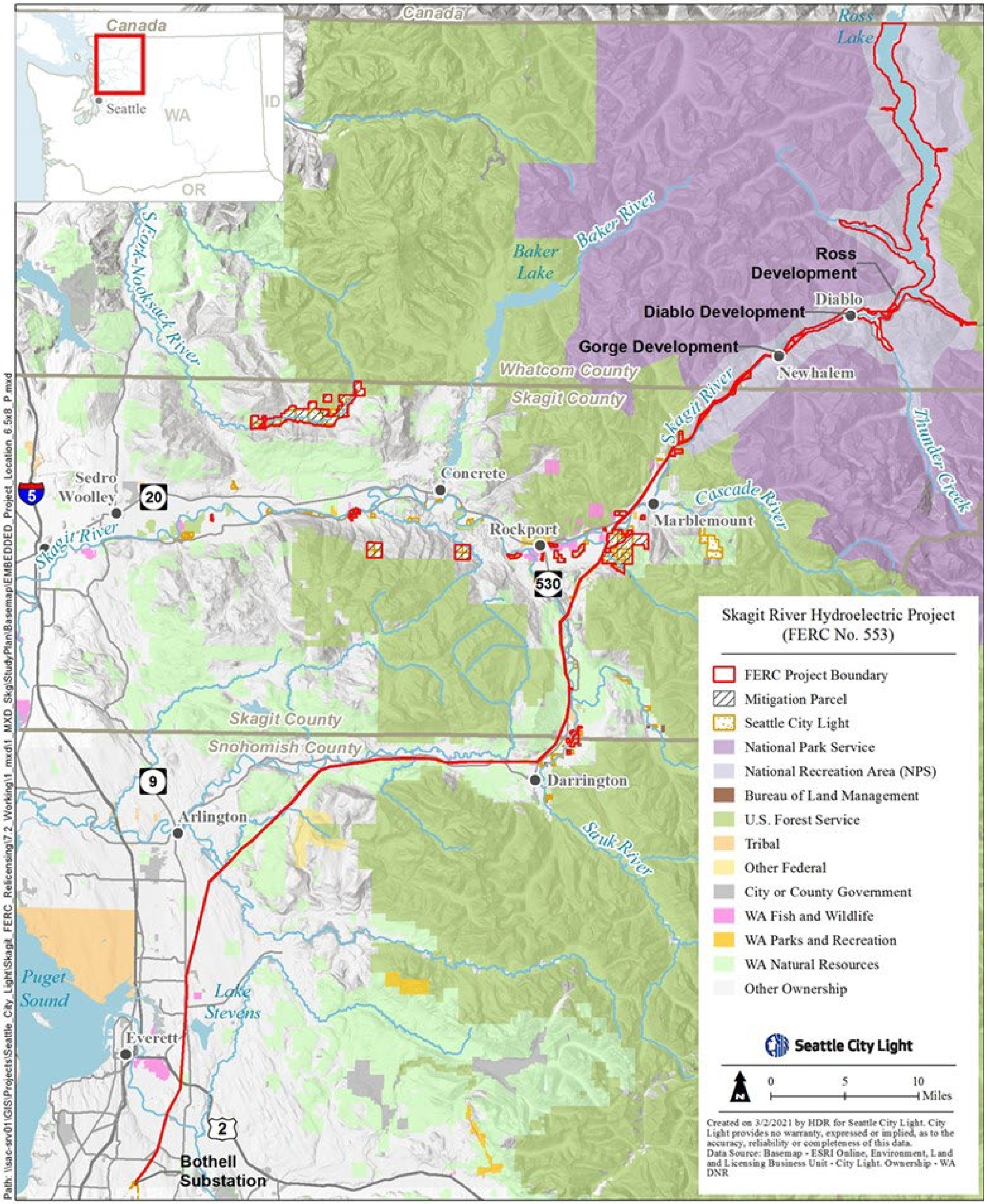

Figure 2.0-1. Project location map.

The Skagit Operations Model utilizes daily average inflows, plant-generating characteristics, and operating criteria of the system to simulate operation, allocate flow releases, and calculate energy production within the system. The Skagit Operations Model calculates reservoir elevation, head losses, net head, turbine discharge, spill, and power generation in one-hour increments. The Skagit Operations Model was designed for long-term analysis of the effects of operational and physical changes made to the modeled hydro/reservoir system.

Skagit Operations Model validation (i.e., determining that the Skagit Operations Model is well-founded and fulfills the purpose for which it was constructed) occurred in two steps. In the first step, the Skagit Operations Model was evaluated by comparing the Skagit Operations Model output to the historical operations record and downstream USGS flow records. The second step verified that the Skagit Operations Model describes and simulates the Project's operating rules by comparing the Current Operations Baseline scenario to historical operations records. The purpose of the Current Operations Baseline scenario is to simulate the current operating system configuration for the selected period of record (POR) to serve as the reference point for relative comparison as alternate scenarios are developed and run.

The Skagit Operations Model was coded to simulate daily operations based on a single set of operating conditions or rules which are a closest-possible match to actual, historical operations. Although actual Project operations generally follow the operating rules, day-to-day conditions such as forced/unforced outages, equipment performance, maintenance activities, changing hydrologic conditions, power demands, and other factors necessitate human intervention in proactive or reactive response to such real-time conditions such that actual operations do not always follow any single set of conditions or rules which may be used in a model.

3.0 PROJECT DATA AND OPERATIONS

The Skagit River Project (FERC No. 553) consists of three developments: Ross, Diablo, and Gorge. The three Skagit River developments are hydraulically coordinated to operate in-concert to prioritize flood control, downstream fish protection, recreation, and power production. From 1991 through 2012, flows in the mainstem Skagit River downstream of Gorge Powerhouse were provided as required by the Project license issued by FERC in 1995[1] which fully incorporated the measures included in the Flow Plan of the Fisheries Settlement Agreement (FSA; City Light 1991). The primary purpose of the Flow Plan was to minimize the effects of Project operations on salmon and steelhead, with measures included in the Flow Plan based on prior research (Pflug and Mobrand 1989).

The Project license was amended in 2013[2] to incorporate a Revised FSA Flow Plan (City Light 2011), which included four measures City Light had been implementing voluntarily since 1995 to further reduce Project effects on steelhead and salmon.

3.1 Ross Development

The Ross Development is the furthest upstream of the three Skagit River Project developments; the powerhouse and nearby dam are about 11 miles north of Newhalem. Most of the water used for Skagit River Project power generation originates in high mountain basins surrounding Ross Lake and upstream along the Skagit River in British Columbia.

Ross Powerhouse is about 1,100 feet downstream of Ross Dam, on the left bank at the eastern end of Diablo Lake. There are four Westinghouse generating units (Units 41, 42, 43, and 44). Two concrete-lined power tunnels deliver water from the reservoir to four penstocks and into the powerhouse. Diablo Lake backs up to the base of Ross Dam and there is no bypass reach or section of free-flowing river between the two developments.

Ross Dam is just upstream of Ross Powerhouse at PRM 105.7 (USGS RM 105.1). At 540 feet from bedrock to crest, it is the highest of the three Project dams. The dam has two spillways, one on each side and each with six gates operated by an electric hoist. In addition to the spillways, Ross Dam has two concrete lined power tunnel intake structures, two butterfly valves and two hollow jet valves near the right bank. The two sets of valves can be opened to evacuate the reservoir once water levels drop below the level of the spill gates.

At nearly 23 miles long, Ross Lake is the largest reservoir in western Washington. It extends into Canada approximately another 1 mile (24 miles total), with about 500 acres in British Columbia.

Ross Lake is the primary storage for the Project and is drawn down in the winter to capture water from spring runoff and to provide for downstream flood control. City Light typically begins drawing down the reservoir shortly after Labor Day. Storage capacity at a normal maximum water surface elevation is approximately 1,435,000 acre-feet; with a usable storage of approximately

1 Skagit River Hydroelectric Project Order Accepting Settlement Agreement, Issuing New License and Terminating Proceeding. 71 FERC ¶ 61,159. May 16, 1995.

2 Order Amending License and Revising Annual Charges, Skagit River Hydroelectric Project, FERC No. 553. 144 FERC ¶ 62,044. July 17, 2013.

1,052,000 acre-feet which is 68 times the combined usable storage of the other two reservoirs. If needed, the reservoir can be surcharged by 2.5 feet to the top of the spill gates to absorb an additional 95,000 acre-feet.

In addition to forecasted precipitation, City Light also uses snowpack data to manage winter drawdown levels in Ross Lake. Snow surveys are conducted monthly from December 1 through April 1 by an independent contractor using a helicopter to access 16 snow course stations on the ridges of the watershed. The data on snow depth and water content are used to predict the amount of spring run-off, which is then used to determine the lowest drawdown level, which is typically reached in late March or early April.

3.2 Diablo Development

The Diablo Development is between the Ross and Gorge developments and in addition to generating power, it reregulates flows between the other two developments. The powerhouse is on the north side of the Skagit River in the town of Diablo, about 4,000 feet downstream from Diablo Dam. Water from the reservoir to the powerhouse is conveyed by a single concrete lined tunnel for 1,900 feet that leads to three steel-lined penstocks. There is a surge tank located near the bottom end of the tunnel, uphill from the powerhouse.

Diablo Powerhouse holds two Westinghouse generators (Units 31 and 32). There are also two smaller, house-unit generators (Units 35 and 36). A reinforced-concrete tailrace on the westerly edge of the powerhouse also serves to support transformers, a switching apparatus, and a crossing for a single-lane road.

Diablo Dam is located at PRM 101.6 (USGS RM 101.2), about four miles upstream of Gorge Dam and four miles downstream of Ross Dam. The concrete arch dam is 389 feet from bedrock to crest and has two spillways, one on each side, and a total of 19 spill gates, seven on the south spillway and 12 on the north. There are two bifurcated intakes at the dam but only one is in use as the second intake was for planned future expansion of the powerhouse and a second tunnel, which were never constructed.

3.3 Gorge Development

Gorge Powerhouse is on the left bank (facing downstream) of the Skagit River just upstream of the town of Newhalem and is reached via a bridge across the river that connects to State Route (SR) 20. There are four Westinghouse generating units (Units 21, 22, 23, and 24).

In addition to generating power, Gorge Powerhouse is responsible for regulating flows to the river downstream of the Project for fish protection, as stipulated by the current Project license. Units 21, 22, and 23 are each connected to steel-lined penstocks through 10-foot-diameter, biplane-type butterfly valves equipped with relief valves, which will discharge a maximum of 65 percent of the turbine flow at full-load rejection. Equipment has also been installed to allow these valves to open and stay open for any required period to maintain fish flows after a plant load rejection/shutdown. Unit 24 is connected to the steel-lined penstock through a 15-foot-diameter butterfly valve.

Water from Gorge Lake is conveyed via an intake structure in Gorge Dam into an 11,000-foot-long concrete lined power tunnel to the powerhouse. The power tunnel passes through the solid rock slope that is adjacent to the Skagit River and then splits into four penstocks. A surge tank and riser with restricted orifice is located at the lower end of the tunnel.

Gorge Dam, located at PRM 97.2 (USGS RM 96.6), is about 2.5 miles upstream of Gorge Powerhouse and four miles downstream from Diablo Dam near Gorge Creek. The dam is a combination concrete arch and gravity structure that rises 300 feet from bedrock to crest. There are two spillways with gates that are operated by an electric hoist on top of the dam.

4.0 HYDROLOGY

The Skagit Operations Model utilizes average daily inflow as the hydrology inputs (i.e., the source of water to the Project). Using average daily flows (hydrology) as input, the Skagit Operations Model simulates Project operations and budget water per operational constraints (physical, environmental, and operational), or to indicate when all competing constraints cannot be maintained. The objective for development/identification of the hydrologic dataset is to compute average daily inflow to each node or calculation point within the Skagit Operations Model.

Appendix 1 to this Skagit Operations Model Logic and Validation Report outlines the development of average daily hydrology in the Skagit River basin based on a combination of USGS gage and Project operations records. For this analysis, a hydrologic dataset of average daily flows was developed for the period January 1, 1988 through December 31, 2020, utilizing available hydrologic data as compiled from USGS gages in the vicinity and Project operations records. This 33-year period of record was identified based on available historical data to provide hydrologic data for scenario simulation, including the Current Operations Baseline (Baseline), and the 24-year period of January 1, 1997 through December 31, 2020 was utilized for simulation of the Skagit Operations Model Verification scenarios. This 24-year period represents the period of available historical operations data, where City Light's Oracle data collection system was in place during this period. The Oracle data collection system contains historical reservoir and powerhouse operations records on an hourly basis. In this report, the Current Operations Baseline is also compared to historical data for the period January 1, 2012 through December 31, 2020, which represents the period since the execution of the most recent operational agreements.

5.0 MODEL INPUTS

This section defines the development of the Verification and Current Operation Baseline scenario set-ups. The Current Operation Baseline scenario was developed to represent the current operations of the Project, including current FERC license requirements; whereas the Skagit Operations Model Verification scenarios were configured to use specific historical data and executed to quantify the ability of the Skagit Operations Model to simulate actual recorded historic operations of the developments. Each subsection defines specific inputs used in the Skagit Operations Model to simulate historical operations. Skagit Operations Model verification was performed using historical operations data provided by City Light.

5.1 Model Logic

Figures 5.1-1 and 5.1-2 give an overview of the Skagit Operations Model logic in sequence.

A model scenario is a collection of detailed settings describing specific details of Project operation and operation requirements. A model scenario setup is organized into four major settings: System Settings, Physical Settings, Operation Settings, and Generation Settings.

The process of creating and summarizing model outputs is shown in Figure 5.1-1. Identification of conditions which vary from the Current Operations Baseline scenario or another existing condition are identified and input into the Skagit Operations Model. The group of conditions which make up the Settings is then created and saved. Lastly, the scenario is created by selecting the desired Settings for each plant. The Skagit Operations Model is then run, and output results reviewed to confirm proper implementation of the modified conditions. Model output summaries are then used to compare the impact of the modified scenario's outputs with the Current Operations Baseline scenario outputs.

As shown in Figure 5.1-2, the Skagit Operations Model starts computations at the upstream development on the first day of the hydrologic period and determines hourly inflows and daily average inflows. Hourly inflows to a plant consist of the incremental accretions plus, if applicable, upstream plant hourly discharges and spill flows. Plant operating requirements are evaluated, and a daily average flow target is determined. This daily average flow target is then used to compute the hourly discharge schedule. Under the default dispatch model logic, explained in Section 5.2.4.6 of this report, this hourly discharge schedule attempts to release as much of the day's target volume as possible during the high demand, or heavy load period, at flow rates usable by the powerhouse units at efficient setpoints. Reservoir elevation constraints are then evaluated for the current development, and detailed discharge schedules are potentially changed to keep the reservoir within elevation restrictions. Spill is computed if applicable, and generation for each timestep is then computed.

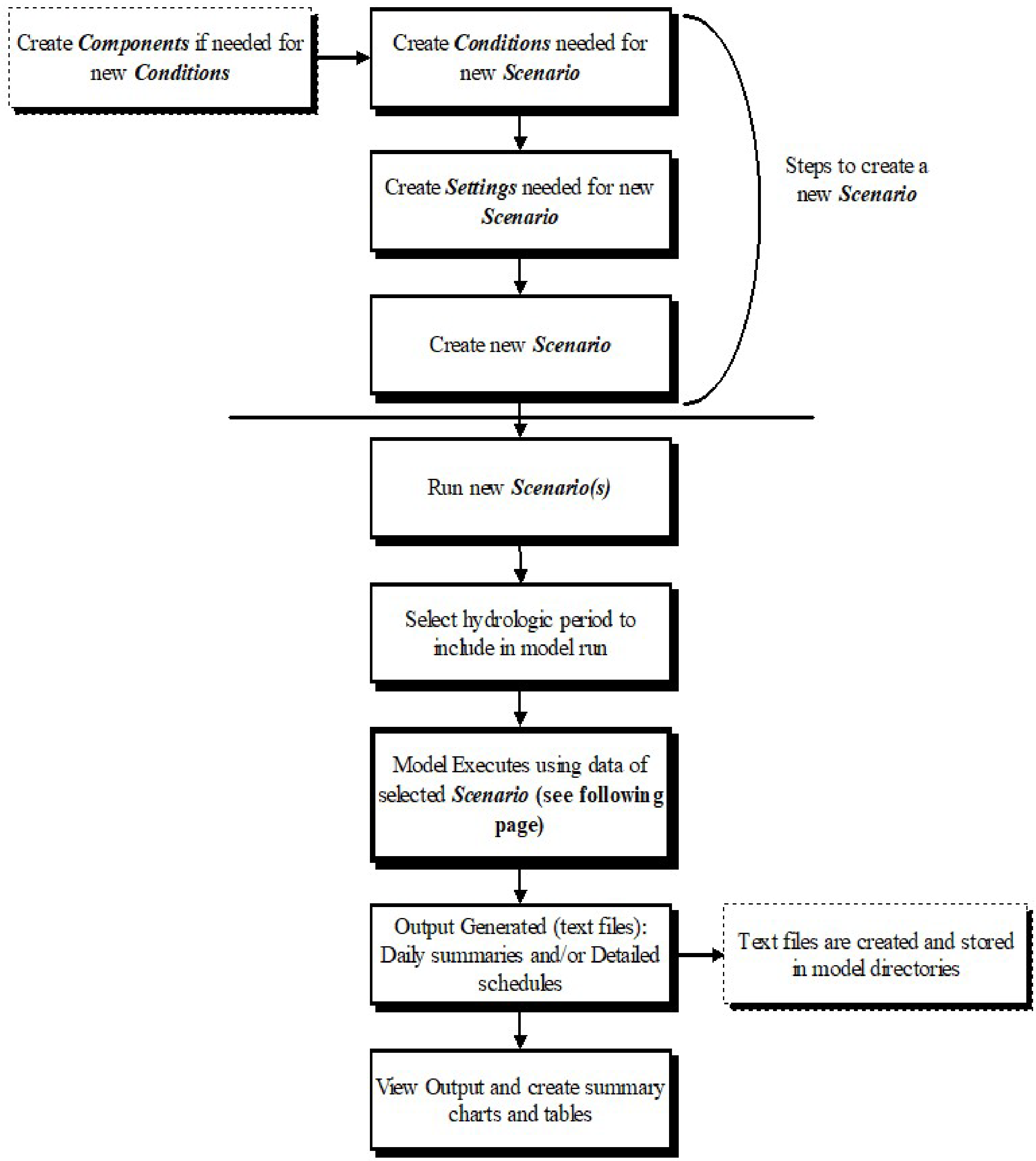

Figure 5.1-1. CHEOPS™ model execution flow chart.

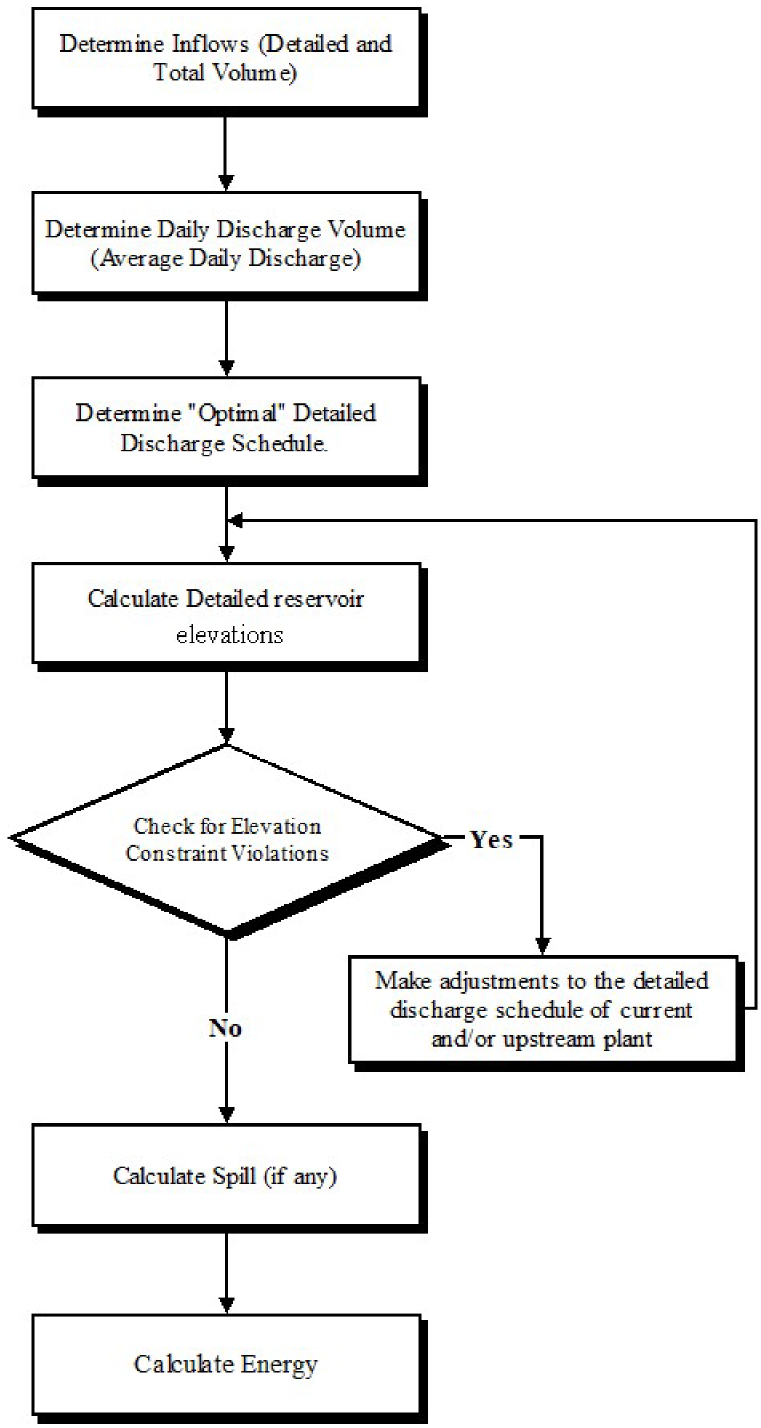

Figure 5.1-2. CHEOPS™ model scheduling flow chart.

5.2 Model Scenario Definition/Input Data

The Project data listed in the following subsections shows the general operational constraints and physical parameters used in the Skagit Operations Model to define scenarios including the Verification and Current Operations Baseline scenarios. As noted in Section 4.0 of this Skagit Operations Model Logic and Validation Report, Appendix 1 outlines the development of average daily hydrology utilized in the simulation of the Verification and Current Operation Baseline scenarios and specifically addresses FERC's SPD to include: (1) a specific description of the reservoir tributaries included in the inflow analysis; (2) the POR used for each; and (3) the source of the flow data for each (e.g., USGS gage flow record or synthetic flow record). The Current Operations Baseline scenario was developed to simulate the current operating system configuration; whereas the Skagit Operations Model Verification scenarios were configured to use specific historical data and executed to quantify the ability of the Skagit Operations Model to simulate recorded historic operations of the developments. To represent historical operations, the Verification scenarios presented in this report are based on the Current Operations Baseline scenario, with the additions or modifications outlined below, and summarized in Table 5.2-1:

- Gorge Development minimum instantaneous outflow of 1,800 cubic feet per second (cfs) to simulate historical Gorge Powerhouse output;
- Daily changing target reservoir elevations to simulate historical operations;
- Daily spillway flow to simulate historical operations at each development;
- Varying Ross Powerhouse unit dispatching;
- Daily changing turbine outages at each development. If a unit was not operated historically, then it was also not operated for the same day in the Verification scenarios; and
- Unit 24 at Gorge Powerhouse was upgraded in 2006, so Verification scenarios were developed to represent pre- and post-upgrade performance for Gorge Powerhouse Unit 24. Pre-upgrade performance simulated 1997 through 2006 and post-upgrade 2007 through 2020.

Table 5.2-1 summarizes the Skagit Operations Model input differences by Verification and Current Operations Baseline scenarios.

Table 5.2-1. Skagit Operations Model input assumptions.

	Scenarios	
	Verification	**Current Operations Baseline**
Hydrology Period for comparison to historical operations	January 1, 1997 through December 31, 2020	January 1, 2012 through December 31, 2020
Dispatch Regime	Two options: (1) Default and (2) Even at Ross Powerhouse, Default elsewhere	Default
Unit Outages	Historical	None
Target Elevations	Historical end of day	Median historical first of month (Ross Lake), Median historical elsewhere
Flow Rules	1,800 cfs minimum instantaneous from Gorge Development only	Flow requirements per Fisheries Settlement Agreement (FSA)
Spillway Flows	Historical daily average	Only when needed based on simulated reservoir elevation
Gorge Powerhouse Unit 24	Pre- and Post-upgrade performance	Post-upgrade performance

Sections 5.2.1 through 5.2.4 are organized following the four Skagit Operations Model setting components of a scenario (System Settings, Physical Settings, Operational Settings, and Generation Settings) used in the Skagit Operations Model to define the system configuration for the Current Operations Baseline and Verification scenario setups.

5.2.1 System Settings

5.2.1.1 Load Shape

The load shape defines the daily schedule of relative power demand, using a duration in hours within each period in the peak, secondary-peak, and off-peak periods. To represent a typical generalized load shape, the peak period was defined as the period starting at hour 6:00 am lasting 16 consecutive hours. Durations for load shape periods were input with eight hours per day as off-peak, during the morning and end of day periods, starting at 10:00 pm lasting eight consecutive hours. The Skagit Operations Model does allow for varying monthly and weekend/weekday load shape inputs, although that was not configured to do so in this model based on the typical 6x16 load shape applied. The Skagit Operations Model uses the load shape data to schedule the release of water throughout the day, prioritizing generation during peak periods. The Skagit Operations Model has an option in the input conditions which can be configured to limit generation during low demand/off-peak periods, however this option was not used in the Verification and Current Operations Baseline scenario set ups.

5.2.1.2 Carry-Over Elevations Condition

The Skagit Operations Model Carry-Over Elevations Condition controls how to treat the beginning- and end-of-year elevations for multi-year scenario simulations. The Skagit Operations Model begins the computation on day 1 of the simulation with each reservoir at its target elevation. If the scenario is computed for a multiple-year period, then the Skagit Operations Model can either start subsequent years with the reservoir at the target elevation or at the previous year's ending elevation. The Carry-Over Elevation option was selected (i.e., the checkbox was checked) in the

Verification and Current Operations Baseline scenario set ups such that subsequent years start using previous year's ending elevation.

5.2.1.3 Forecast Set-Up Condition

The Skagit Operations Model Forecast Set-Up Condition requires two inputs: a number of forecast days and an accuracy of the forecast. The number of days is how many days the Skagit Operations Model can "look ahead" in the inflow hydrology file to calculate how much water the system is going to receive in the defined days ahead. The Current Operations Baseline scenario was set up to look three days ahead with 100 percent accuracy, and since the Verification scenarios target daily historical reservoir elevations, the Verification scenarios were set up to look one day ahead with 100 percent accuracy as the scenarios utilize daily reservoir target elevations. By setting the Current Operations Baseline scenario with a three day look ahead, the Skagit Operations Model will, as in real life, attempt to release more water ahead of high runoff periods, thus building usable storage to avoid or reduce spills. Setting the Verification scenarios look ahead to one day forces the Skagit Operations Model to more rigidly follow the historical elevations which are input as end of day target elevations.

Since the Skagit Operations Model has "perfect" forecasting as it looks at the actual inflow file, the accuracy setting allows the user to evaluate the flexibility of the system to handle unexpected inflows. The accuracy setting adjusts inflow by a fixed multiple. The Skagit Operations Model looks ahead the given number of days, adds up the inflows, multiplies those inflows by the entered value, then schedules releases based on this forecasted inflow volume. If the forecast setting is not 100 percent (1), then the forecasted volume is not accurate. By running the Skagit Operations Model with 90 percent (0.9) forecast, and then running again at 110 percent (1.1) forecast, the user can simulate operations where the operator has an ability to forecast inflows with plus or minus 10 percent accuracy.

5.2.1.4 Custom Logic

CHEOPS™ is highly customizable to implement operating rules specific to each hydropower development. One of the methods of performing this is to code the model to read in an input file specifically formatted to supply operating conditions and implement these as constraints. In the Skagit Operations Model, this is performed with an Excel workbook referred to as the FishFlowFile. The FishFlowFile enables the Skagit Operations Model's custom logic routines that implement custom coding to simulate the flow protocols specified in the FSA. These protocols are specified in the FERC license for the Project, as amended, and involve spawning, incubation, stranding, fry protection flows and ramping rate limitations, and Ross Lake Spawning Control Curve calculations. These flow protocols are briefly summarized in Appendix 2. Use of the FishFlowFile allows for the varying of the quantities of the constraints, e.g., changing the hourly ramping rate restrictions, or maximum or minimum flow requirements for the various fish lifecycle periods, without having to perform code modifications.

With this FishFlowFile selected as an input to a scenario, the Skagit Operations Model code will look for a specific table in the identified file. If this file or table does not exist, the Skagit Operations Model will display an error at Model run time and will not complete the scenario run. With the FishFlowFile input file name left blank, the Skagit Operations Model will follow the requirements as specified in the Operations Settings inputs for the scenario.

5.2.2 Physical Settings

5.2.2.1 Reservoir Storage Volume Curve

The reservoir storage volume curve relates a reservoir water surface elevation and water volume at that elevation. The elevations are in units of "feet" and the volumes are in units of "acre-feet." This relationship was used in the Skagit Operations Model to calculate elevations based on inflows and model-determined releases. Figures 5.2-1 through 5.2-3 show the storage curves used for Ross Lake, Diablo Lake, and Gorge Lake, respectively. These data sets were developed from Project drawings with elevations converted from the City of Seattle Datum (CoSD) to the North American Vertical Datum of 1988 (NAVD 88). This conversion is +6.51 feet (CoSD +6.51 = NAVD 88) at Gorge Lake, +6.36 feet at Diablo Lake, and +6.26 feet at Ross Lake.

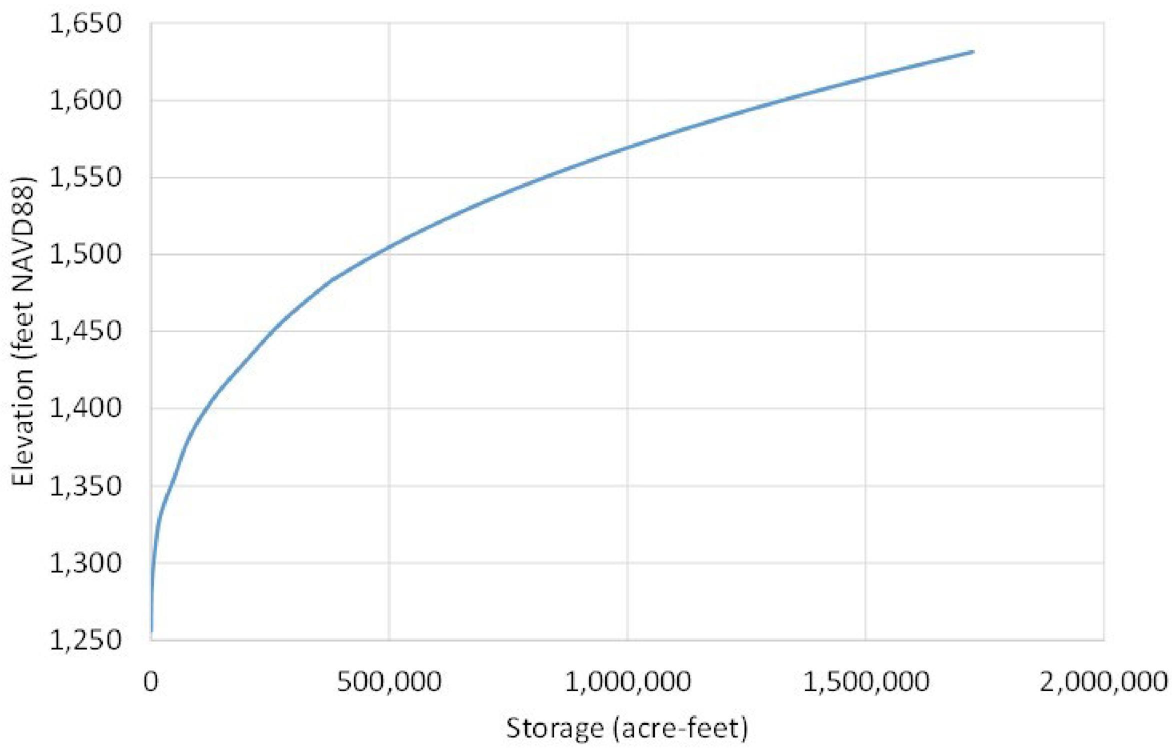

Figure 5.2-1. Ross Lake storage volume curve.

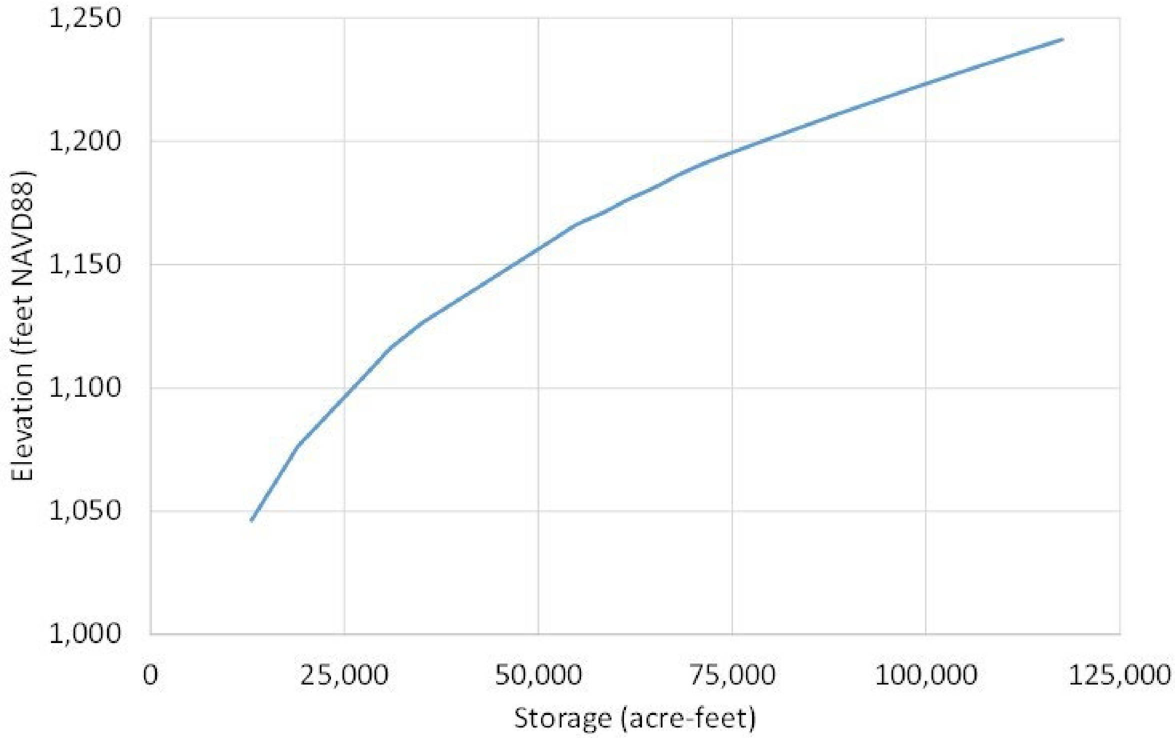

Figure 5.2-2. Diablo Lake storage volume curve.

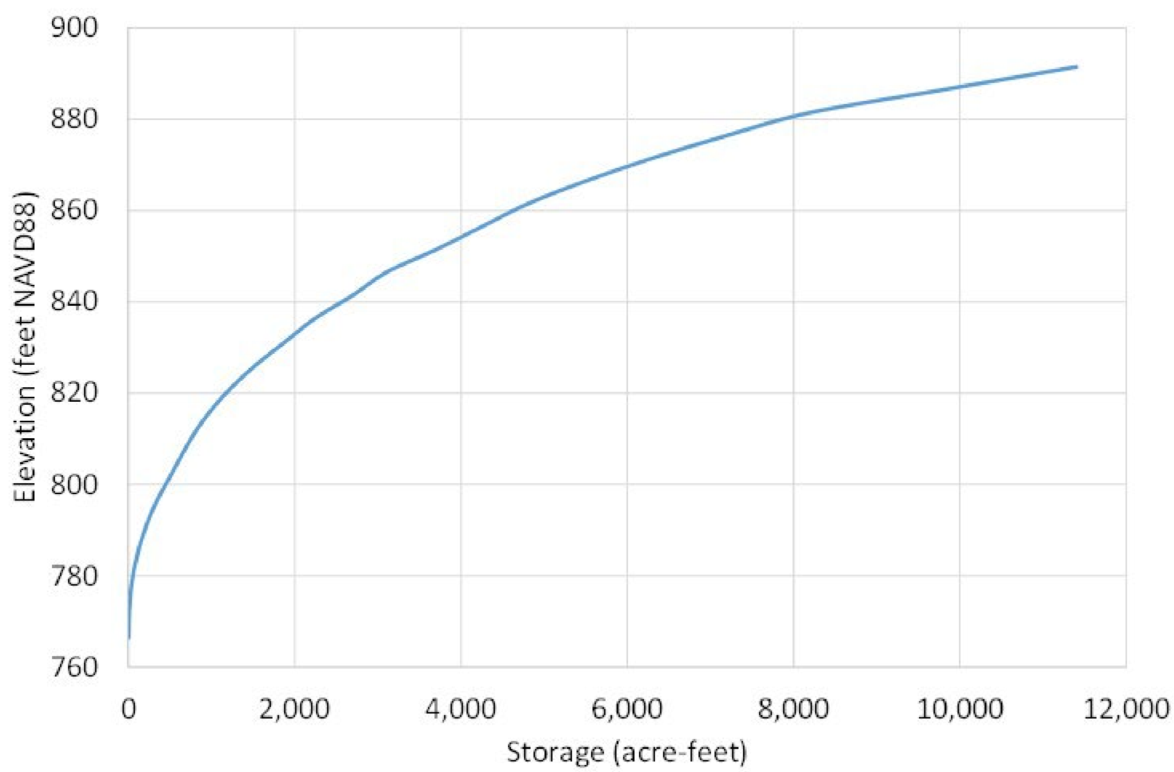

Figure 5.2-3. Gorge Lake storage volume curve.

5.2.2.2 Reservoir Area Curve

The reservoir area curve is an input data set which equates a water surface elevation with the water surface area. At the start of each day, the Skagit Operations Model determines the area from the day's beginning elevation. Figures 5.2-4 through 5.2-6 show the area curves used for Ross Lake, Diablo Lake, and Gorge Lake, respectively. These data sets were developed from Project drawings with elevations converted from CoSD to NAVD 88.

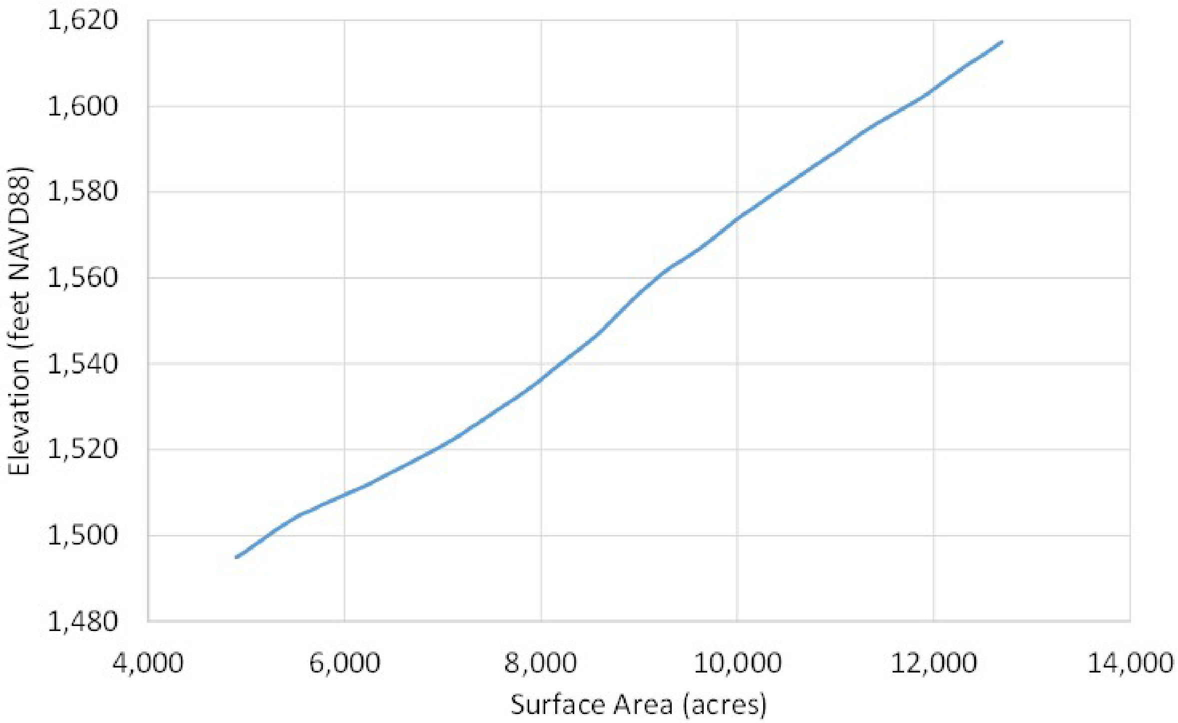

Figure 5.2-4. Ross Lake area curve.

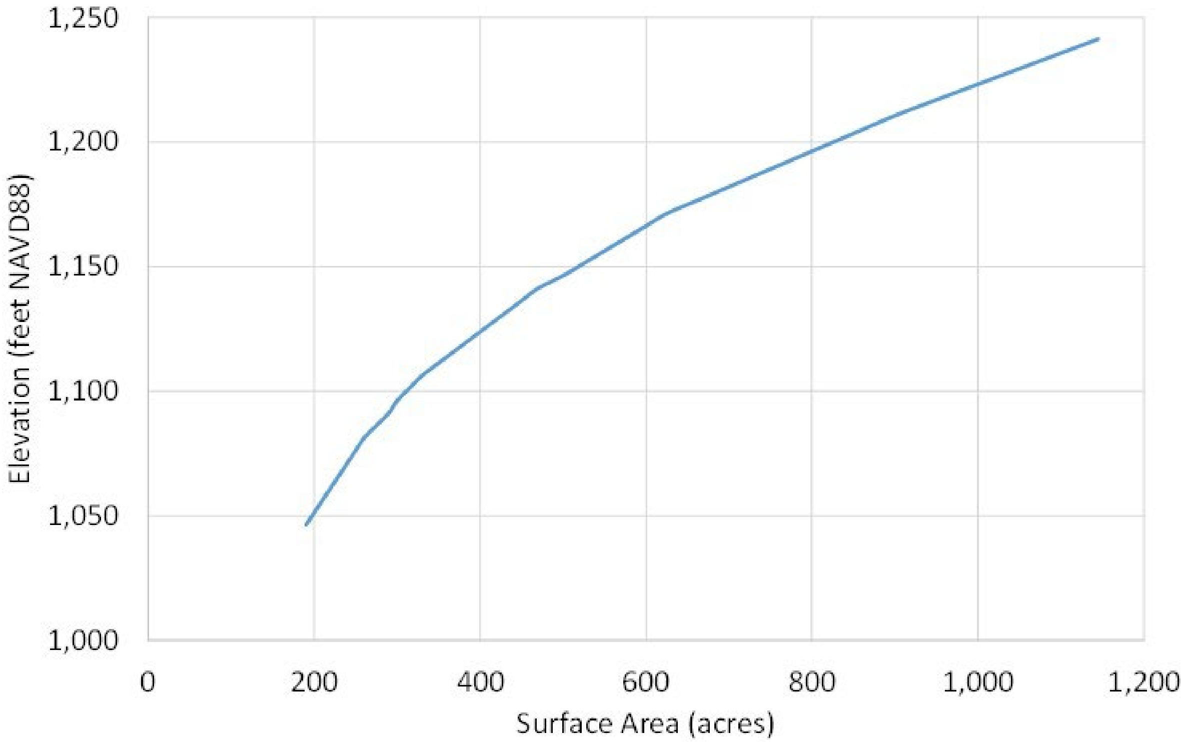

Figure 5.2-5. Diablo Lake area curve.

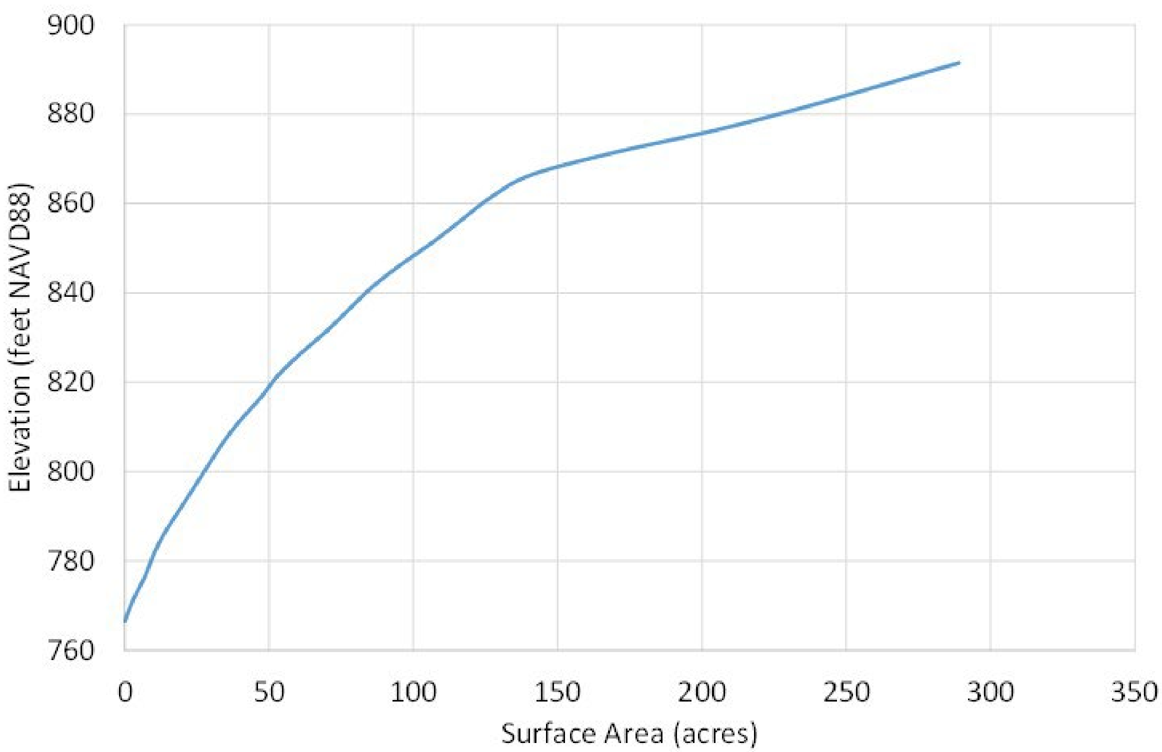

Figure 5.2-6. Gorge Lake area curve.

5.2.2.3 Daily Evaporation

The Daily Evaporation Condition contains daily evaporation coefficients for the reservoir varying by month. The coefficient's units are "feet/acre." To calculate evaporation, the Skagit Operations Model multiplies each start of day's surface area by the evaporation coefficient to determine an evaporation volume for the day in acre-feet. The evaporation volume is converted into a daily average flow and the evaporation flow is removed from the reservoir within the Skagit Operations Model timesteps as an average daily flow. Figure 5.2-7 shows the evaporation coefficients for each reservoir in the system. These monthly average evaporation coefficients were derived from the data summarized in Estimating Reservoir Evaporation Losses for the United States: Fusing Remote Sensing and Modeling Approaches (Zaho and Gao 2019). This estimates evaporation losses from 721 reservoirs in the contiguous United States for the period March 1984 to October 2015 and presents evaporation rate modeled using the Penman Equation in which the lake heat storage term was considered, where evaporation volume can be calculated as the product of the reservoir area and evaporation rate. These data were utilized to calculate an average monthly evaporative loss rate for Ross and Diablo lakes. The loss rates for Gorge Lake were assumed to be the same as Diablo Lake as Gorge Lake was not included in the Zaho and Gao 2019 study.

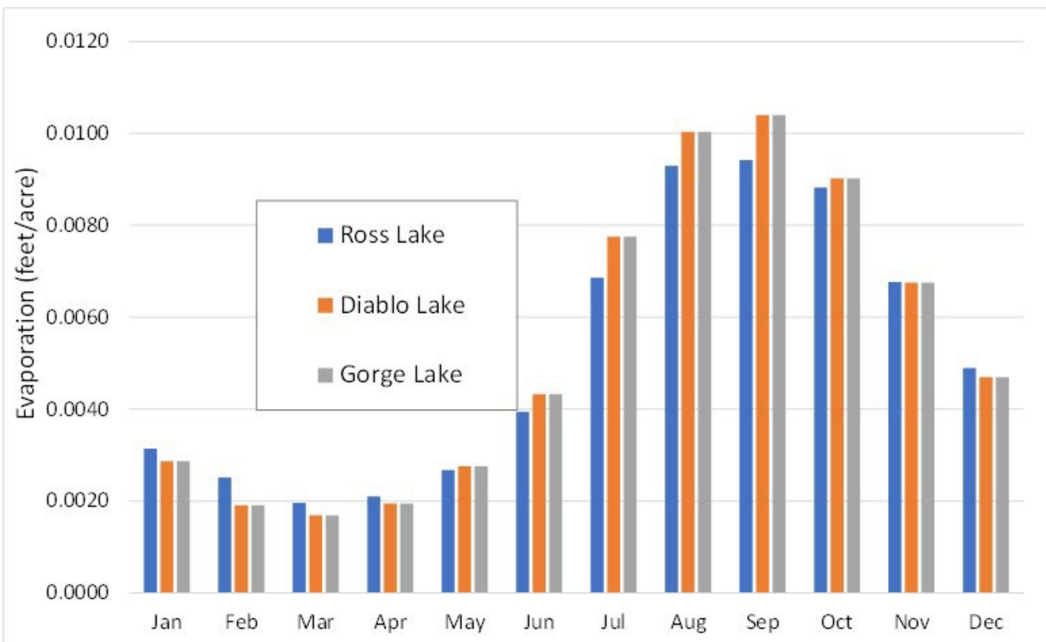

Figure 5.2-7. Evaporation coefficients.

5.2.2.4 Tailwater Rating Curve

The tailwater rating curve relates the powerhouse tailrace water surface elevation to the powerhouse and river outflow. The elevation is in units of feet, while the flow is in units of cfs. The tailwater elevation is subtracted from the reservoir elevation to calculate the gross head used in determining turbine hydraulic performance. The tailwater data was developed from City Light historical hourly operations data adjusted to the NAVD 88 datum (for Gorge Powerhouse tailrace, limited elevation data was available for flows below approximately 2,000 cfs).

Figures 5.2-8 through 5.2-10 show the tailwater curves for the Project developments.

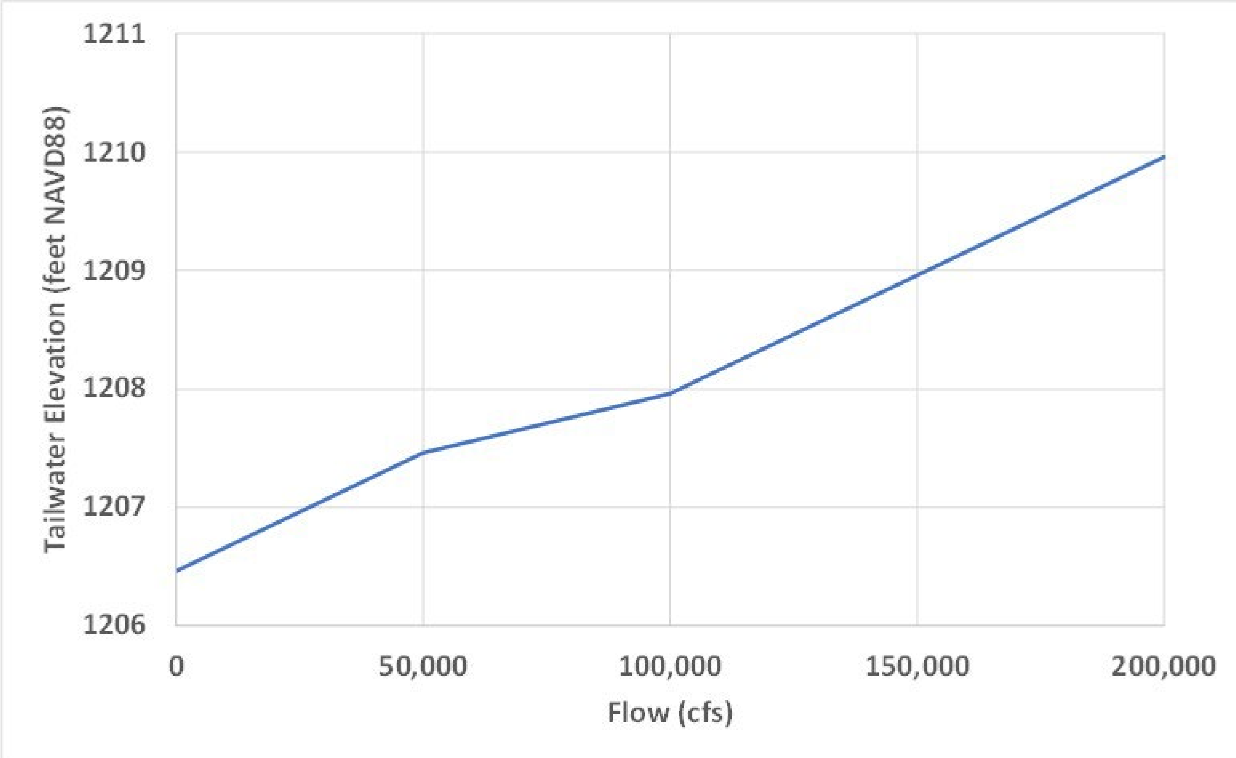

Figure 5.2-8. Ross Powerhouse tailwater curve.

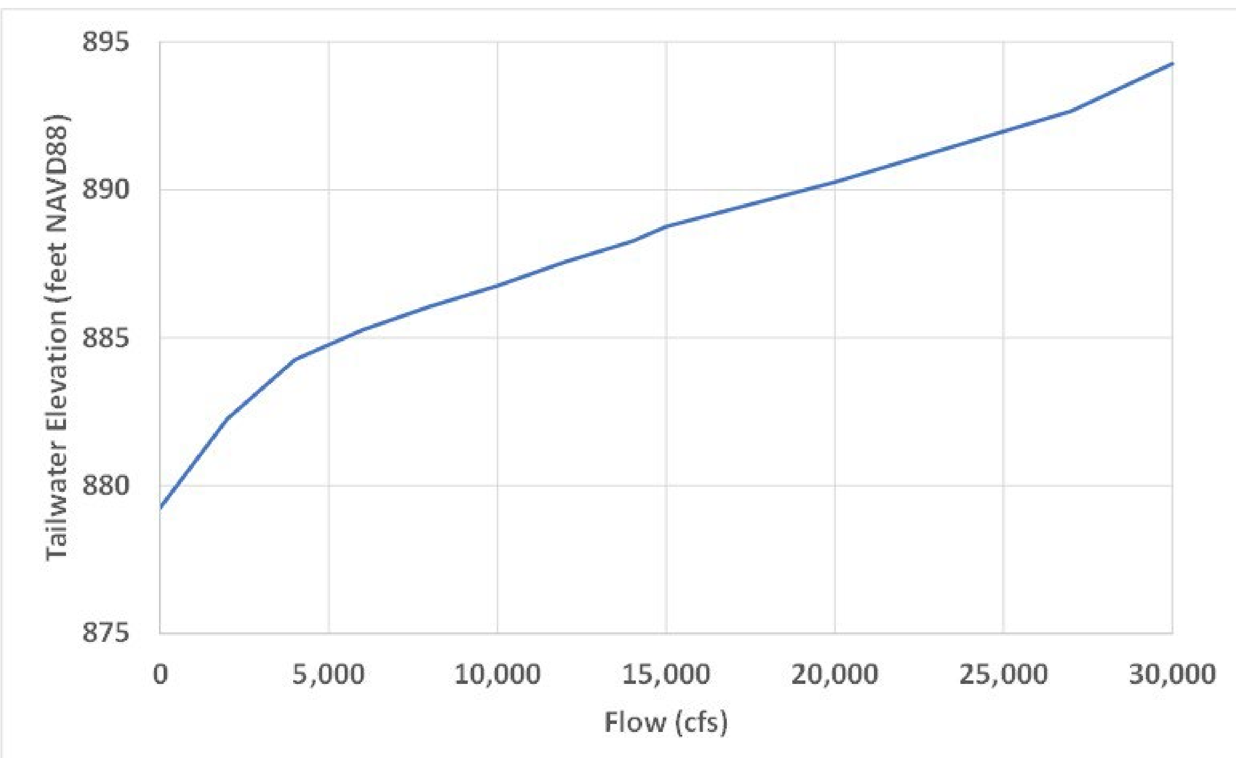

Figure 5.2-9. Diablo Powerhouse tailwater curve.

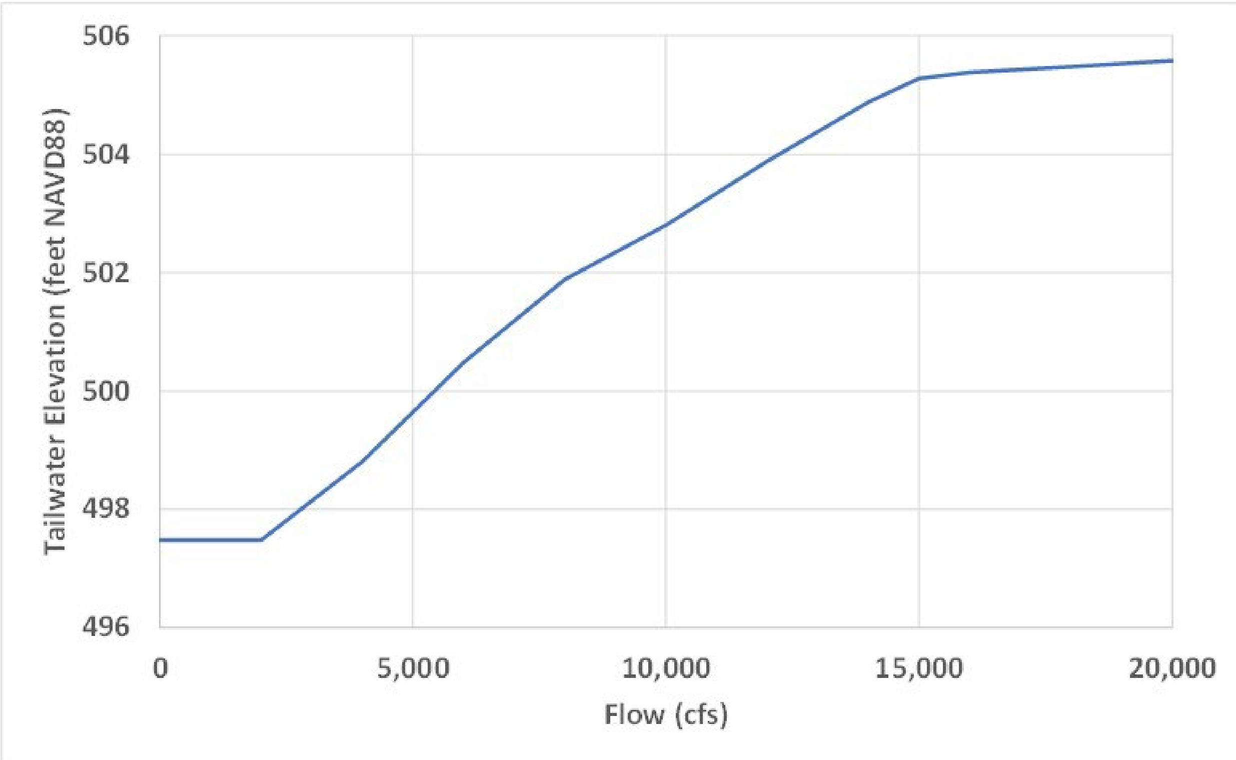

Figure 5.2-10. Gorge Powerhouse tailwater curve.

5.2.2.5 Spillway Capacity Curve

The spillway capacity curve contains the data relating reservoir water surface elevation (feet) and spillway discharge capacity (cfs). This data allows the Skagit Operations Model to determine the maximum amount of water that can be spilled at the current reservoir elevation and is the sum of all spillway conveyances with gates open to maximum setting or controllable spillway crests lowered to the lowest setting. The Skagit Operations Model allows for a simple spillway relationship of elevation and flow; therefore, all spillways are modeled as a relationship of elevation and flow.

Figures 5.2-11 through 5.2-13 show the spillway rating curves entered into the Skagit Operations Model and represents the spillway capacities. These curves were developed from Project drawings.

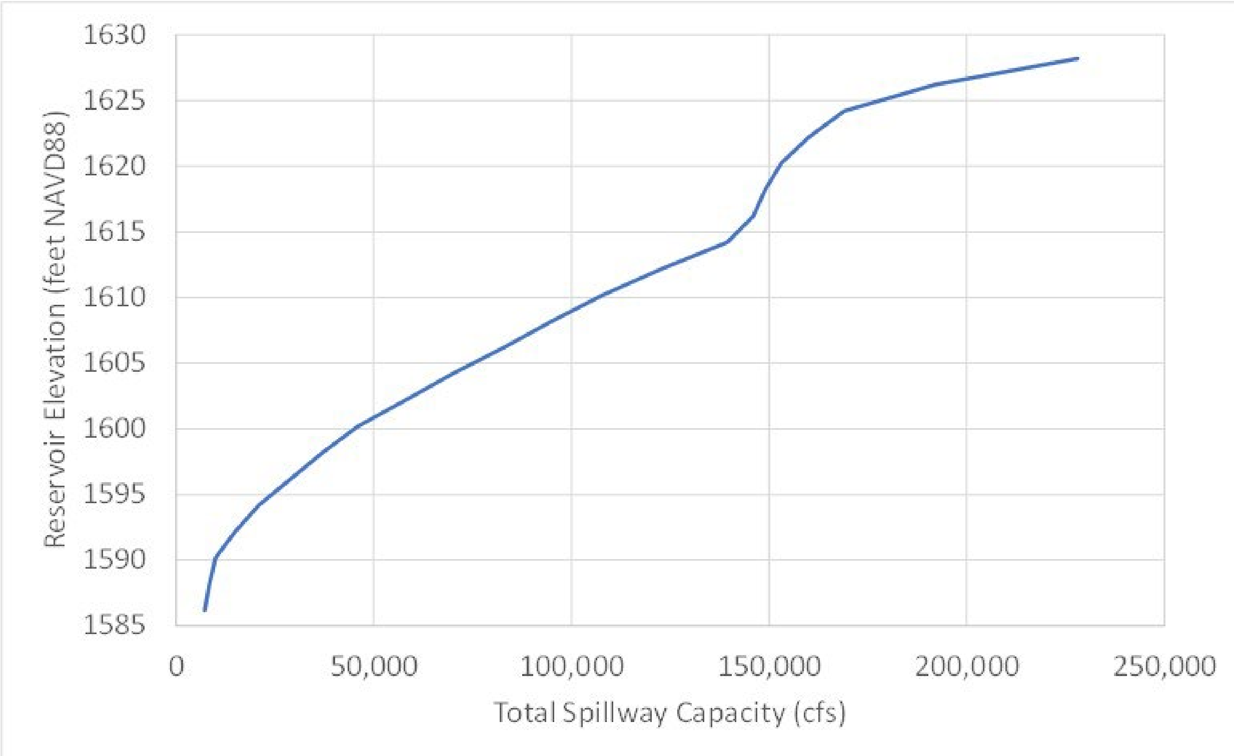

Figure 5.2-11. Ross Dam outlet works and spillway rating curve.

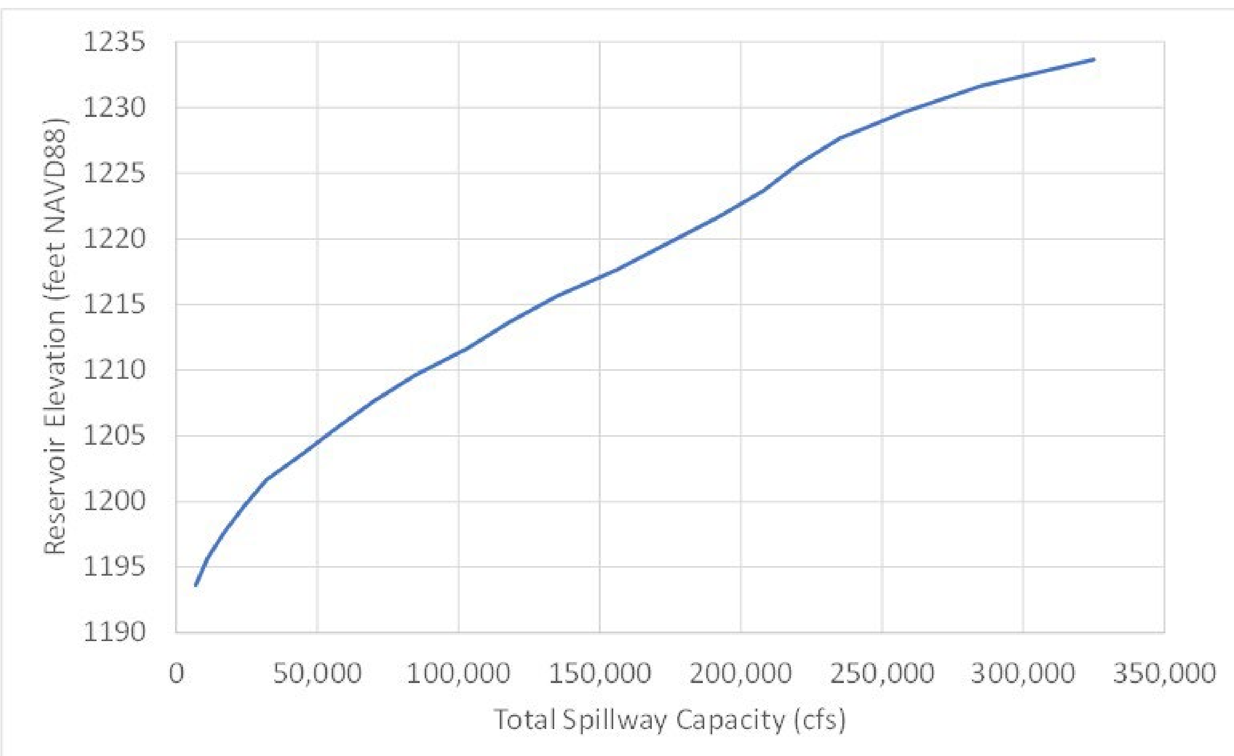

Figure 5.2-12. Diablo Dam outlet works and spillway rating curve.

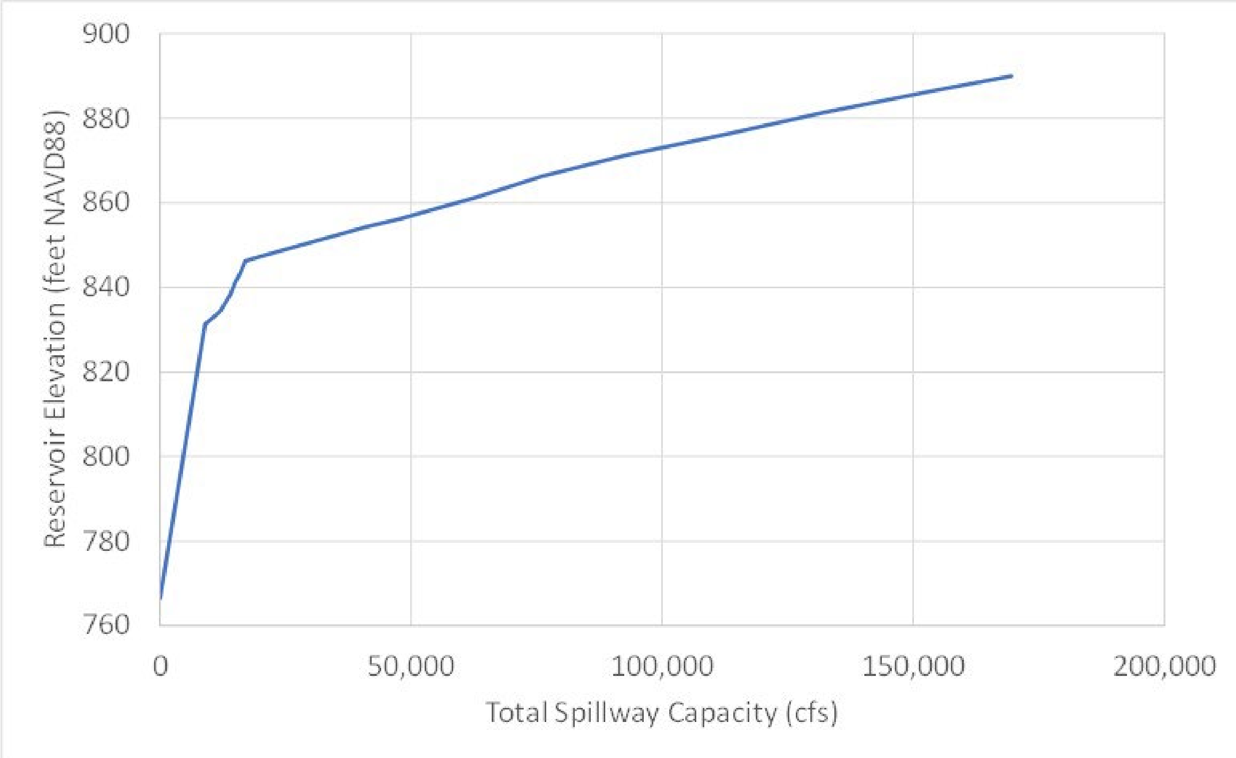

Figure 5.2-13. Gorge Dam outlet works and spillway rating curve.

5.2.2.6 Plant Options

The plant options inputs specify how the Skagit Operations Model classifies and operates the plants. Four different components are used to describe the operation of the plants:

- **Minimum Powerhouse Flow** – The Skagit Operations Model has a zero (0) value entered for the Project since the turbine input curves accurately define the lowest operating flow of the units.
- **Plant Operation Type** – This condition specifies what type of scheduling logic is to be used for the plant. The CHEOPS™ Strictly Peaking plant logic was applied for all three developments as it best represents current Project operations. The Strictly Peaking plants use logic to generate as much power as possible during the defined peak periods, and then off-peak periods.
- **Delinked Owner** – This condition sets the level of water conveyance support a plant receives and provides to other plants operated by the same licensee/operator. All modeled plants have this value unchecked, meaning the plants provide supporting operation to other plants operated by the same owner.
- **Delinked System** – This condition sets the level of support a plant receives and provides to other plants operated by other licensees/operators in the modeled system. All modeled plants have this value unchecked, meaning the plants provide supporting operation to other plants operated by other owners; however, no plants from other owners are in this Skagit Operations Model.

5.2.3 Operational Settings

5.2.3.1 Spill Elevations

The spill or flood control elevation can relate to a variety of physical situations (spillway crest, partial gate coverage, maximum normal pool, etc.), but in the Skagit Operations Model it represents the elevation at which the Skagit Operations Model begins to simulate spill to avoid increasing water surface elevation. When the Skagit Operations Model calculates an end-of-period elevation above the spill elevation, it calculates spill as well as the turbine/diversion discharge. The Skagit Operations Model's logic also attempts to reduce or eliminate occurrences when the reservoir elevation exceeds the spill elevation by increasing turbine/diversion discharge to the maximum capacity.

Spill elevations in the Skagit Operations Model are set to 1,608.76 feet NAVD 88 for Ross Lake, 1,211.36 feet NAVD 88 for Diablo Lake, 881.51 feet NAVD 88 for Gorge Lake, and apply for each day of the year.

5.2.3.2 Target and Minimum Elevations

The target elevation is the user-defined reservoir elevation that the Skagit Operations Model attempts to meet (targets) as the end-of-day reservoir elevation for the number of days ahead of the current day based on the Forecast Days entry (see Section 5.2.1.3 of this report). The Skagit Operations Model linearly interpolates between user input points to identify a target elevation for each day. The Skagit Operations Model deviates from the target when needed to accommodate forecasted inflows, to meet the development's own outflow requirements or constraints, and to support downstream developments' flow requirements.

Target elevation data was developed from analyses of City Light historical operations data for the period January 1, 1997 through December 31, 2020 for each development, adjusted to NAVD 88 datum. Target elevations in the Skagit Operations Model are set to 1,207.9 feet NAVD 88 for Diablo Lake and 878.04 feet NAVD 88 for Gorge Lake. These elevations are the median values from the City Light historical operations data from January 1, 1997 through December 31, 2020 and apply for each day of the year.

Table 5.2-2 shows the target reservoir elevations entered into the Skagit Operations Model for Ross Lake.

Table 5.2-2. Ross Lake target elevation curve.

Date	Elevation (feet NAVD 88)	Date	Elevation (feet NAVD 88)	Date	Elevation (feet NAVD 88)
Jan 1	1,581.67	May 1	1,539.49	Sep 1	1,606.19
Feb 1	1,568.18	Jun 1	1,580.65	Oct 1	1,599.43
Mar 1	1,547.02	Jul 1	1,605.13	Nov 1	1,593.31
Apr 1	1,534.83	Aug 1	1,607.85	Dec 1	1,589.18

The minimum elevation is the minimum allowable reservoir elevation where discretionary discharges are permitted. When performing the Skagit Operations Model's hourly computations, if elevations are forecast to drop below this level, the Skagit Operations Model will reduce powerhouse discharges to keep the elevation above the minimum elevation. The elevation can be specified based on operation regulations or by a physical limit (lowest available outlet invert). In the Skagit Operations Model, by default, certain Project discharges are allowed to draw the reservoir below this minimum level, which are wicket gate leakage, bypass flows, withdrawals, and evaporation.

Minimum elevations can vary by time of year and are entered into the Skagit Operations Model based on day of the year, where the Skagit Operations Model will linearly interpolate between user-entered values. Minimum elevation data entered into the Skagit Operations Model based on City Light historical operation data for the period January 1, 1997 through December 31, 2020, adjusted to NAVD 88 datum, and the Pre-Application Document (PAD) Table 3.4-1 Maximum Drawdown entry.

Minimum elevations in the Skagit Operations Model are set to 1,480.76 feet NAVD 88 for Ross Lake, 1,204.36 feet NAVD 88 for Diablo Lake, 831.51 feet NAVD 88 for Gorge Lake, and apply for each day of the year, except for the Verification scenarios which, to account for significant drawdowns, adjusts the minimum elevations to utilize the minimum of the historical minimum elevations or these elevations.

5.2.3.3 Minimum Flows

Minimum flow requirements can be defined as one of two categories: available for generation if a powerhouse is defined (minimum instantaneous flow), or a bypass flow (not available for generation in the main powerhouse).

There are no minimum flow conditions set in the Skagit Operations Model as they are either set to the historical daily operations for the Verification scenarios or are defined by the FishFlowFile for the Current Operations Baseline scenario.

5.2.3.4 Bypass Flows

Bypass flows are discharges or spills that are unavailable for generation using the primary generation equipment and may be flows spilled or discharged by other means. There are no bypass flow conditions set in the Verification and Current Operations Baseline scenario set ups.

5.2.4 Generation Settings

All unit performance information was computed and modeled based on the information available at the time of Skagit Operations Model development and refined during Skagit Operations Model development and verification.

5.2.4.1 Plant Flow Type

The Plant Flow Type Condition allows the modeler to specify whether powerhouse flows will normally be set to operate at the peak efficiency flows for the units in the powerhouse, or whether the units should be set to operate at the maximum flow value. Setting this condition to the former will result in more generation per water volume, while the latter setting will create more on-peak generation during high demand/peak periods.

To represent the current operation of the Project, the Ross Powerhouse and Diablo Powerhouse are set to operate as maximum flow plants, while Gorge Powerhouse is set to operate at peak efficiency. However, if the water is not available the model will operate the units at lower flow rates.

5.2.4.2 Maximum Output

Maximum output limits the maximum output power from the powerhouse. Output can be limited on a per-unit basis through the generator efficiency curves, or in this setting to limit overall power. The Skagit Operations Model has one limit to represent historical maximum output, where Gorge Powerhouse has a maximum output limit of 177 megawatts (MW) for the Verification and Current Operations Baseline scenario set ups, Ross and Diablo powerhouse output are limited based on the turbine performance inputs.

5.2.4.3 Headloss Coefficients

Headloss for each unit may consist of trashrack headlosses for each unit, plus individual headlosses for each unit. The Skagit Operations Model requires inputs of headloss as a coefficient that is based on the square of the flow value, with units "ft/cfs^2". Thus, as flow increases, headloss increases at an exponential rate. The Skagit Operations Model allows for three common headloss coefficients for the plant and an individual coefficient for each unit. Each turbine-generator has a unit-specific headloss coefficient, and the unit is associated with a common coefficient. Headloss for each unit is calculated by multiplying the unit's common coefficient by the total flow for that common conveyance squared added to the individual coefficient multiplied by the individual unit flow squared. The formula is included below:

$$H_i = \left(\sum_{j=1}^{n} F_j \right)^2 h_c + F_i^2 h_i$$

Where:

- H_i is the unit headloss in feet;
- h_c is the common coefficient for the i^{th} unit;
- h_i is the individual coefficient for the i^{th} unit;
- F_j is the flow for the j^{th} unit;
- J runs from 1 to n; and
- n is the number of units that have the same common conveyance as the unit i.

These headloss coefficients represent losses in different parts of the water conveyance from the forebay to the tailrace. The common coefficient represents the losses that apply to all units and are a function of the flows of all units online. Thus, the common portion of the headloss components are generally the losses from forebay contraction, trashrack constriction, and common portions of the conveyance behind the trashrack. Individual unit headloss components are the result of flows through the water conveyance of one individual unit only, such as water path direction change, pathway constriction, water velocity losses, and expansion in the draft tube.

Ross Powerhouse headlosses were estimated as 5 percent of the gross head. There are two conduits serving the powerhouse. The headloss for Units 41 and 44 were estimated using an individual headloss coefficient of 1.22E-06 and a common headloss of 1.68E-08. The Unit 42 and 43 headlosses were estimated using an individual headloss coefficient of 1.34E-06, and a common headloss of 1.68E-08.

Diablo Powerhouse headlosses were estimated based on Unit 31 performance testing completed in 1995. The Unit 31 and 32 headlosses were estimated using an individual headloss coefficient of 1.62E-06.

Gorge Powerhouse headlosses were estimated as based on available performance testing. There is a single conduit serving the powerhouse. The common headloss was estimated with a modeled common headloss coefficient of 9.82E-07. The headloss for Units 21, 22 and 23 were estimated using an individual headloss coefficient of 1.8E-06. The Unit 24 headloss was estimated using an individual headloss coefficient of 1.75E-07.

5.2.4.4 Turbine Efficiency Curves

Turbine performance was entered into the Skagit Operations Model by development as a relationship between flow and efficiency performance for five separate net heads for each unit. The estimated turbine performance for the developments is presented in Figures 5.2-14 through 5.2-22. These estimated performance curves show an expected change in performance (peak efficiency value and flow rate) at different heads.

Ross Powerhouse turbine performance data for Units 42 and 43 were developed from 1994 unit performance data, Unit 41 was developed from 1957 unit performance data, and Unit 44 was developed from 1954 unit performance data. Each unit was calibrated and verified against City Light historical operations records for the period January 1, 1997 through December 31, 2021. Calibration of unit performance included limiting maximum unit flow/output to simulate maximum total powerhouse output. The comparison of Skagit Operations Model unit performance against the Project historical operations data is summarized in Section 6.0 of this report.

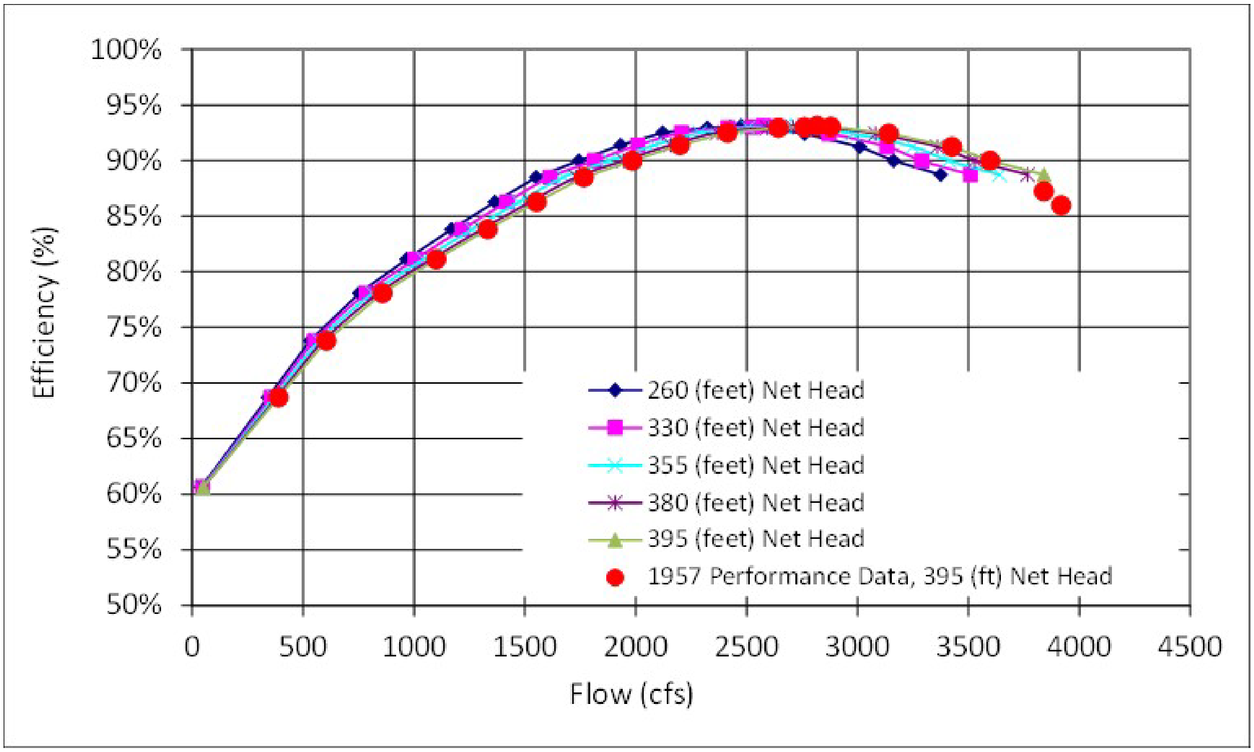

Figure 5.2-14. Ross Powerhouse Unit 41 turbine efficiency.

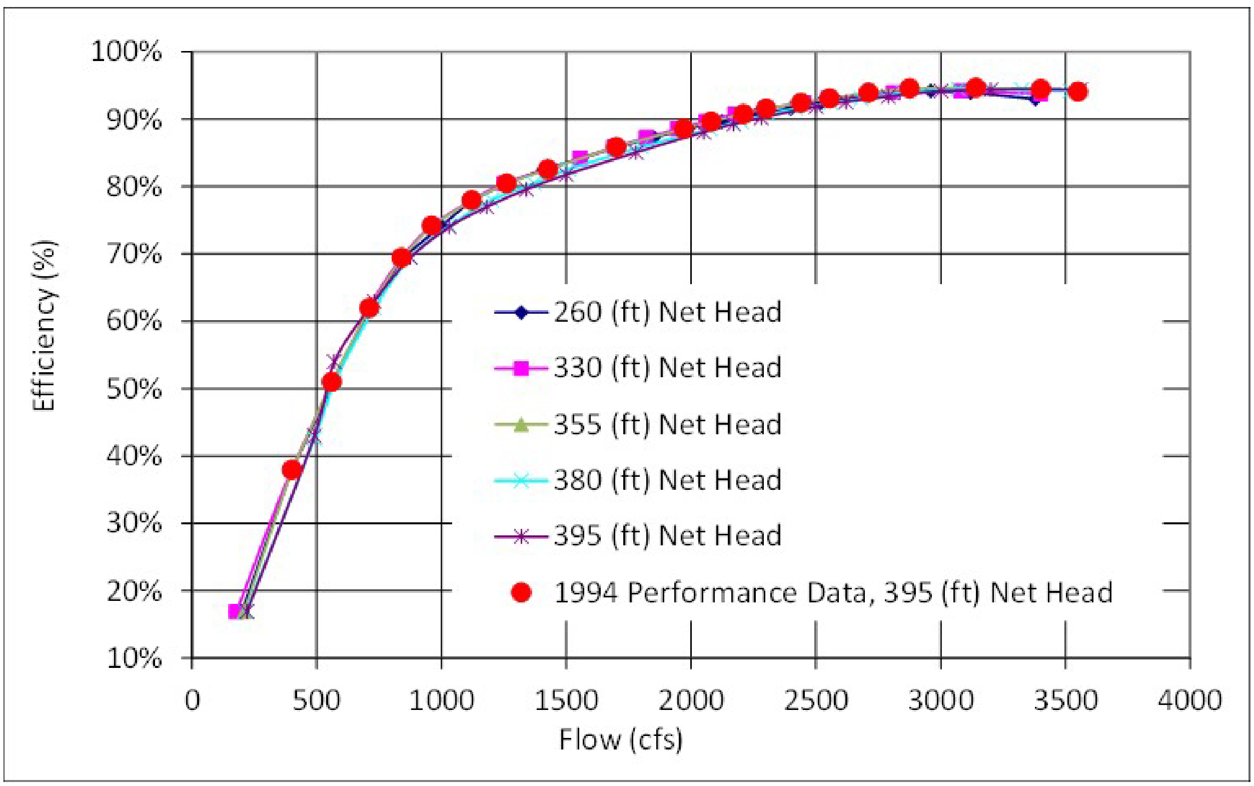

Figure 5.2-15. Ross Powerhouse Units 42 and 43 turbine efficiencies.

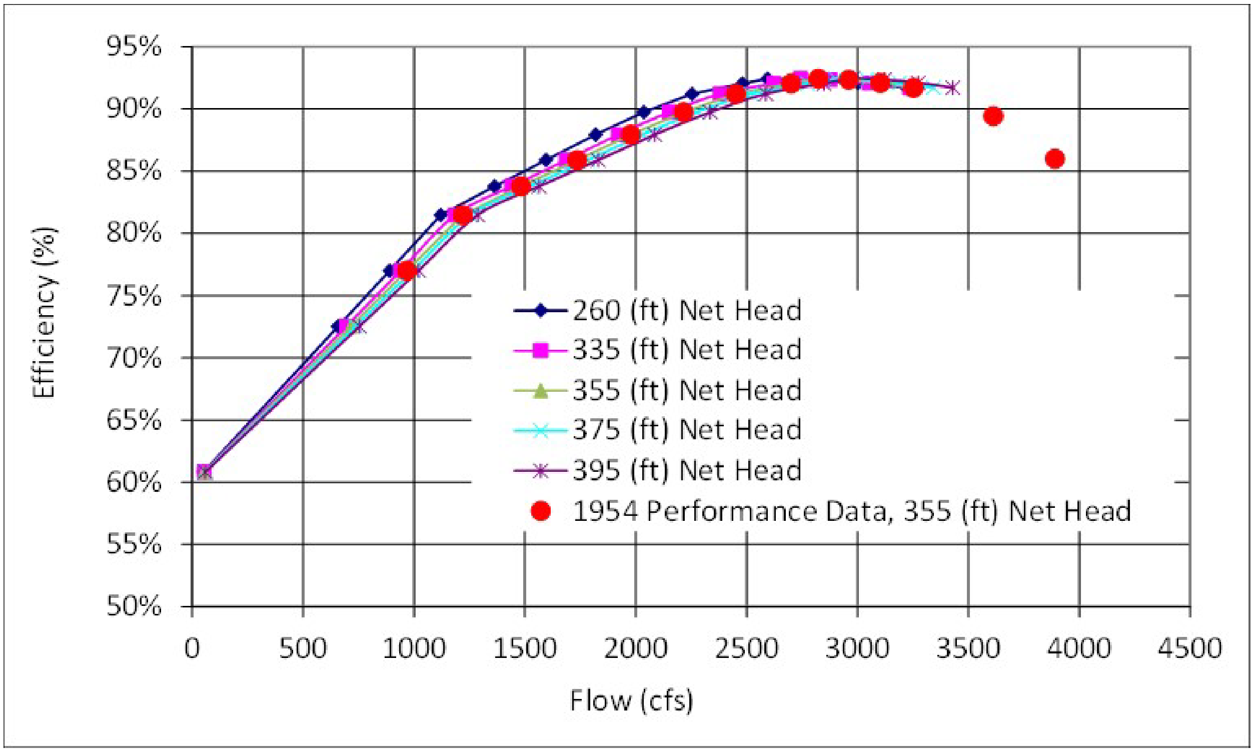

Figure 5.2-16. Ross Powerhouse Unit 44 turbine efficiency.

Diablo Powerhouse turbine performance data for Units 31 and 32 were developed from 1994-1995 unit performance data. Each unit was calibrated and verified against City Light historical operations records for the period January 1, 1997 through December 31, 2021. Calibration of unit performance included limiting maximum unit flow/output to simulate maximum total powerhouse output. The comparison of Skagit Operations Model unit performance against the Project historical operations data is summarized in Section 6.0 of this report. The efficiency of the Diablo Powerhouse minimum flow units, Units 35 and 36, was estimated to range from 70 percent at a flow of 40 cfs to 80 percent at 60 cfs.

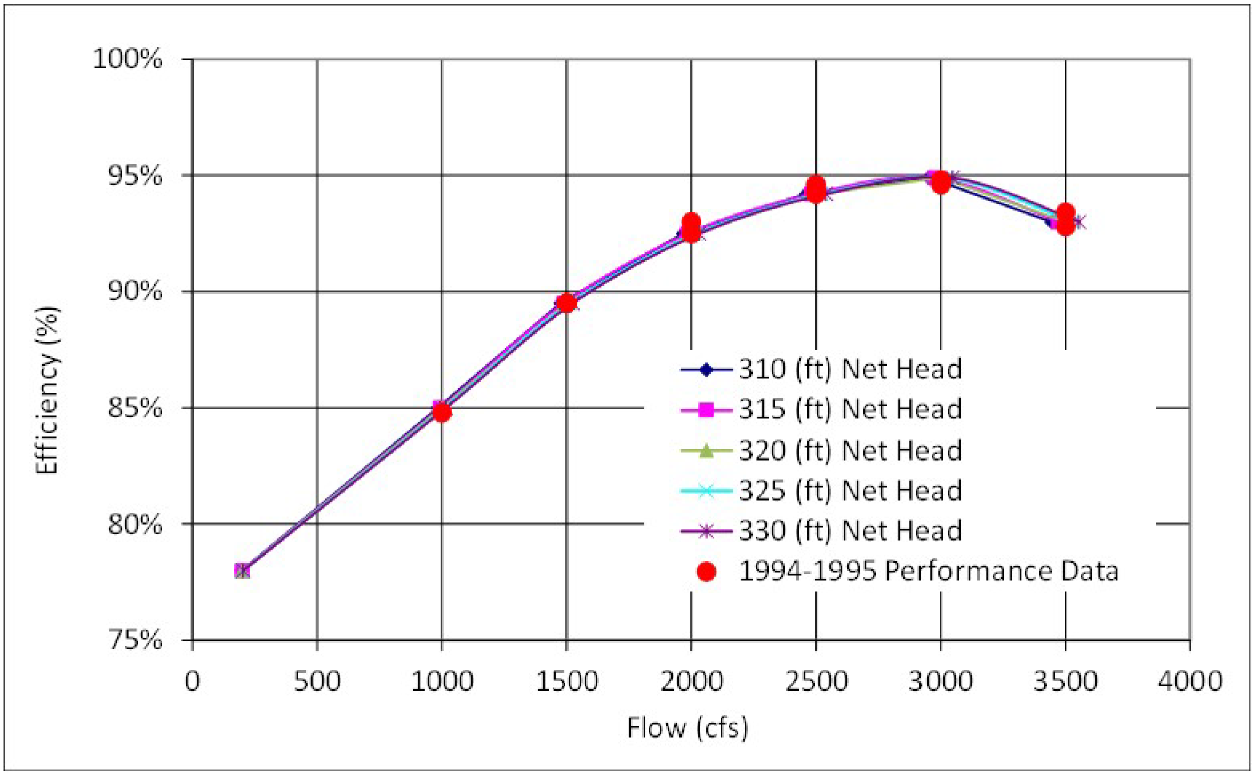

Figure 5.2-17. Diablo Powerhouse Units 31 and 32 turbine efficiencies.

Gorge Powerhouse turbine performance data for Units 21 through 24 were developed from unit index test data. Each unit was calibrated and verified against City Light historical operations records for the period January 1, 1997 through December 31, 2021. Calibration of unit performance included limiting maximum unit flow/output to simulate maximum total powerhouse output. The comparison of Skagit Operations Model unit performance against the Project historical operations data is summarized in Section 6.0 of this report.

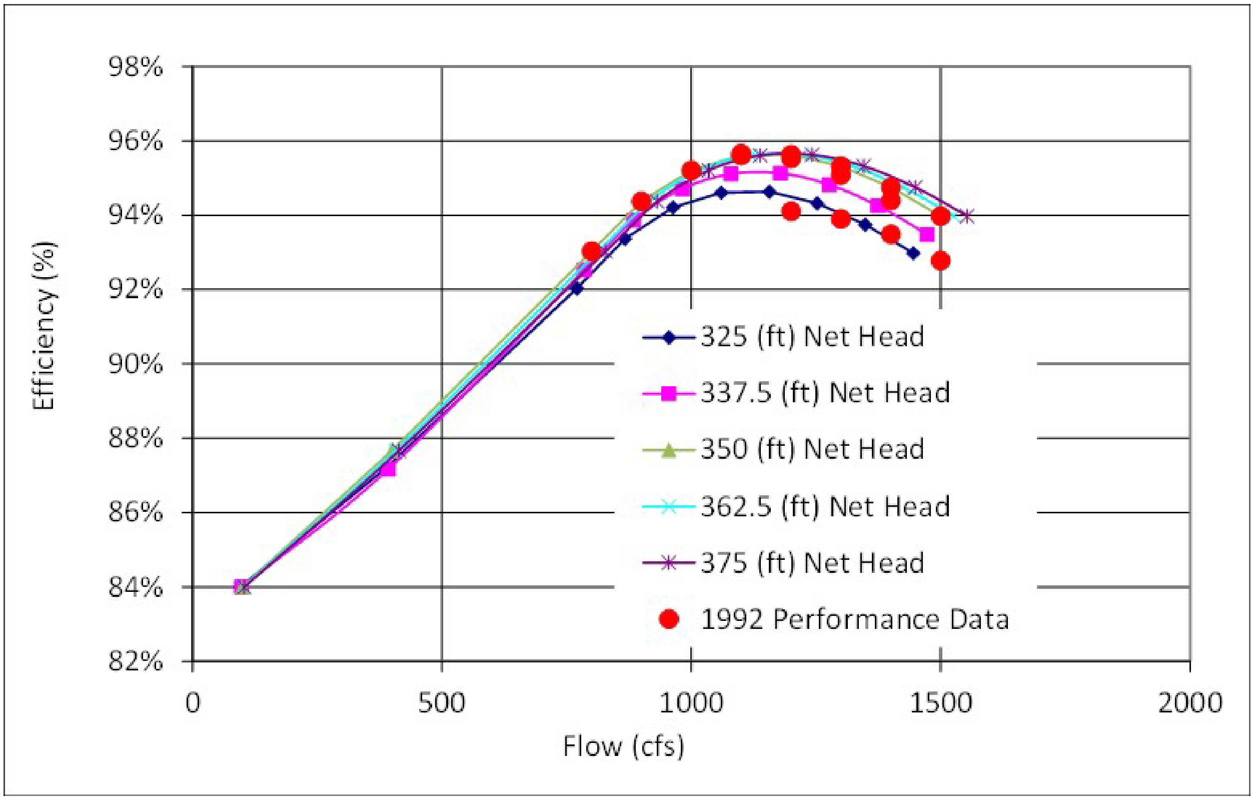

Figure 5.2-18. Gorge Powerhouse Unit 21 turbine efficiency.

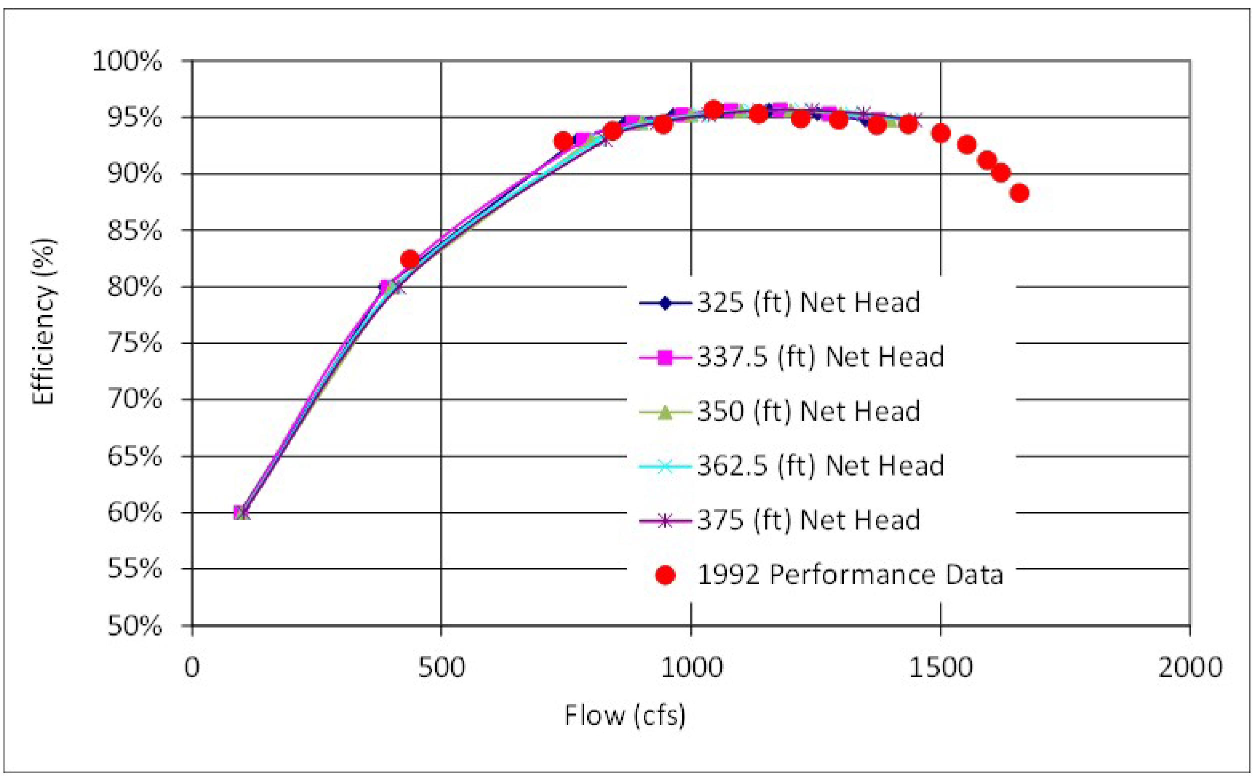

Figure 5.2-19. Gorge Powerhouse Unit 22 turbine efficiency.

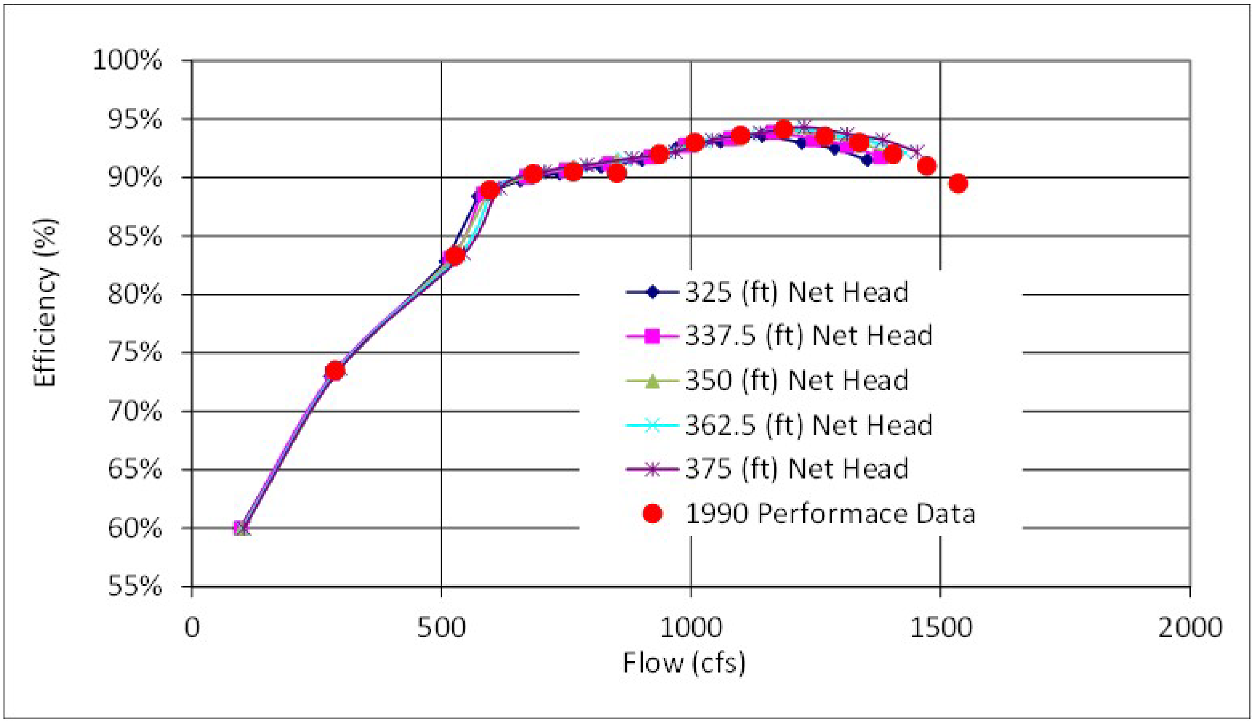

Figure 5.2-20. Gorge Powerhouse Unit 23 turbine efficiency.

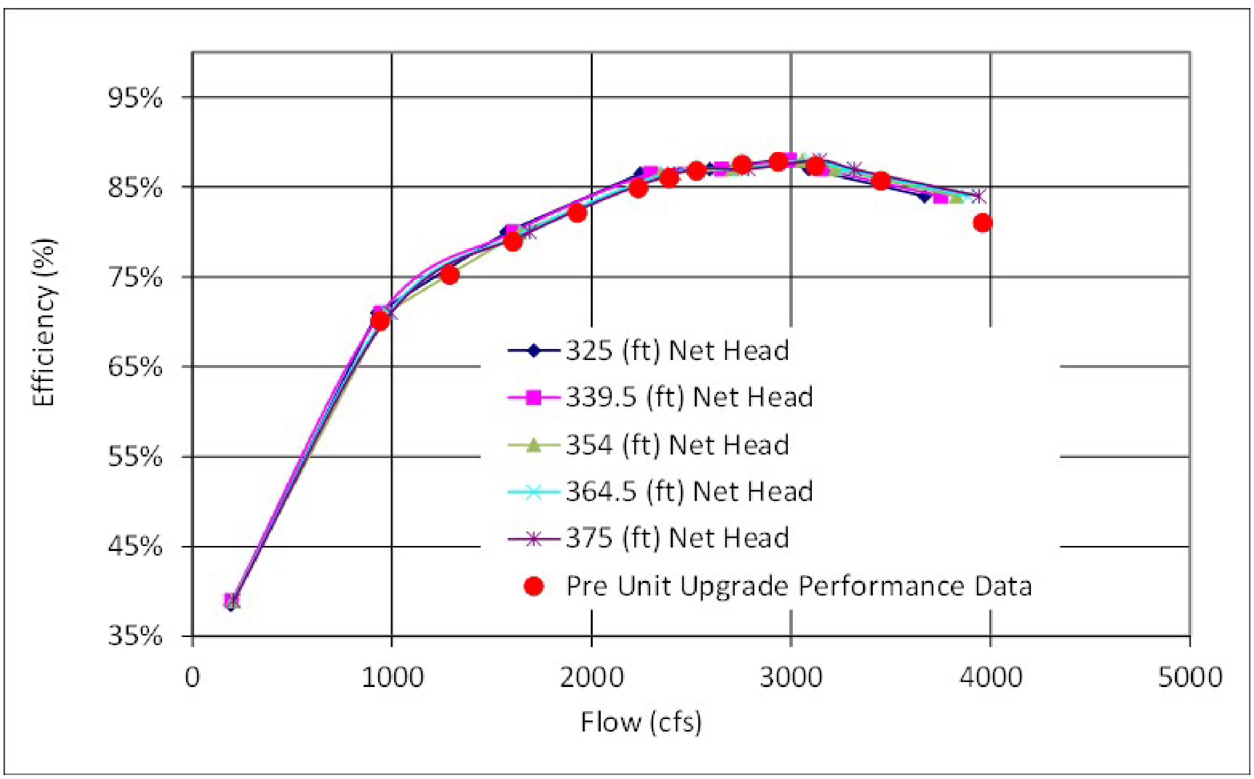

Figure 5.2-21. Gorge Powerhouse Unit 24 pre-upgrade turbine efficiency.

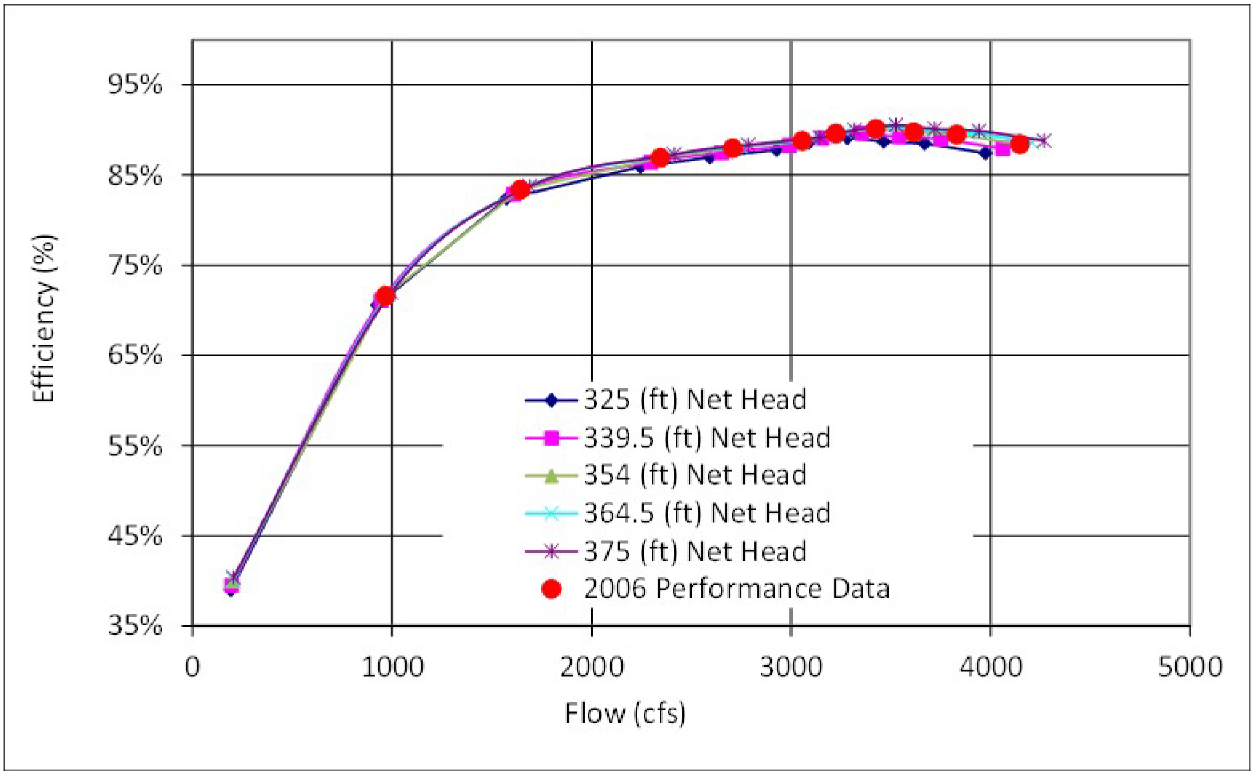

Figure 5.2-22. Gorge Powerhouse Unit 24 post-upgrade turbine efficiency.

5.2.4.5 Generator Efficiency Curves

Generator data, like turbine data, is entered into the Skagit Operations Model by development and then associated with a unit. The generator performance data is a relationship of generator output versus generator efficiency. The generator condition includes a maximum generator output. This value is the maximum generator output the Skagit Operations Model allows, assuming there is turbine capacity to exceed this limit.

The generator performance curves are shown below in Figures 5.2-23 to 5.2-28.

Ross Powerhouse generator performance data was estimated from Unit 41 performance data and calibrated and verified against City Light historical operations records for the period January 1, 1997 through December 31, 2021. The same generator efficiency curve was applied to all of the Ross Powerhouse units, with varying maximum output based on the City Light historical operations data—118 MW for Units 41 and 42, 115 MW for Unit 43, and 113 MW for Unit 44. Calibration of unit performance included limiting maximum unit flow/output to simulate maximum total powerhouse outflow and extrapolating the performance curves down to 1 MW. The comparison of Skagit Operations Model unit performance against the Project historical operations data is summarized in Section 6.0 of this report.

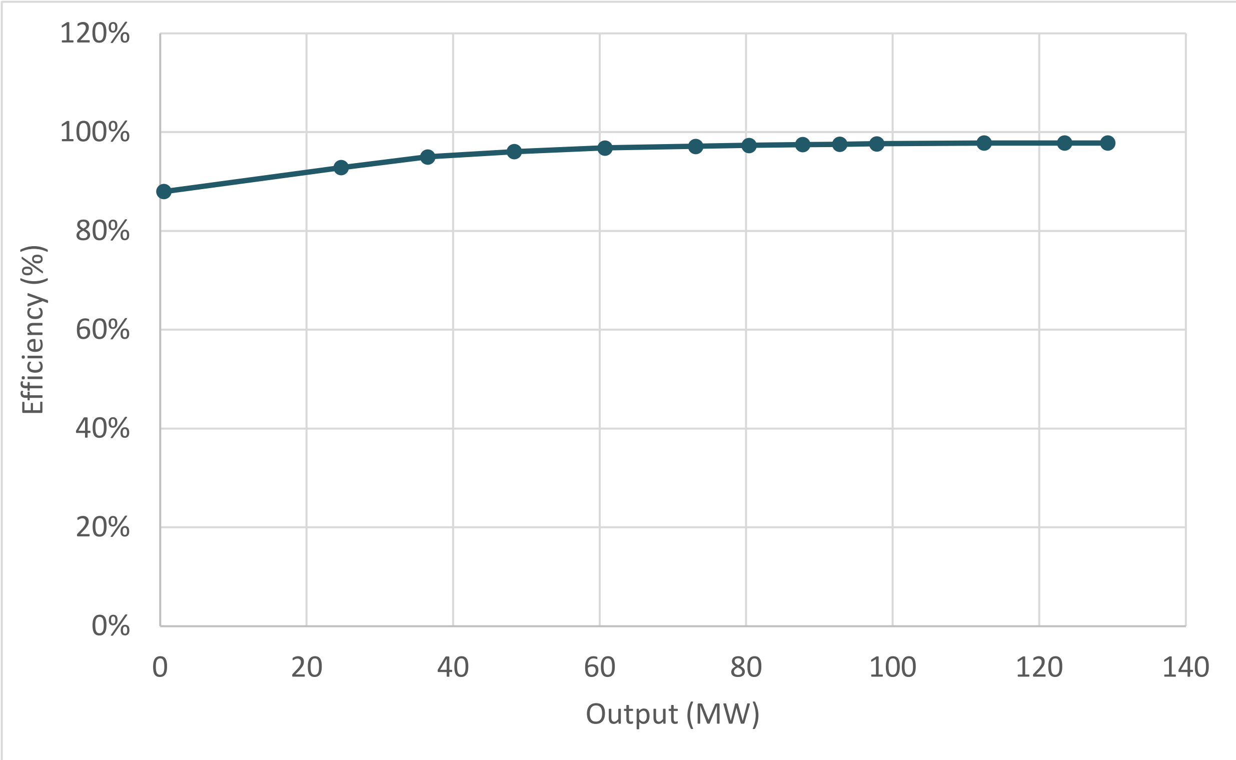

Figure 5.2-23. Ross Powerhouse Units 41 through 44 generator efficiency curve.

Diablo Powerhouse generator performance data was developed from 1994-1995 performance data and calibrated to the City Light historical operations records for the period January 1, 1997 through December 31, 2021. The same generator efficiency curve was applied to Diablo Powerhouse Units 31 and 32 with maximum output based on the City Light historical operations data of 92 MW. The efficiency of the Diablo Powerhouse minimum flow units, Units 35 and 36, was estimated to range from approximately 97.4 percent to 98.6 percent.

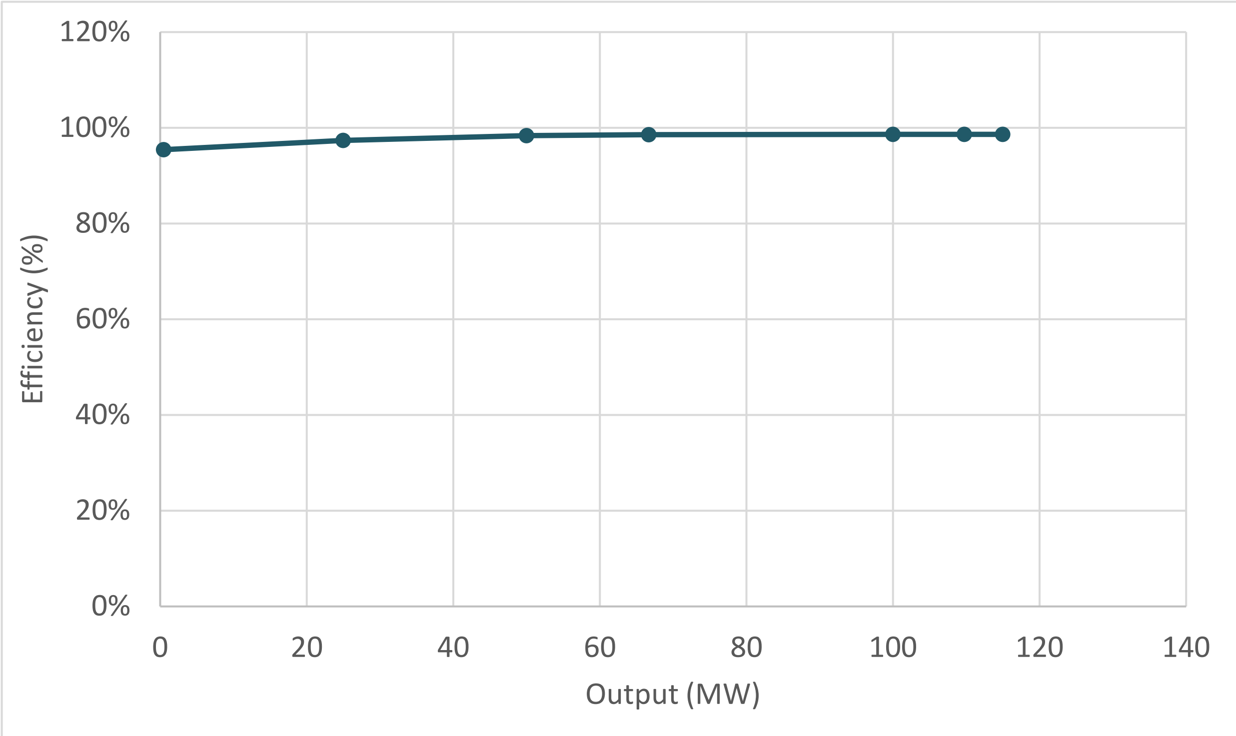

Figure 5.2-24. Diablo Powerhouse Units 31 and 32 generator efficiency curve.

Gorge Powerhouse generator performance data was developed from 1992 performance data for Units 21 and 22, 1990 performance data for Unit 23, pre and post 2006 turbine upgrade performance data for unit 24 and calibrated to the City Light historical operations records for the period January 1, 1997 through December 31, 2021: with a maximum output of 38 MW for Units 21 and 22, 36 MW for Unit 23, and the maximum output varying from 80 MW pre upgrade to 98 MW post upgrade for Unit 24. The Unit 24 performance curve was extrapolated down to 1 MW.

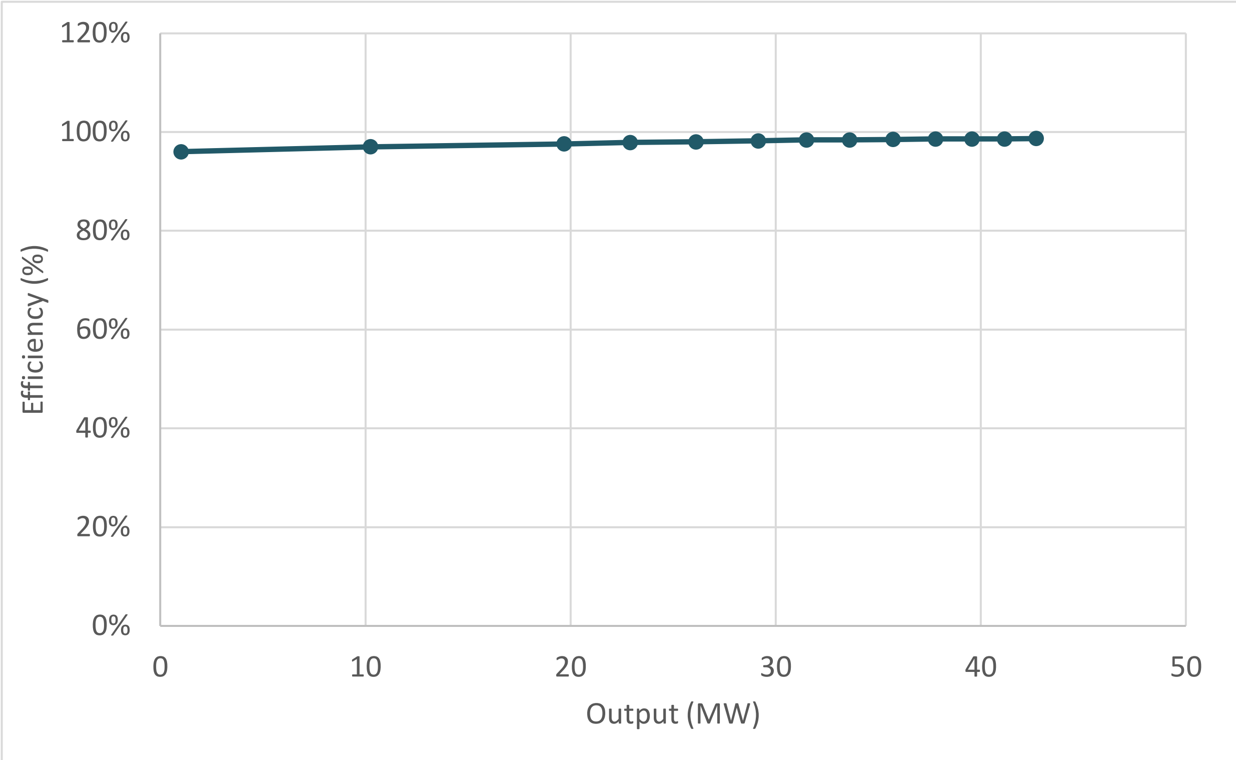

Figure 5.2-25. Gorge Powerhouse Unit 21 generator efficiency curve.

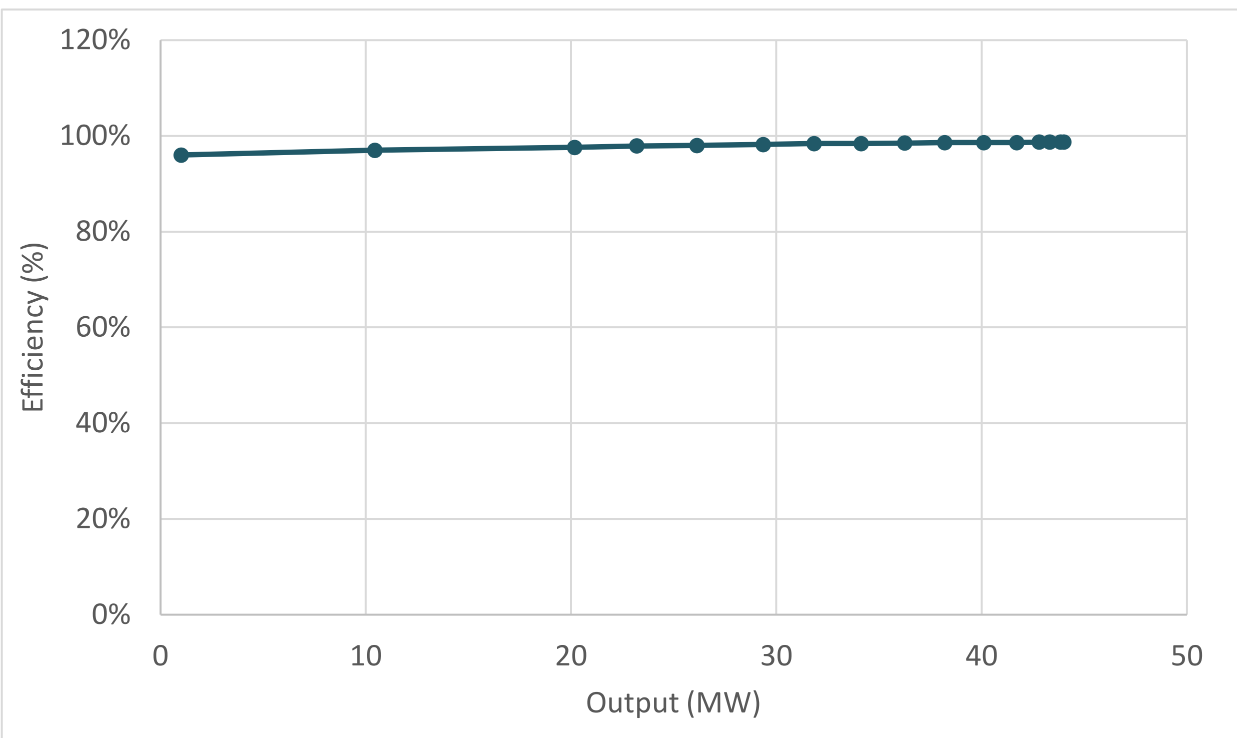

Figure 5.2-26. Gorge Powerhouse Unit 22 generator efficiency curve.

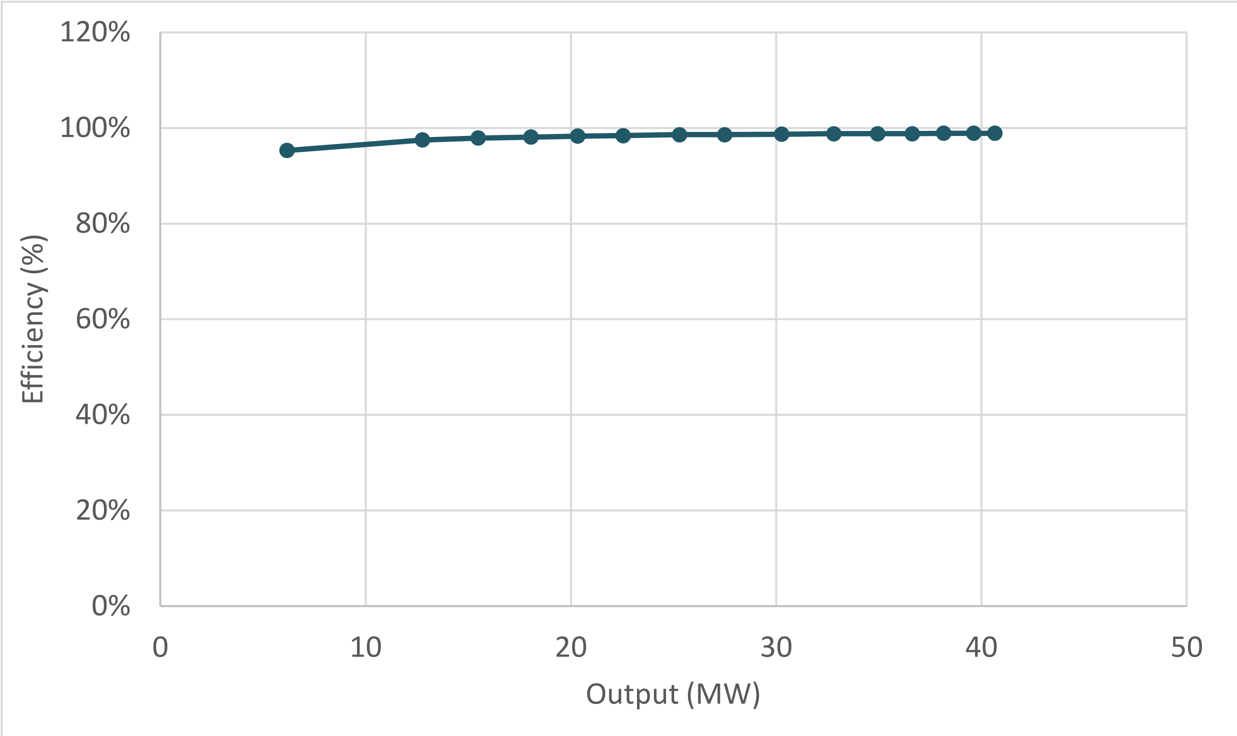

Figure 5.2-27. Gorge Powerhouse Unit 23 generator efficiency curve.

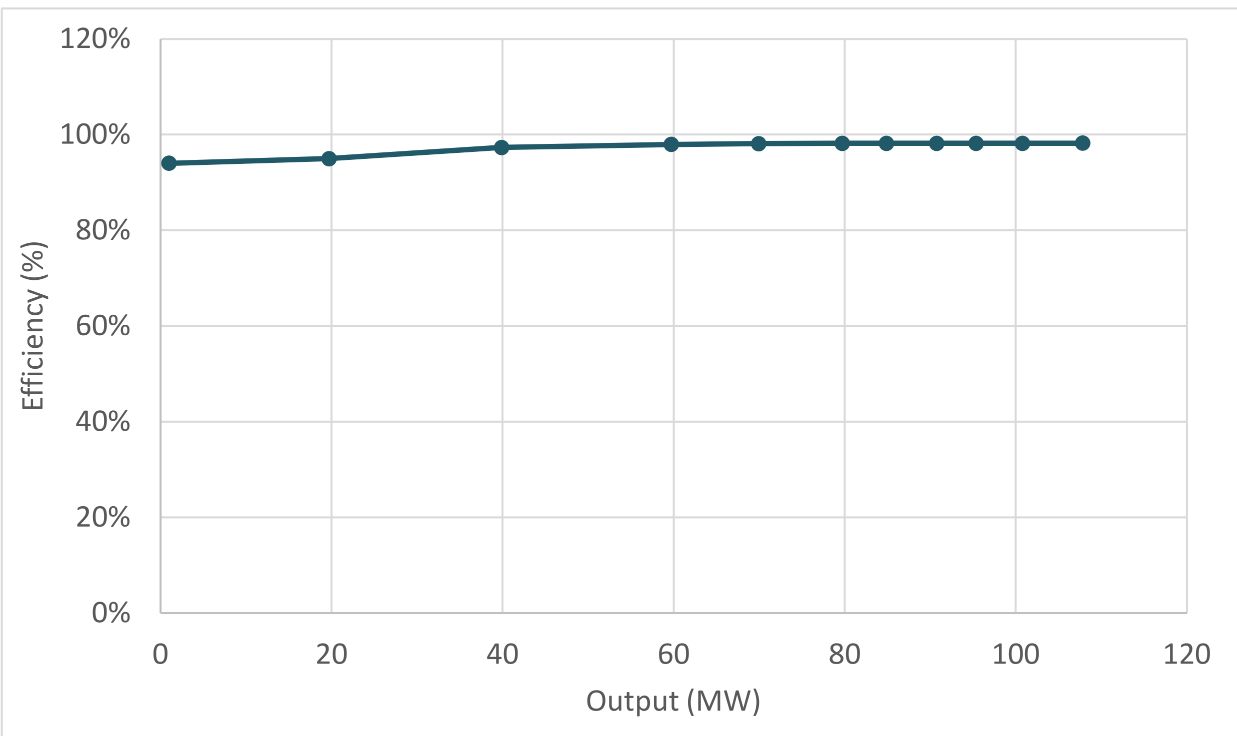

Figure 5.2-28. Gorge Powerhouse Unit 24 pre and post upgrade generator efficiency curve.

5.2.4.6 Unit Dispatch

The Skagit Operations Model uses the Unit Dispatch to compute generation based on the user-provided Powerhouse Setup data. The purpose of the Unit Dispatch is to produce a plant generation matrix or lookup table where plant generation (MW) is plotted against gross head and total plant flow. The Skagit Operations Model will use this lookup table to calculate plant generation in MW for every time-step.

By default, the Skagit Operations Model develops a Unit Dispatch Table based on the efficient combination of unit operation, this is referred to as default unit dispatch. The first step of the process is to generate a Unit Dispatch Table, so the Skagit Operations Model knows how to distribute flows between the units. This step is also referred to as producing the efficient unit dispatch solution based on the unit performance information entered into the Skagit Operations Model. The routines calculate the unit dispatch for each flow. The individual unit distribution is determined utilizing partial differential equations to arrive at the maximum possible generation for the given total plant release. As the plant dispatch routine increases the total plant flow, the Skagit Operations Model uses the previous Unit Dispatch distributions, as well as new distributions, to find the largest possible generation (efficient use of the water) given the plant release. The final result is a collection of flow distributions by unit for the entire range of plant operating flows.

To calculate total plant generation, the Unit Dispatch Table is used in combination with a span of gross operating heads to calculate plant generation utilizing total plant flow, flow distribution between the units, headloss for each unit, and the plant gross head.

The Skagit Operations Model also includes the functionality to develop a Unit Dispatch Table set to distribute water over all available units. This is referred to as even unit dispatch. As noted, development of the Skagit Operations Model (for both Verification and Baseline) included a review of the historical Project operations down to a unit-by-unit basis. This operations review showed significant variation in unit dispatching, or combination of units within a powerhouse for any given flow. The allocation of flow between units is important to the Skagit Operations Model as it impacts the efficiency of the units to generate. City Light operators noted that given the remote nature of the Project, the Ross Development especially, there are times that the units have been operated to limit unit shutdowns. This type of operation can result in a significant impact to the unit operational efficiency. For example, if a flow of 2,500 cfs is passed through a single Ross Powerhouse unit the turbine efficiency is greater than 90 percent, but if that same 2,500 cfs is distributed evenly across all four Ross Powerhouse units the efficiency drops by approximately 20 percent, which significantly impacts the resulting generation for any given flow. The review of historical unit dispatching did not indicate a clearly defined pattern or repetition of operation, rather it varied greatly, even from day to day. As such, part of the analysis outlined in this report includes varying the type of dispatching of Ross Powerhouse units to simulate the potential efficient operation versus evenly dispatching of the units.

5.2.4.7 Leakage

Gate leakage is the amount of water that leaks through the wicket gates when the turbine is offline. The Skagit Operations Model simulates the specified unit leakage flow through the unit when that unit is not generating. For instance, if the powerhouse has three units, each with gate leakage of 15 cfs, and Units 1 and 2 are operating while Unit 3 is off-line, then only Unit 3 is leaking 15 cfs.

When a unit is out for maintenance, its gate leakage is assumed to be negligible. Unit leakage was estimated to be 10 cfs for each of the Ross Powerhouse units; 15 cfs for Diablo Powerhouse units 31 and 32; 7 cfs for Gorge Powerhouse units 21, 22, and 23; and 25 cfs for Gorge Powerhouse Unit 24.

5.2.4.8 Maintenance

The maintenance schedule provides the functionality to take a unit out of service for all or part of each year for a scenario run. No maintenance-related outages were simulated in the Current Operations Baseline scenario. For the Verification scenarios, if a unit was not operated historically, then it was also not operated for the same day in the Verification scenarios.

6.0 MODEL CALIBRATION AND VERIFICATION

Verification was performed to validate the Skagit Operations Model input data and logic so the Skagit Operations Model and the Current Operations Baseline scenario could be used as a tool to assist in evaluating water quantity distribution between the available water conveyances due to changes in model inputs, including various operational modifications and physical plant modifications. Skagit Operations Model verification was performed by comparing actual and model-estimated generation for each powerhouse, as well as comparing the modeled total Skagit River flow at Gorge Powerhouse tailrace to the outflow from Gorge Powerhouse calculated from USGS reported flows (USGS 12178000 Skagit River at Newhalem gage downstream of Gorge Development). A 24-year period of January 1, 1997 through December 31, 2020 was utilized for simulation of the Skagit Operations Model Verification scenarios. This 24-year period represents the period of available historical operations data, where City Light's Oracle data collection system was in place during this period. The Oracle data collection system contains historical reservoir and powerhouse operations records on an hourly basis.

The primary purpose of the Verification scenarios is to apply specific historical data in order to quantify (verify) the ability of the Skagit Operations model to perform its intended functions and simulate actual recorded historical operations of the developments. Generation data is typically available for hydropower developments and is a metered value that has good accuracy compared to other forms of data that are not metered or are based on estimated values with lower accuracy. Modeled generation is a function of flow available for generation, head, and storage volume, which relates to inflows and reservoir elevations. When performing verification of water quantity models with power generation, it is not unusual to find discrepancies between observed data and modeled output for generation and reservoir elevation when looking at a small sample of time periods (day, week, or month). This is due to the difference between the set of rules used to represent operations in the Skagit Operations Model versus the actual day-to-day decisions common in power developments that respond to power grid demands as well as storm forecasts and other non-measured impacts on the reservoir and equipment. Modeled results from the Verification scenarios were compared with historical generation, and reservoir levels for relatively recent years, representative of current operating conditions.

The Skagit Operations Model was coded to simulate daily operations based on a single set of operating conditions or rules which are a closest-possible match to actual, historical operations. Although actual Project operations generally follow the operating rules, day-to-day conditions such as forced/unforced outages, equipment performance, maintenance activities, changing hydrologic conditions, power demands, and other factors necessitate human intervention in proactive or reactive response to such real-time conditions such that actual operations do not always follow any single set of conditions or rules which may be used in a model.

6.1 Summary of Modeled Results versus Historical Data

Verification of the Skagit Operations Model was performed using historical operations data and the Verification scenarios, or model runs. The scenarios were performed to verify the Skagit Operations Model input data, logic, and conditions on a multiple-year basis, confirming CHEOPS™ operations closely simulate actual reservoir operations, releases, and generation.

6.1.1 Verification Scenarios

The Verification scenarios were established in the Skagit Operations Model following the historical operating requirements of the system by simulating daily changing target elevations to match historic elevations, historical reported spillway flows, and unit outages to simulate historical daily turbine operations. The intent of the Verification scenarios was to demonstrate the ability of the Skagit Operations Model to perform its intended functions and simulate actual recorded historical operations of the developments.

As previously noted, development of the Skagit Operations Model (for both Verification and Current Operations Baseline scenarios) included a review of the historical Project operations down to a unit-by-unit basis. This operations review showed significant variation in unit dispatching, or combination of units within a powerhouse for any given flow. The allocation of flow between units is important to the Skagit Operations Model as it impacts the efficiency of the units to generate. The actual historical operations of the units across the Project vary greatly, most significantly at Ross Powerhouse; therefore, an even unit dispatch functionality was also simulated for the Ross Powerhouse as part of the Skagit Operations Model verification.

To represent historical operations, the Verification scenarios presented in this report are based on the Current Operations Baseline scenario, with the additions or modifications outlined below:

- Gorge Development minimum instantaneous outflow of 1,800 cfs to simulate historical Gorge Powerhouse output;
- Daily changing target reservoir elevations to simulate historical operations;
- Daily spillway flow to simulate historical operations at each development;
- Varying Ross Powerhouse unit dispatching;
- Daily changing turbine outages at each development. If a unit was not operated historically, then it was also not operated for the same day in the Verification scenarios; and
- Unit 24 at Gorge Powerhouse was upgraded in 2006, so Verification scenarios were developed to represent pre- and post-upgrade performance for Gorge Powerhouse Unit 24. Pre-upgrade performance simulated 1997 through 2006 and post-upgrade 2007 through 2020.

The larger differences in annual generation between historical and simulated by the Verification scenarios are likely due to differences in estimated unit performance, unit dispatching operations, and actual inflows versus the modeled input series. Although similar over a longer period, when viewed on a monthly or annual basis, the timing and extent of runoff events can vary between the basins. As previously noted, the Verification scenarios were simulated under two unit dispatching regimes for Ross Powerhouse, as the operation of the Ross Powerhouse units varies most significantly. The default logic in the Skagit Operations Model is to operate the units at either peak efficiency or max capacity and to turn the units on and off to optimize for the efficient use of water through the units, however in actuality, the units were often operated at a point below peak efficiency leading to significant deviations in resulting generation. Figures 6.1-1 through 6.1-3 show the Ross Powerhouse output for the periods 1997 through 2020; 2000; and 2019. As shown in these figures the output from Ross Powerhouse varies significantly.

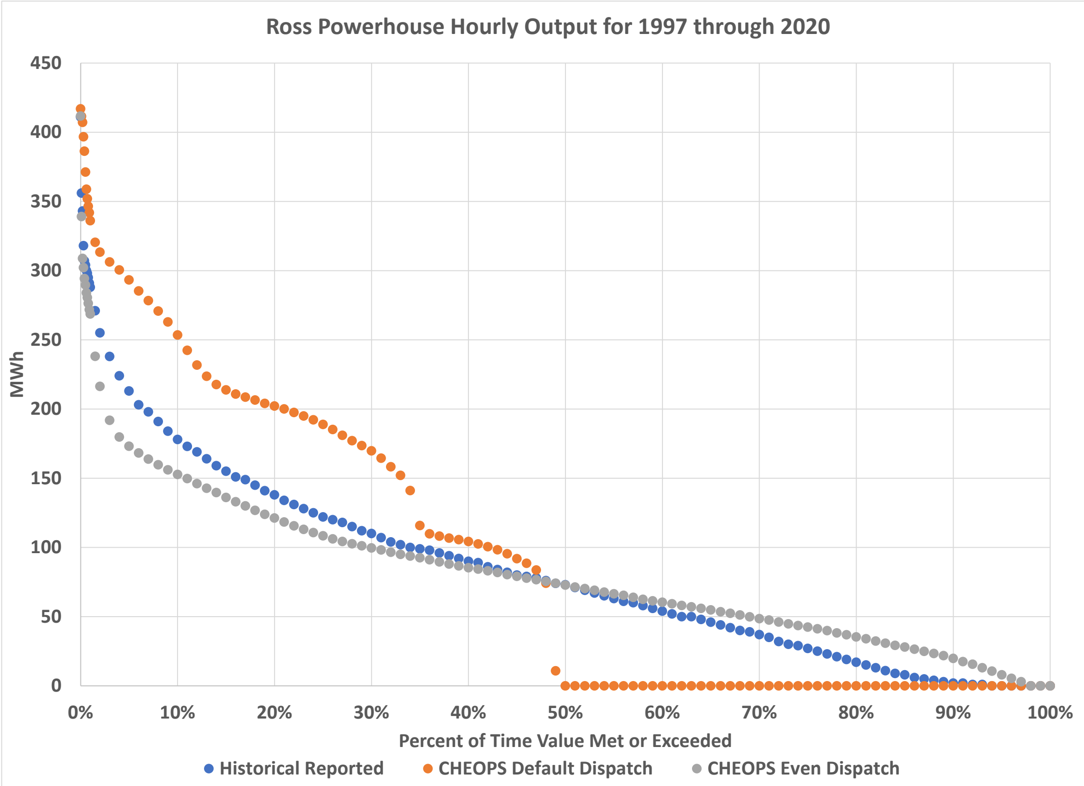

Figure 6.1-1. Ross Powerhouse output 1997 through 2020.

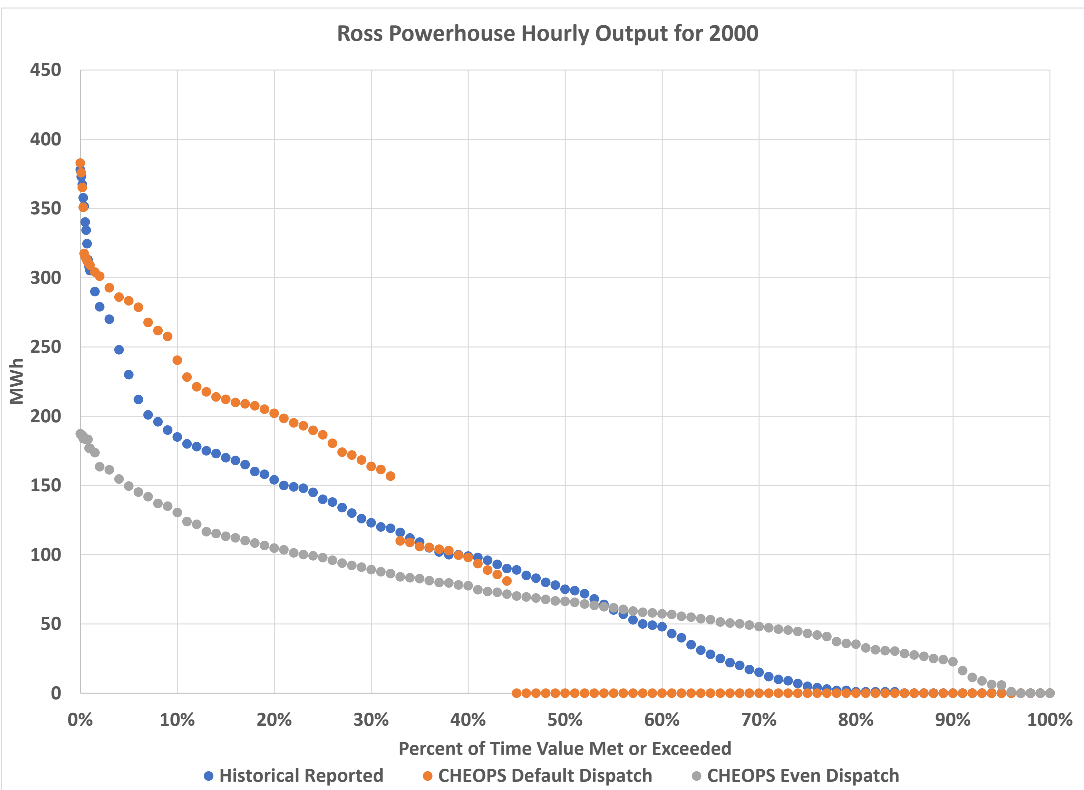

Figure 6.1-2. Ross Powerhouse output 2000.

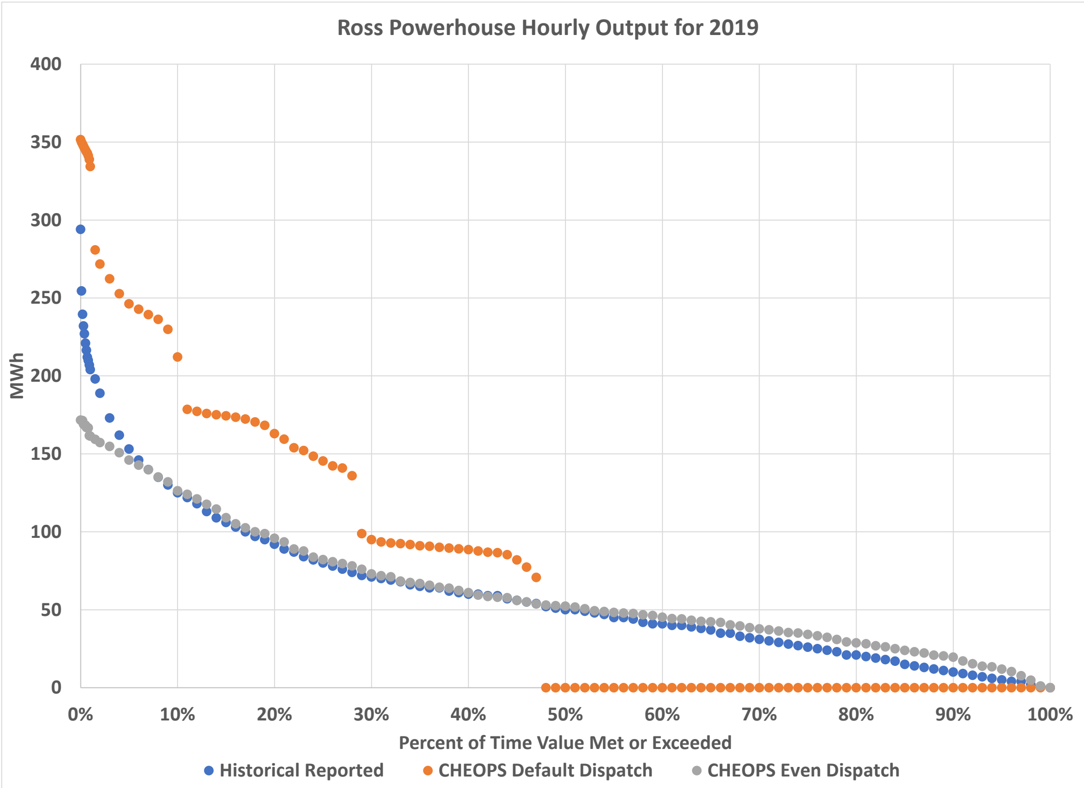

Figure 6.1-3. Ross Powerhouse output 2019.

As shown in Table 6.1-1, for the period of the Verification scenario runs, Ross Powerhouse was modeled to generate 801,585 MWh average per year under the default dispatch and 708,315 MWh under the even dispatch (or 10.3 percent more and -2.5 percent less than historical generation respectively for the same period).

At Diablo Powerhouse, as shown in Table 6.1-2, the Skagit Operations Model estimated generation of 805,540 MWh average per year under the default dispatch and 808,833 MWh under the even dispatch (or 3.1 percent and 3.5 percent more than historical generation respectively for the same period).

At Gorge Powerhouse, as shown in Table 6.1-3, the Skagit Operations Model estimated generation of 982,520 MWh average per year under the default dispatch and 982,144 under the even dispatch (or 2.8 percent and 2.8 percent more than historical generation respectively for the same period).

Appendix 3 contains graphical Skagit Operations Model output results with historical elevations and Gorge Development outflows. Appendix 3 shows good correlation (for both the even and default dispatch Verification scenarios) between the modeled reservoir and historical reservoir elevations, as well as the simulated Gorge Development Gross Outflow and the USGS Skagit River at Newhalem reported flows.

Table 6.1-1. Ross Powerhouse Verification generation comparison.

Year	Historical Generation (MWh)	Default Dispatch[1]		Even Dispatch[2]	
		Simulated Generation (MWh)	Percent Difference from Historical (%)	Simulated Generation (MWh)	Percent Difference from Historical (%)
1997	1,078,556	1,025,708	-4.9%	995,218	-7.7%
1998	610,158	622,641	2.0%	531,849	-12.8%
1999	962,413	964,130	0.2%	855,432	-11.1%
2000	741,712	738,749	-0.4%	622,711	-16.0%
2001	392,877	380,154	-3.2%	305,132	-22.3%
2002	837,228	829,202	-1.0%	727,800	-13.1%
2003	727,719	768,339	5.6%	650,858	-10.6%
2004	681,147	717,047	5.3%	635,770	-6.7%
2005	563,305	602,242	6.9%	506,256	-10.1%
2006	640,831	702,500	9.6%	619,805	-3.3%
2007	859,169	927,816	8.0%	840,784	-2.1%
2008	658,554	739,952	12.4%	653,188	-0.8%
2009	621,571	717,695	15.5%	624,757	0.5%
2010	647,906	763,504	17.8%	675,949	4.3%
2011	870,372	989,963	13.7%	914,540	5.1%
2012	939,857	1,030,774	9.7%	978,122	4.1%
2013	726,520	872,791	20.1%	778,976	7.2%
2014	796,575	979,460	23.0%	849,060	6.6%
2015	684,653	822,733	20.2%	731,426	6.8%
2016	791,484	959,185	21.2%	838,631	6.0%
2017	741,459	889,769	20.0%	771,084	4.0%
2018	690,008	820,410	18.9%	702,587	1.8%
2019	524,602	636,999	21.4%	545,379	4.0%
2020	655,496	736,281	12.3%	644,243	-1.7%
Average	**726,841**	**801,585**	**10.3%**	**708,315**	**-2.5%**

1 Scenario simulated with Ross, Diablo, and Gorge powerhouse units dispatched using default dispatch logic.
2 Scenario simulated with Ross Powerhouse units dispatched using even dispatch logic; Diablo and Gorge powerhouse units dispatched using default dispatch logic.

Table 6.1-2. Diablo Powerhouse Verification generation comparison.

Year	Historical Generation (MWh)	Default Dispatch[1]		Even Dispatch[2]	
		Simulated Generation (MWh)	Percent Difference from Historical (%)	Simulated Generation (MWh)	Percent Difference from Historical (%)
1997	1,064,565	1,021,195	-4.1%	1,030,951	-3.2%
1998	718,017	694,317	-3.3%	701,532	-2.3%
1999	1,022,487	978,401	-4.3%	994,987	-2.7%
2000	814,769	794,679	-2.5%	807,168	-0.9%
2001	477,609	475,161	-0.5%	478,884	0.3%
2002	900,251	870,090	-3.4%	877,211	-2.6%
2003	744,029	742,346	-0.2%	745,429	0.2%
2004	777,606	769,597	-1.0%	783,232	0.7%
2005	655,148	648,708	-1.0%	654,855	0.0%
2006	745,575	750,401	0.6%	755,850	1.4%
2007	834,979	846,486	1.4%	852,841	2.1%
2008	756,344	793,660	4.9%	802,460	6.1%
2009	691,560	744,267	7.6%	748,179	8.2%
2010	720,234	782,180	8.6%	788,556	9.5%
2011	920,967	980,859	6.5%	994,588	8.0%
2012	937,600	991,718	5.8%	994,331	6.1%
2013	828,224	891,063	7.6%	893,648	7.9%
2014	857,724	926,394	8.0%	933,265	8.8%
2015	775,016	848,986	9.5%	856,322	10.5%
2016	870,202	940,970	8.1%	947,539	8.9%
2017	692,900	745,509	7.6%	740,938	6.9%
2018	626,122	685,307	9.5%	650,924	4.0%
2019	611,029	667,299	9.2%	642,263	5.1%
2020	703,671	743,359	5.6%	736,033	4.6%
Average	**781,110**	**805,540**	**3.1%**	**808,833**	**3.5%**

1 Scenario simulated with Ross, Diablo, and Gorge powerhouse units dispatched using default dispatch logic.
2 Scenario simulated with Ross Powerhouse units dispatched using even dispatch logic; Diablo and Gorge powerhouse units dispatched using default dispatch logic.

Table 6.1-3. Gorge Powerhouse Verification generation comparison.

Year	Historical Generation (MWh)	Default Dispatch[1]		Even Dispatch[2]	
		Simulated Generation (MWh)	Percent Difference from Historical (%)	Simulated Generation (MWh)	Percent Difference from Historical (%)
1997	1,158,654	1,139,450	-1.7%	1,137,678	-1.8%
1998	860,632	827,555	-3.8%	827,267	-3.9%
1999	1,186,513	1,160,629	-2.2%	1,162,577	-2.0%
2000	959,811	940,975	-2.0%	940,827	-2.0%
2001	616,751	611,183	-0.9%	606,074	-1.7%
2002	1,025,289	1,018,401	-0.7%	1,018,025	-0.7%
2003	930,779	940,137	1.0%	938,883	0.9%
2004	923,759	927,029	0.4%	926,340	0.3%
2005	777,113	772,906	-0.5%	772,478	-0.6%
2006	872,061	894,995	2.6%	894,465	2.6%
2007	1,076,524	1,110,746	3.2%	1,110,833	3.2%
2008	916,816	966,055	5.4%	965,262	5.3%
2009	840,308	887,369	5.6%	887,475	5.6%
2010	871,682	931,262	6.8%	930,000	6.7%
2011	1,094,519	1,159,077	5.9%	1,161,033	6.1%
2012	1,081,322	1,147,487	6.1%	1,148,536	6.2%
2013	955,266	1,027,209	7.5%	1,027,285	7.5%
2014	1,057,836	1,113,204	5.2%	1,112,529	5.2%
2015	953,633	1,010,964	6.0%	1,007,022	5.6%
2016	1,036,509	1,092,302	5.4%	1,092,074	5.4%
2017	998,752	1,067,109	6.8%	1,076,588	7.8%
2018	946,975	1,003,861	6.0%	1,004,829	6.1%
2019	832,864	876,142	5.2%	868,150	4.2%
2020	958,183	954,435	-0.4%	955,216	-0.3%
Average	**955,523**	**982,520**	**2.8%**	**982,144**	**2.8%**

1 Scenario simulated with Ross, Diablo, and Gorge powerhouse units dispatched using default dispatch logic.
2 Scenario simulated with Ross Powerhouse units dispatched using even dispatch logic; Diablo and Gorge powerhouse units dispatched using default dispatch logic.

In addition to verifying that the Skagit Operations Model represents reservoir operations by comparing generation, the total river flow over the period of the Verification scenarios was also evaluated. The modeled total river flow at Gorge Powerhouse tailrace closely represents the USGS gage flow values. Table 6.1-4 shows the Verification scenarios modeled total river flow below Gorge Development with the calculated outflow from the Gorge Development calculated from USGS reported flows (as described in Appendix 1).

Table 6.1-4. Gorge Development discharge comparison.

Year	USGS Skagit River at Newhalem Based Gorge Outflow Volume (acre-feet)	Default Dispatch[1]		Even Dispatch[2]	
		Simulated Gorge Outflow Volume (acre-feet)	Percent Difference from USGS (%)	Simulated Gorge Outflow Volume (acre-feet)	Percent Difference from USGS (%)
1997	4,311,541	4,316,824	0.1%	4,317,044	0.1%
1998	2,644,763	2,644,362	0.0%	2,644,258	0.0%
1999	4,069,597	4,069,652	0.0%	4,069,561	0.0%
2000	3,038,428	3,038,101	0.0%	3,038,154	0.0%
2001	1,856,229	1,855,849	0.0%	1,855,811	0.0%
2002	3,441,426	3,442,345	0.0%	3,441,277	0.0%
2003	3,214,375	3,213,376	0.0%	3,214,429	0.0%
2004	3,004,636	3,003,911	0.0%	3,004,572	0.0%
2005	2,520,148	2,520,965	0.0%	2,520,009	0.0%
2006	3,031,120	3,031,469	0.0%	3,031,467	0.0%
2007	3,668,995	3,668,618	0.0%	3,668,786	0.0%
2008	3,120,661	3,120,709	0.0%	3,120,832	0.0%
2009	2,893,903	2,893,572	0.0%	2,893,506	0.0%
2010	2,968,249	2,967,985	0.0%	2,967,935	0.0%
2011	3,886,577	3,886,845	0.0%	3,886,865	0.0%
2012	4,139,861	4,139,720	0.0%	4,139,832	0.0%
2013	3,451,199	3,450,727	0.0%	3,450,630	0.0%
2014	3,884,408	3,883,629	0.0%	3,883,655	0.0%
2015	3,303,134	3,287,703	-0.5%	3,288,740	-0.4%
2016	3,675,062	3,674,813	0.0%	3,673,786	0.0%
2017	3,602,873	3,583,089	-0.5%	3,600,836	-0.1%
2018	3,490,361	3,467,009	-0.7%	3,489,454	0.0%
2019	2,738,236	2,781,518	1.6%	2,741,784	0.1%
2020	3,206,458	3,206,160	0.0%	3,206,039	0.0%
Average	**3,298,427**	**3,297,873**	**0.0%**	**3,297,886**	**0.0%**

1 Scenario simulated with Ross, Diablo, and Gorge powerhouse units dispatched using default dispatch logic.
2 Scenario simulated with Ross Powerhouse units dispatched using even dispatch logic; Diablo and Gorge powerhouse units dispatched using default dispatch logic.

7.0 CURRENT OPERATIONS BASELINE SCENARIO

In the modeling process, the existing requirements, physical conditions, and operating agreements are grouped together to create a Current Operations Baseline scenario against which varying alternatives are (will be) compared. The process of comparing back to a common baseline allows the determination of incremental or relative change of varying the scenario inputs while removing the effects of human intervention or operations outside of the norm. That is, the baseline scenario "locks down" the representation of operations as they exist today so as to clearly isolate and assess incremental or relative change resulting from adjusting various parameters as alternate scenarios are identified, run and compared to the baseline. The Current Operations Baseline scenario utilizes custom logic to simulate Project operation restrictions/requirements associated with spawning, incubation, stranding, and fry protection. These include the specific flow measures and ramping rate restrictions included in the Project license as amended in 2013 and the Revised FSA Flow Plan.

In addition to the fishery flow logic, this code also includes logic to forecast the inflows to Ross Lake for determination of the Ross Lake drawdown and refill schedule. Appendix 4 contains graphical Model output results with historical elevations and Gorge Development outflows. Appendix 4 shows the Current Operations Baseline scenario to have good correlation to the historical Project reservoir and flow operations. The Current Operations Baseline scenario, which will be the basis for comparison of all subsequent Skagit Operations Model scenarios, was expected to vary more from historical generation than the Verification scenarios, as this Baseline scenario assumes default unit dispatching and does not include historical unit outages. The CHEOPS™ even unit dispatch logic requires the plant to operate a daily average flow, with no flow fluctuation within the day. Therefore, the default dispatching regime was selected for the Current Operations Baseline as, though it may more efficiently simulate generation from flow, it represents the flow fluctuations that may occur from Ross Powerhouse within a day. Given the good correlation between historical and simulated Gorge Powerhouse outflow, the historical variation in unit dispatching, as discussed in the verification, as well as unit outages are the major contributing factors in the significant differences between the simulated Current Operations Baseline and historical generation. The deviations between the simulated and actual drawdown/refill of Ross Lake are most likely due to the difference in actual forecasted inflows and the model simulation of inflow forecasts.

Tables 7.0-1, 7.0-2 and 7.0-3 show a comparison of the simulated Current Operations Baseline generation compared to the historical generation for the same period. The period of January 01, 2012 through December 31, 2021 was selected as it represents the period since the current operational requirements went into place. Table 7.0-4 shows a comparison of the historical Gorge Development outflow to the Gorge Development outflow estimated from USGS gage data, as outlined in Appendix 1.

Table 7.0-1. Ross Powerhouse Current Operations Baseline generation comparison.

Year	Historical Generation (MWh)	Simulated Generation Default[1] Dispatch (MWh)	Default Dispatch[1] Percent Difference from Historical (%)
2012	939,857	1,033,575	10.0%
2013	726,520	953,916	31.3%
2014	796,575	954,704	19.9%
2015	684,653	835,965	22.1%
2016	791,484	992,268	25.4%
2017	741,459	894,199	20.6%
2018	690,008	905,474	31.2%
2019	524,602	623,231	18.8%
2020	655,496	875,277	33.5%
Average	**727,850**	**896,512**	**23.2%**

1 Scenario simulated with Ross, Diablo, and Gorge powerhouse units dispatched using default dispatch logic.

Table 7.0-2. Diablo Powerhouse Current Operations Baseline generation comparison.

Year	Historical Generation (MWh)	Simulated Generation Default[1] Dispatch (MWh)	Default Dispatch[1] Percent Difference from Historical (%)
2012	937,600	914,120	-2.5%
2013	828,224	893,033	7.8%
2014	857,724	886,385	3.3%
2015	775,016	828,168	6.9%
2016	870,202	939,465	8.0%
2017	692,900	849,025	22.5%
2018	626,122	876,132	39.9%
2019	611,029	666,796	9.1%
2020	703,671	860,934	22.3%
Average	**766,943**	**857,118**	**11.8%**

1 Scenario simulated with Ross, Diablo, and Gorge powerhouse units dispatched using default dispatch logic.

Table 7.0-3. Gorge Powerhouse Current Operations Baseline generation comparison.

Year	Historical Generation (MWh)	Simulated Generation Default[1] Dispatch (MWh)	Default Dispatch[1] Percent Difference from Historical (%)
2012	1,081,322	1,112,124	2.8%
2013	955,266	1,077,082	12.8%
2014	1,057,836	1,084,698	2.5%
2015	953,633	998,530	4.7%
2016	1,036,509	1,121,845	8.2%
2017	998,752	1,043,527	4.5%
2018	946,975	1,071,227	13.1%
2019	832,864	838,860	0.7%
2020	958,183	1,054,333	10.0%
Average	**980,149**	**1,044,692**	**6.6%**

1 Scenario simulated with Ross, Diablo, and Gorge powerhouse units dispatched using default dispatch logic.

Table 7.0-4. Gorge Development Current Operations Baseline discharge comparison.

Year	USGS Skagit River at Newhalem Based Gorge Outflow Volume (acre-feet)	Simulated Gorge Outflow Volume Default Dispatch[1] (acre-feet)	Default Dispatch[1] Percent Difference from USGS (%)
2012	4,139,861	4,018,865	-2.9%
2013	3,451,199	3,571,287	3.5%
2014	3,884,408	3,787,030	-2.5%
2015	3,303,134	3,256,193	-1.4%
2016	3,675,062	3,686,274	0.3%
2017	3,602,873	3,548,315	-1.5%
2018	3,490,361	3,561,070	2.0%
2019	2,738,236	2,552,957	-6.8%
2020	3,206,458	3,478,018	8.5%
Average	**3,499,066**	**3,495,557**	**-0.1%**

1 Scenario simulated with Ross, Diablo, and Gorge powerhouse units dispatched using default dispatch logic.

8.0 MODEL SUMMARY AND CONCLUSIONS

This report documents inputs and assumptions used in Skagit Operations Model development to demonstrate that the Skagit Operations Model characterizes operations of the system and is appropriate for use in evaluating the effects of alternative operating scenarios on generation, reservoir levels, and outflows from the Project. When applying the Skagit Operations Model for evaluating the effects of alternative operating scenarios on generation, it is important to consider the Skagit Operations Model was developed for application in an alternative operating scenario incremental analysis. Historically, unit dispatching operations have varied significantly, but the alternative operating scenarios will be simulated with a discrete rule set.

CHEOPS™ software and the Skagit Operations Model are tools to evaluate relative sensitivity and response of the system to changing operational constraints. The Skagit Operations Model is a tool and does not predict future conditions or outcomes. Skagit Operations Model results must be analyzed and interpreted based on knowledge of hydrologic and hydraulic principles and understanding of results viewed in a relative, rather than an absolute, context.

8.1 Conclusions

As discussed in Section 4, the Skagit Operations Model verification process includes comparisons between modeled output and historical data. The modeled release from the Gorge Development was compared to historical data to show the Skagit Operations Model describes and simulates Project's operations throughout the year (e.g., the timing, magnitude, and duration of operations).

As shown, the Skagit Operations Model can be configured to closely simulate long-term generation at the Skagit developments and is representative of historical operations. However, there are many factors inherent in the Skagit Operations Model data and setups that can contribute to output discrepancies (i.e., deviations) when compared to historical data. In many cases, several of these factors may be involved simultaneously, which makes it difficult to isolate individual sources of difference. Potential sources for deviations from historical data include actual discretionary reservoir operations versus simulated generic operations, including spillway discharges, estimated unit performance curves, unit dispatch, historical unit outages, hydrology, minimum flow requirements, and leakage:

- **Unit Performance** – The Skagit Operations Model was set up with available unit performance information, some of which dates back to the 1950s.
- **Unit Dispatch** - Significant variations in the dispatching of units has occurred historically, with the most significant variations occurring at Ross Powerhouse due to the remote nature of the powerhouse. However, the historical unit dispatching at both Diablo and Gorge powerhouses have been less than peak flow efficiency at times, which accounts for some of the deviations in the calculation of generation as compared to historical data.
- **Historical Unit Outages** – The Verification scenarios did take into account historical unit outage information. If a unit was not operated historically, then it was also not operated for the same day in the Verification scenarios, but the Skagit Operations Model keeps units out of service for an entire day. Actual power demand and generation likely varied from the entire-day rule set that the Skagit Operations Model follows, and the historical data indicated many days with unit operation for a couple of hours, or less.

- **Hydrology –** The Skagit Operations Model utilizes data from USGS gages as reference gages for calculation of inflow to the Project sub-basins. The overall hydrologic data set appears to represent inflow to the Project and is acceptable for use in alternative analyses. Although similar over a longer period, when viewed on a daily basis, the timing and extent of runoff events can vary between the sub-basins and lead to short-term variations in generation when compared to historical data.
- **Leakage –** Unit leakage was estimated for the Verification and Current Operations Baseline Skagit Operations Model scenarios.

In interpreting the information provided in this report, it is important to reflect on the purpose of the Skagit Operations Model: to characterize system operations and evaluate the effects of alternative operating scenarios on generation, reservoir levels, and outflows from the Project. Comparing Skagit Operations Model results with historical data confirms use of the Skagit Operations Model as a tool for simulating “real” operations.

Small changes in input data or Skagit Operations Model logic can often result in large swings in output. This is due to a number of reasons, including (but not limited to) runoff characteristics, reliance on coordinated operations, and numerous/variable flow requirements. Each of these elements individually contributes to the sensitivity of the system. Combined, they multiply that sensitivity exponentially. The input data and logic in the historical base scenario is an attempt to consolidate the effects of these variables to achieve an approximation of “characteristic operations.”

The sensitivity described above also means that those factors that are unable to be accounted for in the Skagit Operations Model (short-term operations decisions based on pricing, demand, forecasts, etc.) as well as data that is impossible to replicate exactly (synthesized hydrology data, outages, etc.), can result in relatively large discrepancies between modeled output and historical data on a per-month/per-development basis. The factors and sensitivity warrant careful Skagit Operations Model review with awareness of the potential for outliers. The ultimate acceptance of the results should not hinge on the extremes, but rather on the overall impression of consistency between modeled and historical operations. Particularly, it must always be foremost in model discussions that the Skagit Operations Model should be used to assess the relative impacts between scenarios. What this means is model verification is the only time it is appropriate to compare Skagit Operations Model results with historical data.

When considering the impact of significant variation in historical unit dispatching on generation, the Verification and Current Operations Baseline scenario results show the Skagit Operations Model compares well to historical data, characterizes system operations, and is appropriate for use in evaluating the effects of alternative operating scenarios on generation, reservoir levels, and outflows from the Project. However, appropriate use of the results is necessary. As with any model, accuracy is highly dependent on input data; consequently, model results should be viewed in a relative, rather than absolute, context. The Skagit Operations Model is a tool that, as this report demonstrates, can be successfully used to evaluate the relative sensitivity and response of the Project to changing operational constraints, including water demands from the system. The Skagit Operations Model was developed based on information available at the time of this report. Refinements to the model may be implemented if additional information becomes available.

9.0 REFERENCES

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OPERATIONS MODEL STUDY
SKAGIT OPERATIONS MODEL LOGIC AND VALIDATION REPORT

APPENDIX 1

USGS BASED HYDROLOGY CALCULATION SUMMARY MEMO

Memo

Date:	Tuesday, March 01, 2022
Project:	Skagit River Project FERC Relicensing
To:	Seattle City Light
From:	HDR
Subject:	USGS Based Hydrology Calculation Summary

1.0 INTRODUCTION

For this analysis, a hydrologic dataset of mean daily flows was developed for the period January 1, 1988 through December 31, 2020, utilizing available hydrologic data as compiled from U.S. Geologic Survey (USGS) gages in the vicinity and Skagit River Hydroelectric Project (Project) operations records. This hydrologic 33-year period of record (POR) was selected to provide hydrologic data for scenario simulation and the 24-year period of January 1, 1997 through December 31, 2020 for validation of the Skagit Operations Model. Figure 1 shows the location of the three dams and the key USGS gages utilized in this analysis.

All four of the sub-basins of interest in the Skagit River basin have hydrologic records influenced by the operation of Ross, Diablo, and Gorge Dams. Therefore, the hydrology of the study drainage area was developed from historical stream gage data utilized as surrogate or reference basins by applying one of two methodologies:

(1) The proration method which is a “straight line” or linear proration method based on drainage area; or

(2) The summation method which utilizes a regression relation and Project operations.

The proration method estimates flows for a region of interest by utilizing one or more reference basins with available representative data. The proration method gives an estimate of flows for a given watershed of interest by scaling the reference basin as follows:

$$Q_{target} = \left(\frac{A_{target}}{A_{reference}} \right) Q_{reference}$$

Where:

Q_{target} is the flow (cubic feet per second [cfs]) for the basin of interest;

$Q_{reference}$ is the flow (cfs) for the reference basin;

A_{target} is the drainage area (square miles) for the basin of interest; and

$A_{reference}$ is the drainage area (square miles) for the reference basin.

Flow data and basin drainage area sizes were taken directly from USGS gages where records were available, or by utilizing available Project records.

For the three reservoir sub-basins, the summation method incorporates the determination of inflows using the hydrologic water budget equation:

$$Qi = Qo + \Delta S + \text{losses}$$

Where the inflow (Qi) equals outflow (Qo) plus the change in storage (ΔS).

The historical evaporative losses are embedded in the streamflows reported by the utilized USGS Skagit River gages. An approximation of the average monthly historical evaporative losses was added into the mainstem Skagit gage flows to account for the historical evaporative losses. The monthly average losses were estimated utilizing the March 1984 through October 2015 TerraClimate estimated evaporation rates for Ross and Diablo from the study by Gang Zhao and Huilin Gao entitled Estimating reservoir evaporation losses for the United States: Fusing remote sensing and modeling approaches (Zaho and Gao 2019). Monthly average evaporative loss rates were calculated by averaging the available TerraClimate data and applying the monthly average loss rate to the reported historical daily reservoir surface area. The estimated reservoir evaporation varies from 0 to 1 cubic feet per second (cfs) for Gorge, 1 to 5 cfs for Diablo, and 4 to 56 cfs for Ross.

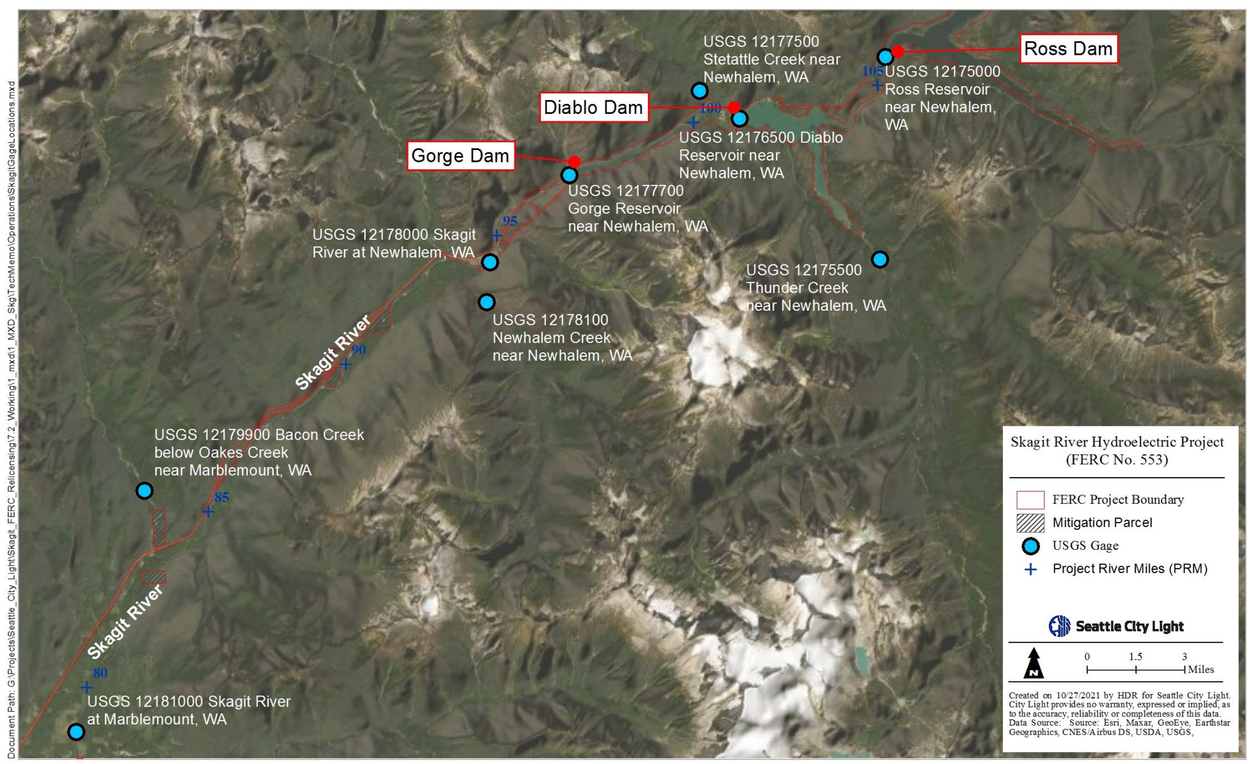

Figure 1. Key points of interest.

2.0 HYDROLOGY DEVELOPMENT

Development of the hydrologic data for the four sub-basins consisted of identification of available data and construction of a water balance for each area of interest. There are eight USGS gages along the mainstem of the Skagit River; however, only two of these gages (Skagit River at Marblemount and Skagit River at Newhalem) include flow records for the POR of January 1, 1990 through December 31, 2020. Table 1 summarizes the Skagit River USGS gages. Table 2 summarizes the USGS gages located on tributaries to the Skagit River utilized in this hydrologic analysis. The grayed text in both tables represent gages not used in this analysis.

Table 1. Skagit River USGS gages located on the Skagit River.

Gage Name	Gage Number	Drainage Area (sq. miles)	Productivity (cfs/sq. mile)	Period of Available Records	Missing Records through 12/31/2020
Skagit River at Marblemount	12181000	1,381	4.4	9/1/1943 - Present	7/8/1944 - 9/30/1946 9/30/1951 - 5/19/1976
Skagit River at Newhalem	12178000	1,184[1]	3.8	12/21/1908 - Present	6/1/1914 - 9/30/1920 12/1/2014 - 3/29/2015
Skagit River above Bacon Creek	12179800	1,289	3.8	4/27/1977 - 10/25/1983	10/9/1983 - 10/11/1983 10/15/1983 - 10/19/1983
Skagit River above Alma Creek	12179000	1,274	4.2	10/1/1950 - Present	10/1/1995 - 6/11/2020
Skagit River at Reflector Bar	12177000	1,125	3.6	12/1/1913 - 9/29/1922	
Skagit River below Ruby Creek	12174500	999	3.2	6/1/1919 - 9/29/1930	
Skagit River near Newhalem	12172500	765	3.5	3/1/1930 - 3/31/1940	
Skagit River above Devils Creek	12171500	655	2.3	4/1/1940 - 9/29/1945	

1 Updated based on USGS 12-digit Hydrologic Unit Code (HUC12) Watershed Boundary Dataset of Subwatersheds.

Table 2. USGS gages located on Tributaries to the Skagit River.

Gage Name	Gage Number	Drainage Area (sq. miles)	Productivity (cfs/sq. mile)	Period of Available Records	Missing Records through 12/31/2020
Bacon Creek below Oakes Creek	12179900	49.7	8.9	8/1/1943 - Present	9/30/1950 - 9/30/1998
Newhalem Creek near Newhalem	12178100	26.9	6.6	2/1/1961 - Present	
Stetattle Creek near Newhalem	12177500	22	8.4	1/1/1914 - 11/23/1983	5/1/1915 - 9/30/1933
Thunder Creek near Newhalem	12175500	105	5.9	10/1/1930 - Present	

2.1 Incremental Flow between Marblemount and Gorge Dam

The first step in calculating the total incremental flow between USGS Skagit River at Marblemount gage and Gorge Dam was to calculate the incremental flow between the two current Skagit River gages which are within this reach: USGS Skagit River at Marblemount gage, and USGS Skagit River at Newhalem gage.

There are also two tributaries to the Skagit River within this reach with gage records during the period of interest: USGS Bacon Creek below Oakes Creek gage, and USGS Newhalem Creek near Newhalem gage. There are also multiple other un-gaged tributaries.

The incremental flow between the USGS Skagit River at Marblemount gage and USGS Skagit River at Newhalem gage was calculated by subtracting the reported flow at the USGS Skagit River at Newhalem gage from the reported flow at the USGS Skagit River at Marblemount gage. This calculation resulted in zero or negative incremental flow for 1.1 percent of the time, or 127 days out of 12,054 days in the POR, with the negative difference ranging from 0.15 to 25.68 percent of the Marblemount gage flow and only 11 days exceeding a negative difference of more than 5 percent of the Marblemount gage flow. Potential sources for the calculated zero or negative incremental inflow, based on the daily average flow records of the USGS Skagit River at Marblemount gage and USGS Skagit River at Newhalem gage, include erroneous gage data, gage accuracy, flow timing and attenuation, and the loss of water due to evapotranspiration or infiltration to ground water.

Additionally, the USGS Skagit River at Newhalem gage is missing records for 119 days within the POR. To supplement the hydrologic data for these 246 days, incremental flows between the location of the USGS Skagit River at Marblemount gage and the USGS Skagit River at Newhalem gage were estimated by applying a monthly linear proration factor to the sum of the daily records for the USGS Newhalem Creek near Newhalem gage and USGS Bacon Creek below Oakes Creek gage. The monthly linear proration factor was calculated by applying a linear trend fit to monthly plots of the sum of the USGS Newhalem Creek near Newhalem gage and USGS Bacon Creek below Oakes Creek gage versus the USGS Skagit River at Marblemount gage minus USGS Skagit River at Newhalem gage. As shown in Table 3, the R^2 of these monthly linear fits to the data ranges from approximately 0.89 in September to 0.99 in May. The monthly linear trend fits to monthly plots of the sum of the USGS Newhalem Creek near Newhalem gage and USGS Bacon Creek below Oakes Creek gage versus the USGS Skagit River at Marblemount gage minus USGS Skagit River at Newhalem gage assumes a zero intercept.

Table 3. Inflow linear fit for modeling reach between Marblemount and Newhalem.

Month	Linear Equation	R^2	Month	Linear Equation	R^2
January	y = 2.54x	$R^2 = 0.96$	July	y = 2.21x	$R^2 = 0.97$
February	y = 2.59x	$R^2 = 0.96$	August	y = 2.16x	$R^2 = 0.94$
March	y = 2.61x	$R^2 = 0.96$	September	y = 2.29x	$R^2 = 0.89$
April	y = 2.63x	$R^2 = 0.98$	October	y = 2.14x	$R^2 = 0.95$
May	y = 2.43x	$R^2 = 0.99$	November	y = 2.51x	$R^2 = 0.95$
June	y = 2.34x	$R^2 = 0.98$	December	y = 2.58x	$R^2 = 0.95$

Figure 2 shows a comparison of the resulting estimated daily flows from applying the monthly linear fit to the sum of the USGS Newhalem Creek near Newhalem gage and USGS Bacon Creek below Oakes Creek gage versus the USGS Skagit River at Marblemount gage minus USGS Skagit River at Newhalem gage. This plot, and the monthly linear trend fits, are based on the period of USGS Bacon Creek below Oakes Creek gage available records: October 1, 1998 through December 31, 2020. The close relationship in the data, as shown in Figure 2, indicates that flow for 240 of the 246 days previously identified could be estimated by applying the monthly relationship shown in Table 3, where: y = the incremental flow between USGS Skagit River at Marblemount gage and USGS Skagit River at Newhalem gage, and x = sum of the reported flow for USGS Newhalem Creek near Newhalem gage and USGS Bacon Creek below Oakes Creek gage. The remaining 6 days of the 245 previously identified were interpolated from the adjoining daily flow records, as there were no Bacon Creek gage records for these six days.

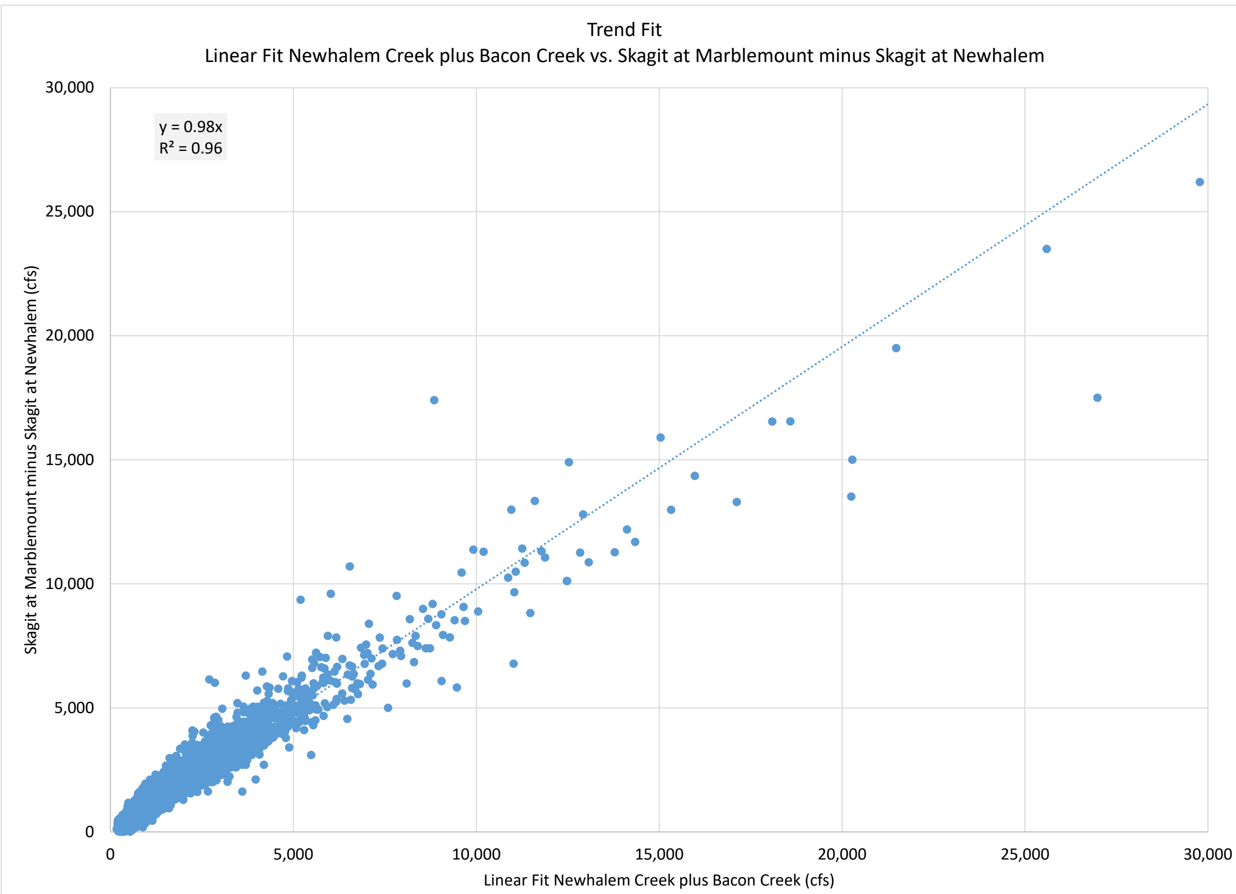

Figure 2. **Inflow polynomial fit for modeling reach between Marblemount and Newhalem.**

The incremental flow for the area between USGS Skagit River at Newhalem gage and Gorge Dam was calculated utilizing the proration method. The USGS Newhalem Creek near Newhalem gage flow was prorated by a factor of 0.45, which is based on a drainage area proration and calculated using the 12 square miles for the area between USGS Skagit River at Newhalem gage and Gorge Dam divided by the 26.9 square miles drainage area of the USGS Newhalem Creek near Newhalem gage. The total incremental inflow between USGS Skagit River at Marblemount gage and Gorge

Dam is the sum of the incremental flow between USGS Skagit River at Marblemount gage and USGS Skagit River at Newhalem gage and the incremental flow between USGS Skagit River at Newhalem gage and Gorge Dam.

2.2 Incremental Flow between Gorge and Diablo Dams

The Gorge Lake sub-basin includes Stetattle Creek and other small tributaries. A USGS gage does exist for Stetattle Creek (named Stetattle Creek near Newhalem); however, records ended in 1983. Given the lack of recent site-specific data, incremental inflows for the area between Gorge and Diablo Dams were estimated utilizing the proration method and a linear trend fit. Three comparisons were completed against the discontinued USGS Stetattle Creek near Newhalem gage to identify the best reference dataset for the Gorge Lake sub-basin.

First, the USGS gage records from the Newhalem Creek near Newhalem gage, which is a tributary entering the Skagit River in the reach below Gorge Dam, was compared to the USGS Stetattle Creek near Newhalem gage. These two datasets overlap for the period February 1, 1961 through November 23, 1983. For this period, the R^2 of a linear trend fit between the Newhalem Creek and Stetattle Creek records is approximately 0.95. Secondly, the incremental flow between Marblemount and Newhalem was extended for the period from September 1, 1943 through November 23, 1983, which is the period of overlap with the discontinued Stetattle Creek near Newhalem gage. Utilizing a linear trend fit with a zero intercept, for this period, the R^2 for Stetattle Creek gage and the incremental flow between Marblemount and Newhalem is approximately 0.87. Thirdly, the USGS gage records from the Thunder Creek near Newhalem gage, which is a tributary entering the Skagit River in the Diablo Lake sub-basin, were also compared to the USGS Stetattle Creek near Newhalem gage. These two datasets overlap for the period September 1, 1933 through November 23, 1983. For this period, the R^2 of a linear trend fit with a zero intercept between the USGS Thunder Creek and Stetattle Creek gage records is 0.77.

Given the correlation comparisons, incremental flows between the Gorge and Diablo Dams (Gorge Lake sub-basin) were estimated by applying a monthly linear based proration to the USGS Newhalem Creek near Newhalem gage data. Monthly linear equations, shown in Table 4, were developed by comparing the USGS Newhalem Creek near Newhalem gage data with the discontinued USGS Stetattle Creek near Newhalem gage data for the period September 1, 1943 through November 23, 1983, where: y = USGS Stetattle Creek near Newhalem gage flows, and x = USGS Newhalem Creek near Newhalem gage flows.

These linear relationships provided estimated flows at USGS Stetattle Creek near Newhalem gage, which had a drainage area of 22 square miles. These estimated flows were then prorated by a factor of approximately 1.68, which is based on a drainage area proration determined by dividing the 37 square miles watershed for the area between Gorge and Diablo Dams by the 22 square mile watershed area of the USGS Stetattle Creek near Newhalem gage.

Table 4. Inflow linear fit for modeling reach between Gorge and Diablo Dams.

Month	Linear Equation	R^2	Month	Linear Equation	R^2
January	y = 1.04x	$R^2 = 0.94$	July	y = 1.05x	$R^2 = 0.97$
February	y = 1.21x	$R^2 = 0.94$	August	y = 1.15x	$R^2 = 0.98$
March	y = 1.10x	$R^2 = 0.96$	September	y = 1.12x	$R^2 = 0.95$
April	y = 1.25x	$R^2 = 0.94$	October	y = 1.12x	$R^2 = 0.94$
May	y = 1.13x	$R^2 = 0.98$	November	y = 1.09x	$R^2 = 0.94$
June	y = 0.99x	$R^2 = 0.99$	December	y = 0.90x	$R^2 = 0.90$

2.3 Incremental Flow between Diablo and Ross Dams

The Diablo Lake sub-basin includes Thunder Creek and other small tributaries. The incremental flow for the area between Diablo and Ross Dams (Diablo Lake sub-basin) was calculated utilizing the proration method. Flow records for the USGS gage, Thunder Creek near Newhalem, were prorated by a factor of 1.21, which is based on a drainage area proration and was determined by dividing the 127 square mile watershed for the area between Diablo and Ross Dams by the 105 square mile watershed area of the USGS Thunder Creek near Newhalem gage.

2.4 Inflow to Ross Lake

The Ross Lake sub-basin includes several tributaries, including three which were historically gaged by the USGS (Lightning Creek, Ruby Creek, and Big Beaver Creek). However, none of these gages included records for the full POR.

Given the lack of site-specific gaged flows for the POR, the inflow to Ross Lake was calculated with the summation method utilizing data from the Skagit River at Newhalem gage, the calculated downstream incremental inflows, and the change in storage of the three reservoirs.

For the three reservoirs, the summation method incorporates the determination of inflows using the hydrologic water budget equation:

$$Qi = Qo + \Delta S$$

Where the inflow (Qi) equals outflow (Qo) plus the change in storage (ΔS).

The change in storage relies on historical reservoir elevations and the storage-elevation relationships for each reservoir. USGS data of reservoir water-surface elevations were used, except for the periods of missing Diablo data which were filled in with Project operations records. The USGS gages recording for the daily reservoir levels are: Gorge Reservoir near Newhalem, Diablo Reservoir near Newhalem, and Ross Reservoir near Newhalem.

The inflow to Ross Lake was calculated by subtracting the sum of the calculated incremental flow between USGS Skagit River at Newhalem gage (including the estimated Lake evaporation, as previously noted) and Gorge Dam, the calculated incremental flow for the area between Gorge and

Diablo Dams, the calculated incremental flow for the area between Diablo and Ross Dams, and the change in storage for the three reservoirs from the USGS Skagit River at Newhalem gage flow.

This summation method, which includes change in storage, resulted in 3 days in the POR where this summation method calculated negative inflow to Ross Lake. To account for the negative flow and the large swing in inflow, while still maintaining the overall water balance (not adding or subtracting volume), the inflow to Ross Lake was smoothed by applying a 3-day average of daily flows for the negative inflows, the averaged days included January 25, 1988 through January 27, 1988, May 7, 1988 through May 9, 1988, and March 7, 1988 through March 9, 1988.

3.0 REFERENCES

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OPERATIONS MODEL STUDY
SKAGIT OPERATIONS MODEL LOGIC AND VALIDATION REPORT

APPENDIX 2

CUSTOM LOGIC SUMMARY

Custom Logic Summary

The following summary briefly outlines the month-to-month logic coded into the model through the FishFlowFile to simulate Skagit River Hydroelectric Project operation restrictions/requirements associated with spawning, incubation, stranding, and fry protection. These include the specific flow measures and ramping rate restrictions included in the Project license as amended in 2013 and the Revised Fisheries Settlement Agreement (FSA) Flow Plan Section 6.3.

In addition to the fishery flow logic, this code also includes algorithms to compute the inflows and outflows to Ross Lake for determination of the Ross Lake Spawning Control Curve (SCC) drawdown and refill schedule for the period March 15 to June 15 annually as specified in FSA Appendix E.[1] The FSA delineates the formulas to compute the monthly spawning flow for each month from March through June, including fixed monthly average sidestream inflows (inflow from tributaries between Ross Dam and Newhalem gage) to use in these calculations. The formulas also specify the use of forecast inflows into Ross Reservoir. Since the Skagit Operations Model does not include a forecast inflow dataset, the algorithms use the Ross daily average inflows from the hydrology input file. Once these monthly average inflow and outflow values are determined, daily target elevations are computed using the starting elevation on the first day of the month. These daily target elevations are restricted to not go below the minimum elevation nor above the spill elevation set in the scenario. These daily target elevations replicate functionality of the end-of-month Spawning Elevation Control Curve (SECC) specified in FSA Appendix E, and then becomes the initial guideline in scheduling releases from Ross in support of spawning flows at Newhalem gage.

January:

- Maximum Daily Average Flow: Chum spawning season ending January 6, maximum daily average flow of 4,600 cfs for Chum spawning, otherwise no limit.
- Minimum Instantaneous Flow at Newhalem: The highest incubation flow based on the spawning flows and incubation flow tables.
- Target Minimum Flow: 3,000 cfs Marblemount.
- Downramp Amplitude/Rate:
  - Daytime - daily 3,000 cfs/24-hr and hourly 1,500 cfs/hr.
  - Nighttime - hourly downramping of 3,000 cfs/hr.
  - No daytime downramping when predicted Marblemount flows are less than or equal to 4,700 cfs.

February:

- Maximum Daily Average Flow: None.
- Minimum Instantaneous Flow at Newhalem: The highest incubation flow based on the

[1] FSA Appendix E is followed to the extent possible, excluding the constraints of the Variable Energy Content Curve (VECC) and the Spill Control Curve (SPCC) since these include forecast inflow percentiles, which the Model does not contain.

spawning flows and incubation flow tables, but not less than 1,800 cfs.

- Target Minimum Flow: 3,000 cfs Marblemount.
- Downramp Amplitude/Restriction:
  - Daytime - daily 4,000 cfs/24-hr and hourly 1,500 cfs/hr.
  - Nighttime - hourly downramping of 3,000 cfs/hr.
  - No daytime downramping when predicted Marblemount flows are less than or equal to 4,700 cfs.

March:

- Maximum Daily Average Flow: none March 1-14; maximum daily average flow of 5,000 cfs March 15-31.
- Minimum Instantaneous Flow at Newhalem: The highest incubation flow based on the incubation flow tables or spawning target flow, but not less than 1,800 cfs.
- Target Minimum Flow: 3,000 cfs Marblemount.
- Downramp Amplitude/Rate:
  - Daytime - daily 4,000 cfs/24-hr and hourly 1,500 cfs/hr.
  - Nighttime - hourly downramping of 3,000 cfs/hr.
  - No daytime downramping when predicted Marblemount flows are less than or equal to 4,700 cfs.

April:

- Maximum Daily Average Flow: 5,000 cfs.
- Minimum Instantaneous Flow at Newhalem: The highest incubation flow based on the incubation flow tables or spawning target flow, but not less than 1,800 cfs.
- Target Minimum Flow: 3,000 cfs Marblemount.
- Downramp Amplitude/Rate:
  - Daytime - daily 4,000 cfs/24-hr and hourly 1,500 cfs/hr.
  - Nighttime - hourly downramping of 3,000 cfs/hr.
  - No daytime downramping when predicted Marblemount flows are less than or equal to 4,700 cfs.

May:

- Maximum Daily Average Flow: 4,000 cfs.
- Minimum Instantaneous Flow at Newhalem: The highest incubation flow based on the incubation flow tables or spawning target flow, but not less than 1,500 cfs.
- Target Minimum Flow: 3,000 cfs Marblemount.
- Downramp Amplitude/Rate:

- Daytime - daily 4,000 cfs/24-hr and hourly 1,500 cfs/hr.
- Nighttime - hourly downramping of 3,000 cfs/hr.
- No daytime downramping when predicted Marblemount flows are less than or equal to 4,700 cfs.

June:

- Maximum Daily Average Flow: maximum daily average flow of 4,000 cfs June 1-15; none June 16-30.
- Minimum Instantaneous Flow at Newhalem: The highest incubation flow based on the incubation flow tables or spawning target flow, but not less than 1,500 cfs June 1-15; 1,500 cfs June 16-30.
- Downramp Amplitude/Rate:
  - If predicted Newhalem flows are greater than 4,000 cfs.
    - Daily 3,000 cfs/24-hr and hourly 1,000 cfs/hr.
  - If predicted Newhalem flows are less than or equal to 4,000 cfs.
    - Daily 2,000 cfs/24-hr and hourly 500 cfs/hr.

July:

- Maximum Daily Average Flow: None.
- Minimum Instantaneous Flow at Newhalem: The highest incubation flow based on the incubation flow tables, but not less than 1,500 cfs.
- Downramp Amplitude/Rate:
  - If predicted Newhalem flows are greater than 4,000 cfs.
    - Daily 3,000 cfs/24-hr and hourly 1000 cfs/hr.
  - If predicted Newhalem flows are less than or equal to 4,000 cfs.
    - Daily 2,000 cfs/24-hr and hourly 500 cfs/hr.

August:

- Maximum Daily Average Flow: none August 1-19; 4,500 cfs August 20-31.
- Minimum Instantaneous Flow at Newhalem: 2,000 cfs August 1-19; The highest incubation flow based on the incubation flow tables, but not less than 2,000 cfs.
- Downramp Amplitude/Rate:
  - If predicted Newhalem flows are greater than 4,000 cfs.
    - Daily 3,000 cfs/24-hr and hourly 1,000 cfs/hr.
  - If predicted Newhalem flows are less than or equal to 4,000 cfs.
    - Daily 2,000 cfs/24-hr and hourly 500 cfs/hr.

September:

- Maximum Daily Average Flow: 4,500 cfs even years, 4,000 cfs odd years.
- Minimum Instantaneous Flow at Newhalem: The highest incubation flow based on the incubation flow tables, but not less than 1,500 cfs.
- Downramp Amplitude/Rate:
  - If predicted Newhalem flows are greater than 4,000 cfs.
    - Daily 3,000 cfs/24-hr and hourly 1,000 cfs/hr.
  - If predicted Newhalem flows are less than or equal to 4,000 cfs.
    - Daily 2,500 cfs/24-hr and hourly 500 cfs/hr.

October:

- Maximum Daily Average Flow:4,500 cfs even years, 4,000 cfs odd years.
- Minimum Instantaneous Flow at Newhalem: The highest incubation flow based on the incubation flow tables, but not less than 1,500 cfs.
- Downramp Amplitude/Rate:
  - If predicted Newhalem flows are greater than 4,000 cfs.
    - Daily 3,000 cfs/24-hr and hourly 1,000 cfs/hr.
  - If predicted Newhalem flows are less than or equal to 4,000 cfs.
    - Daily 2,500 cfs/24-hr and hourly 500 cfs/hr.

November:

- Maximum Daily Average Flow: 4,600 cfs.
- Minimum Instantaneous Flow at Newhalem: The highest incubation flow based on the incubation flow tables.
- Downramp Amplitude/Rate:
  - Daily 3,000 cfs/24-hr; hourly - none.

December:

- Maximum Daily Average Flow: 4,600 cfs.
- Minimum Instantaneous Flow at Newhalem: The highest incubation flow based on the incubation flow tables.
- Downramp Amplitude/Rate:
- Daily 3,000 cfs/24-hr; hourly - none.

OPERATIONS MODEL STUDY
SKAGIT OPERATIONS MODEL LOGIC AND VALIDATION REPORT

APPENDIX 3

VERIFICATION SCENARIOS GRAPHICAL RESULTS

Verification Scenarios Graphical Results

Scenarios Presented

Verification Scenario with Default Dispatch

Verification Scenario with Even Dispatch

Data Presented:

Gross Inflow (cfs) – represents the simulated daily average total inflow to the reservoir, including incremental inflow from the hydrology inflow dataset; and, if applicable, simulated discharge and spills from the upstream plant.

Gross Outflow (cfs) – represents the simulated daily average total outflow from the reservoir, which includes powerhouse discharge, spillway flows and evaporative losses. This time series is only visible on the plots when spillway flow occurs, all other times the timeseries follows the powerhouse discharge (Discharge Flow).

Discharge Flow (cfs) – represents the simulated daily average powerhouse discharge.

Spill Elev (ft) – represents the elevation in feet, NAVD 88 datum, at which the model will being to calculate spill. For the verification scenarios, historical spills are also simulated and are represented within the Gross Outflow series.

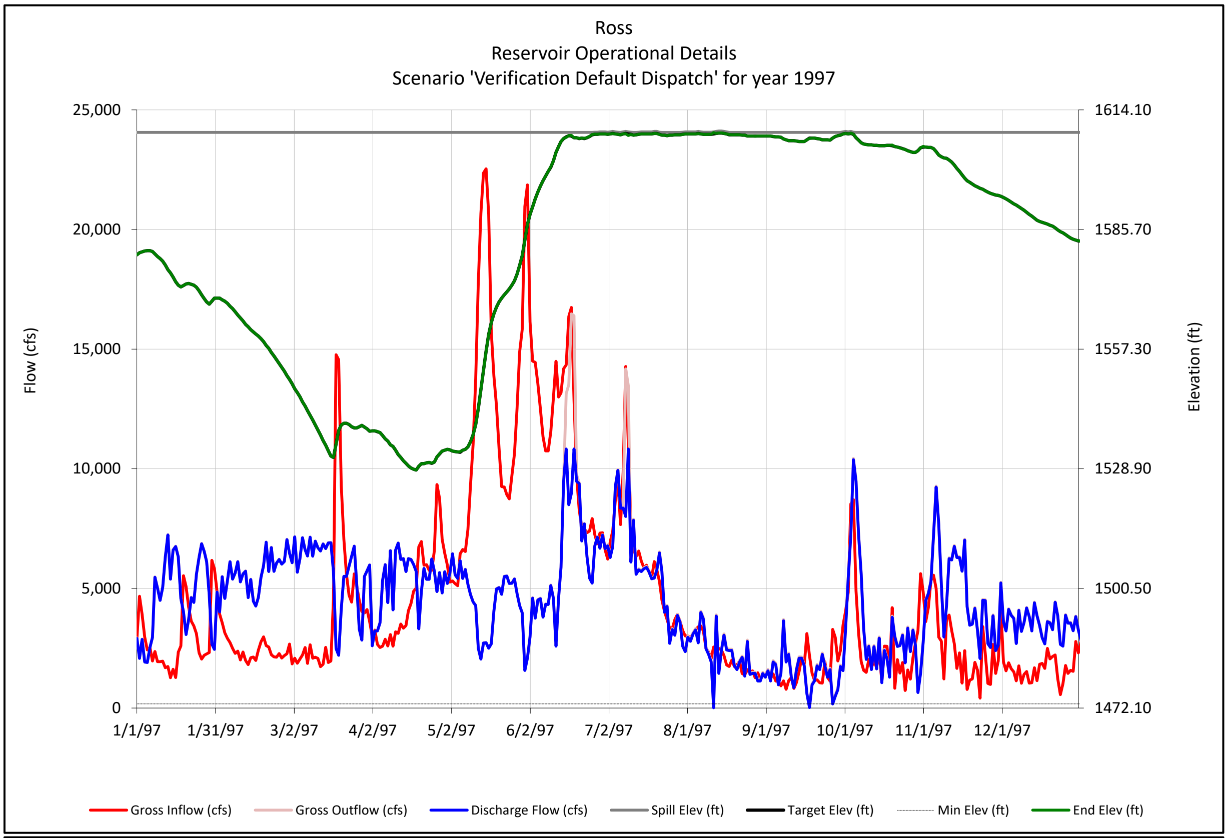
Target Elev (ft) – this is the water surface elevation in feet, NAVD 88 datum, the model attempts to meet at the end of each day. For the verification scenarios, this timeseries is only visible on the plots when the model is unable to meet this elevation and the End Elev deviates from the target elevation either due to insufficient inflows, releases to support downstream flow requirements, or to prevent spill at a downstream reservoir; otherwise, the timeseries follows the End Elev series. In these scenarios, the target elevation is the historical end of day elevation from the historical operations database converted to NAVD 88.

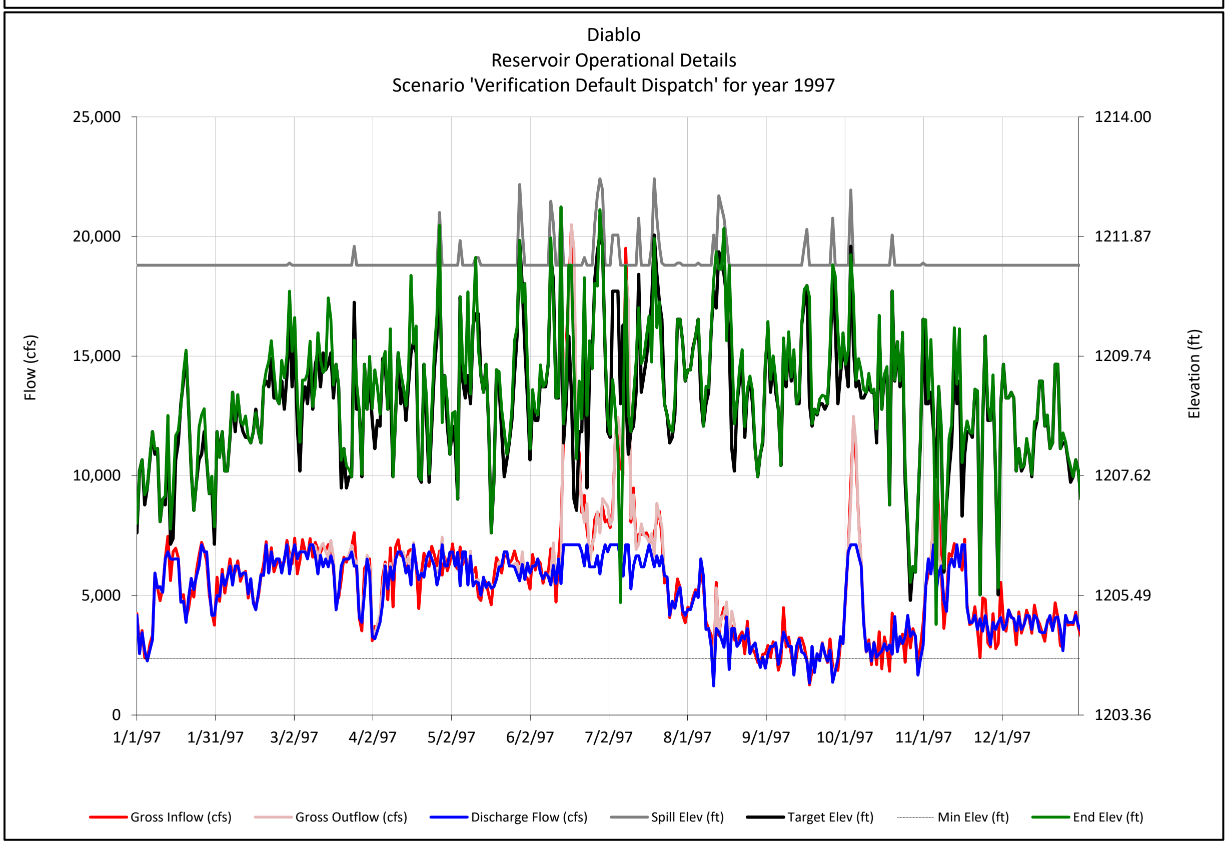
Min Elev (ft) – represents the elevation in feet, NAVD 88 datum, at which the model will cease powerhouse discharge.

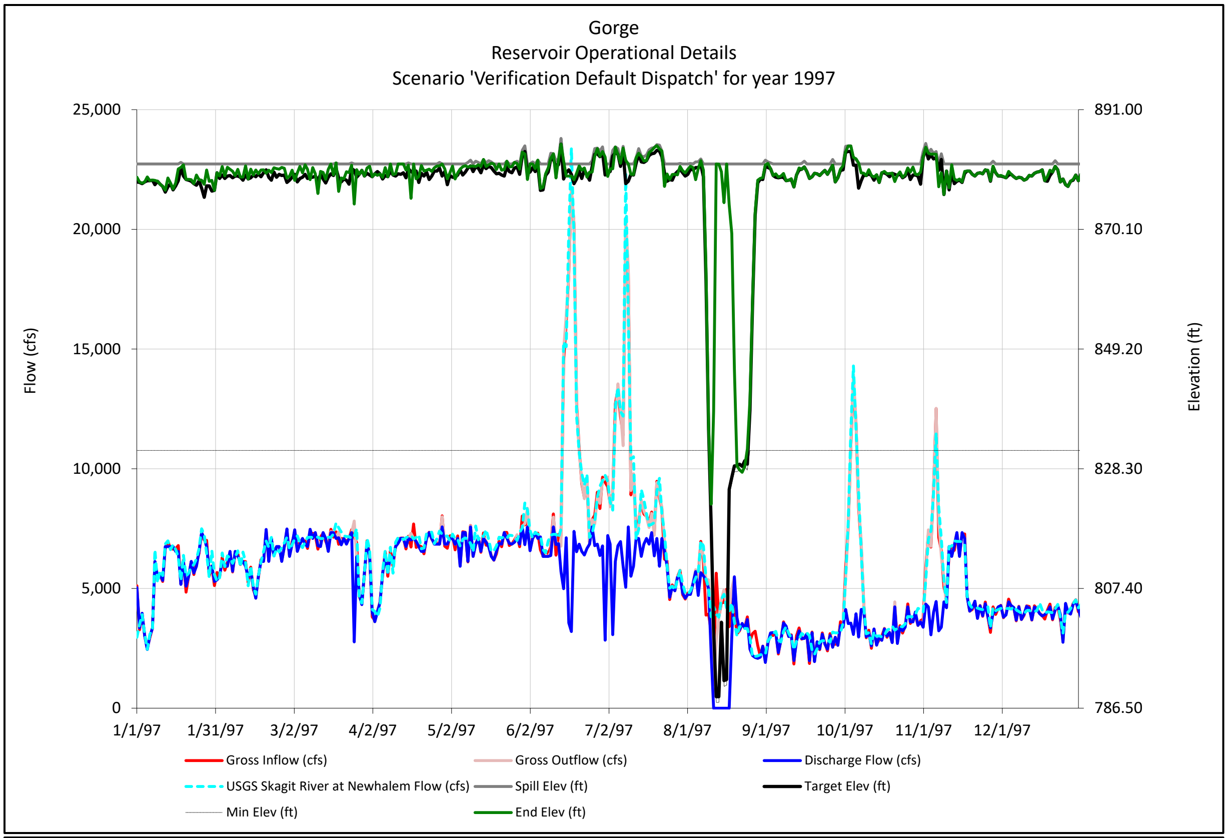
End Elev (ft) – represents the simulated end of day elevation in feet, NAVD 88 datum.

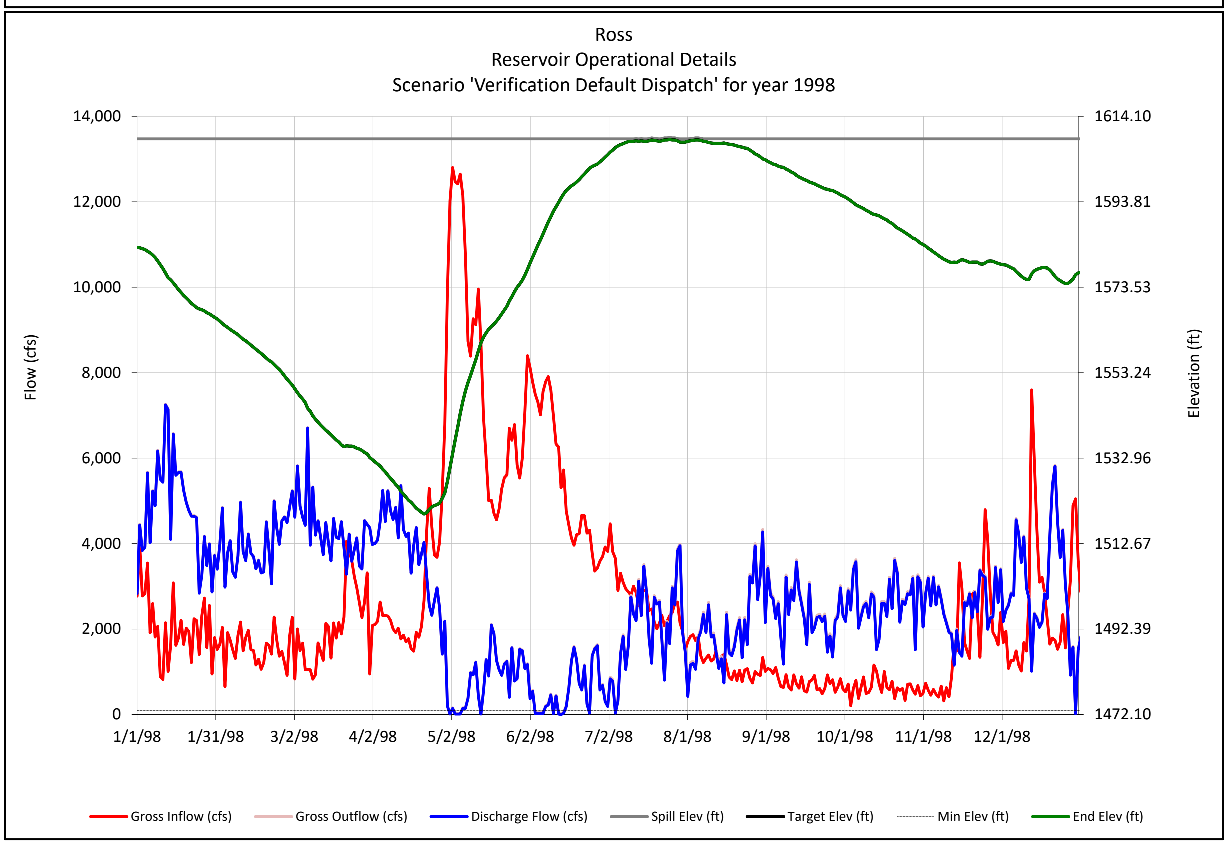
USGS Skagit River at Newhalem Flow (cfs) – represents the flows reported by the USGS. Note the gage is missing data for the period 12/1/2014 through 3/29/2015.

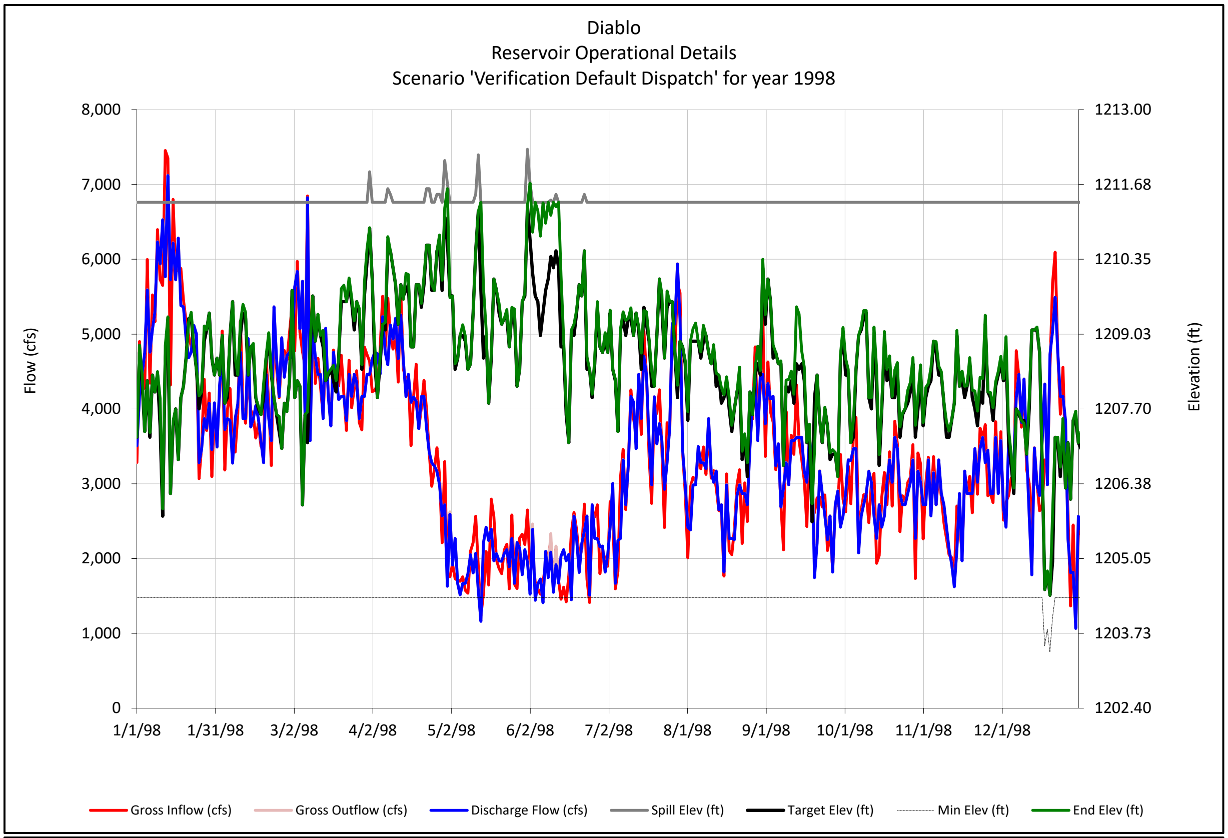
Verification Scenario with Default Dispatch

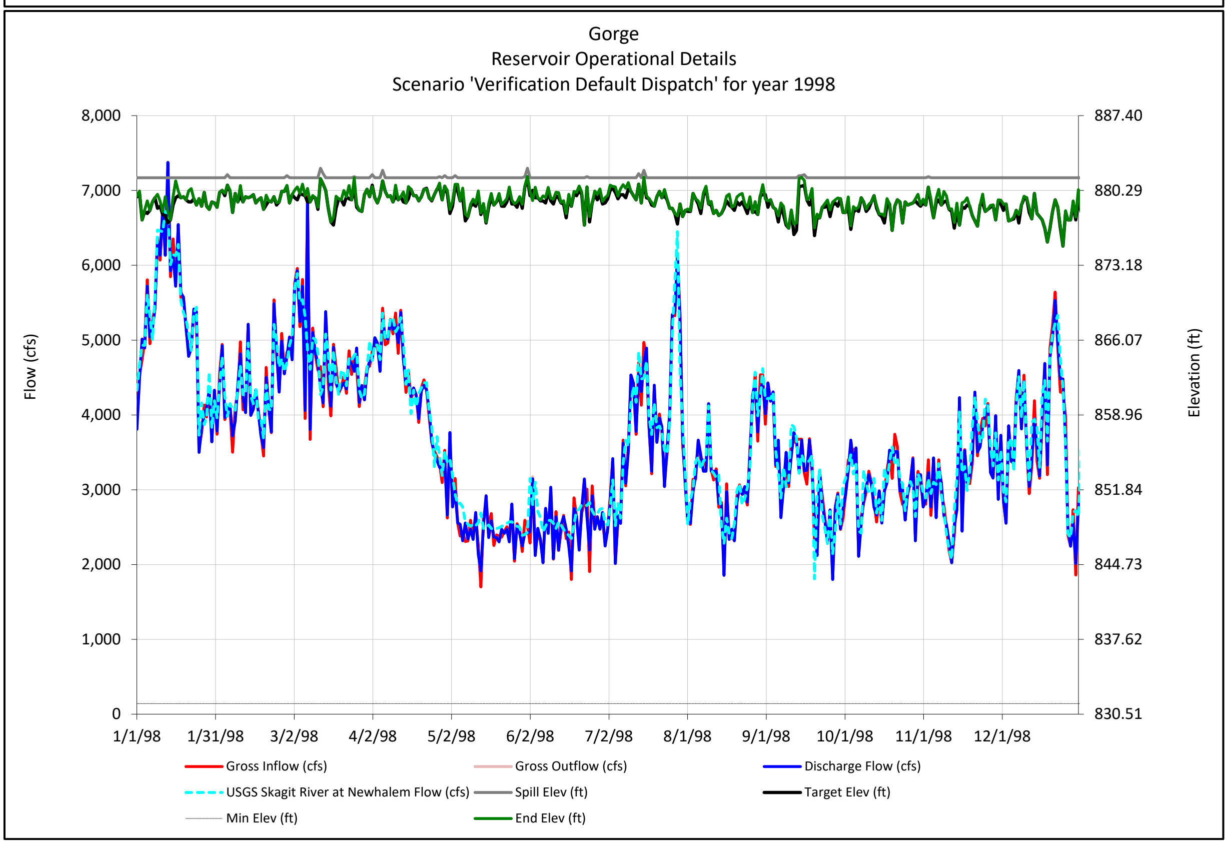


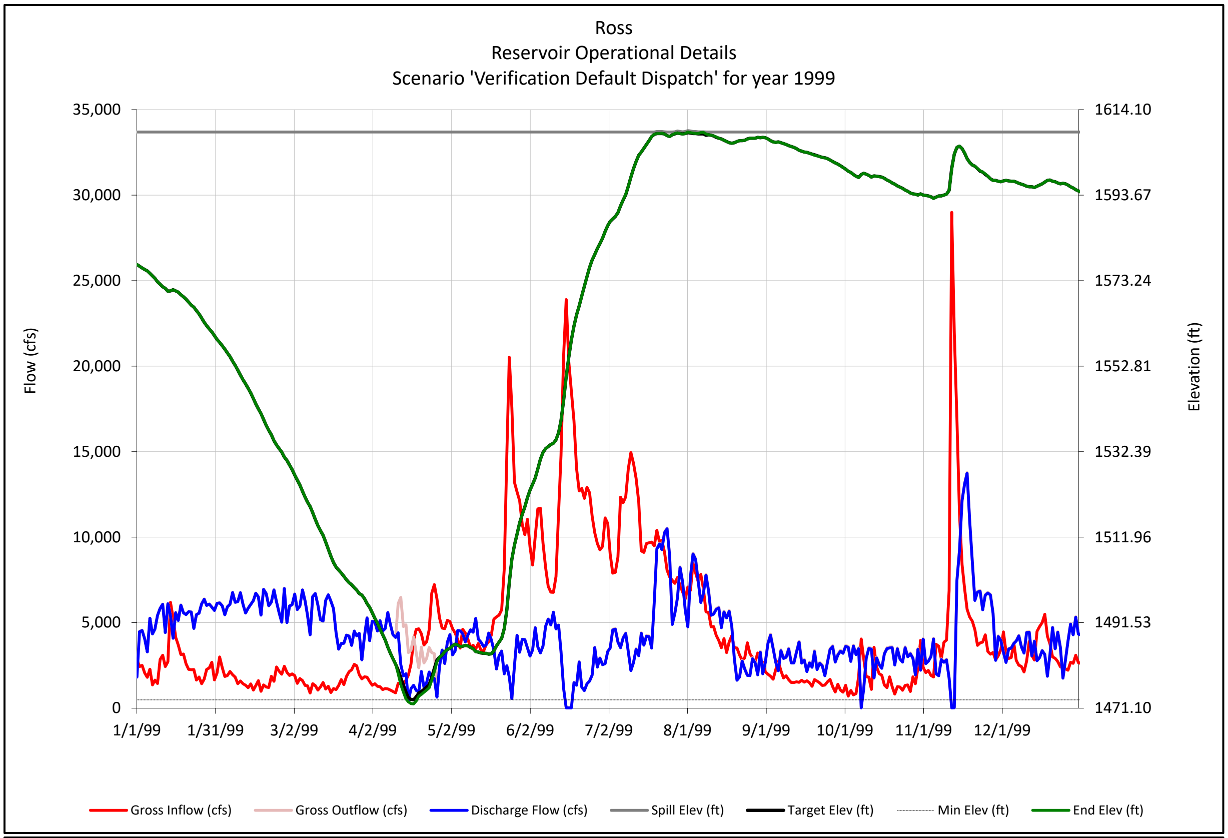


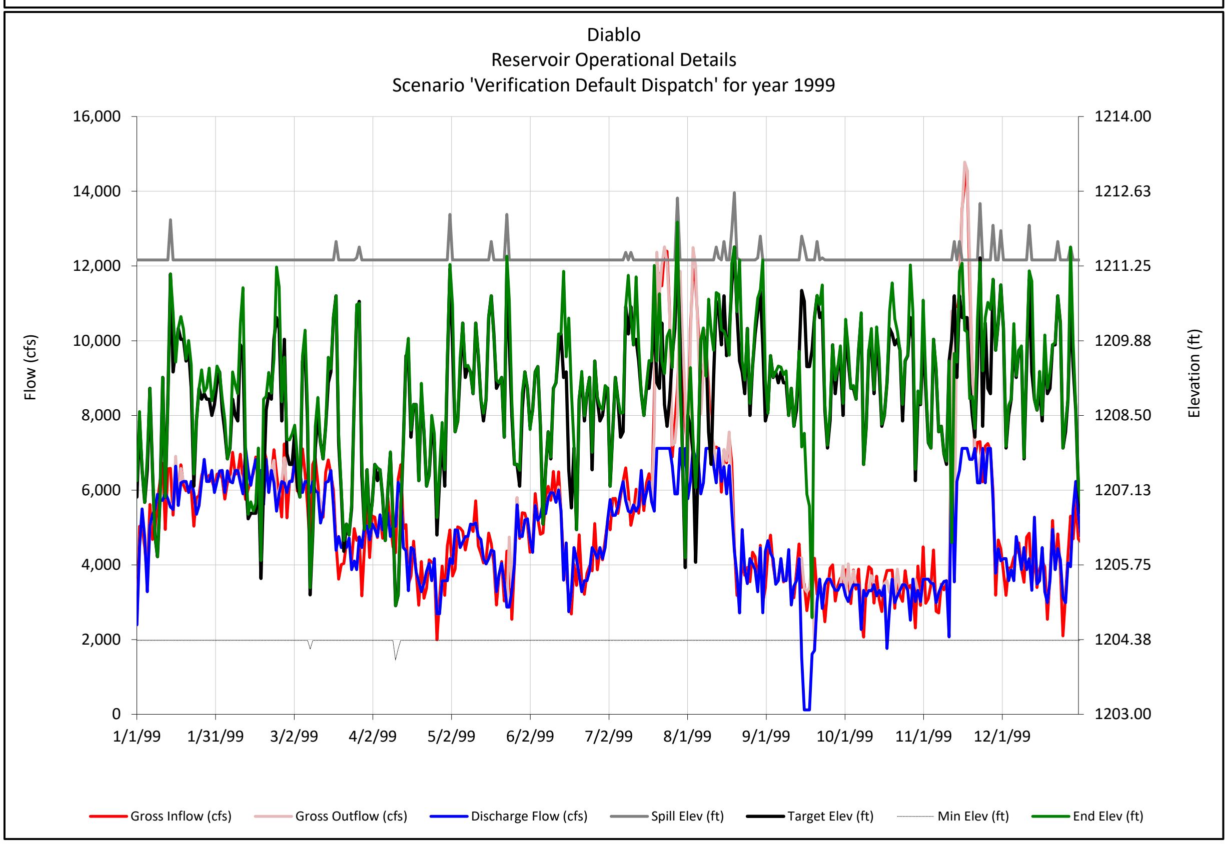

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 1997
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
891.00
870.10
849.20
828.30
807.40
786.50
1/1/97
1/31/97
3/2/97
4/2/97
5/2/97
6/2/97
7/2/97
8/1/97
9/1/97
10/1/97
11/1/97
12/1/97
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

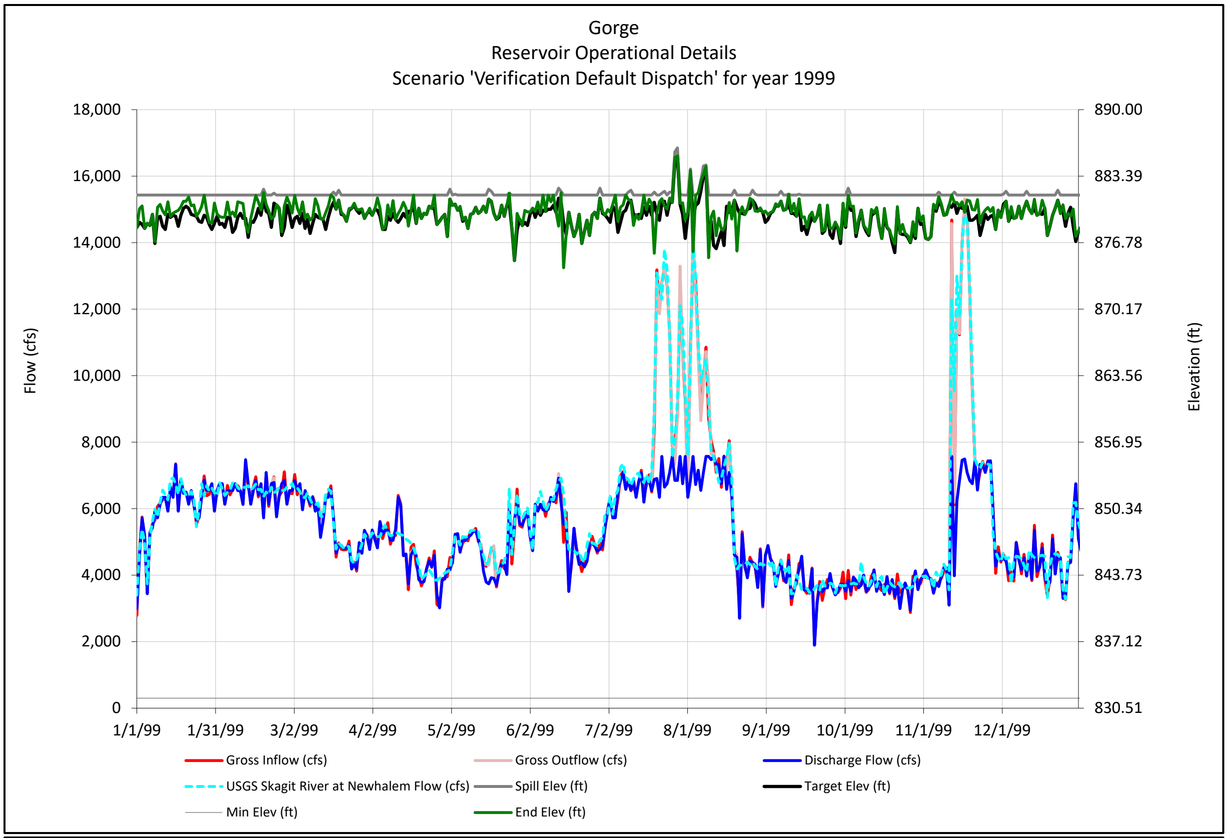

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 1998
Flow (cfs)
Elevation (ft)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1614.10
1593.81
1573.53
1553.24
1532.96
1512.67
1492.39
1472.10
1/1/98
1/31/98
3/2/98
4/2/98
5/2/98
6/2/98
7/2/98
8/1/98
9/1/98
10/1/98
11/1/98
12/1/98
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

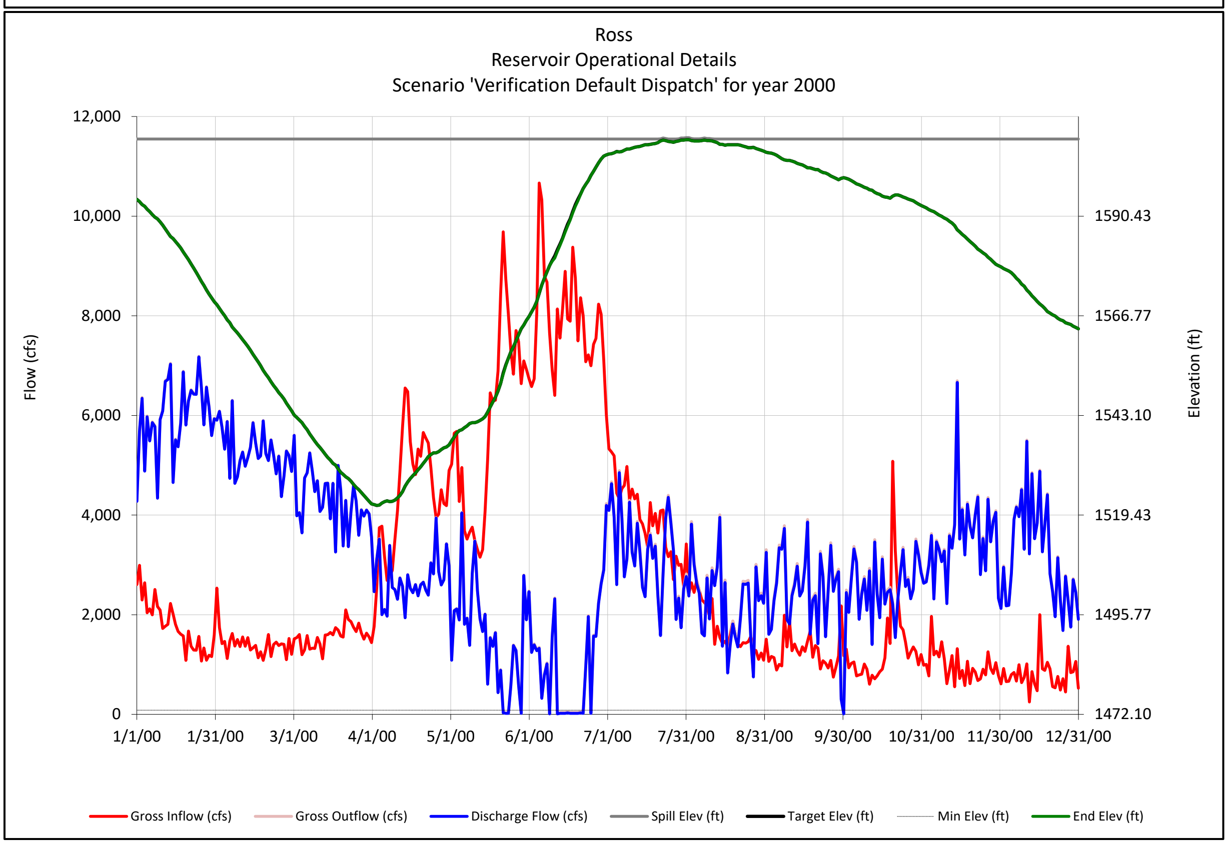

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 1998
Flow (cfs)
Elevation (ft)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1213.00
1211.68
1210.35
1209.03
1207.70
1206.38
1205.05
1203.73
1202.40
1/1/98
1/31/98
3/2/98
4/2/98
5/2/98
6/2/98
7/2/98
8/1/98
9/1/98
10/1/98
11/1/98
12/1/98
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

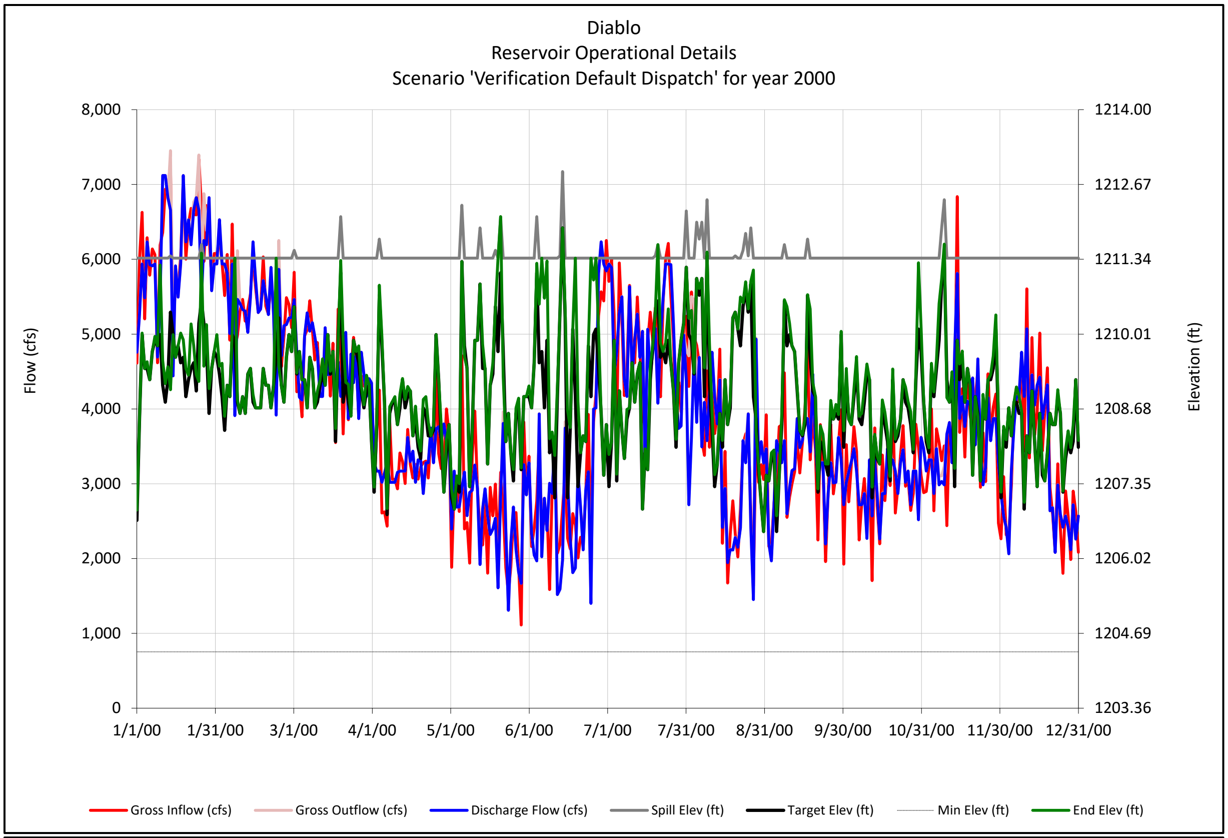

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 1998
Flow (cfs)
Elevation (ft)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
887.40
880.29
873.18
866.07
858.96
851.84
844.73
837.62
830.51
1/1/98
1/31/98
3/2/98
4/2/98
5/2/98
6/2/98
7/2/98
8/1/98
9/1/98
10/1/98
11/1/98
12/1/98
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

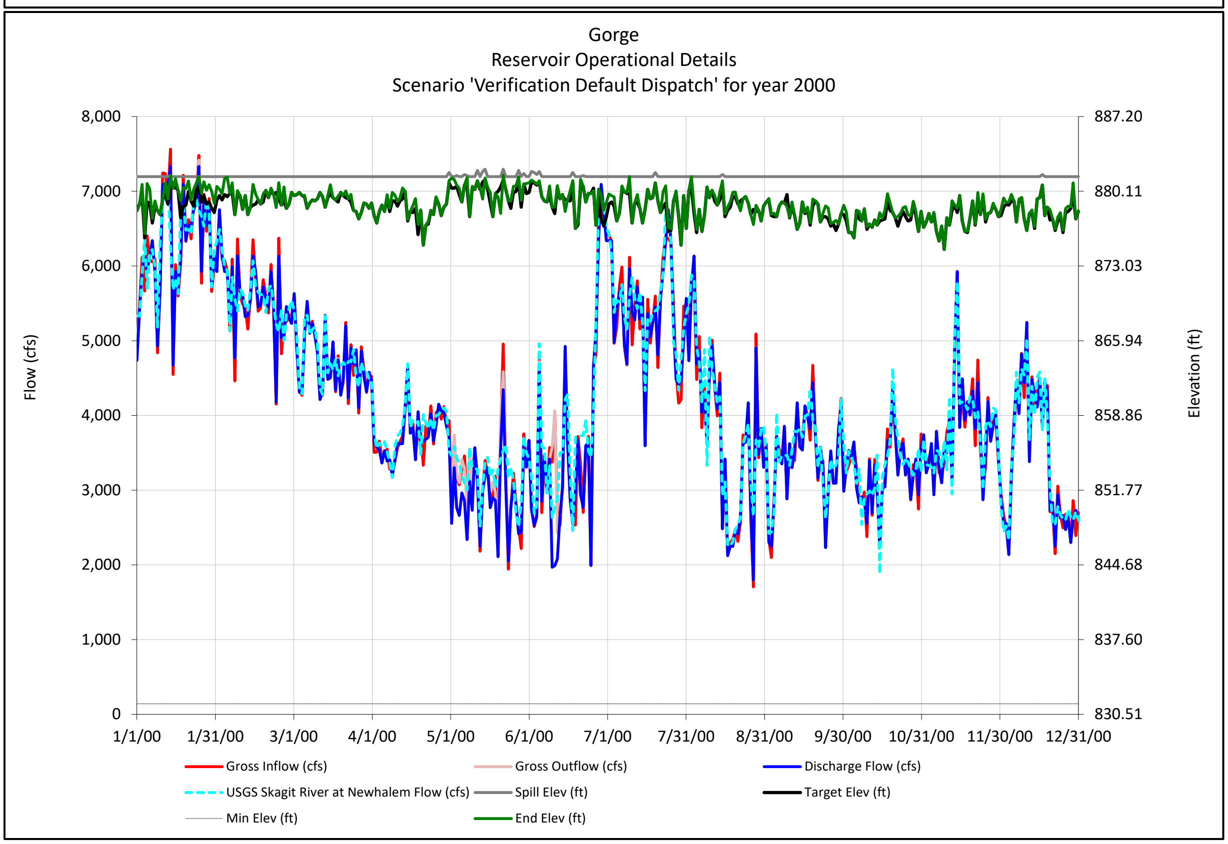

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 1999
Flow (cfs)
Elevation (ft)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1614.10
1593.67
1573.24
1552.81
1532.39
1511.96
1491.53
1471.10
1/1/99
1/31/99
3/2/99
4/2/99
5/2/99
6/2/99
7/2/99
8/1/99
9/1/99
10/1/99
11/1/99
12/1/99
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

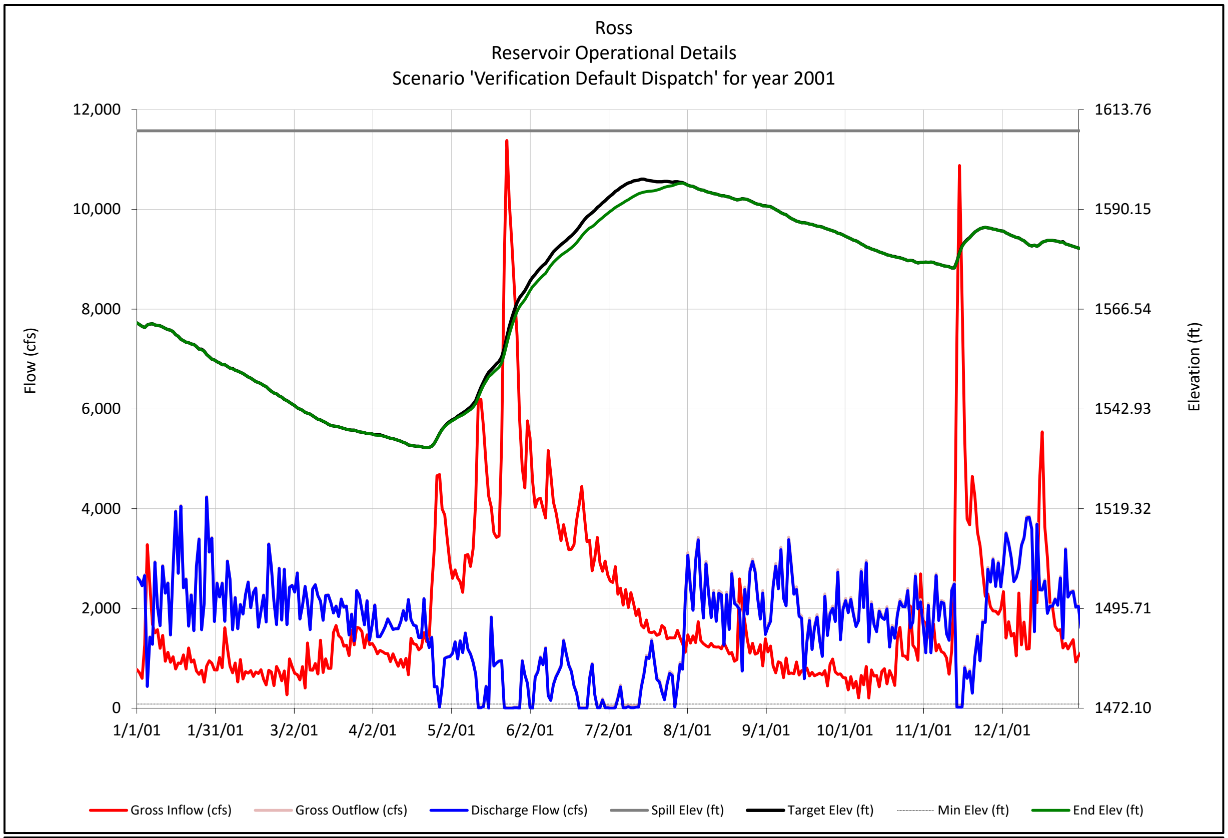

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 1999
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1214.00
1212.63
1211.25
1209.88
1208.50
1207.13
1205.75
1204.38
1203.00
1/1/99
1/31/99
3/2/99
4/2/99
5/2/99
6/2/99
7/2/99
8/1/99
9/1/99
10/1/99
11/1/99
12/1/99
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

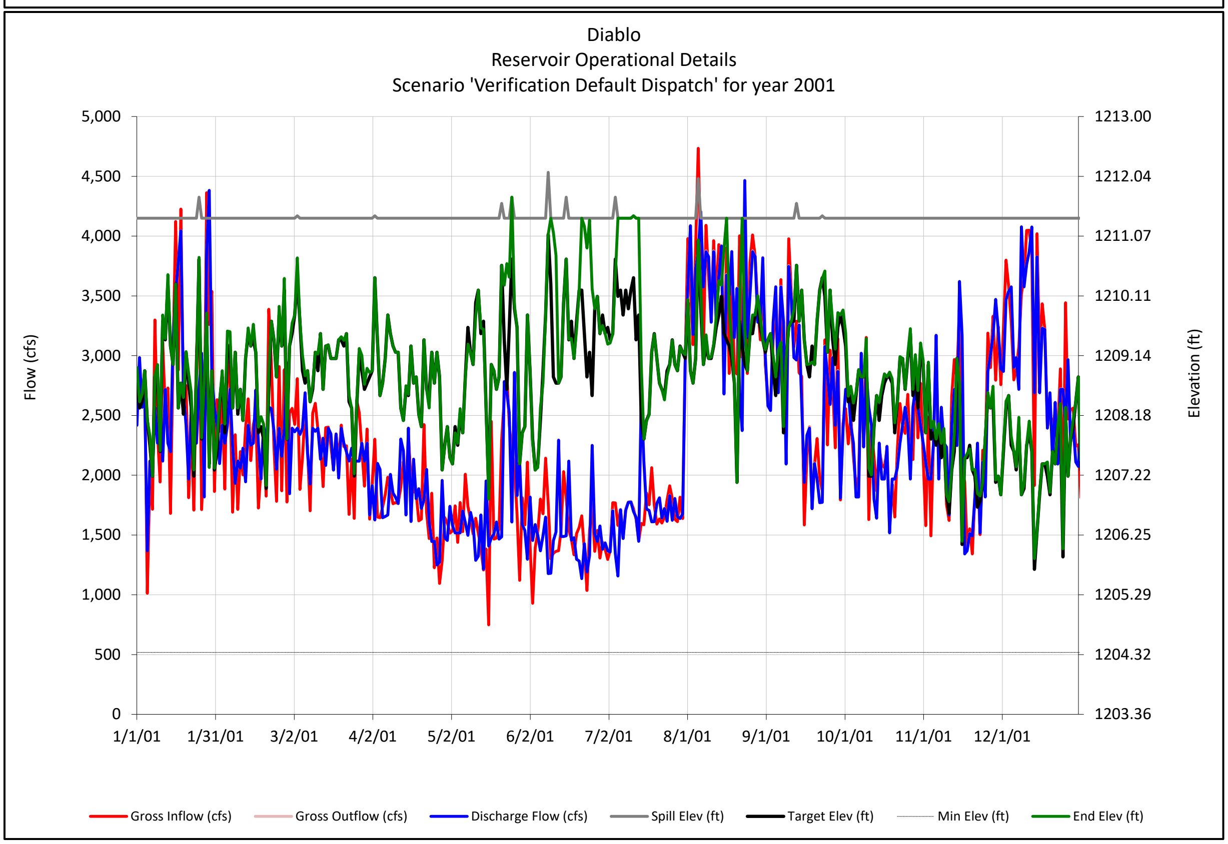

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 1999
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
890.00
883.39
876.78
870.17
863.56
856.95
850.34
843.73
837.12
830.51
1/1/99
1/31/99
3/2/99
4/2/99
5/2/99
6/2/99
7/2/99
8/1/99
9/1/99
10/1/99
11/1/99
12/1/99
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

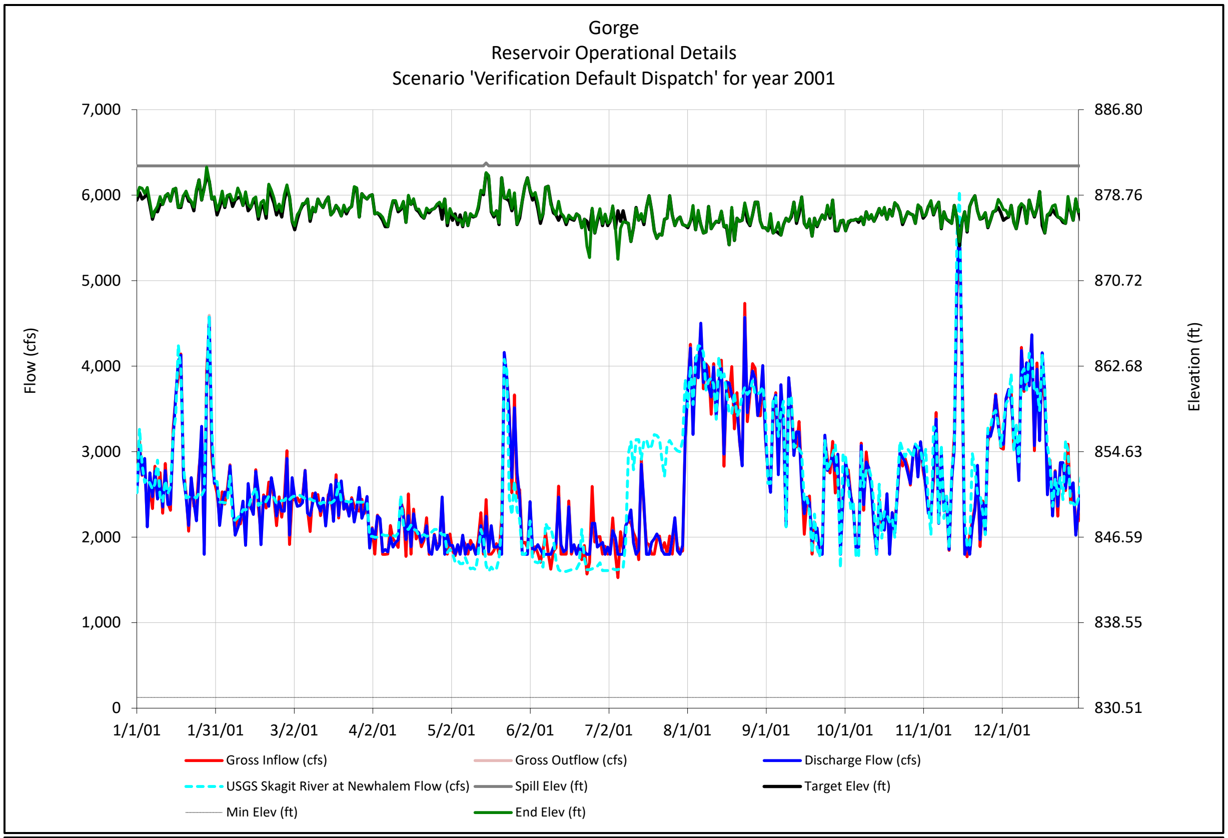

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2000
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1590.43
1566.77
1543.10
1519.43
1495.77
1472.10
1/1/00
1/31/00
3/1/00
4/1/00
5/1/00
6/1/00
7/1/00
7/31/00
8/31/00
9/30/00
10/31/00
11/30/00
12/31/00
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

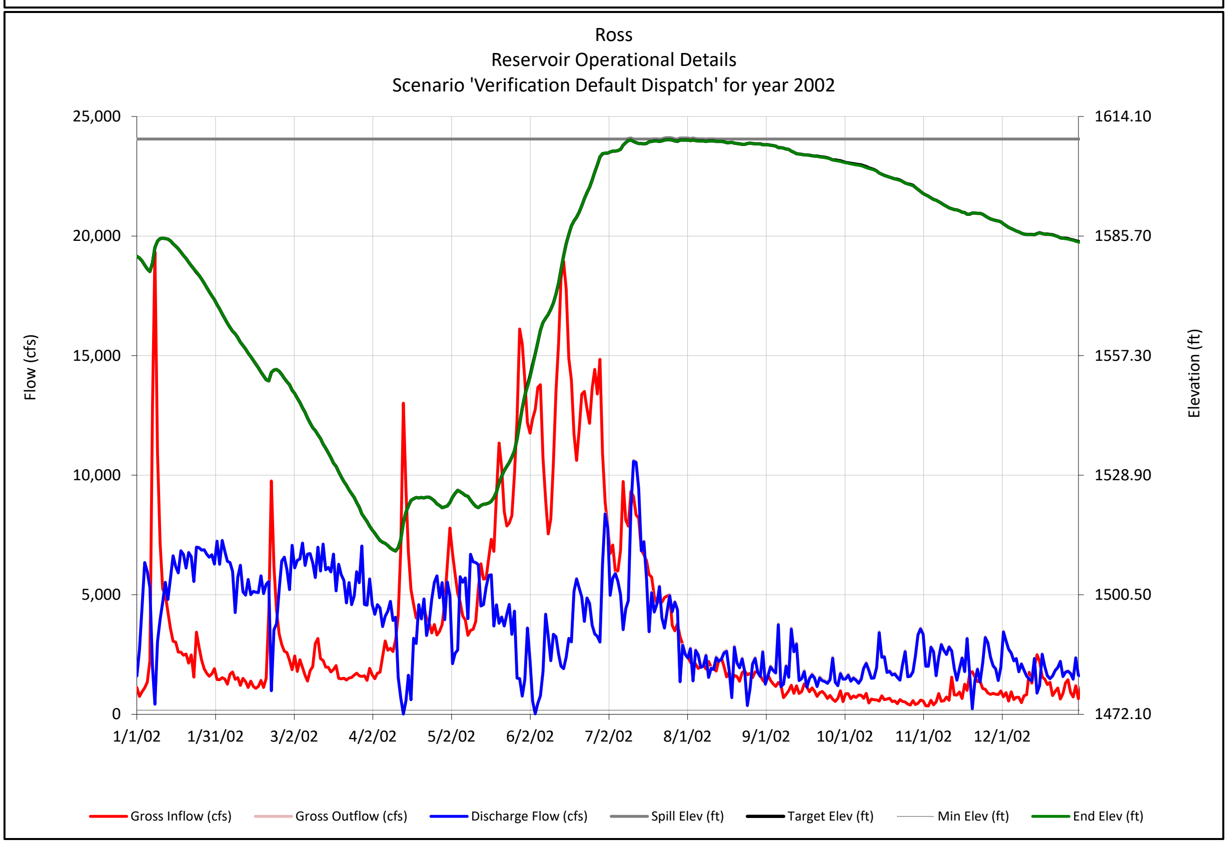

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2000
Flow (cfs)
Elevation (ft)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1214.00
1212.67
1211.34
1210.01
1208.68
1207.35
1206.02
1204.69
1203.36
1/1/00
1/31/00
3/1/00
4/1/00
5/1/00
6/1/00
7/1/00
7/31/00
8/31/00
9/30/00
10/31/00
11/30/00
12/31/00
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

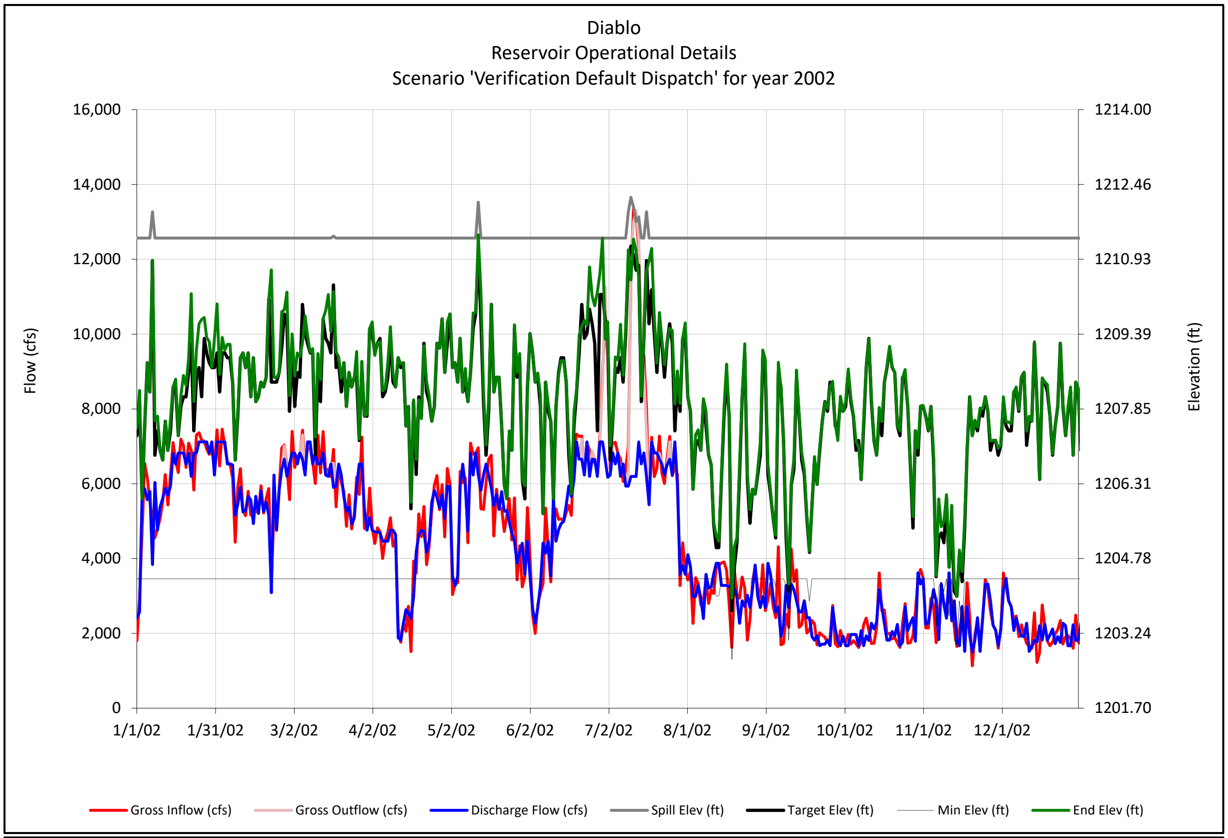

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2000
Flow (cfs)
Elevation (ft)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
887.20
880.11
873.03
865.94
858.86
851.77
844.68
837.60
830.51
1/1/00
1/31/00
3/1/00
4/1/00
5/1/00
6/1/00
7/1/00
7/31/00
8/31/00
9/30/00
10/31/00
11/30/00
12/31/00
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

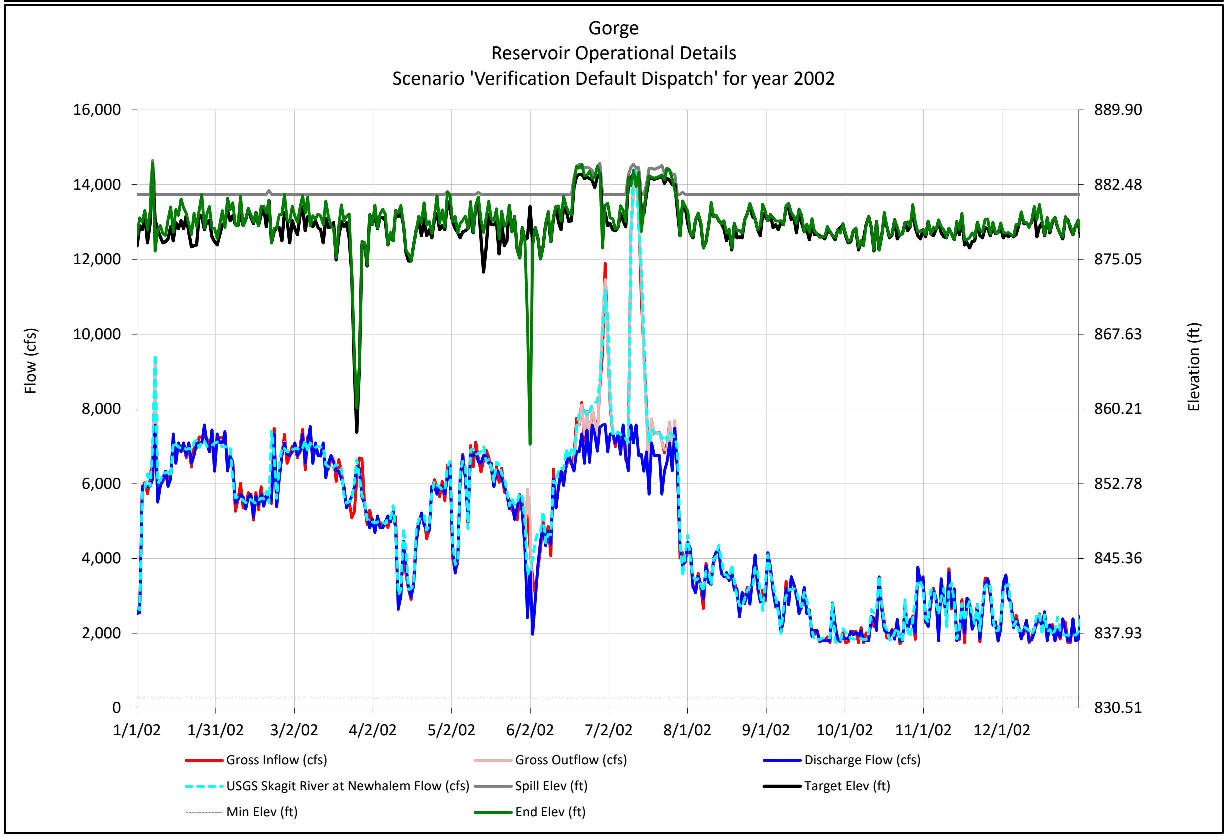

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2001
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1590.15
1566.54
1542.93
1519.32
1495.71
1472.10
1/1/01
1/31/01
3/2/01
4/2/01
5/2/01
6/2/01
7/2/01
8/1/01
9/1/01
10/1/01
11/1/01
12/1/01
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

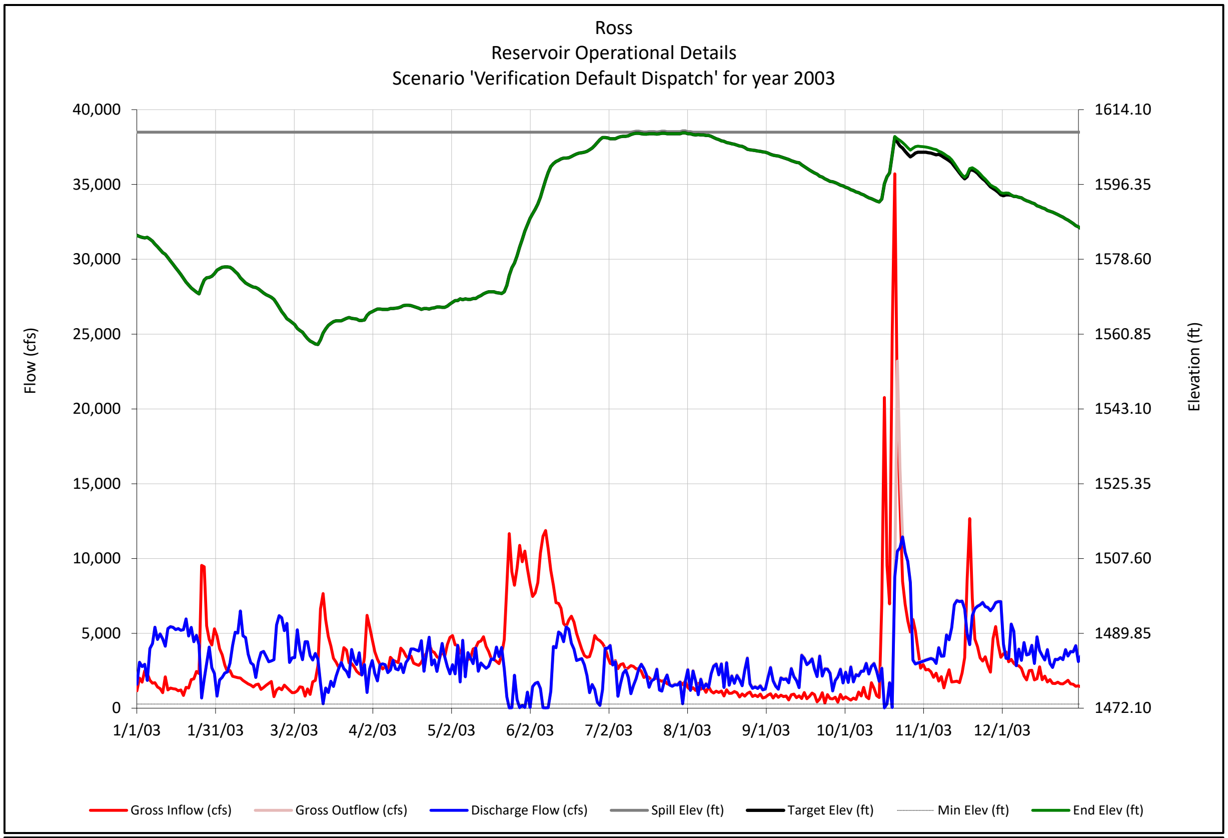

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2001
Flow (cfs)
Elevation (ft)
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1213.00
1212.04
1211.07
1210.11
1209.14
1208.18
1207.22
1206.25
1205.29
1204.32
1203.36
1/1/01
1/31/01
3/2/01
4/2/01
5/2/01
6/2/01
7/2/01
8/1/01
9/1/01
10/1/01
11/1/01
12/1/01
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2001
Flow (cfs)
Elevation (ft)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
886.80
878.76
870.72
862.68
854.63
846.59
838.55
830.51
1/1/01
1/31/01
3/2/01
4/2/01
5/2/01
6/2/01
7/2/01
8/1/01
9/1/01
10/1/01
11/1/01
12/1/01
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

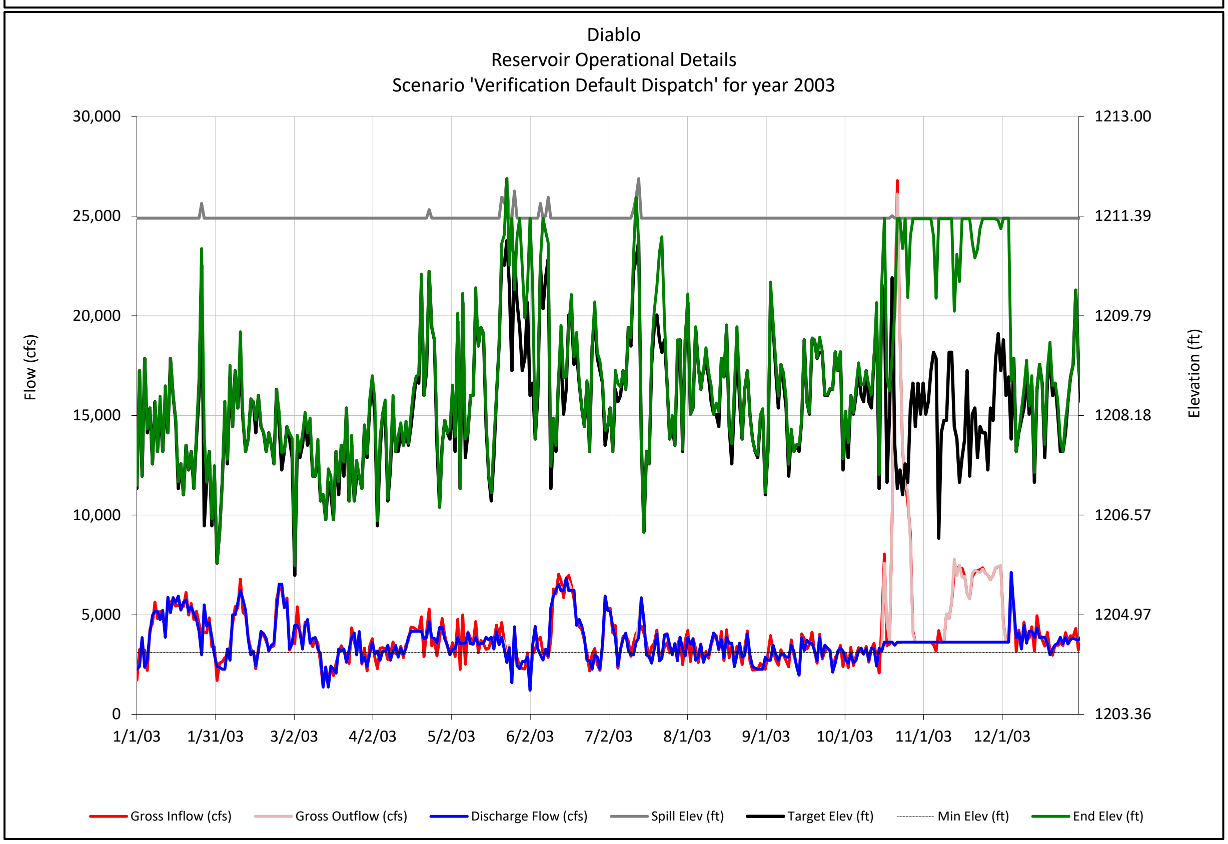

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2002
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
1614.10
1585.70
1557.30
1528.90
1500.50
1472.10
1/1/02
1/31/02
3/2/02
4/2/02
5/2/02
6/2/02
7/2/02
8/1/02
9/1/02
10/1/02
11/1/02
12/1/02
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2002
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1214.00
1212.46
1210.93
1209.39
1207.85
1206.31
1204.78
1203.24
1201.70
1/1/02
1/31/02
3/2/02
4/2/02
5/2/02
6/2/02
7/2/02
8/1/02
9/1/02
10/1/02
11/1/02
12/1/02
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2002
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
889.90
882.48
875.05
867.63
860.21
852.78
845.36
837.93
830.51
1/1/02
1/31/02
3/2/02
4/2/02
5/2/02
6/2/02
7/2/02
8/1/02
9/1/02
10/1/02
11/1/02
12/1/02
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

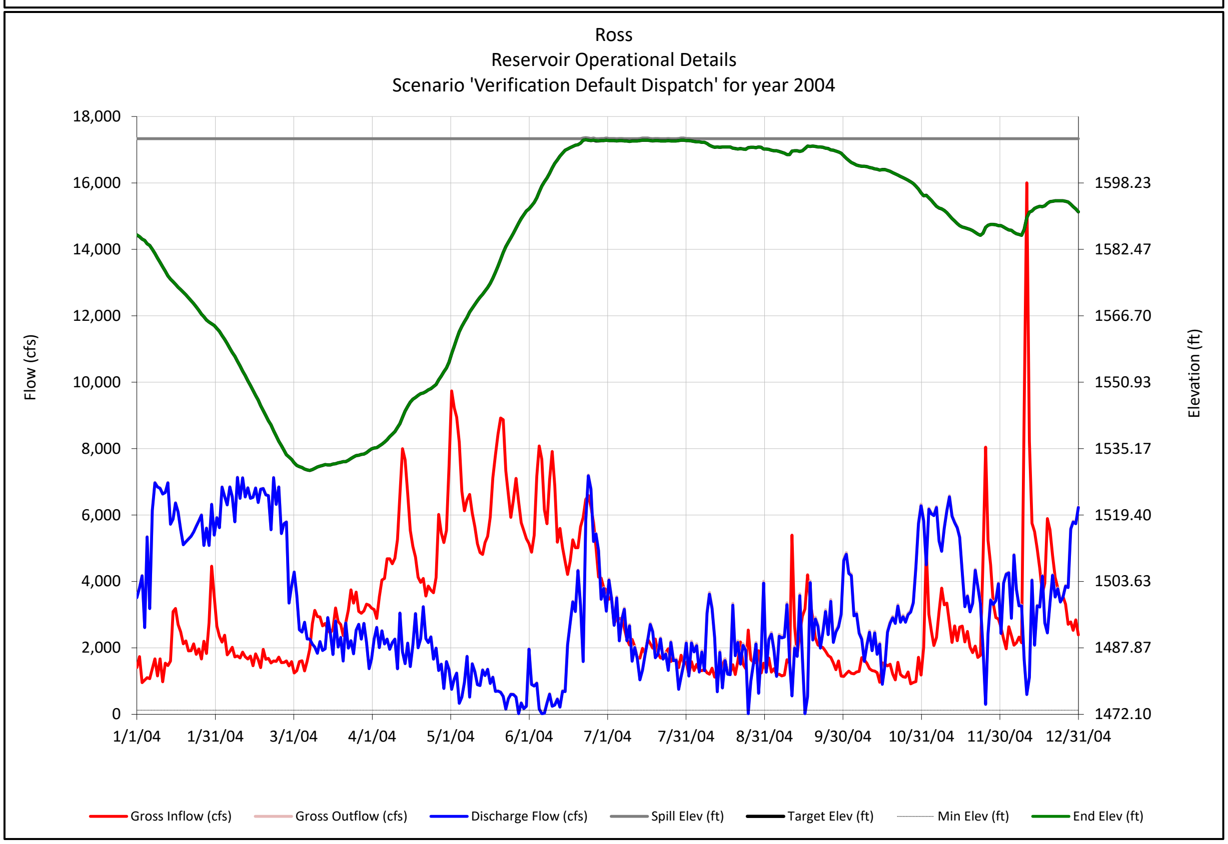


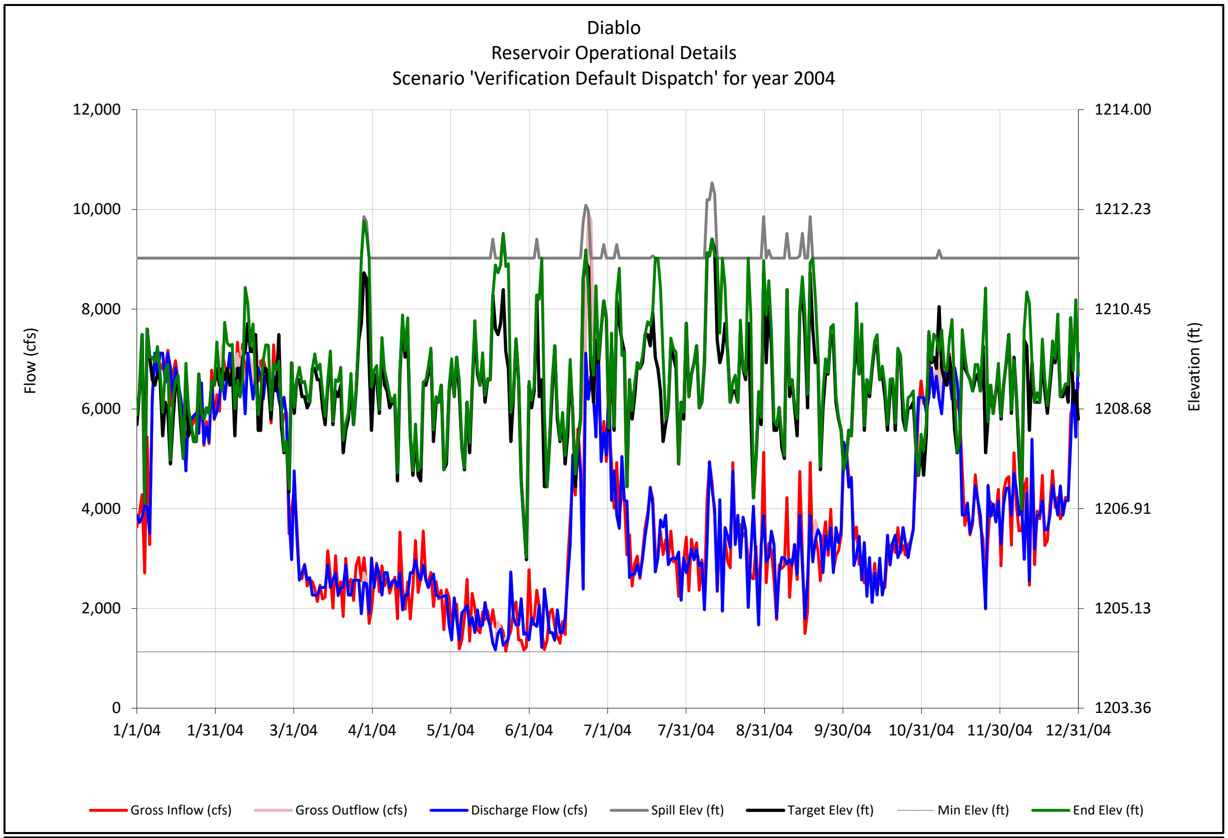
Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2003
Flow (cfs)
Elevation (ft)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1614.10
1596.35
1578.60
1560.85
1543.10
1525.35
1507.60
1489.85
1472.10
1/1/03
1/31/03
3/2/03
4/2/03
5/2/03
6/2/03
7/2/03
8/1/03
9/1/03
10/1/03
11/1/03
12/1/03
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

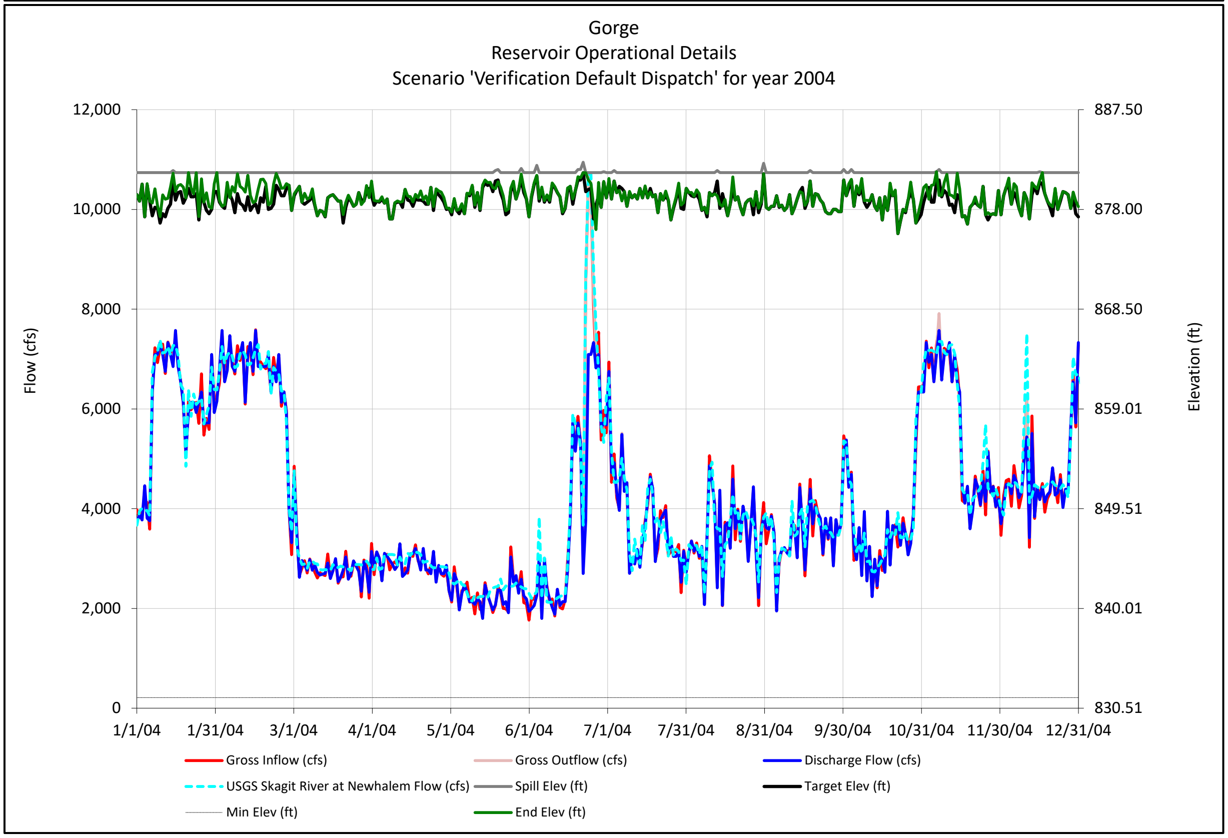


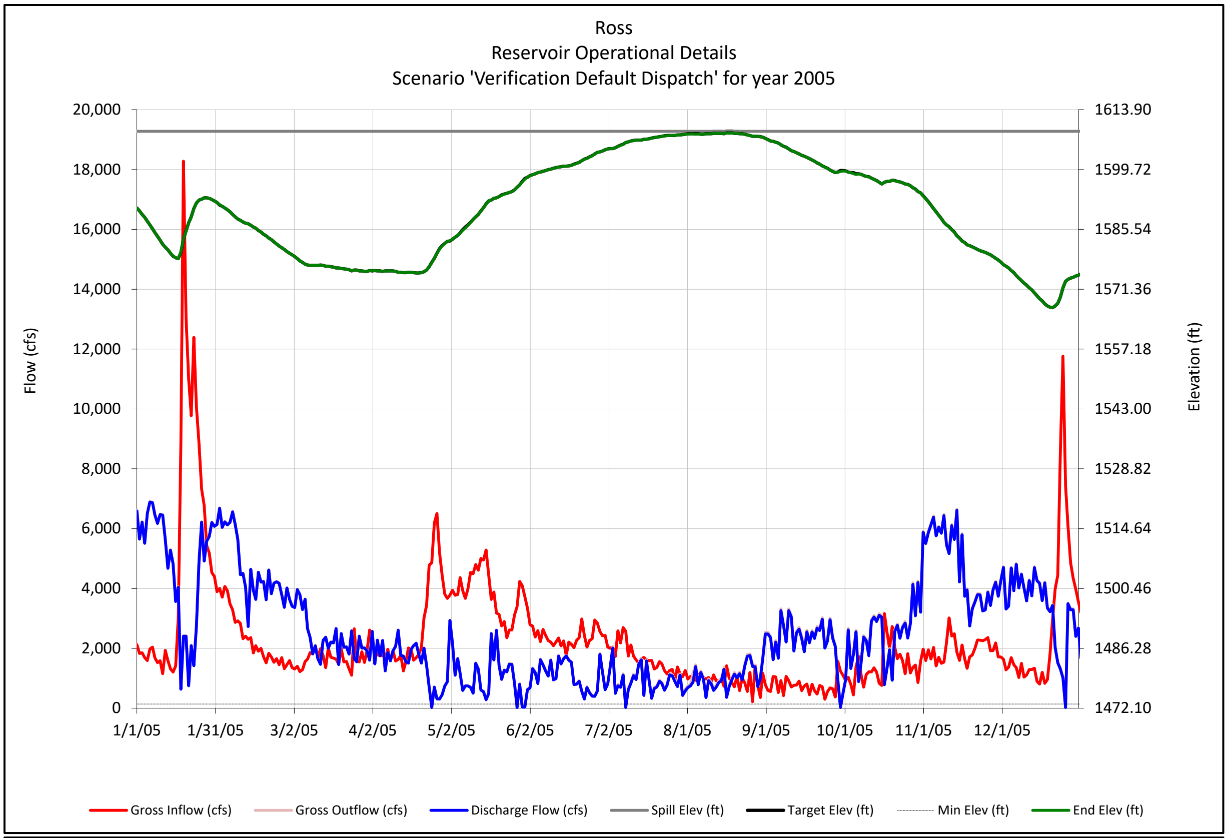
Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2003
Flow (cfs)
Elevation (ft)
30,000
25,000
20,000
15,000
10,000
5,000
0
1213.00
1211.39
1209.79
1208.18
1206.57
1204.97
1203.36
1/1/03
1/31/03
3/2/03
4/2/03
5/2/03
6/2/03
7/2/03
8/1/03
9/1/03
10/1/03
11/1/03
12/1/03
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

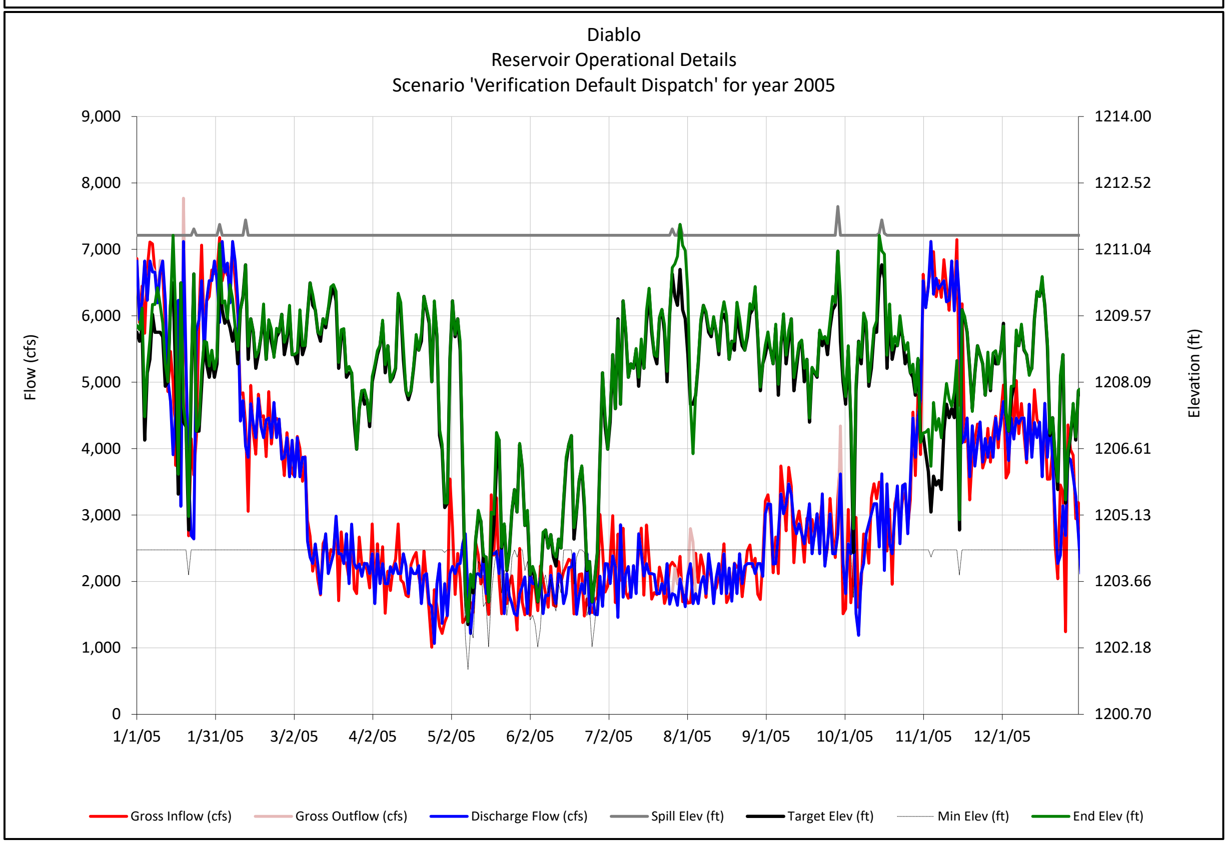

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2003
Flow (cfs)
Elevation (ft)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
889.20
879.97
870.74
861.51
852.29
843.06
833.83
824.60
1/1/03
1/31/03
3/2/03
4/2/03
5/2/03
6/2/03
7/2/03
8/1/03
9/1/03
10/1/03
11/1/03
12/1/03
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2004
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1598.23
1582.47
1566.70
1550.93
1535.17
1519.40
1503.63
1487.87
1472.10
1/1/04
1/31/04
3/1/04
4/1/04
5/1/04
6/1/04
7/1/04
7/31/04
8/31/04
9/30/04
10/31/04
11/30/04
12/31/04
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

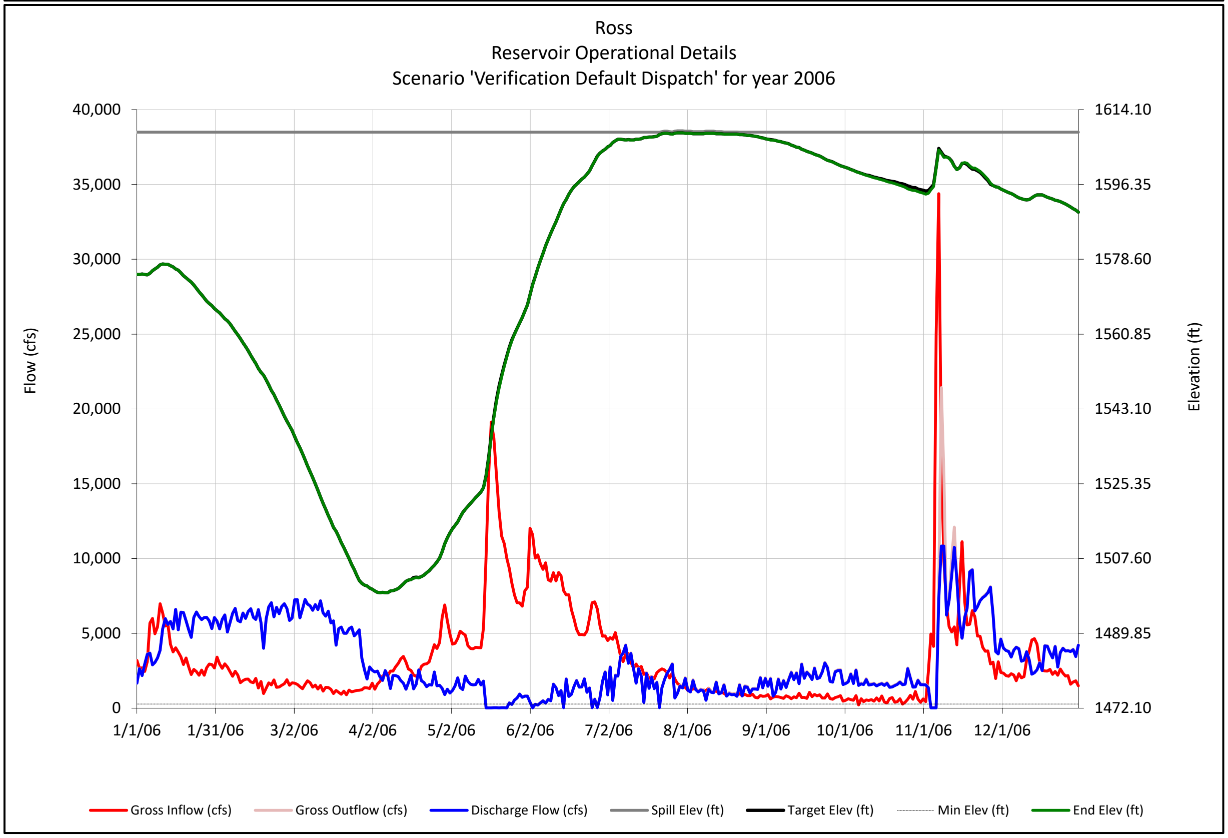

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2004
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1214.00
1212.23
1210.45
1208.68
1206.91
1205.13
1203.36
1/1/04
1/31/04
3/1/04
4/1/04
5/1/04
6/1/04
7/1/04
7/31/04
8/31/04
9/30/04
10/31/04
11/30/04
12/31/04
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

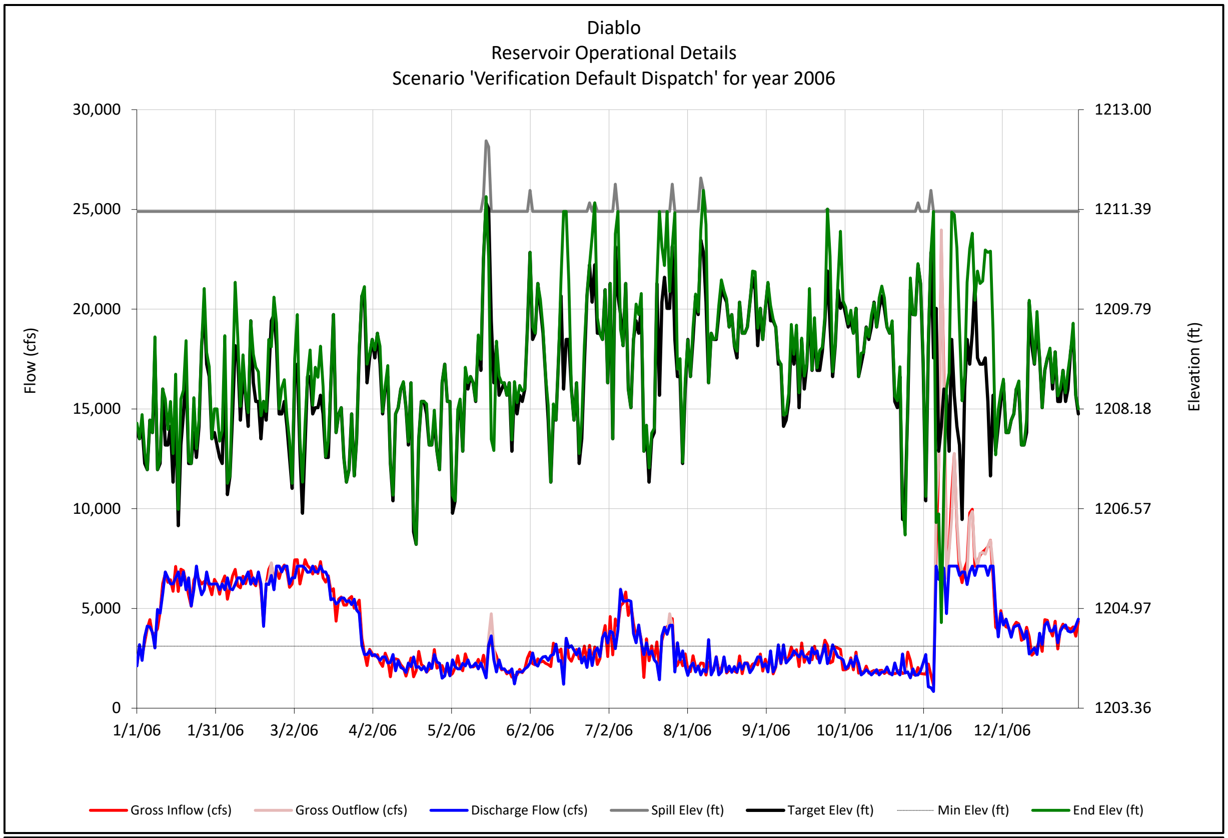

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2004
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
887.50
878.00
868.50
859.01
849.51
840.01
830.51
1/1/04
1/31/04
3/1/04
4/1/04
5/1/04
6/1/04
7/1/04
7/31/04
8/31/04
9/30/04
10/31/04
11/30/04
12/31/04
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

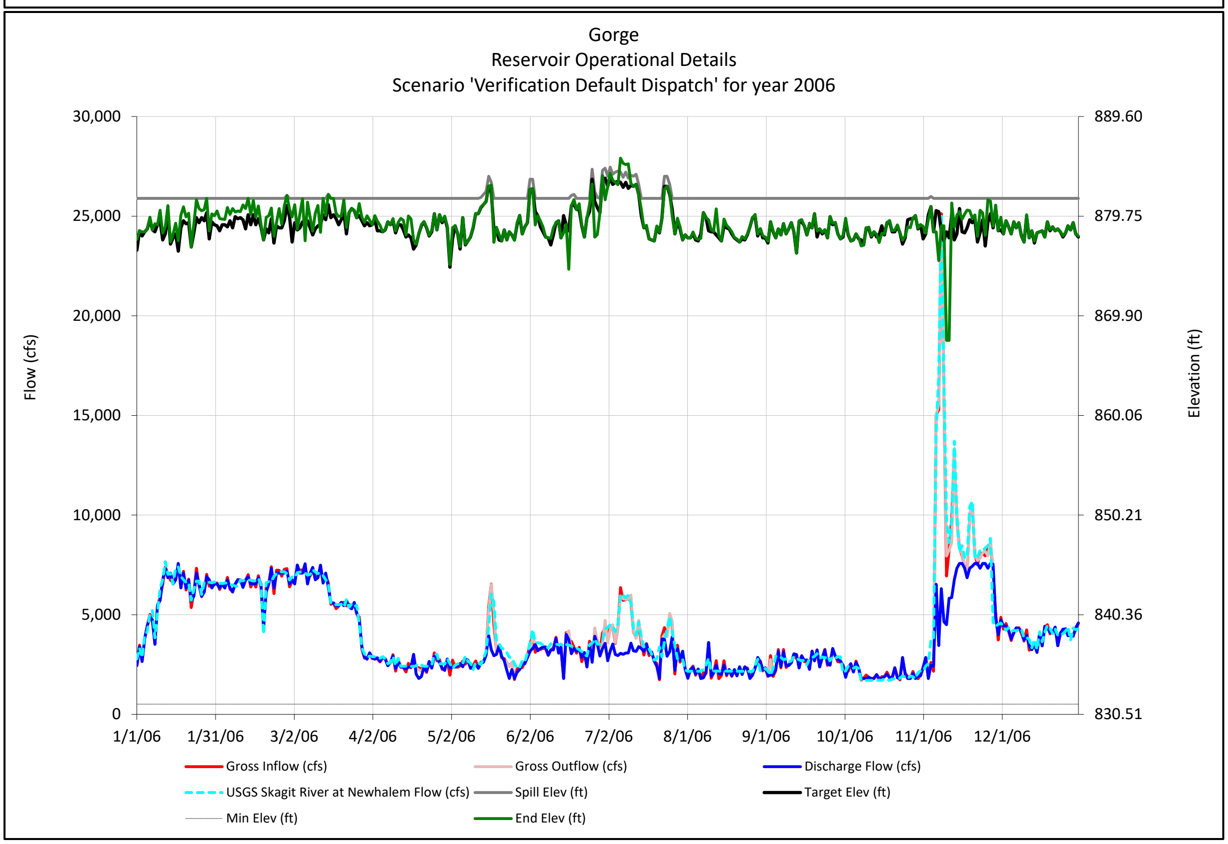

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2005
Flow (cfs)
Elevation (ft)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.90
1599.72
1585.54
1571.36
1557.18
1543.00
1528.82
1514.64
1500.46
1486.28
1472.10
1/1/05
1/31/05
3/2/05
4/2/05
5/2/05
6/2/05
7/2/05
8/1/05
9/1/05
10/1/05
11/1/05
12/1/05
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

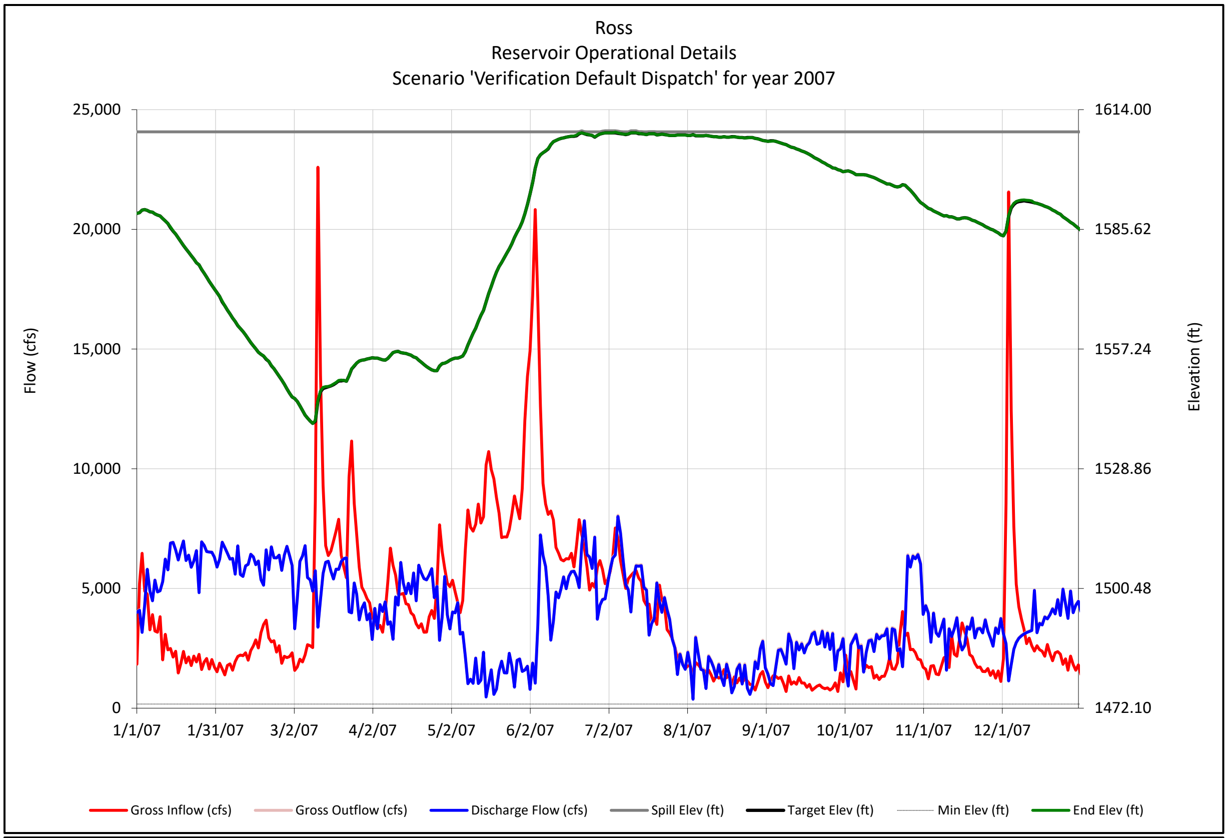

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2005
Flow (cfs)
Elevation (ft)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1214.00
1212.52
1211.04
1209.57
1208.09
1206.61
1205.13
1203.66
1202.18
1200.70
1/1/05
1/31/05
3/2/05
4/2/05
5/2/05
6/2/05
7/2/05
8/1/05
9/1/05
10/1/05
11/1/05
12/1/05
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

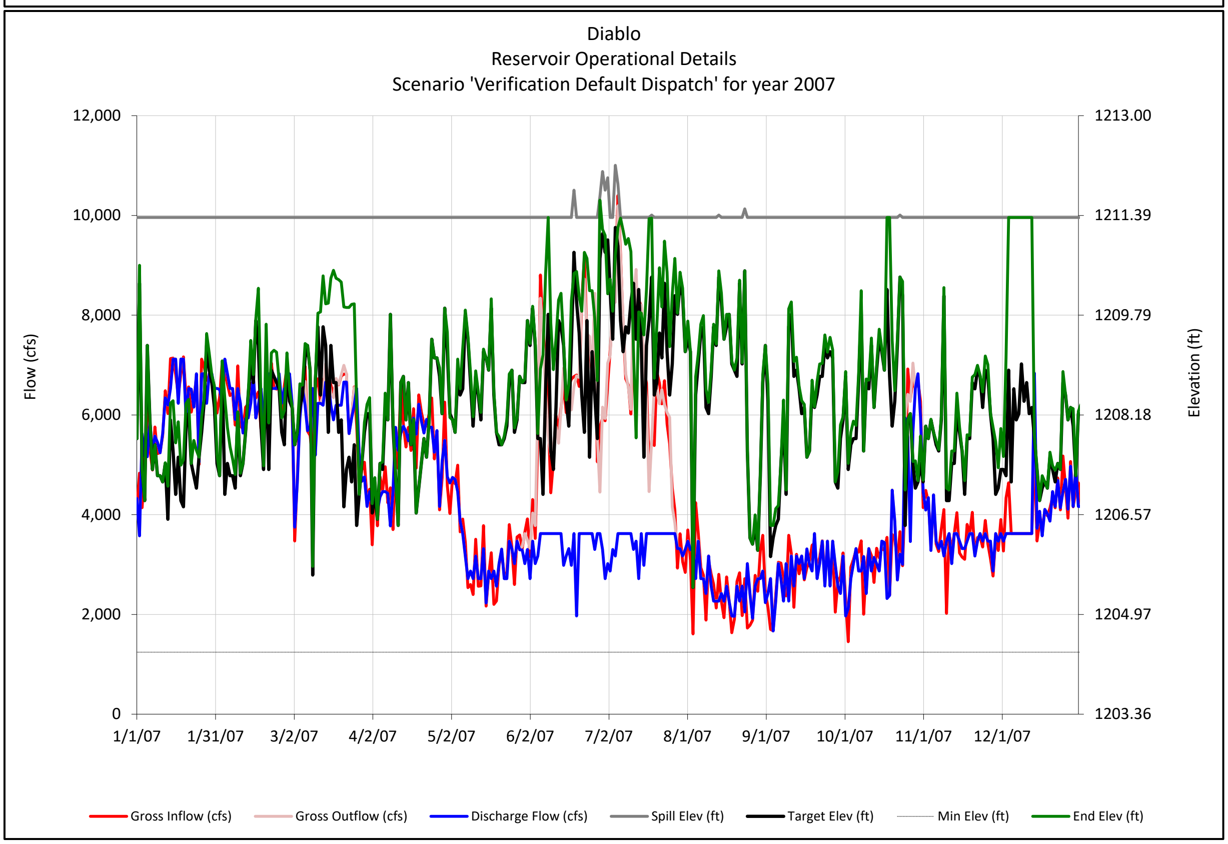

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2005
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
887.90
878.34
868.77
859.21
849.64
840.08
830.51
1/1/05
1/31/05
3/2/05
4/2/05
5/2/05
6/2/05
7/2/05
8/1/05
9/1/05
10/1/05
11/1/05
12/1/05
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

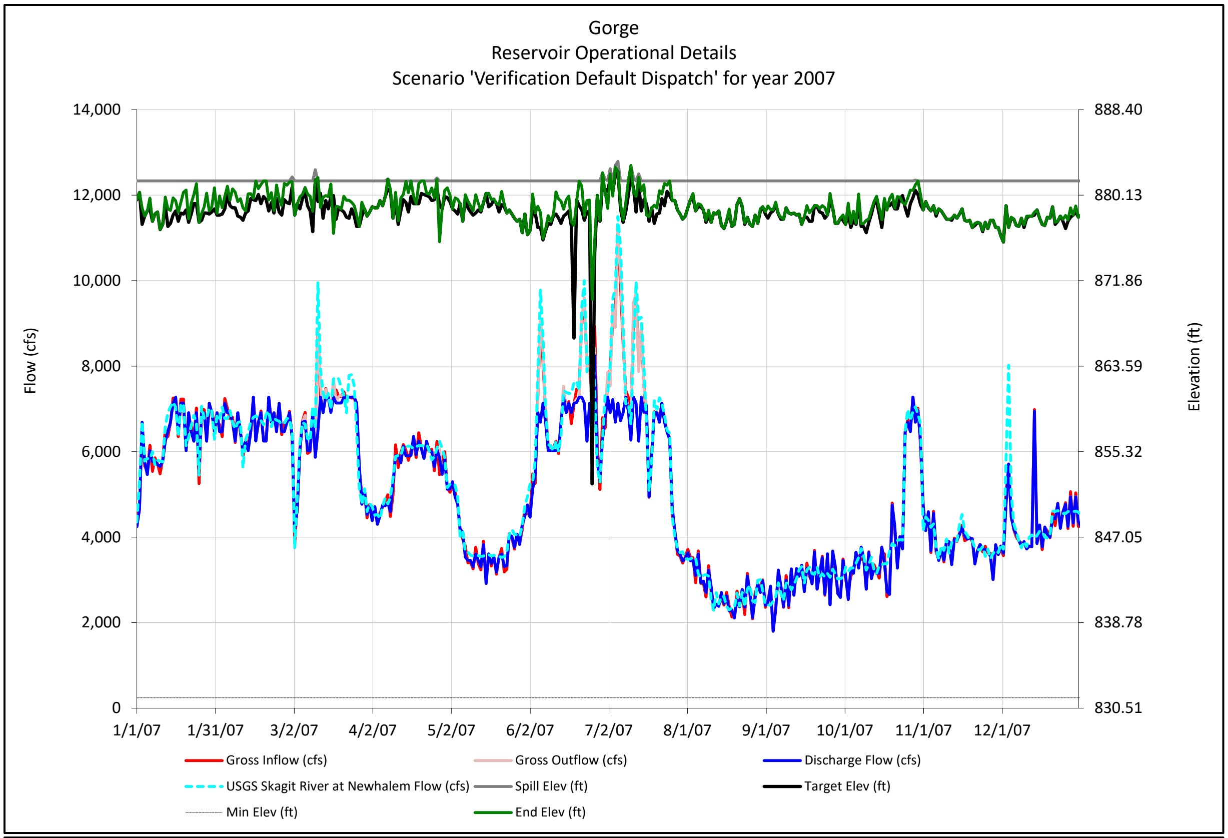

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2006
Flow (cfs)
Elevation (ft)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1614.10
1596.35
1578.60
1560.85
1543.10
1525.35
1507.60
1489.85
1472.10
1/1/06
1/31/06
3/2/06
4/2/06
5/2/06
6/2/06
7/2/06
8/1/06
9/1/06
10/1/06
11/1/06
12/1/06
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

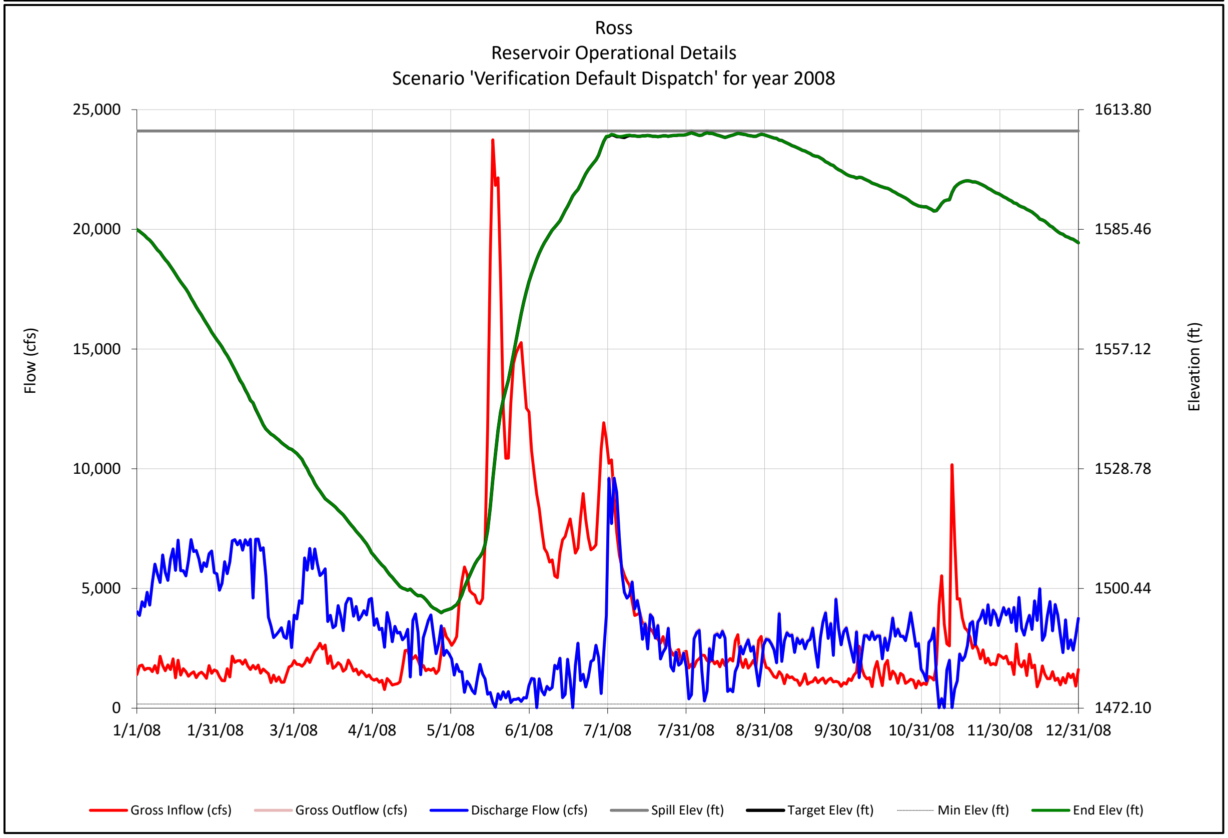

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2006
Flow (cfs)
Elevation (ft)
30,000
25,000
20,000
15,000
10,000
5,000
0
1213.00
1211.39
1209.79
1208.18
1206.57
1204.97
1203.36
1/1/06
1/31/06
3/2/06
4/2/06
5/2/06
6/2/06
7/2/06
8/1/06
9/1/06
10/1/06
11/1/06
12/1/06
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

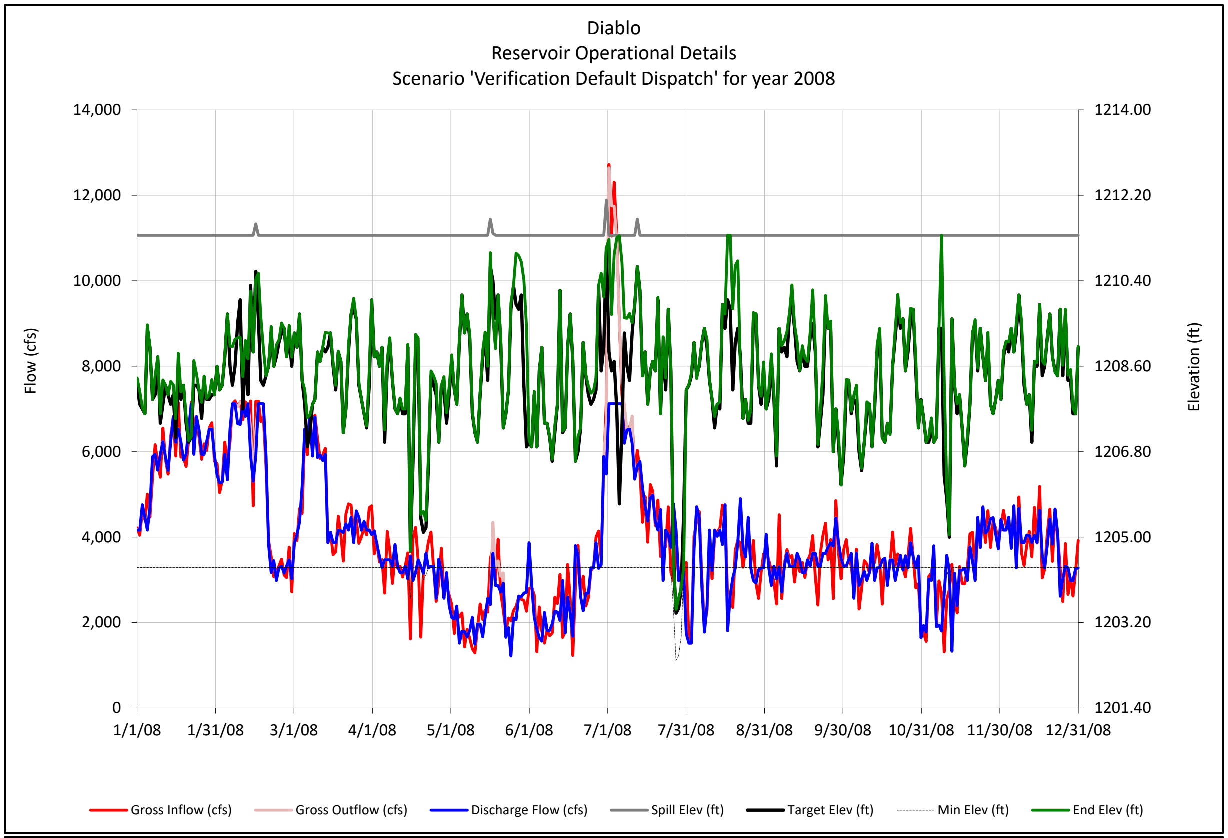

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2006
Flow (cfs)
Elevation (ft)
30,000
25,000
20,000
15,000
10,000
5,000
0
889.60
879.75
869.90
860.06
850.21
840.36
830.51
1/1/06
1/31/06
3/2/06
4/2/06
5/2/06
6/2/06
7/2/06
8/1/06
9/1/06
10/1/06
11/1/06
12/1/06
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

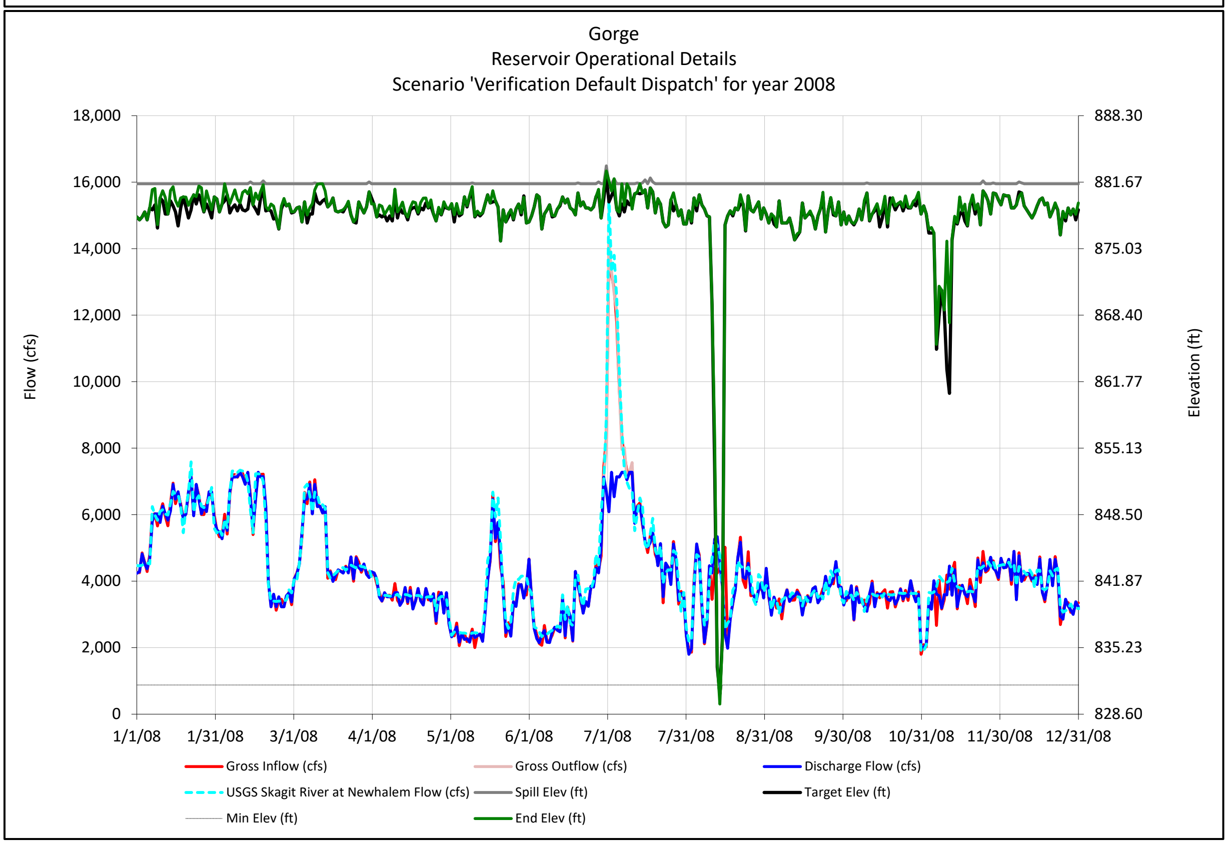

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2007
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
1614.00
1585.62
1557.24
1528.86
1500.48
1472.10
1/1/07
1/31/07
3/2/07
4/2/07
5/2/07
6/2/07
7/2/07
8/1/07
9/1/07
10/1/07
11/1/07
12/1/07
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

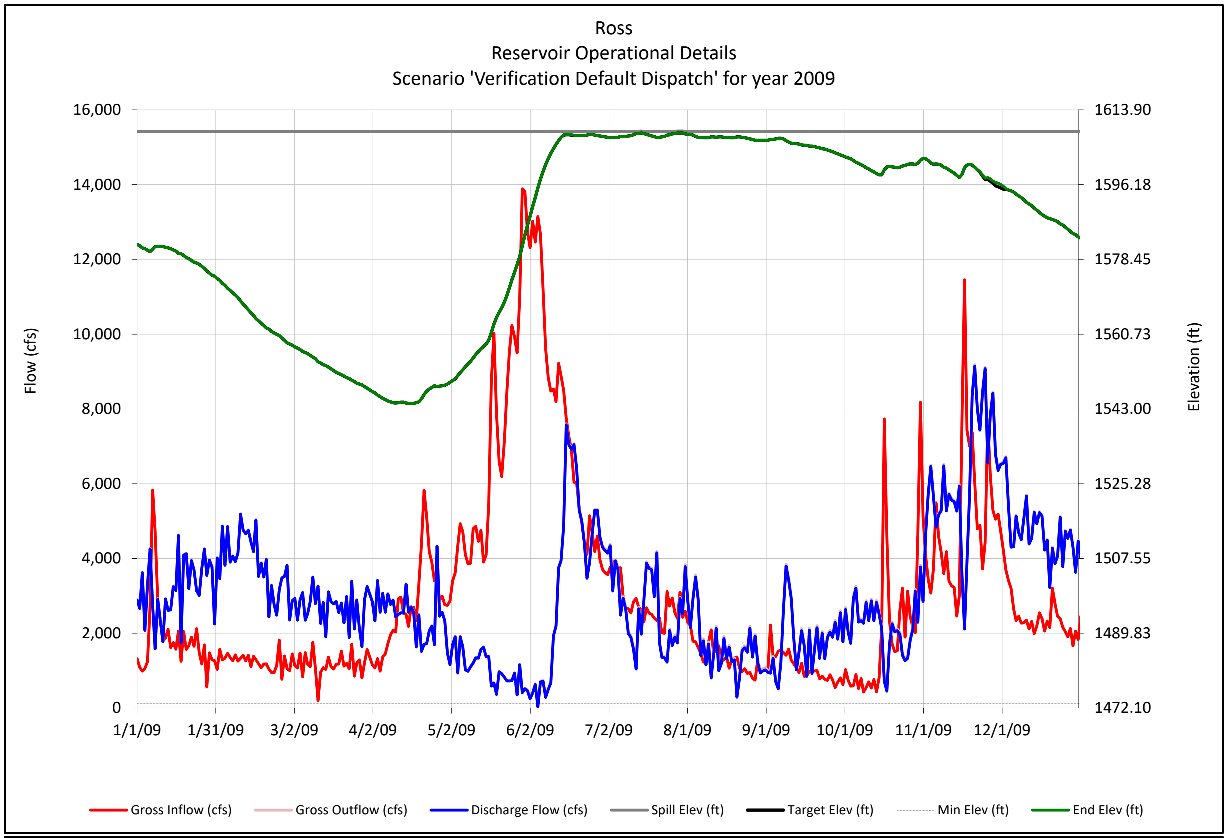

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2007
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1213.00
1211.39
1209.79
1208.18
1206.57
1204.97
1203.36
1/1/07
1/31/07
3/2/07
4/2/07
5/2/07
6/2/07
7/2/07
8/1/07
9/1/07
10/1/07
11/1/07
12/1/07
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

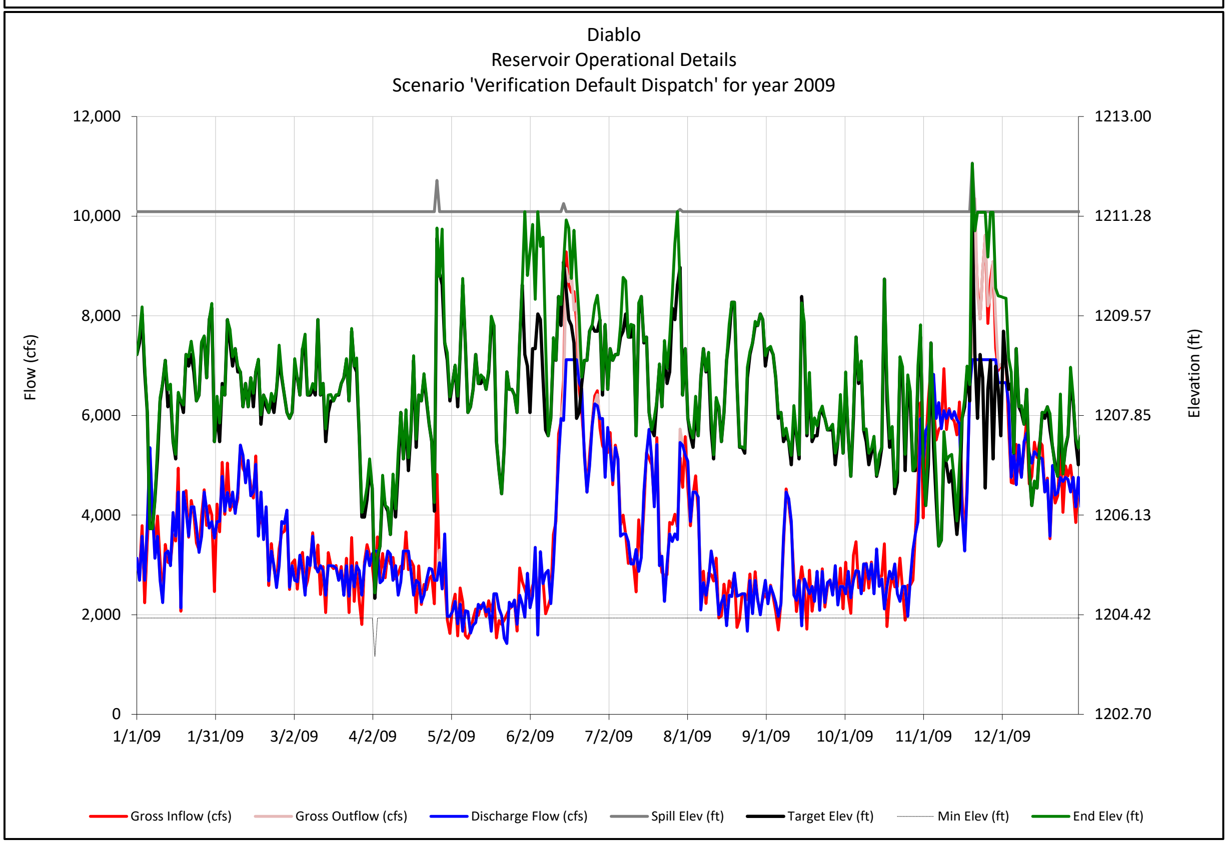

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2007
Flow (cfs)
Elevation (ft)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
888.40
880.13
871.86
863.59
855.32
847.05
838.78
830.51
1/1/07
1/31/07
3/2/07
4/2/07
5/2/07
6/2/07
7/2/07
8/1/07
9/1/07
10/1/07
11/1/07
12/1/07
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

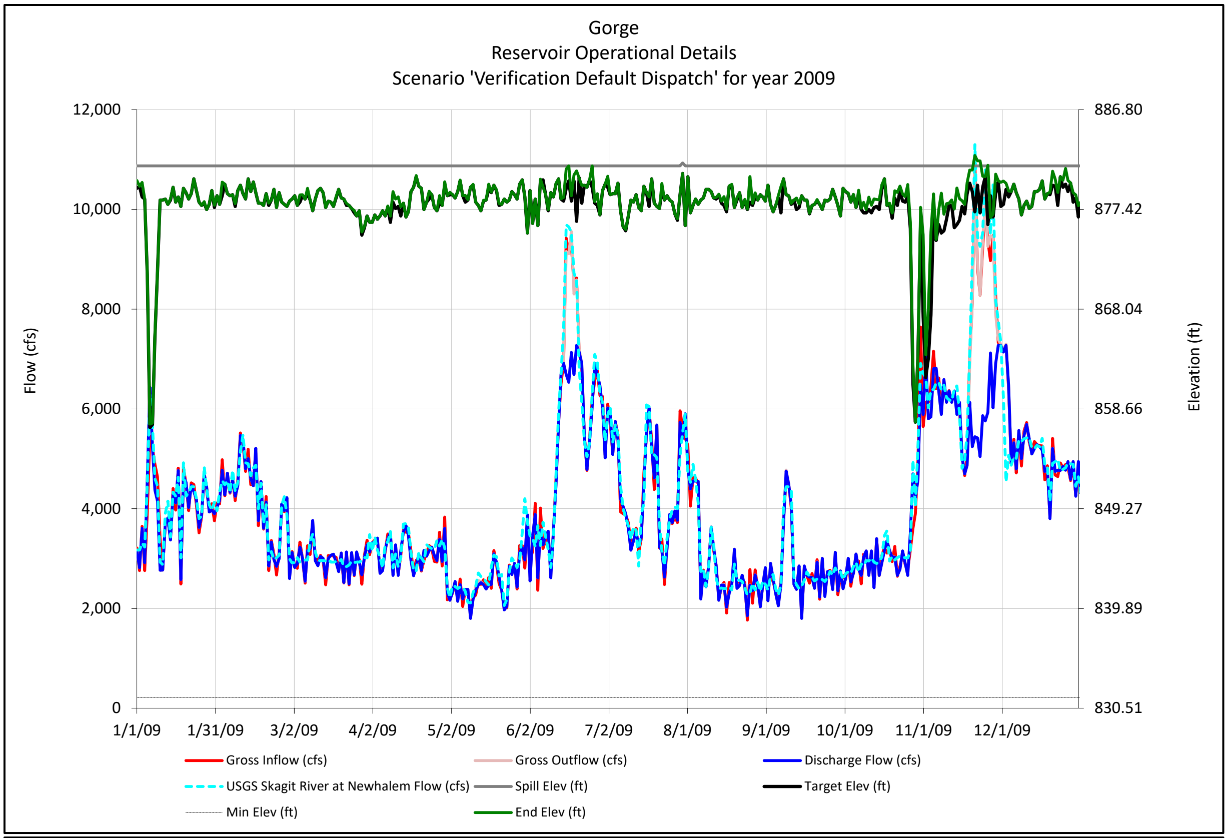

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2008
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
1613.80
1585.46
1557.12
1528.78
1500.44
1472.10
1/1/08
1/31/08
3/1/08
4/1/08
5/1/08
6/1/08
7/1/08
7/31/08
8/31/08
9/30/08
10/31/08
11/30/08
12/31/08
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

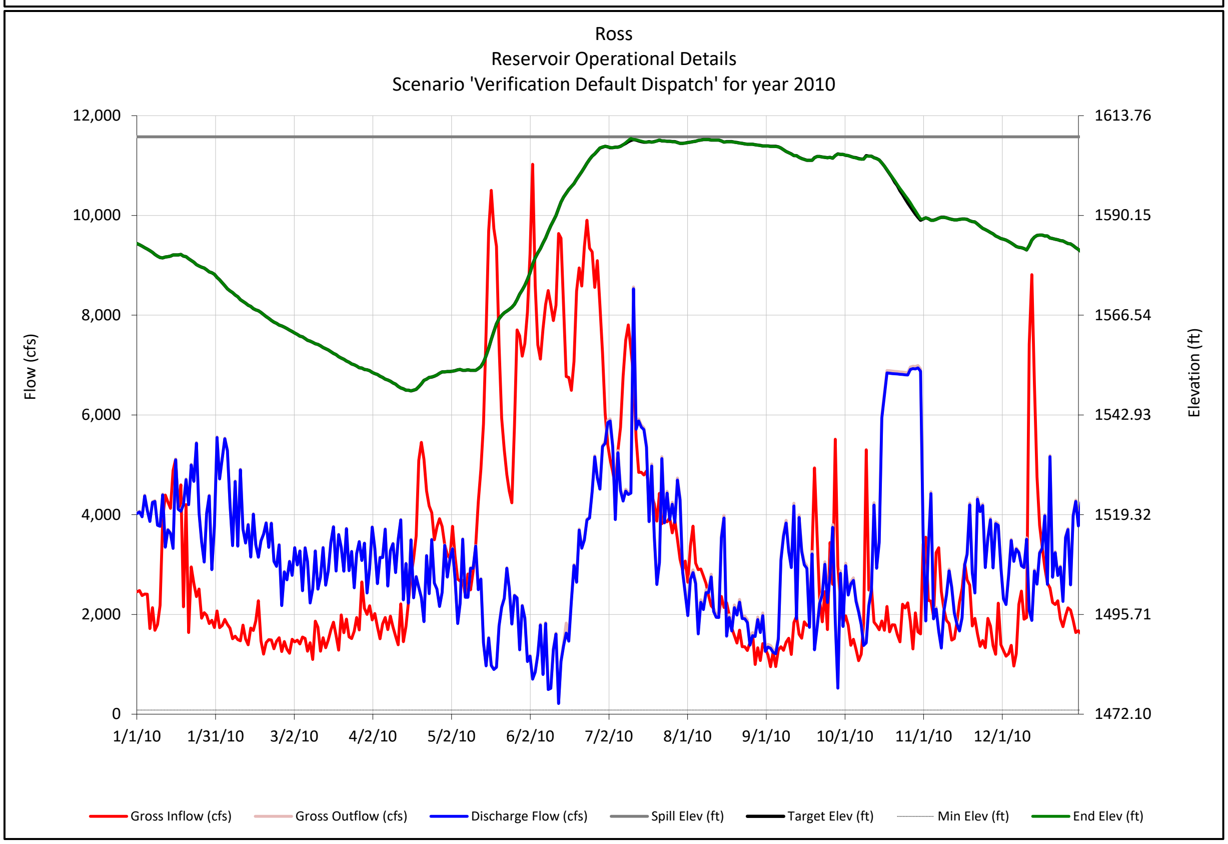

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2008
Flow (cfs)
Elevation (ft)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1214.00
1212.20
1210.40
1208.60
1206.80
1205.00
1203.20
1201.40
1/1/08
1/31/08
3/1/08
4/1/08
5/1/08
6/1/08
7/1/08
7/31/08
8/31/08
9/30/08
10/31/08
11/30/08
12/31/08
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

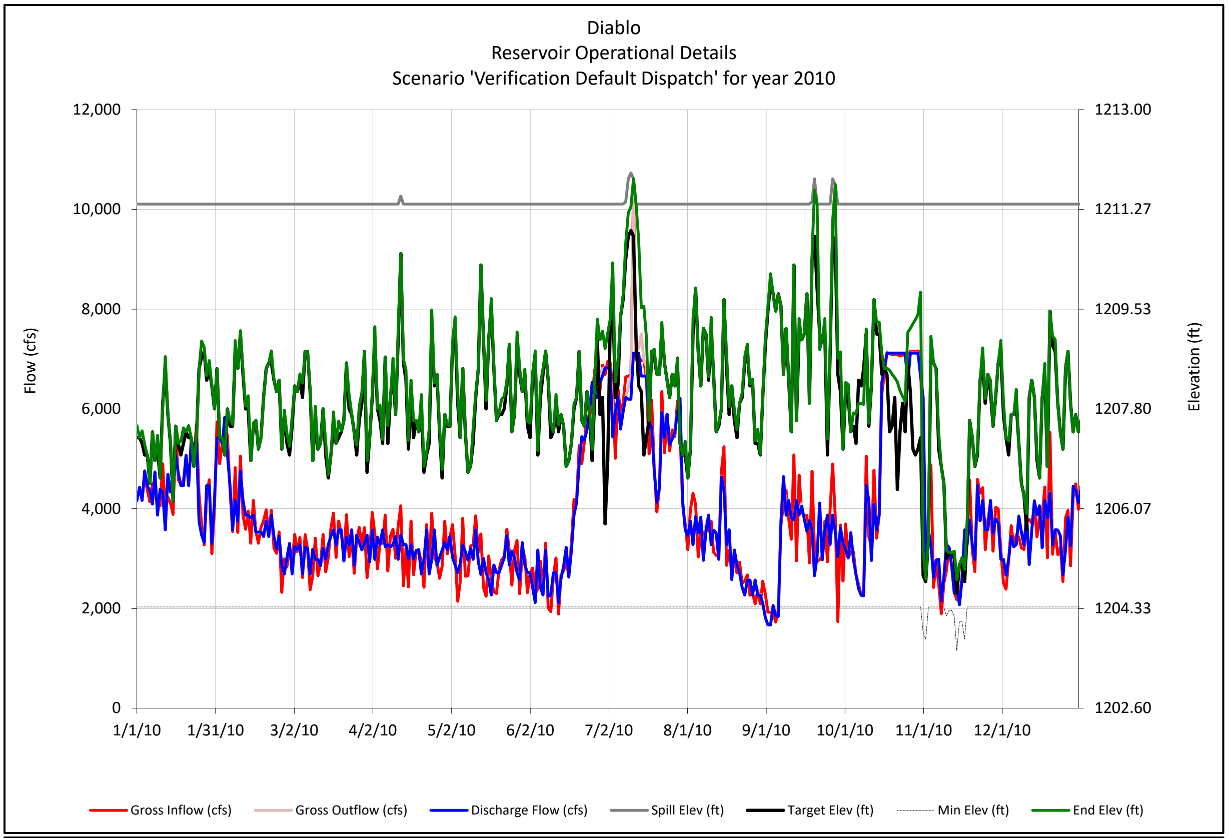

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2008
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
888.30
881.67
875.03
868.40
861.77
855.13
848.50
841.87
835.23
828.60
1/1/08
1/31/08
3/1/08
4/1/08
5/1/08
6/1/08
7/1/08
7/31/08
8/31/08
9/30/08
10/31/08
11/30/08
12/31/08
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

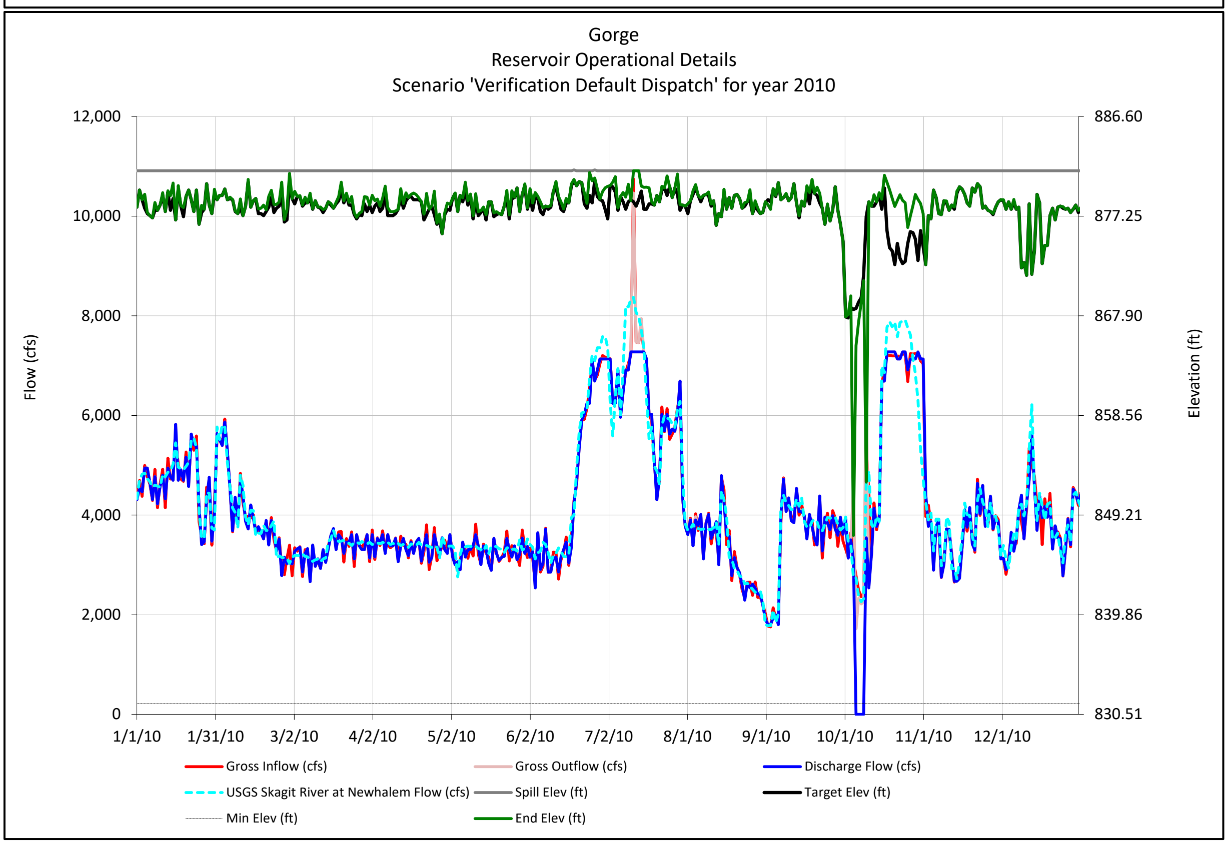

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2009
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.90
1596.18
1578.45
1560.73
1543.00
1525.28
1507.55
1489.83
1472.10
1/1/09
1/31/09
3/2/09
4/2/09
5/2/09
6/2/09
7/2/09
8/1/09
9/1/09
10/1/09
11/1/09
12/1/09
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

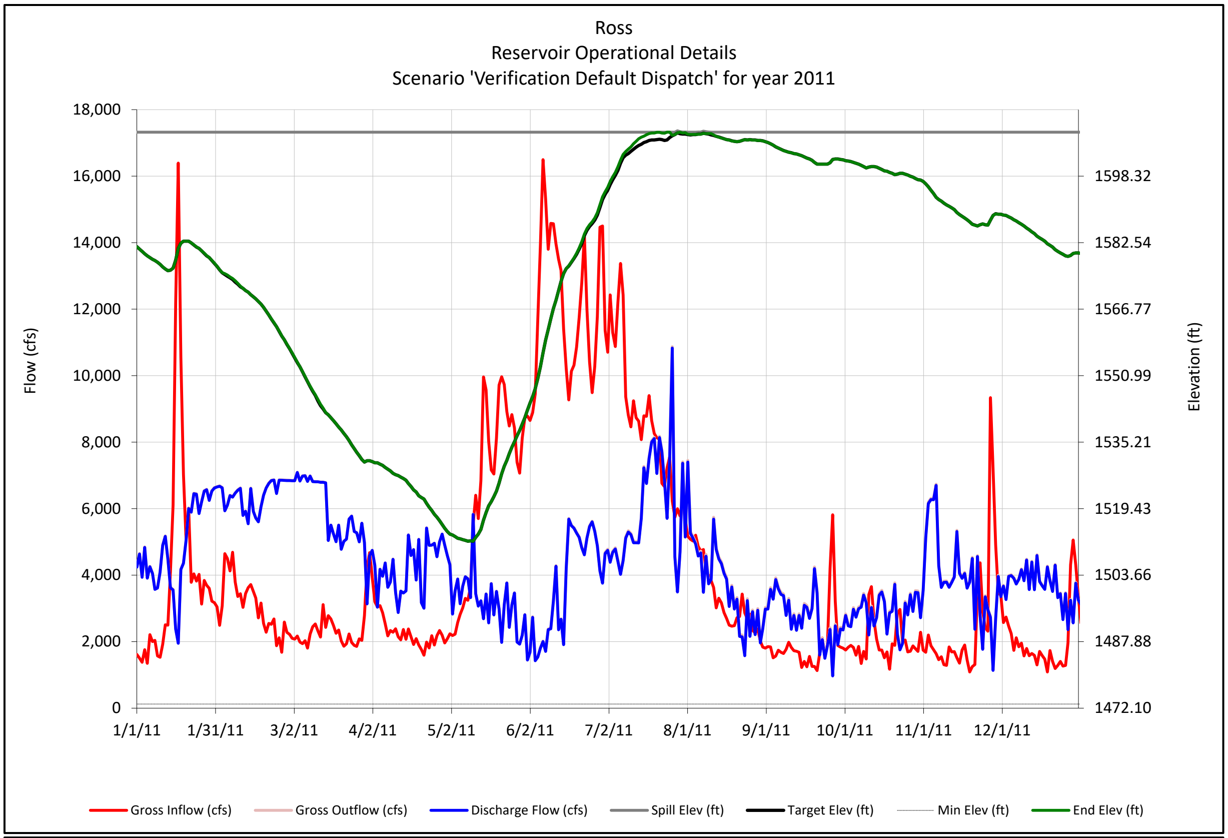

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2009
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1213.00
1211.28
1209.57
1207.85
1206.13
1204.42
1202.70
1/1/09
1/31/09
3/2/09
4/2/09
5/2/09
6/2/09
7/2/09
8/1/09
9/1/09
10/1/09
11/1/09
12/1/09
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

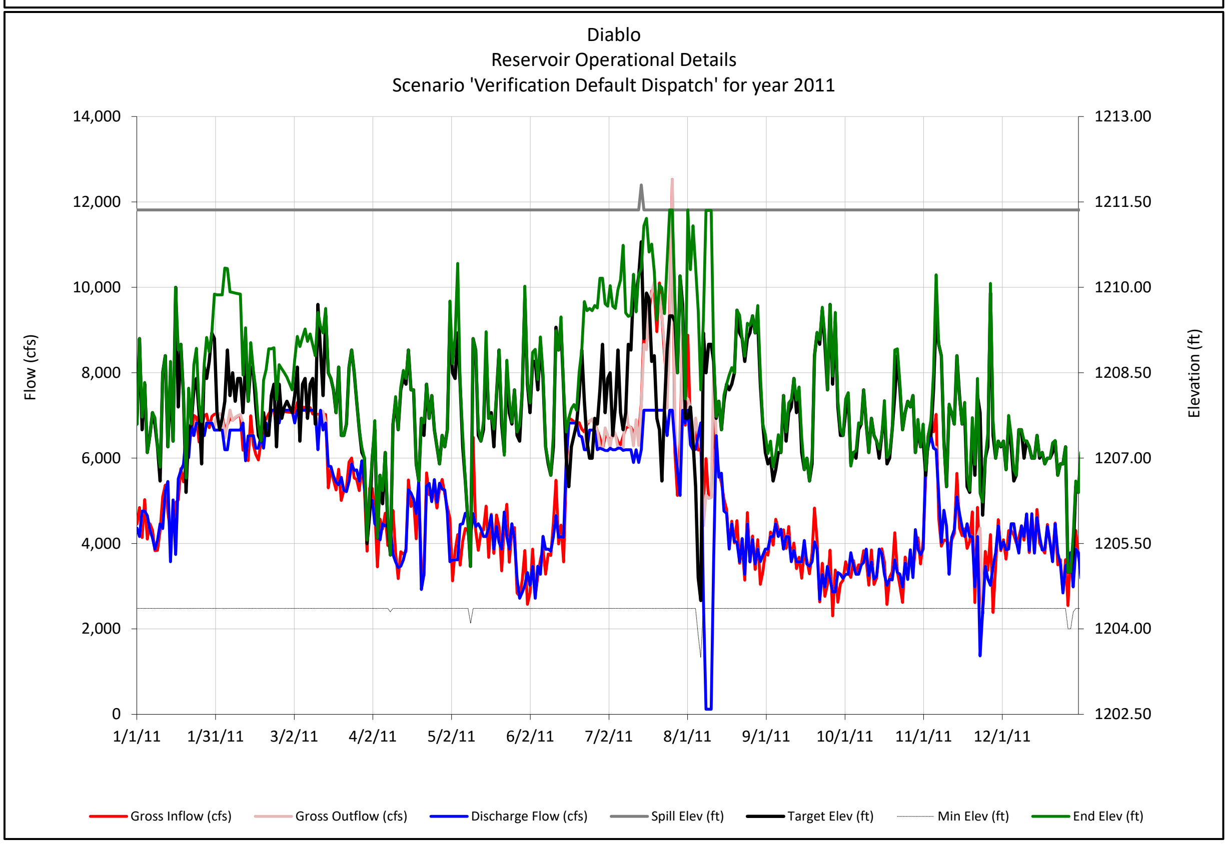

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2009
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
886.80
877.42
868.04
858.66
849.27
839.89
830.51
1/1/09
1/31/09
3/2/09
4/2/09
5/2/09
6/2/09
7/2/09
8/1/09
9/1/09
10/1/09
11/1/09
12/1/09
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

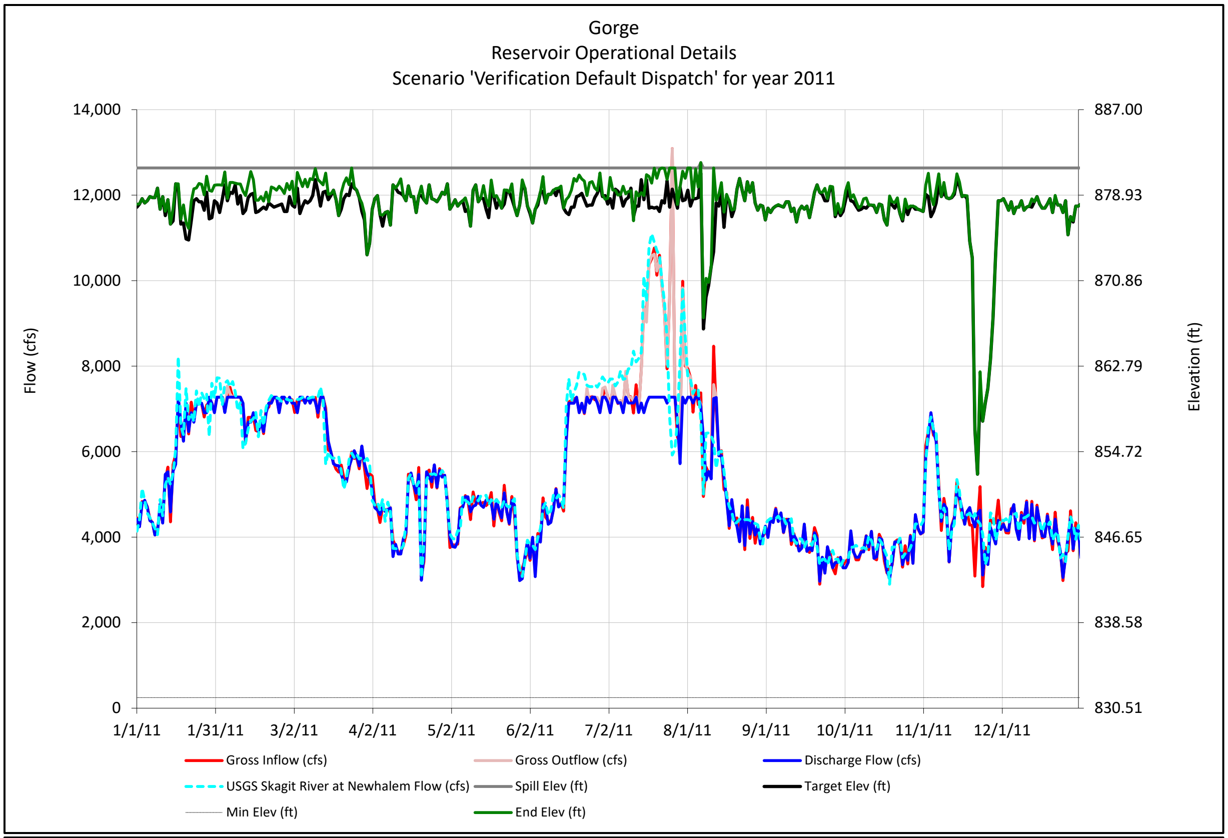

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2010
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1590.15
1566.54
1542.93
1519.32
1495.71
1472.10
1/1/10
1/31/10
3/2/10
4/2/10
5/2/10
6/2/10
7/2/10
8/1/10
9/1/10
10/1/10
11/1/10
12/1/10
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

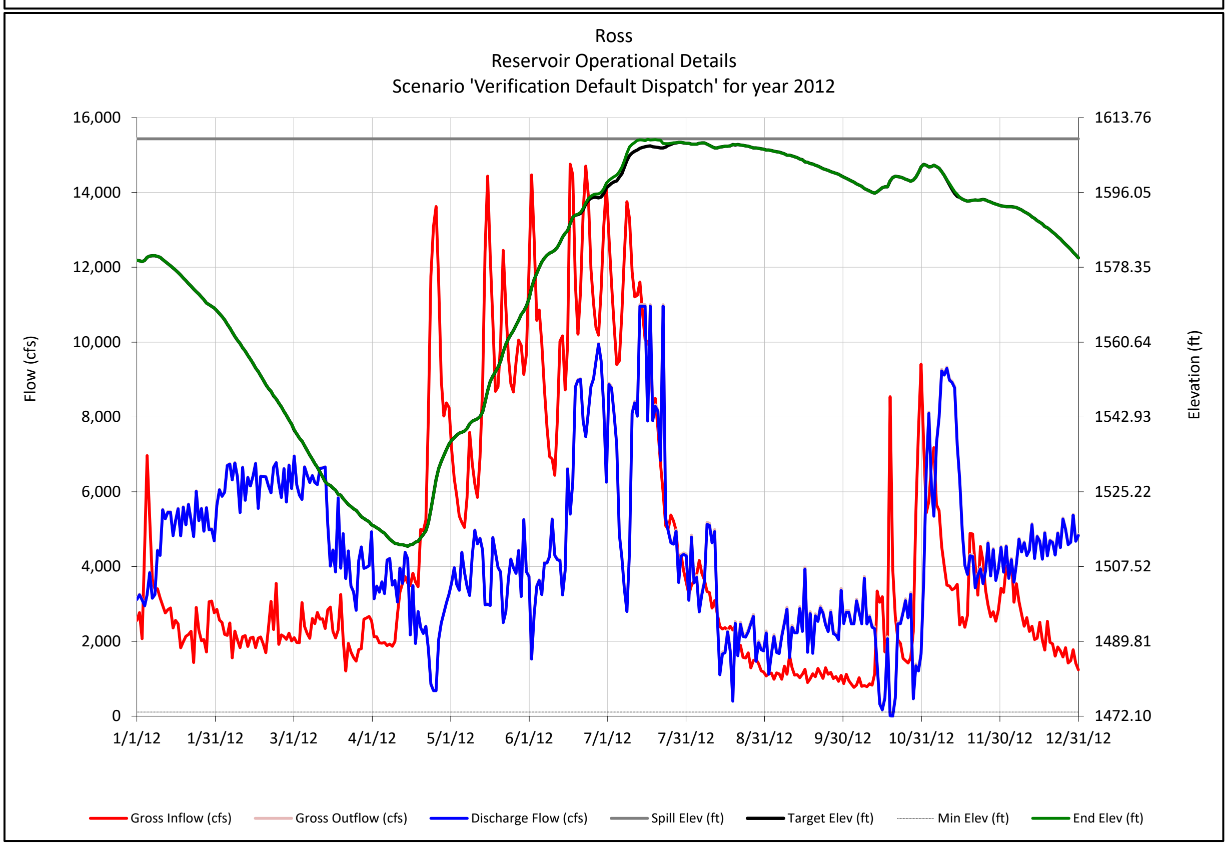

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2010
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1213.00
1211.27
1209.53
1207.80
1206.07
1204.33
1202.60
1/1/10
1/31/10
3/2/10
4/2/10
5/2/10
6/2/10
7/2/10
8/1/10
9/1/10
10/1/10
11/1/10
12/1/10
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

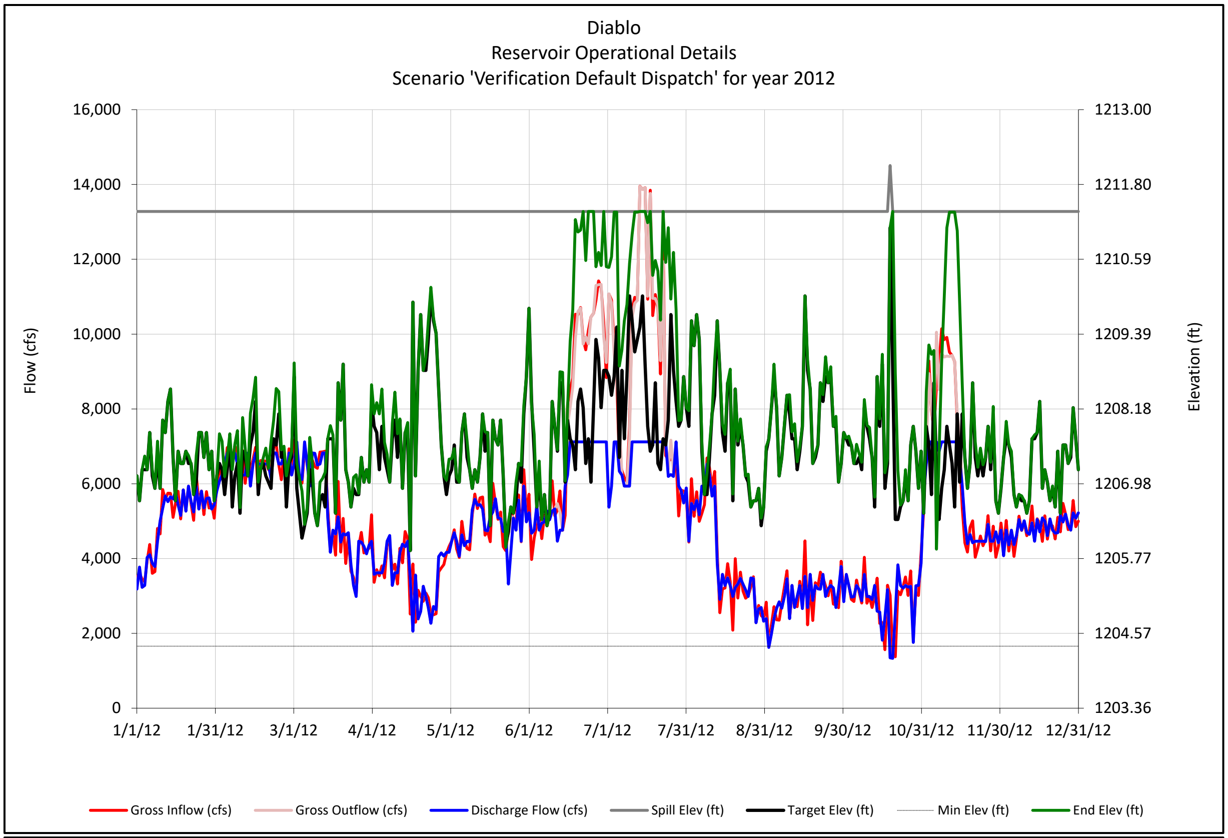

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2010
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
886.60
877.25
867.90
858.56
849.21
839.86
830.51
1/1/10
1/31/10
3/2/10
4/2/10
5/2/10
6/2/10
7/2/10
8/1/10
9/1/10
10/1/10
11/1/10
12/1/10
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

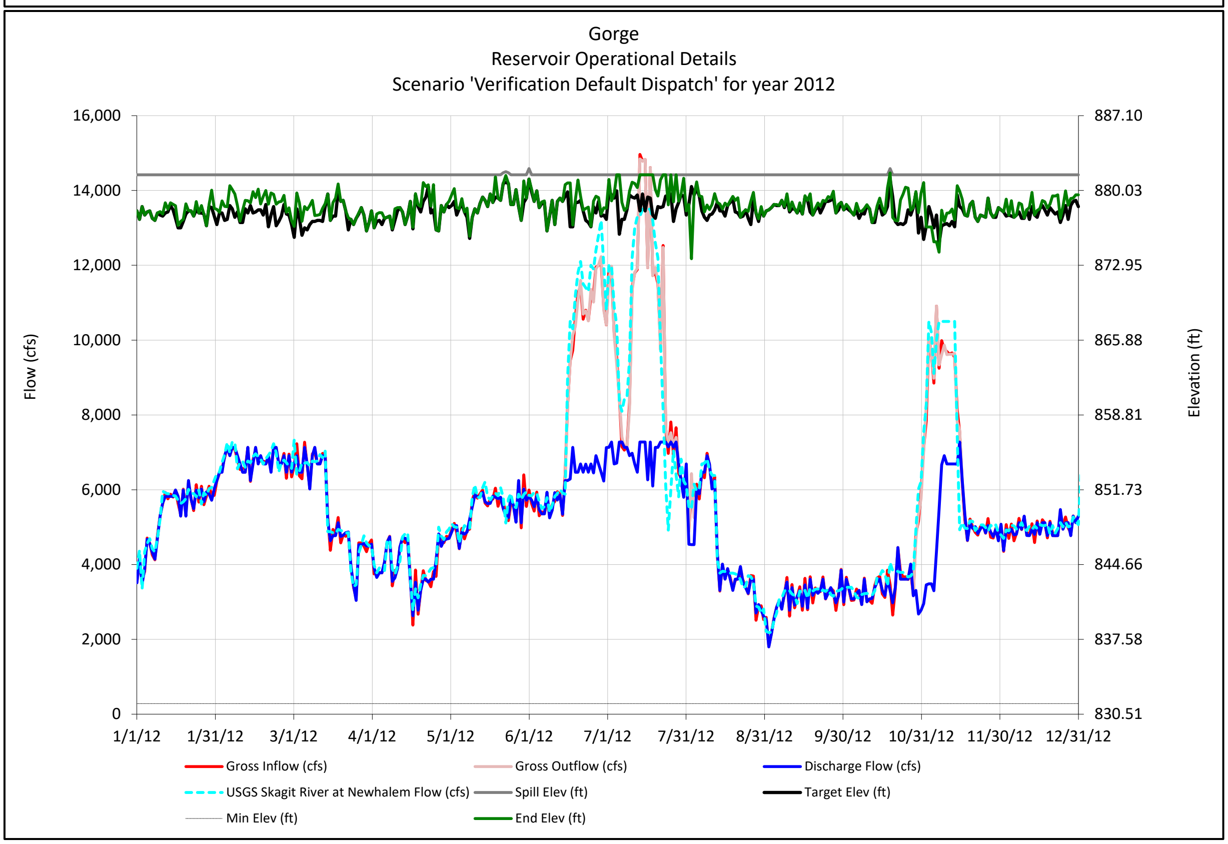

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2011
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1598.32
1582.54
1566.77
1550.99
1535.21
1519.43
1503.66
1487.88
1472.10
1/1/11
1/31/11
3/2/11
4/2/11
5/2/11
6/2/11
7/2/11
8/1/11
9/1/11
10/1/11
11/1/11
12/1/11
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

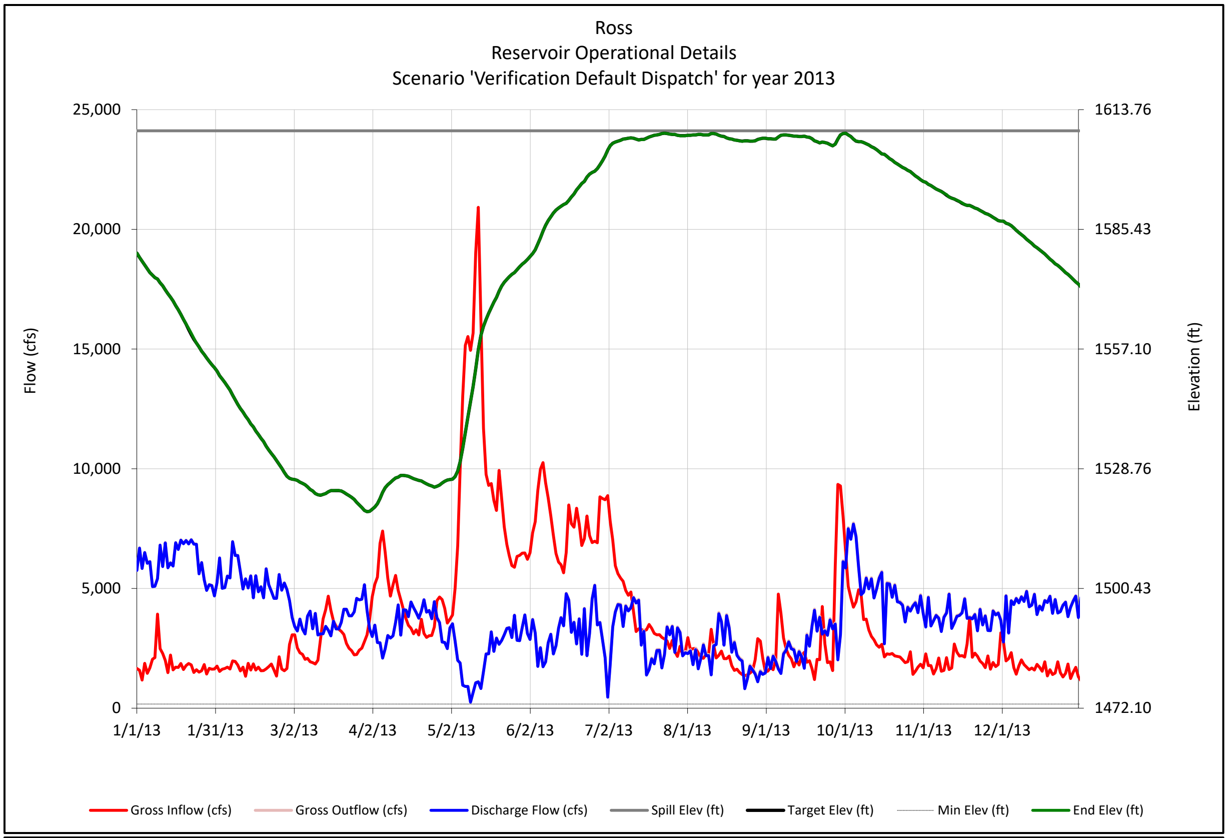

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2011
Flow (cfs)
Elevation (ft)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1213.00
1211.50
1210.00
1208.50
1207.00
1205.50
1204.00
1202.50
1/1/11
1/31/11
3/2/11
4/2/11
5/2/11
6/2/11
7/2/11
8/1/11
9/1/11
10/1/11
11/1/11
12/1/11
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

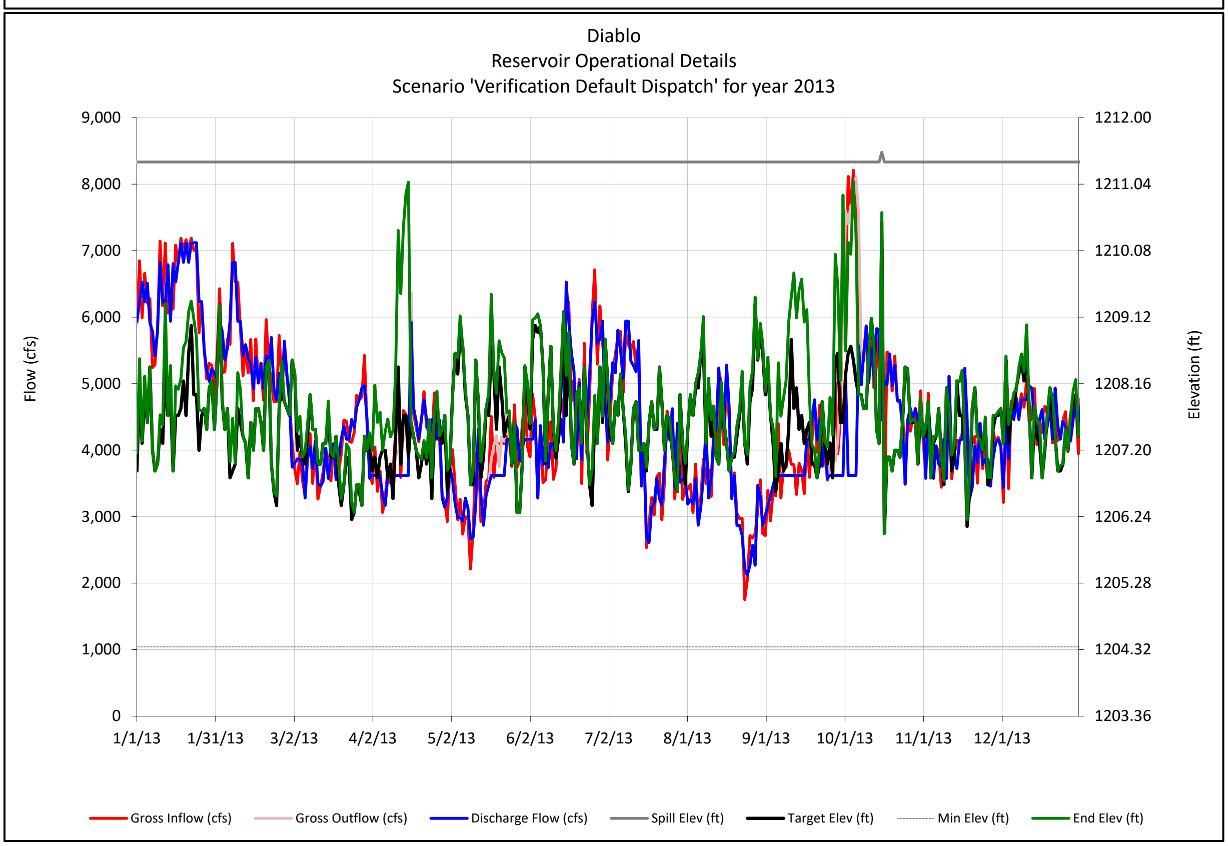

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2011
Flow (cfs)
Elevation (ft)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
887.00
878.93
870.86
862.79
854.72
846.65
838.58
830.51
1/1/11
1/31/11
3/2/11
4/2/11
5/2/11
6/2/11
7/2/11
8/1/11
9/1/11
10/1/11
11/1/11
12/1/11
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

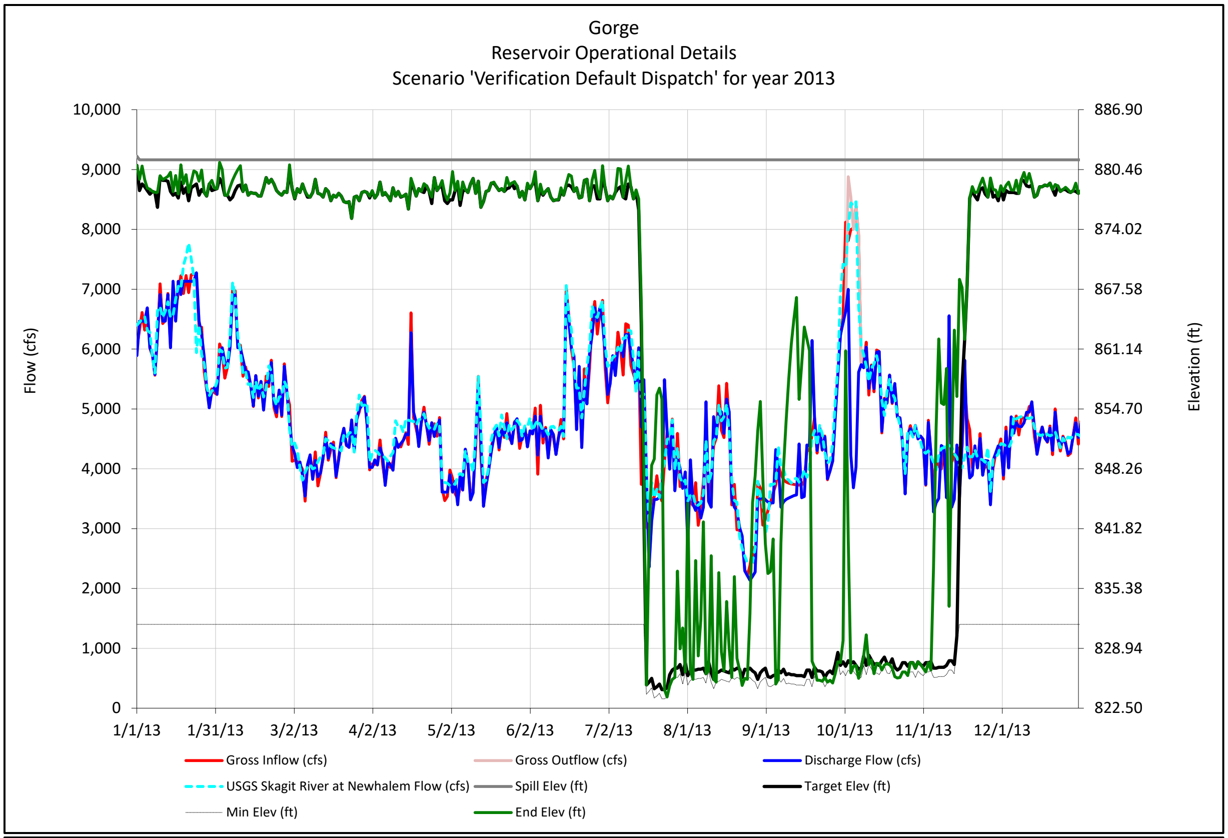

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2012
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1596.05
1578.35
1560.64
1542.93
1525.22
1507.52
1489.81
1472.10
1/1/12
1/31/12
3/1/12
4/1/12
5/1/12
6/1/12
7/1/12
7/31/12
8/31/12
9/30/12
10/31/12
11/30/12
12/31/12
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

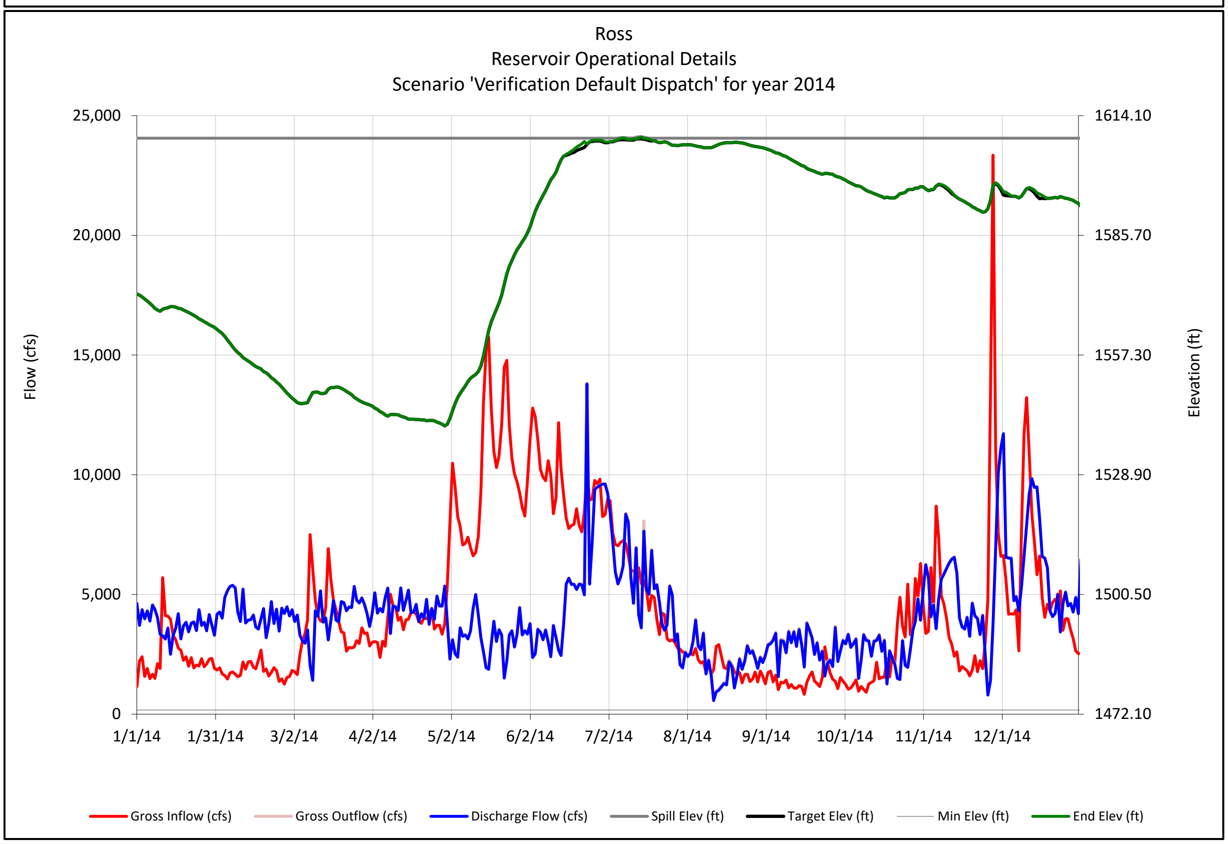

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2012
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1213.00
1211.80
1210.59
1209.39
1208.18
1206.98
1205.77
1204.57
1203.36
1/1/12
1/31/12
3/1/12
4/1/12
5/1/12
6/1/12
7/1/12
7/31/12
8/31/12
9/30/12
10/31/12
11/30/12
12/31/12
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

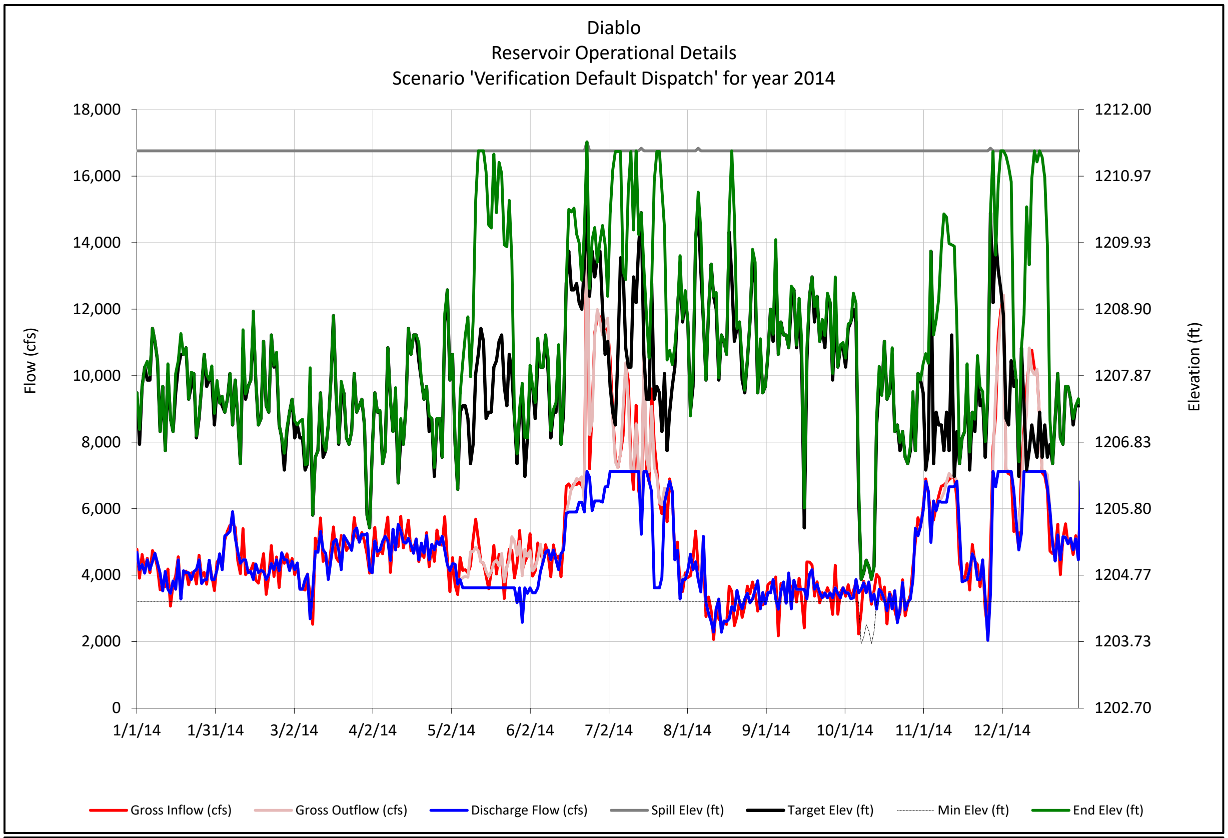

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2012
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
887.10
880.03
872.95
865.88
858.81
851.73
844.66
837.58
830.51
1/1/12
1/31/12
3/1/12
4/1/12
5/1/12
6/1/12
7/1/12
7/31/12
8/31/12
9/30/12
10/31/12
11/30/12
12/31/12
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

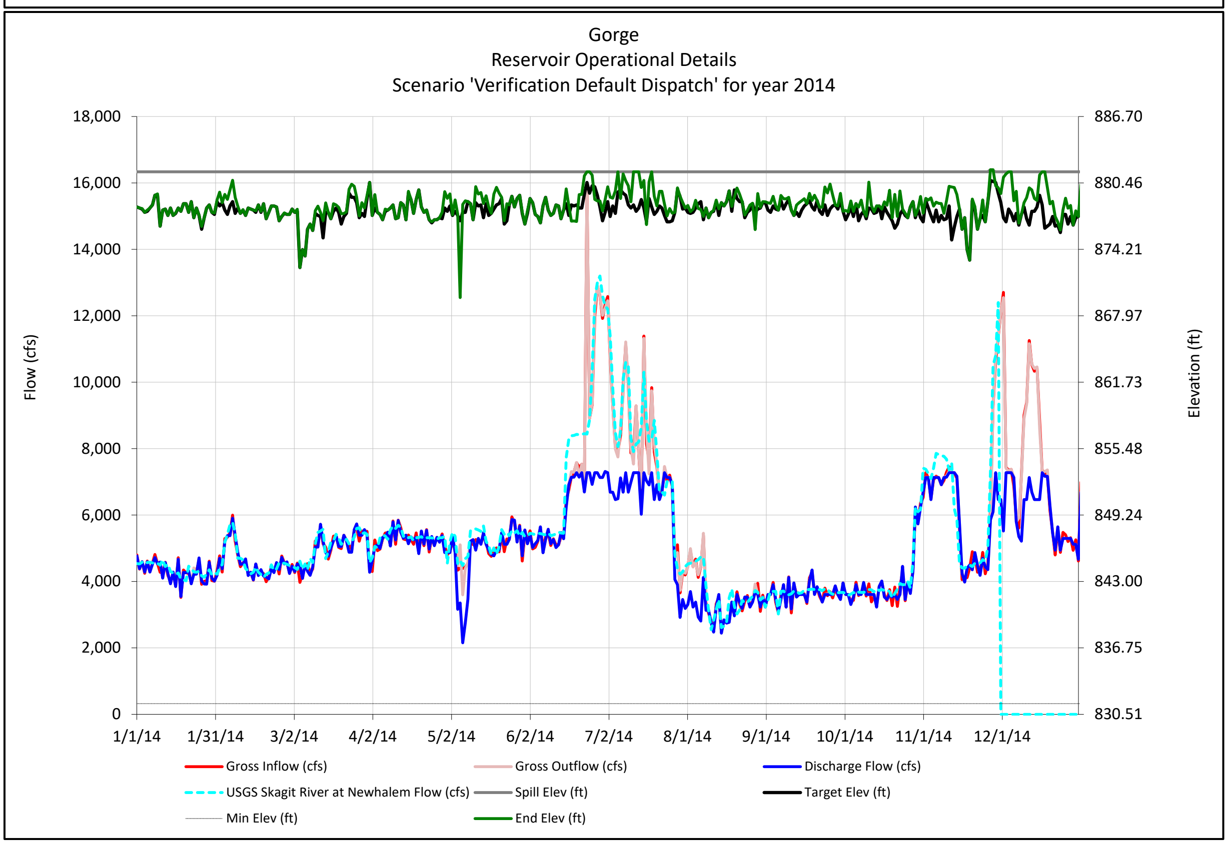

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2013
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
1613.76
1585.43
1557.10
1528.76
1500.43
1472.10
1/1/13
1/31/13
3/2/13
4/2/13
5/2/13
6/2/13
7/2/13
8/1/13
9/1/13
10/1/13
11/1/13
12/1/13
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

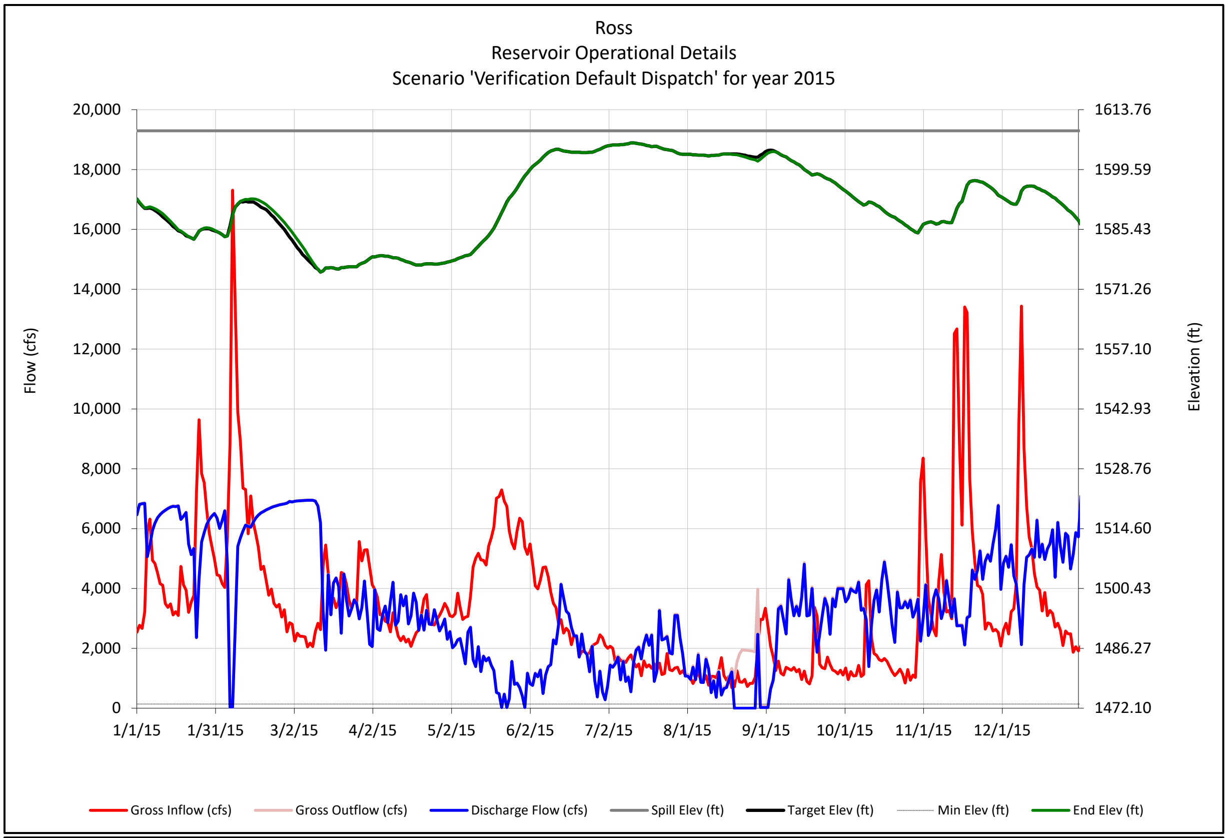

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2013
Flow (cfs)
Elevation (ft)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1212.00
1211.04
1210.08
1209.12
1208.16
1207.20
1206.24
1205.28
1204.32
1203.36
1/1/13
1/31/13
3/2/13
4/2/13
5/2/13
6/2/13
7/2/13
8/1/13
9/1/13
10/1/13
11/1/13
12/1/13
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

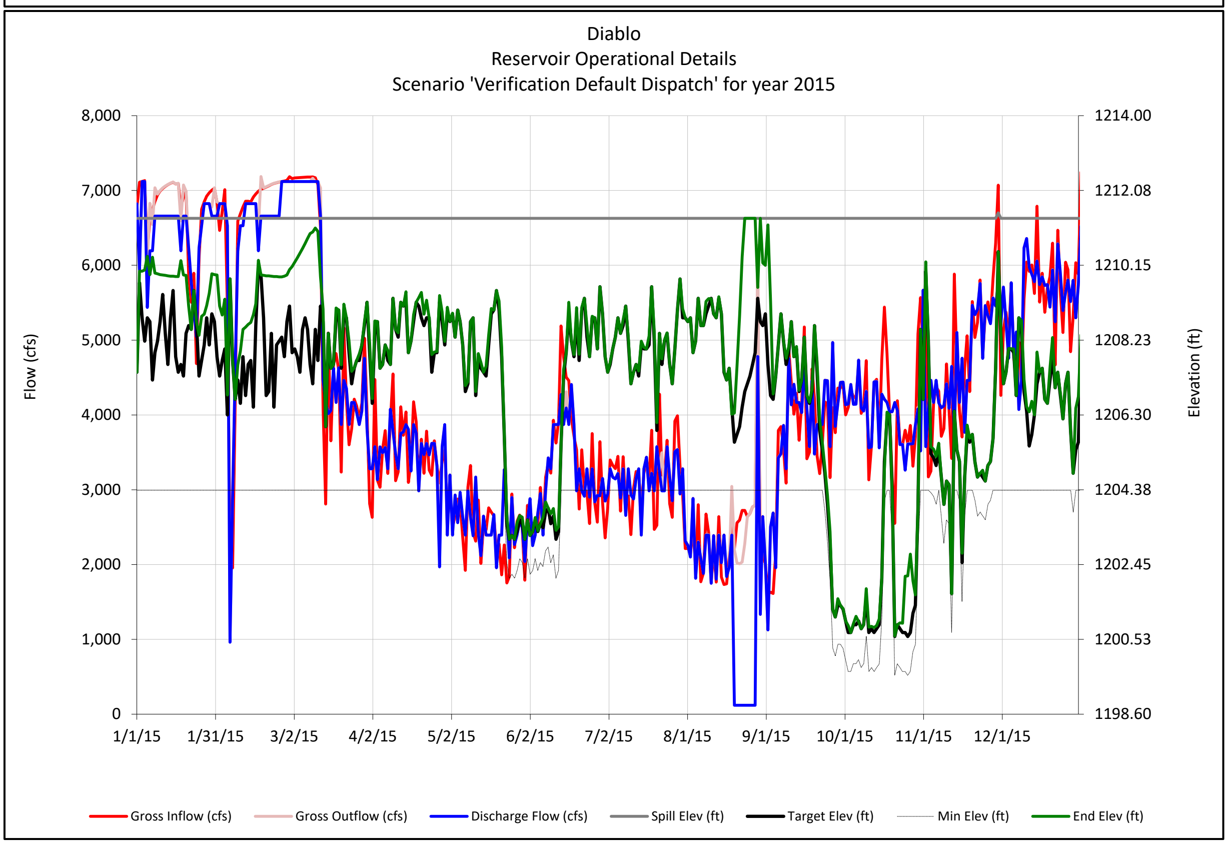

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2013
Flow (cfs)
Elevation (ft)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
886.90
880.46
874.02
867.58
861.14
854.70
848.26
841.82
835.38
828.94
822.50
1/1/13
1/31/13
3/2/13
4/2/13
5/2/13
6/2/13
7/2/13
8/1/13
9/1/13
10/1/13
11/1/13
12/1/13
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

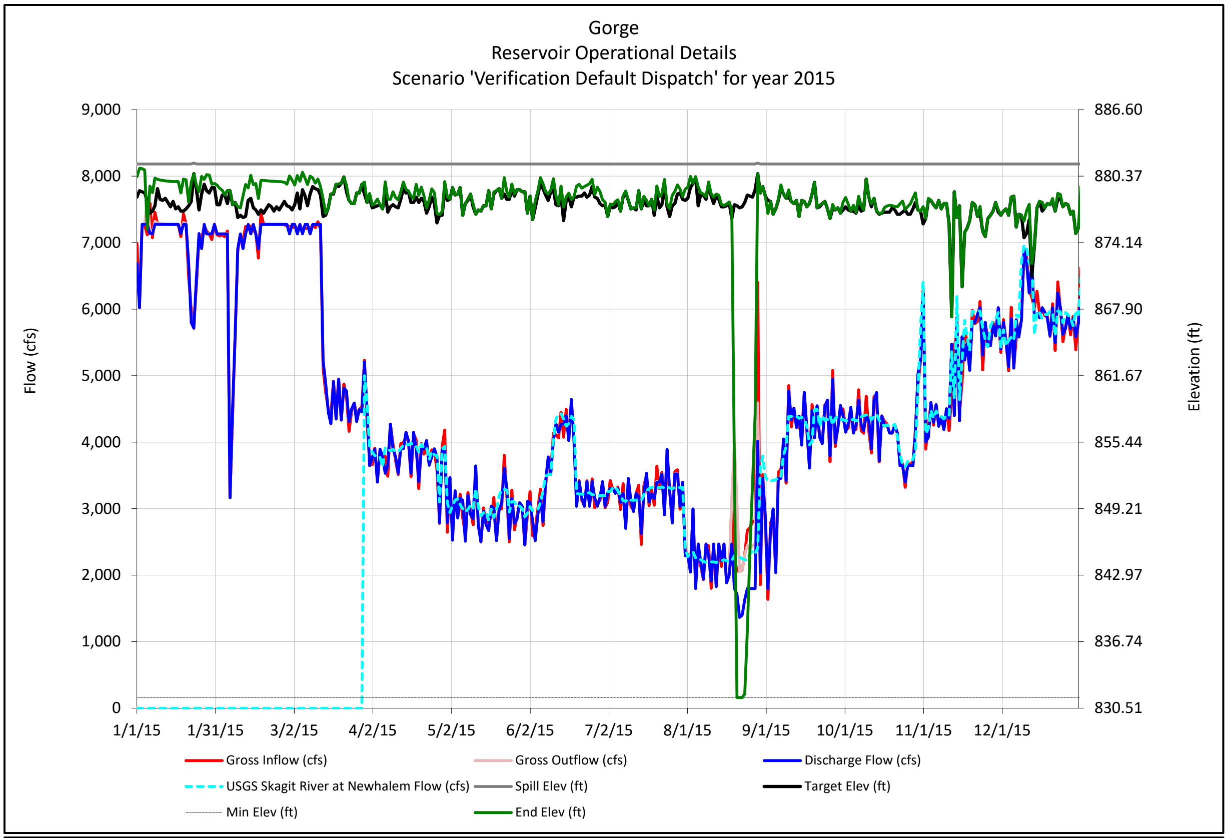

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2014
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
1614.10
1585.70
1557.30
1528.90
1500.50
1472.10
1/1/14
1/31/14
3/2/14
4/2/14
5/2/14
6/2/14
7/2/14
8/1/14
9/1/14
10/1/14
11/1/14
12/1/14
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

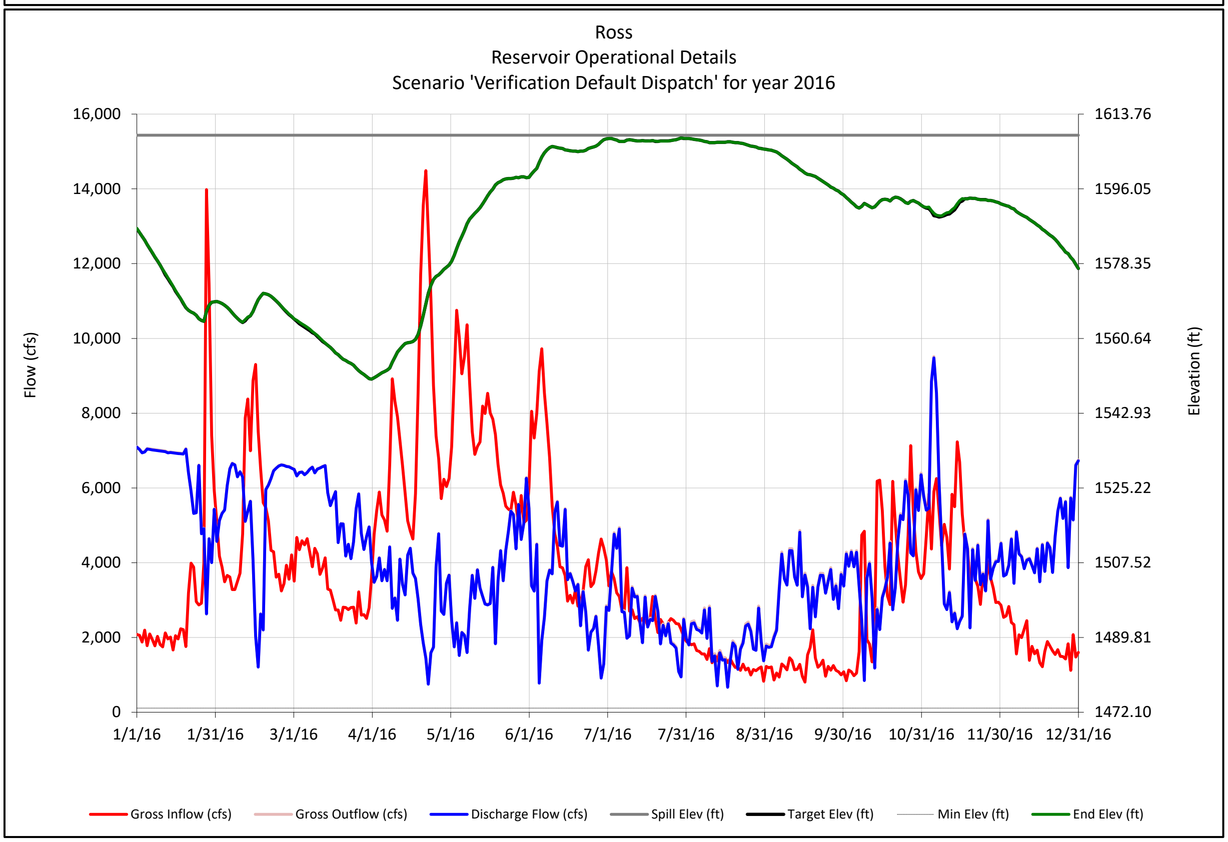

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2014
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1212.00
1210.97
1209.93
1208.90
1207.87
1206.83
1205.80
1204.77
1203.73
1202.70
1/1/14
1/31/14
3/2/14
4/2/14
5/2/14
6/2/14
7/2/14
8/1/14
9/1/14
10/1/14
11/1/14
12/1/14
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

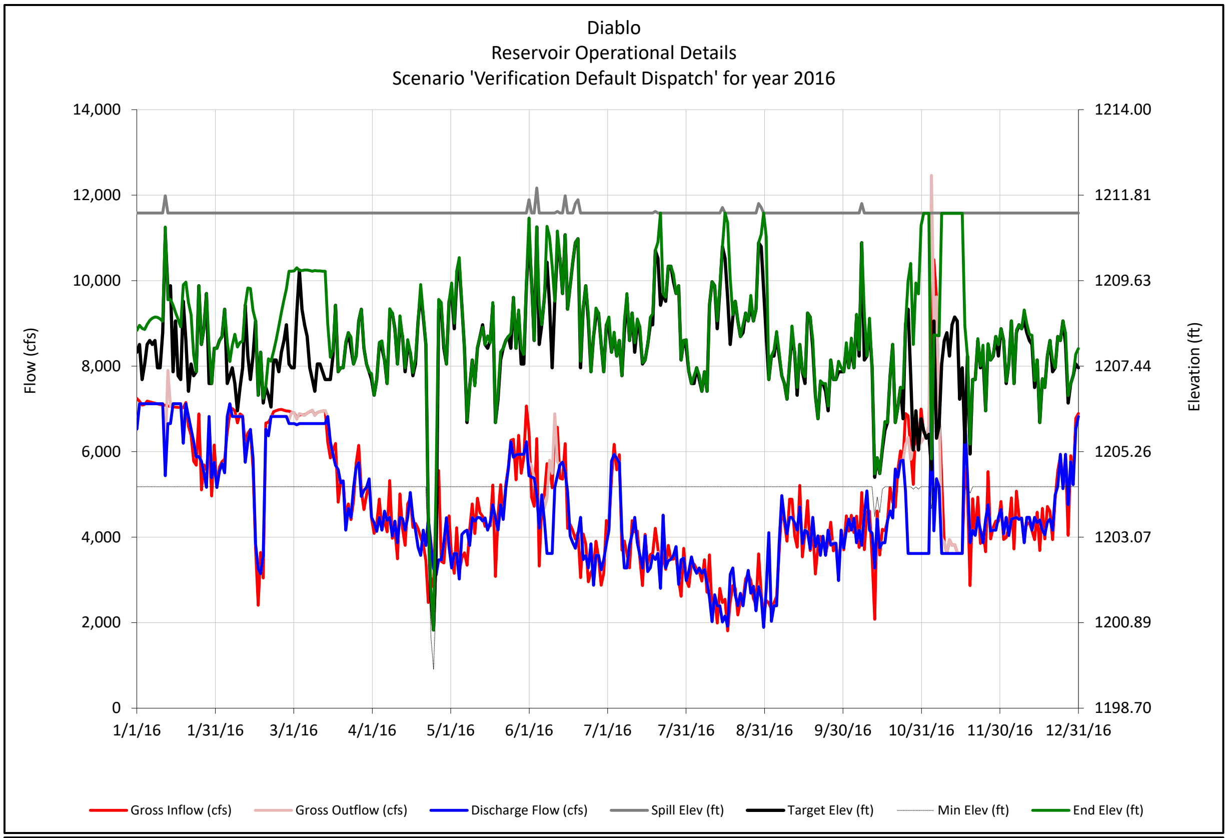

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2014
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
886.70
880.46
874.21
867.97
861.73
855.48
849.24
843.00
836.75
830.51
1/1/14
1/31/14
3/2/14
4/2/14
5/2/14
6/2/14
7/2/14
8/1/14
9/1/14
10/1/14
11/1/14
12/1/14
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

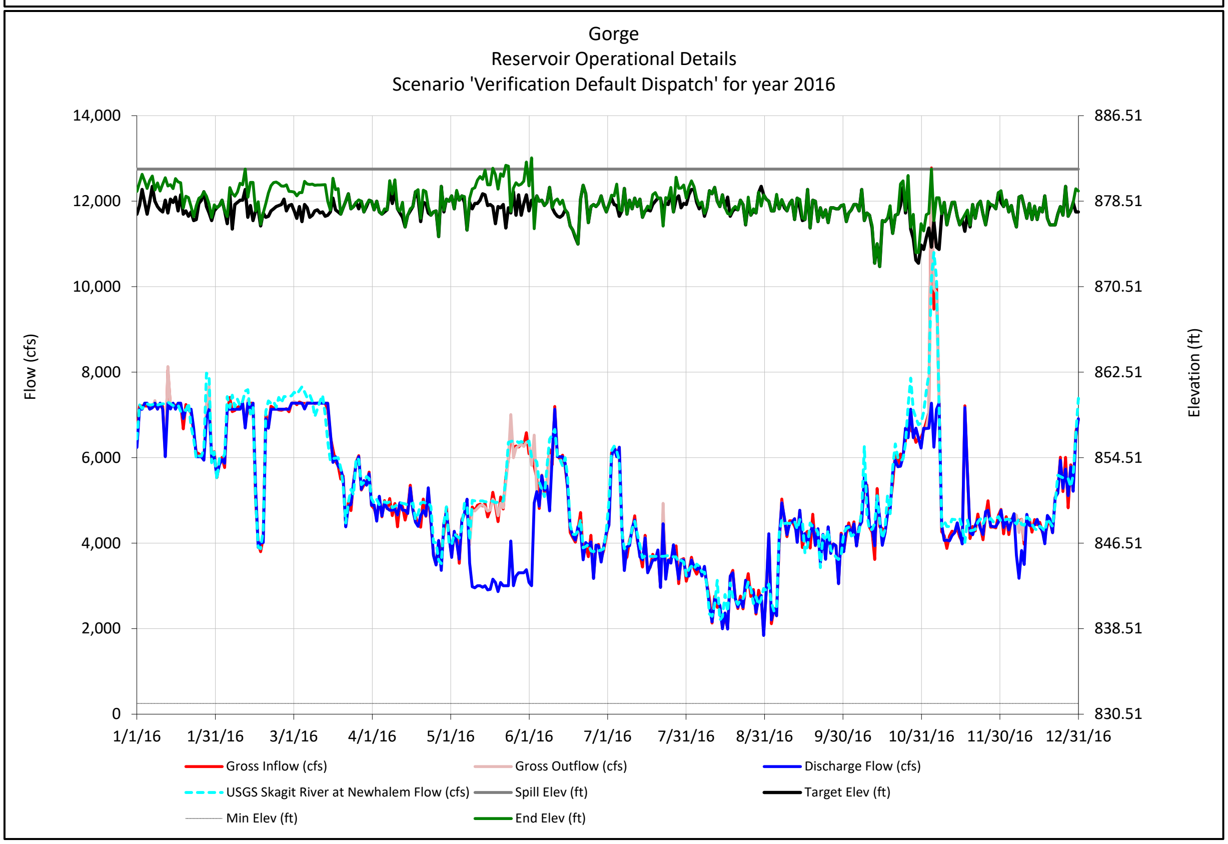

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2015
Flow (cfs)
Elevation (ft)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1599.59
1585.43
1571.26
1557.10
1542.93
1528.76
1514.60
1500.43
1486.27
1472.10
1/1/15
1/31/15
3/2/15
4/2/15
5/2/15
6/2/15
7/2/15
8/1/15
9/1/15
10/1/15
11/1/15
12/1/15
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

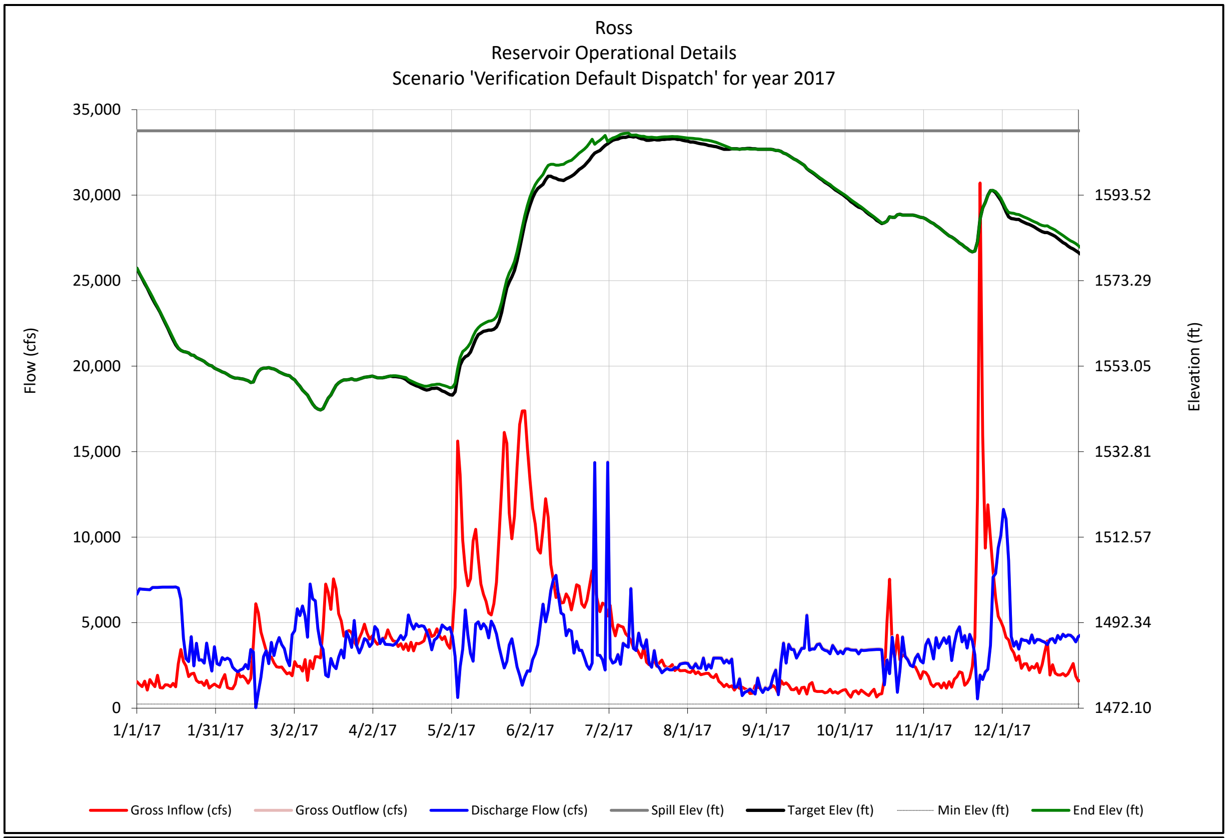

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2015
Flow (cfs)
Elevation (ft)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1214.00
1212.08
1210.15
1208.23
1206.30
1204.38
1202.45
1200.53
1198.60
1/1/15
1/31/15
3/2/15
4/2/15
5/2/15
6/2/15
7/2/15
8/1/15
9/1/15
10/1/15
11/1/15
12/1/15
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

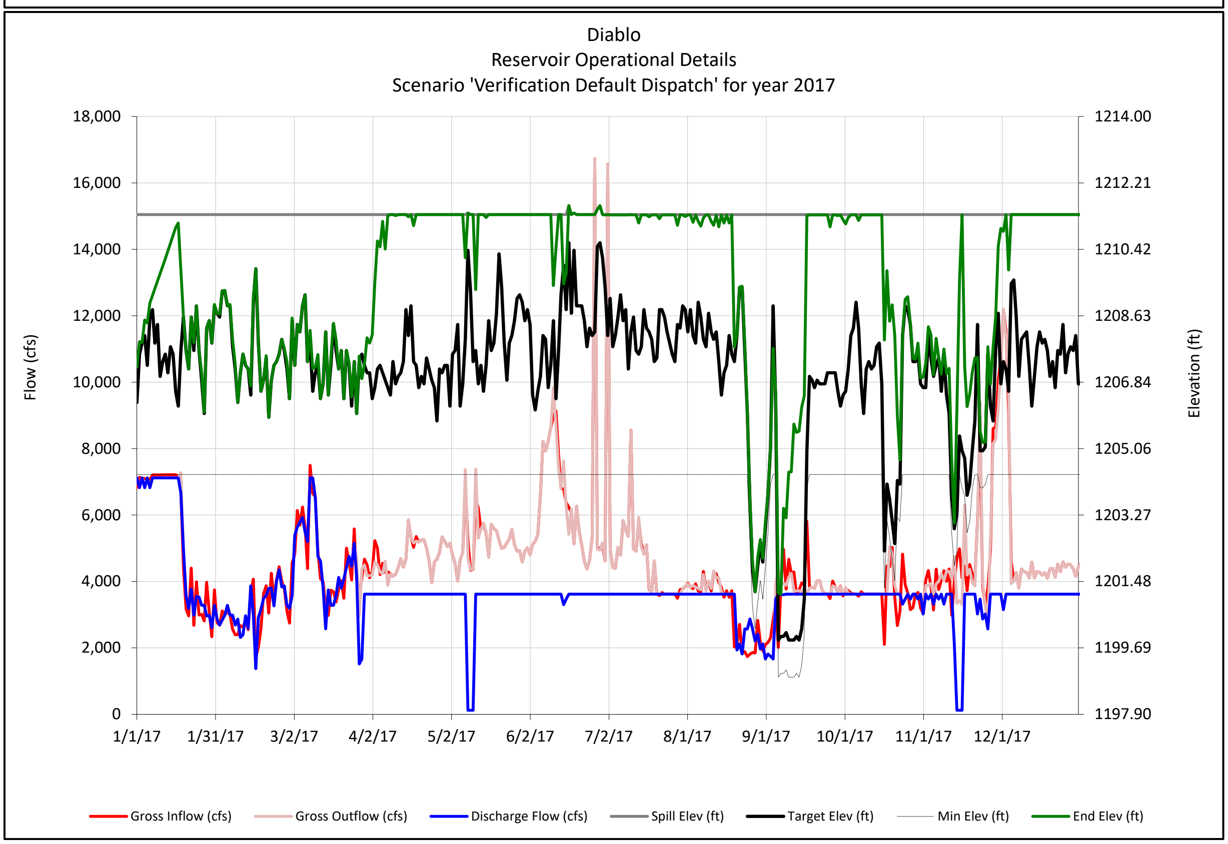

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2015
Flow (cfs)
Elevation (ft)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
886.60
880.37
874.14
867.90
861.67
855.44
849.21
842.97
836.74
830.51
1/1/15
1/31/15
3/2/15
4/2/15
5/2/15
6/2/15
7/2/15
8/1/15
9/1/15
10/1/15
11/1/15
12/1/15
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

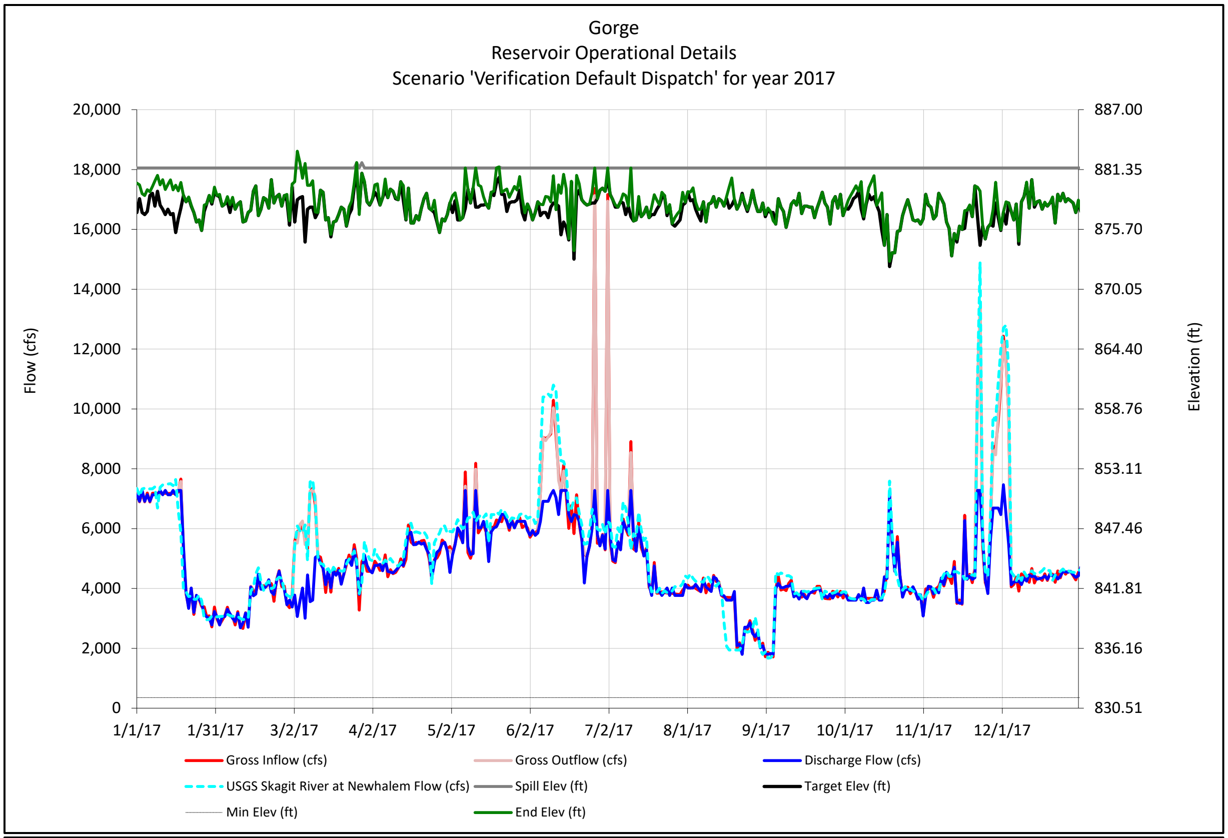

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2016
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1596.05
1578.35
1560.64
1542.93
1525.22
1507.52
1489.81
1472.10
1/1/16
1/31/16
3/1/16
4/1/16
5/1/16
6/1/16
7/1/16
7/31/16
8/31/16
9/30/16
10/31/16
11/30/16
12/31/16
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

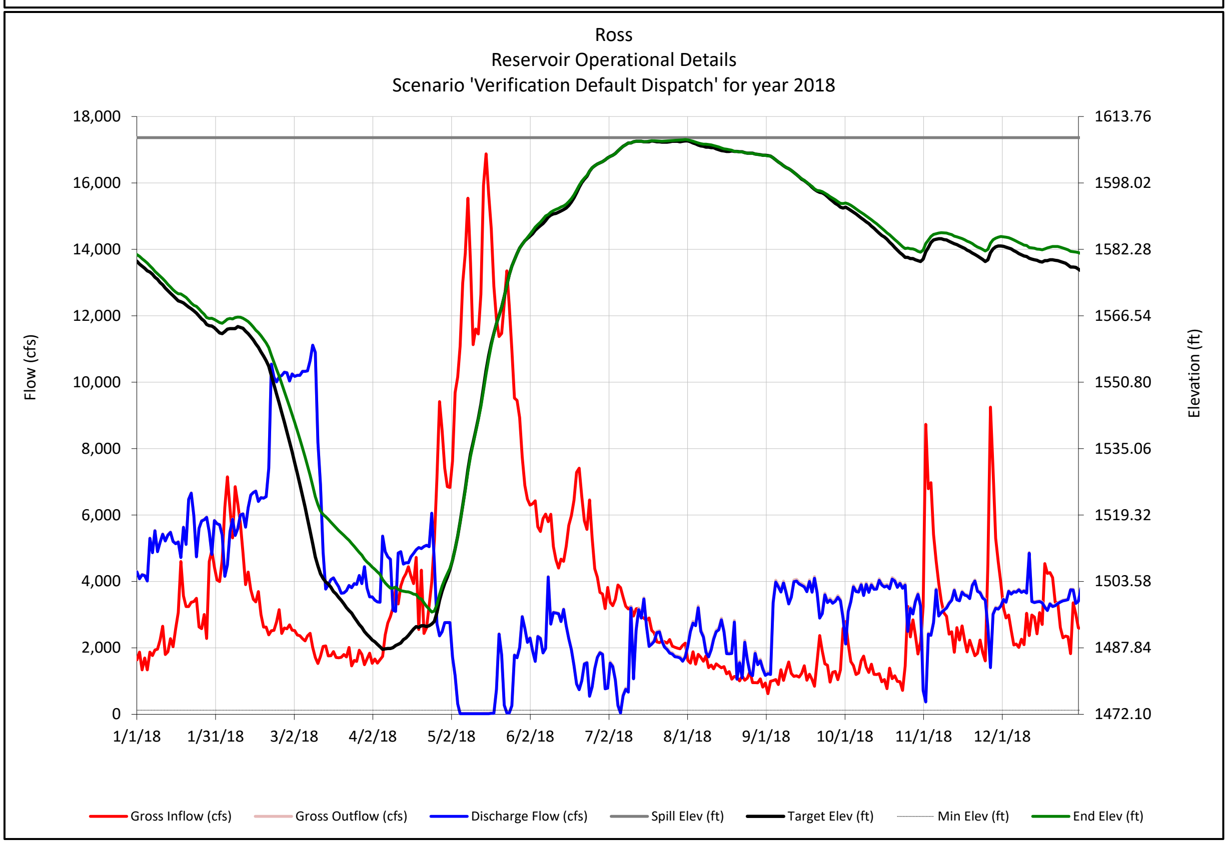

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2016
Flow (cfs)
Elevation (ft)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1214.00
1211.81
1209.63
1207.44
1205.26
1203.07
1200.89
1198.70
1/1/16
1/31/16
3/1/16
4/1/16
5/1/16
6/1/16
7/1/16
7/31/16
8/31/16
9/30/16
10/31/16
11/30/16
12/31/16
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

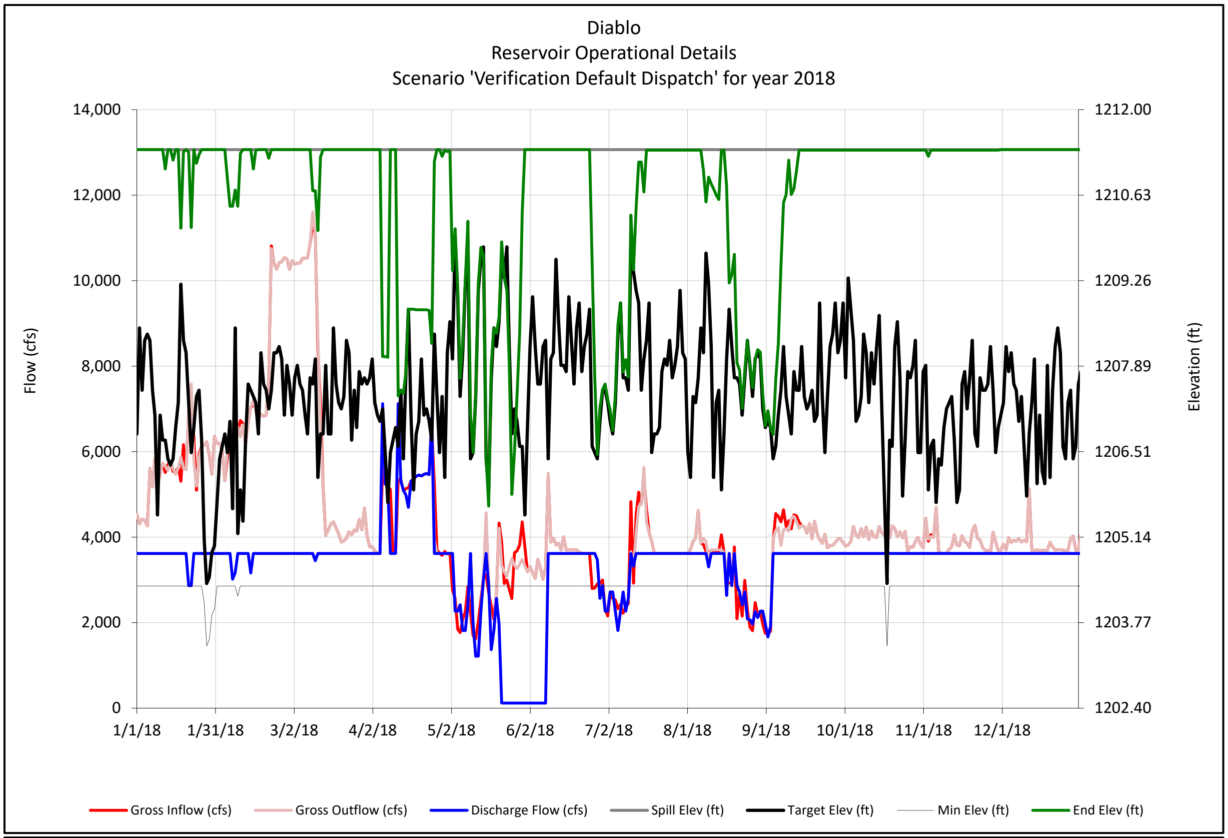

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2016
Flow (cfs)
Elevation (ft)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
886.51
878.51
870.51
862.51
854.51
846.51
838.51
830.51
1/1/16
1/31/16
3/1/16
4/1/16
5/1/16
6/1/16
7/1/16
7/31/16
8/31/16
9/30/16
10/31/16
11/30/16
12/31/16
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

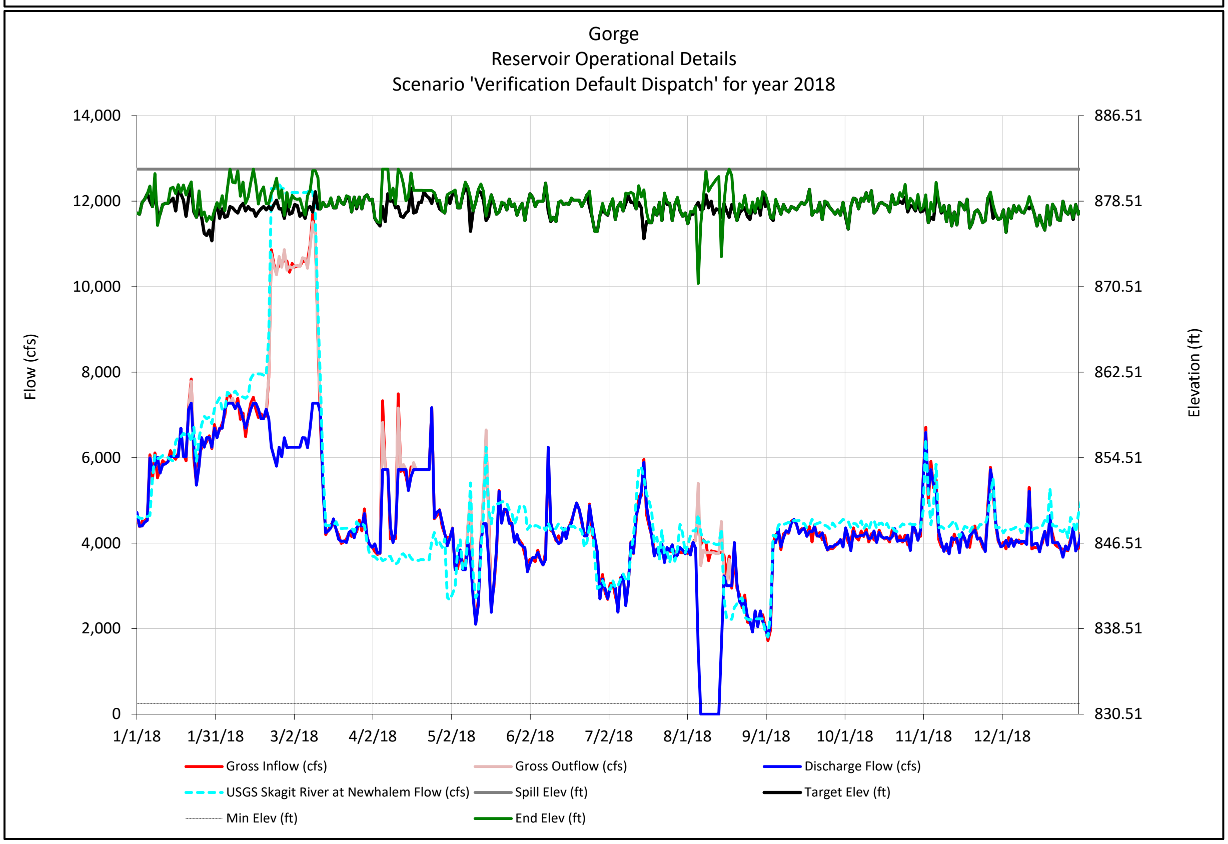

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2017
Flow (cfs)
Elevation (ft)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1593.52
1573.29
1553.05
1532.81
1512.57
1492.34
1472.10
1/1/17
1/31/17
3/2/17
4/2/17
5/2/17
6/2/17
7/2/17
8/1/17
9/1/17
10/1/17
11/1/17
12/1/17
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

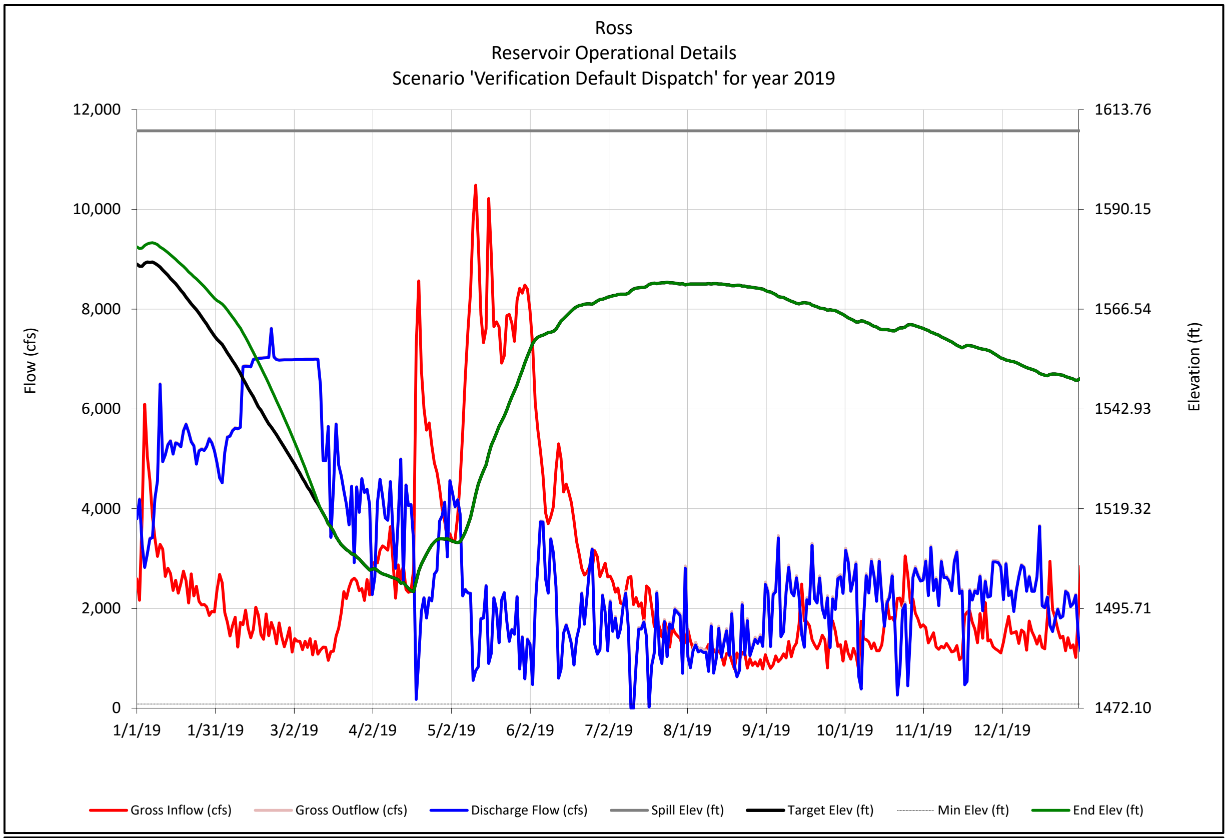

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2017
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1214.00
1212.21
1210.42
1208.63
1206.84
1205.06
1203.27
1201.48
1199.69
1197.90
1/1/17
1/31/17
3/2/17
4/2/17
5/2/17
6/2/17
7/2/17
8/1/17
9/1/17
10/1/17
11/1/17
12/1/17
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

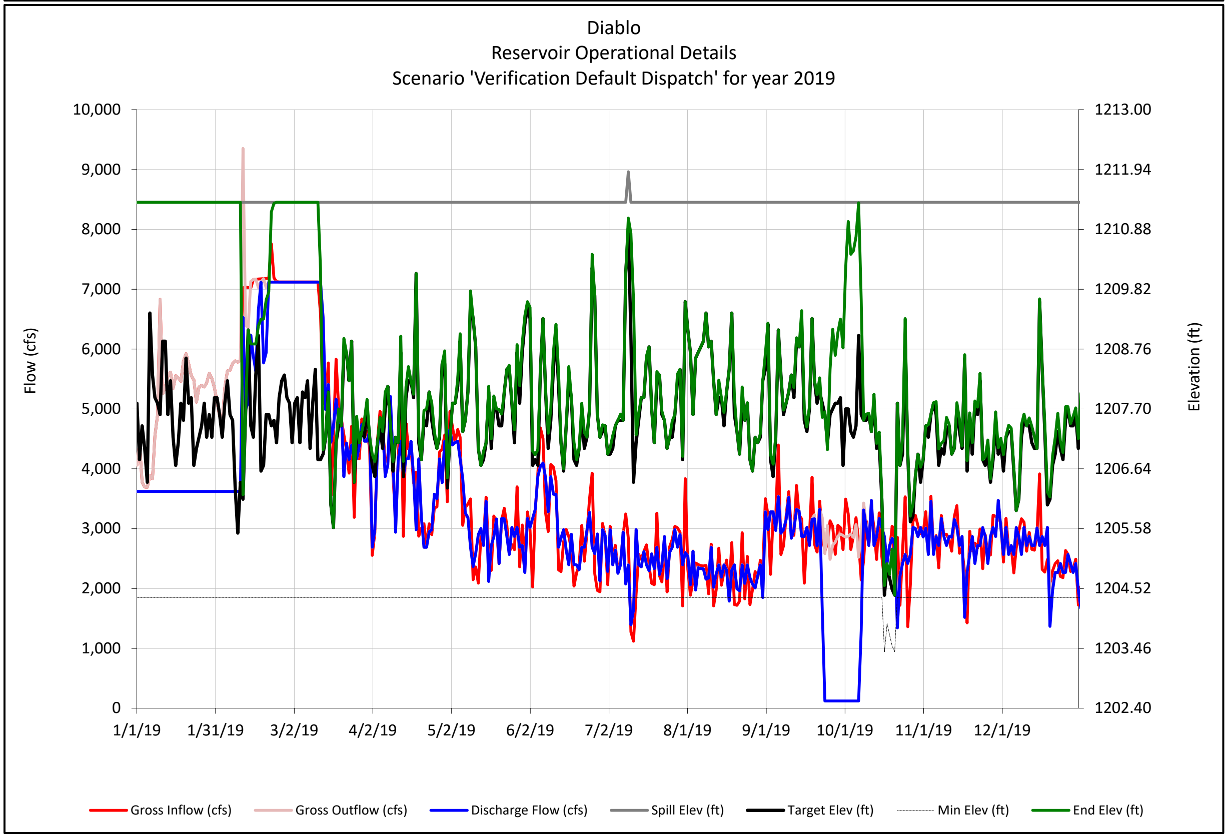

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2017
Flow (cfs)
Elevation (ft)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
887.00
881.35
875.70
870.05
864.40
858.76
853.11
847.46
841.81
836.16
830.51
1/1/17
1/31/17
3/2/17
4/2/17
5/2/17
6/2/17
7/2/17
8/1/17
9/1/17
10/1/17
11/1/17
12/1/17
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

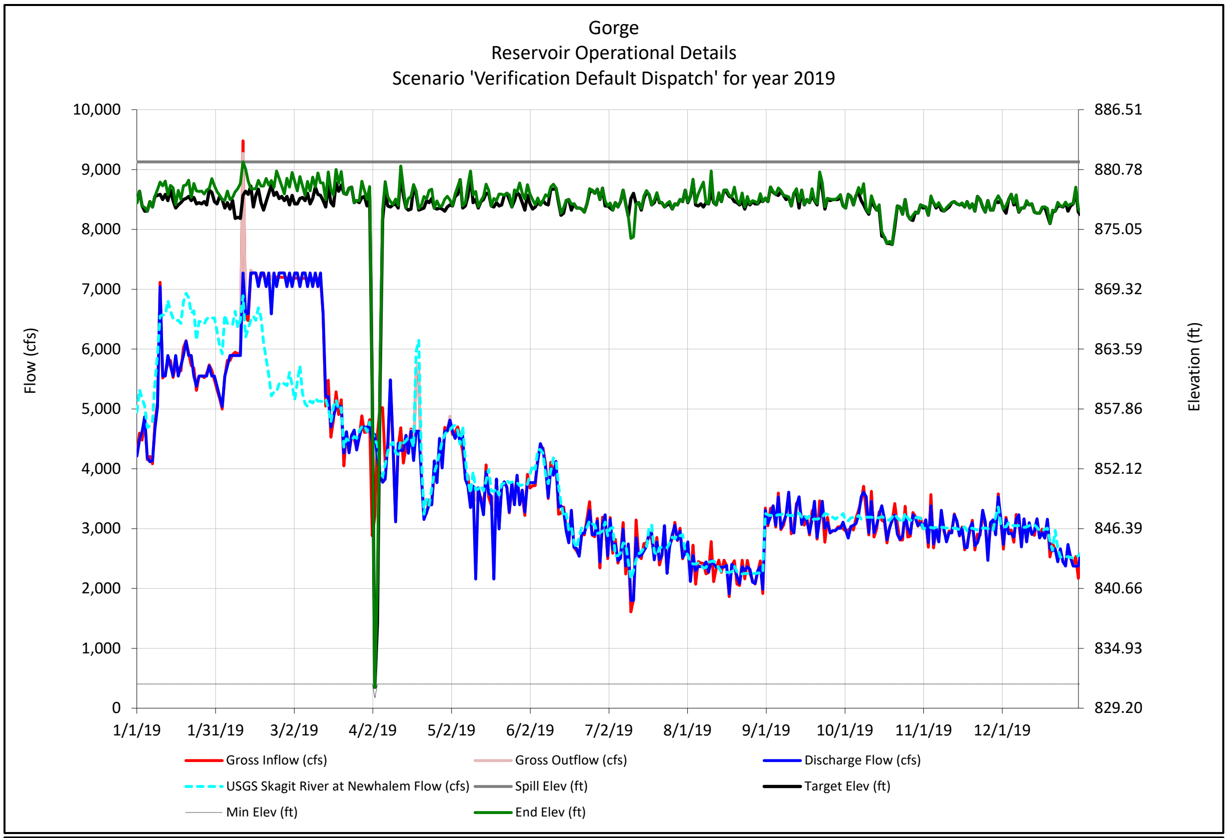

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2018
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1598.02
1582.28
1566.54
1550.80
1535.06
1519.32
1503.58
1487.84
1472.10
1/1/18
1/31/18
3/2/18
4/2/18
5/2/18
6/2/18
7/2/18
8/1/18
9/1/18
10/1/18
11/1/18
12/1/18
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

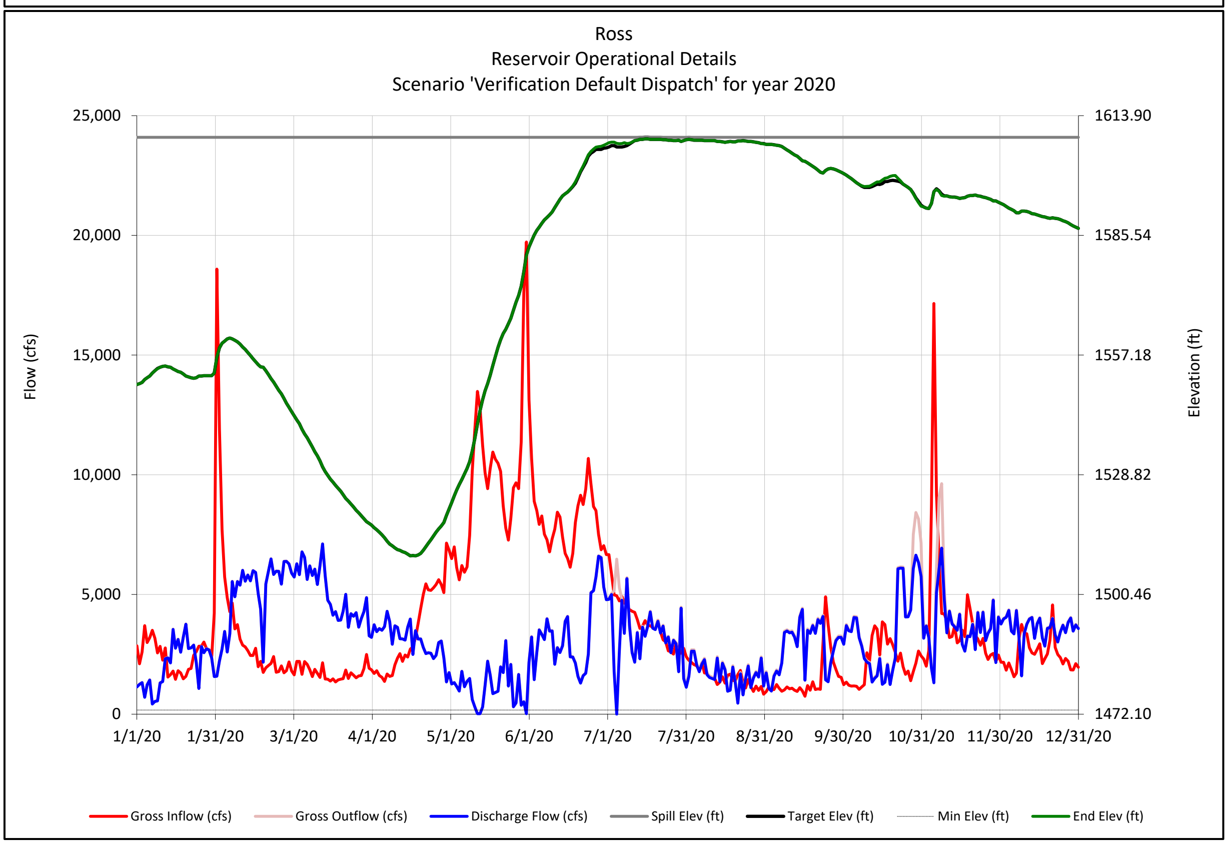

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2018
Flow (cfs)
Elevation (ft)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1212.00
1210.63
1209.26
1207.89
1206.51
1205.14
1203.77
1202.40
1/1/18
1/31/18
3/2/18
4/2/18
5/2/18
6/2/18
7/2/18
8/1/18
9/1/18
10/1/18
11/1/18
12/1/18
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

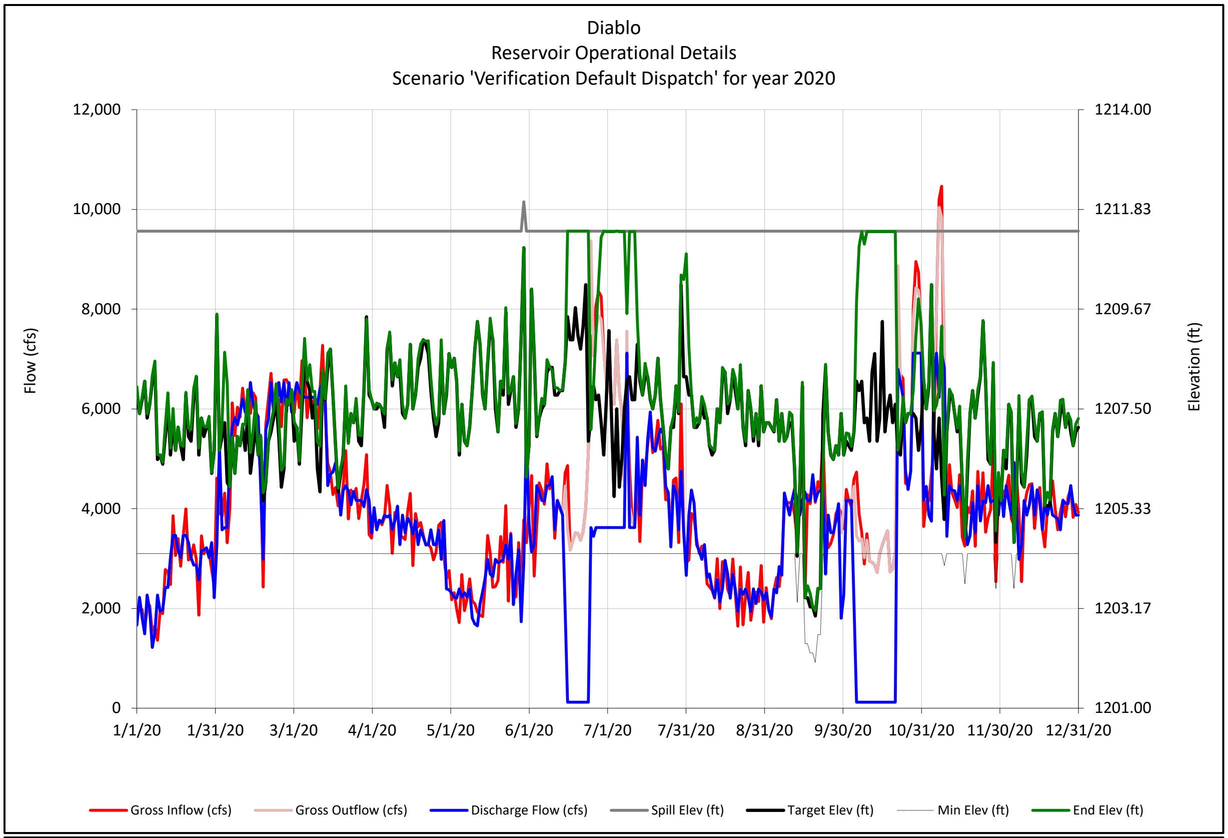

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2018
Flow (cfs)
Elevation (ft)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
886.51
878.51
870.51
862.51
854.51
846.51
838.51
830.51
1/1/18
1/31/18
3/2/18
4/2/18
5/2/18
6/2/18
7/2/18
8/1/18
9/1/18
10/1/18
11/1/18
12/1/18
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

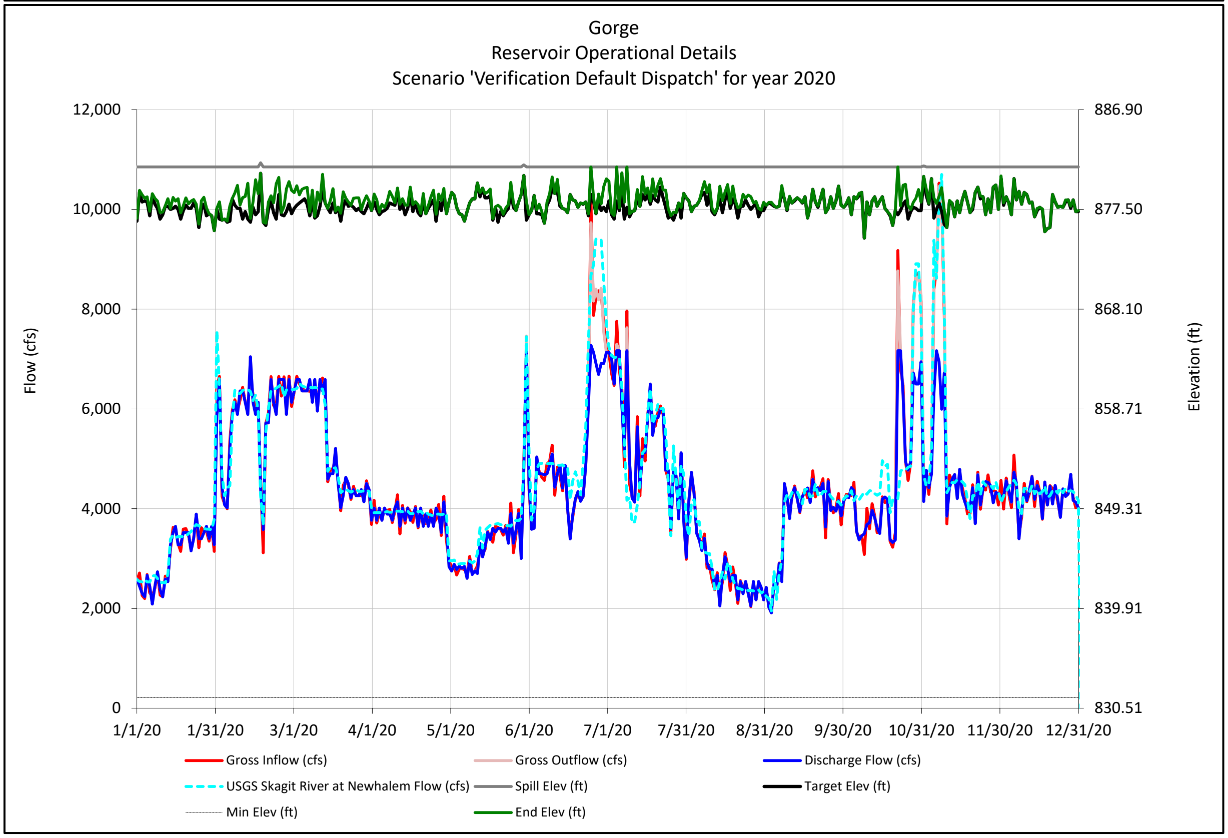

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2019
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1590.15
1566.54
1542.93
1519.32
1495.71
1472.10
1/1/19
1/31/19
3/2/19
4/2/19
5/2/19
6/2/19
7/2/19
8/1/19
9/1/19
10/1/19
11/1/19
12/1/19
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2019
Flow (cfs)
Elevation (ft)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1213.00
1211.94
1210.88
1209.82
1208.76
1207.70
1206.64
1205.58
1204.52
1203.46
1202.40
1/1/19
1/31/19
3/2/19
4/2/19
5/2/19
6/2/19
7/2/19
8/1/19
9/1/19
10/1/19
11/1/19
12/1/19
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

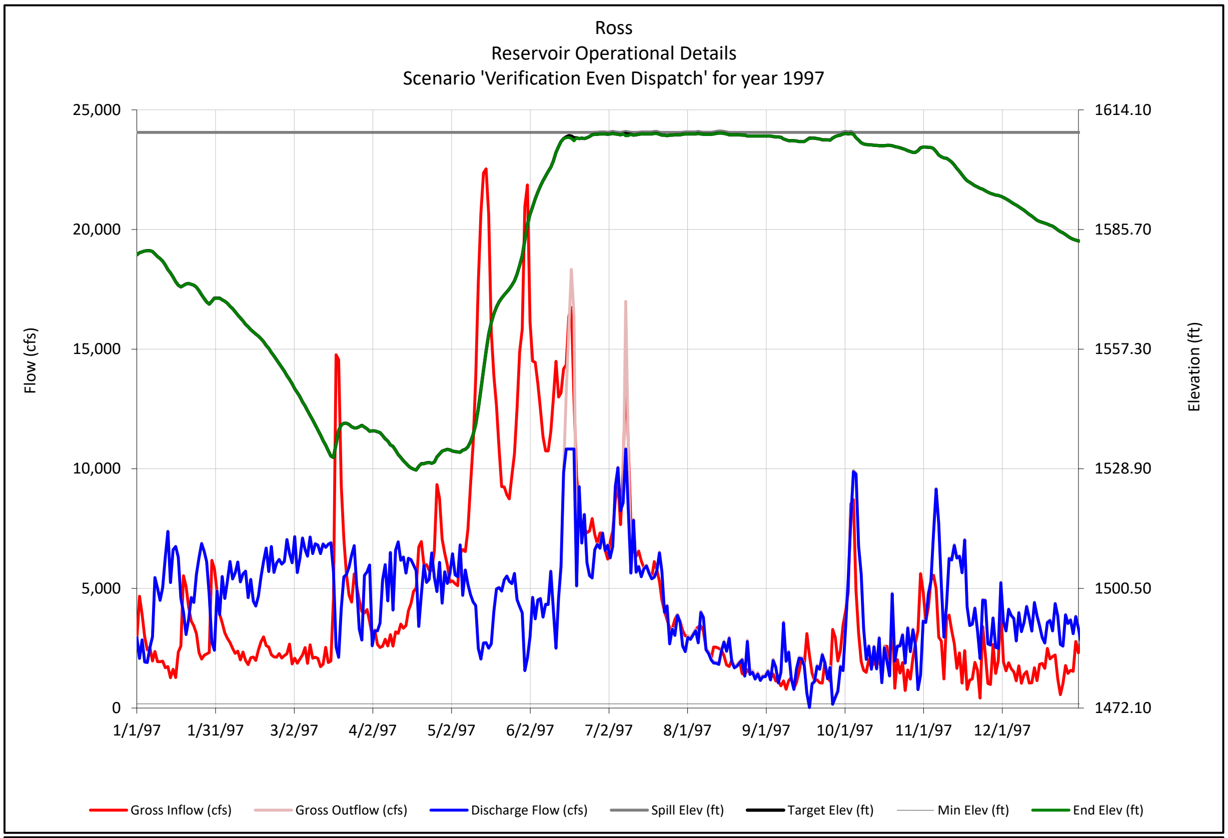

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2019
Flow (cfs)
Elevation (ft)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
886.51
880.78
875.05
869.32
863.59
857.86
852.12
846.39
840.66
834.93
829.20
1/1/19
1/31/19
3/2/19
4/2/19
5/2/19
6/2/19
7/2/19
8/1/19
9/1/19
10/1/19
11/1/19
12/1/19
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

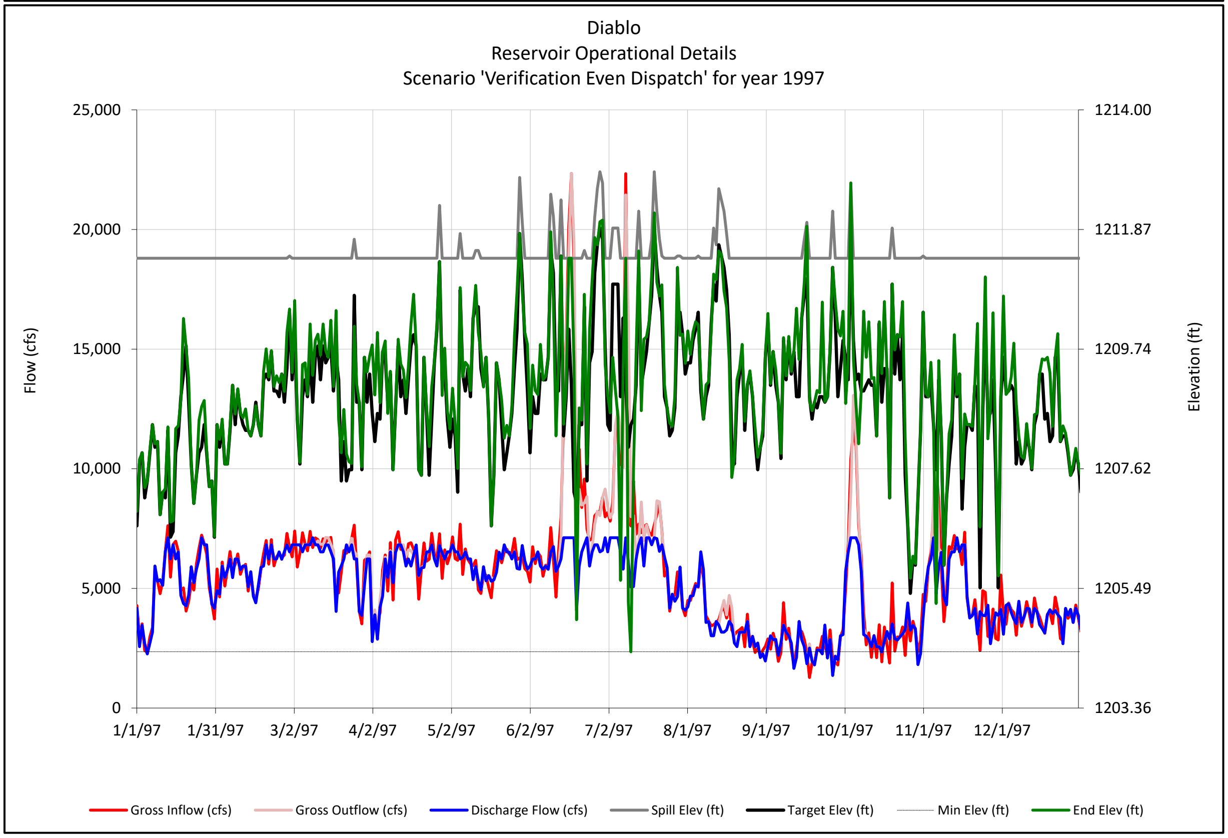

Ross
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2020
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
1613.90
1585.54
1557.18
1528.82
1500.46
1472.10
1/1/20
1/31/20
3/1/20
4/1/20
5/1/20
6/1/20
7/1/20
7/31/20
8/31/20
9/30/20
10/31/20
11/30/20
12/31/20
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

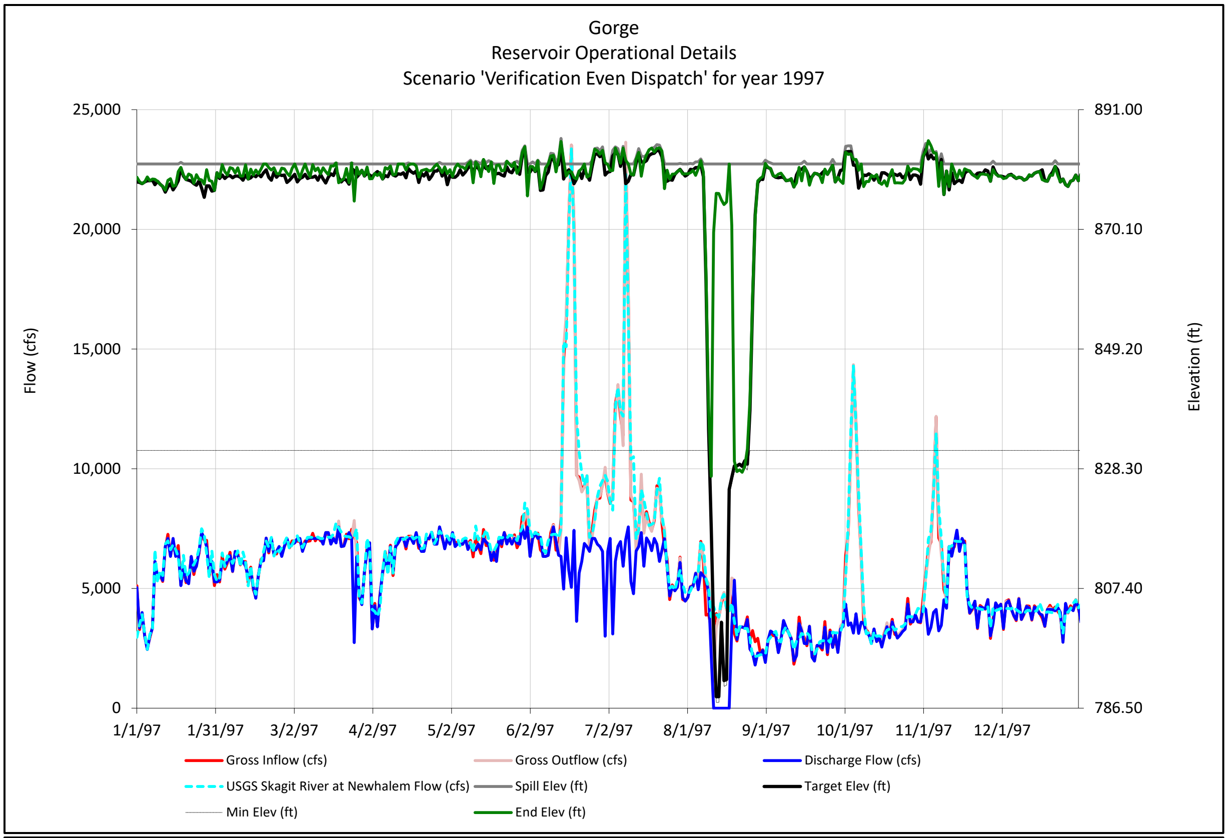

Diablo
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2020
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1214.00
1211.83
1209.67
1207.50
1205.33
1203.17
1201.00
1/1/20
1/31/20
3/1/20
4/1/20
5/1/20
6/1/20
7/1/20
7/31/20
8/31/20
9/30/20
10/31/20
11/30/20
12/31/20
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

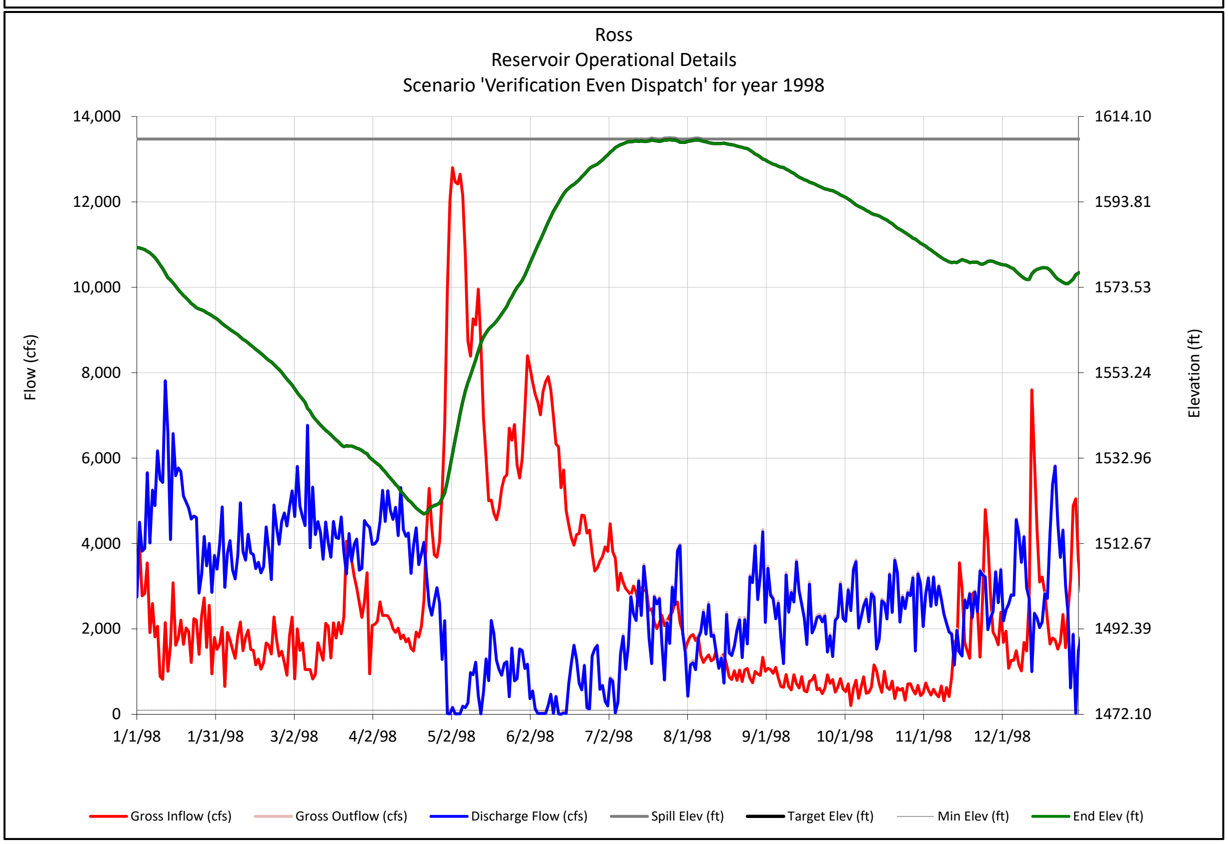

Gorge
Reservoir Operational Details
Scenario 'Verification Default Dispatch' for year 2020
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
886.90
877.50
868.10
858.71
849.31
839.91
830.51
1/1/20
1/31/20
3/1/20
4/1/20
5/1/20
6/1/20
7/1/20
7/31/20
8/31/20
9/30/20
10/31/20
11/30/20
12/31/20
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

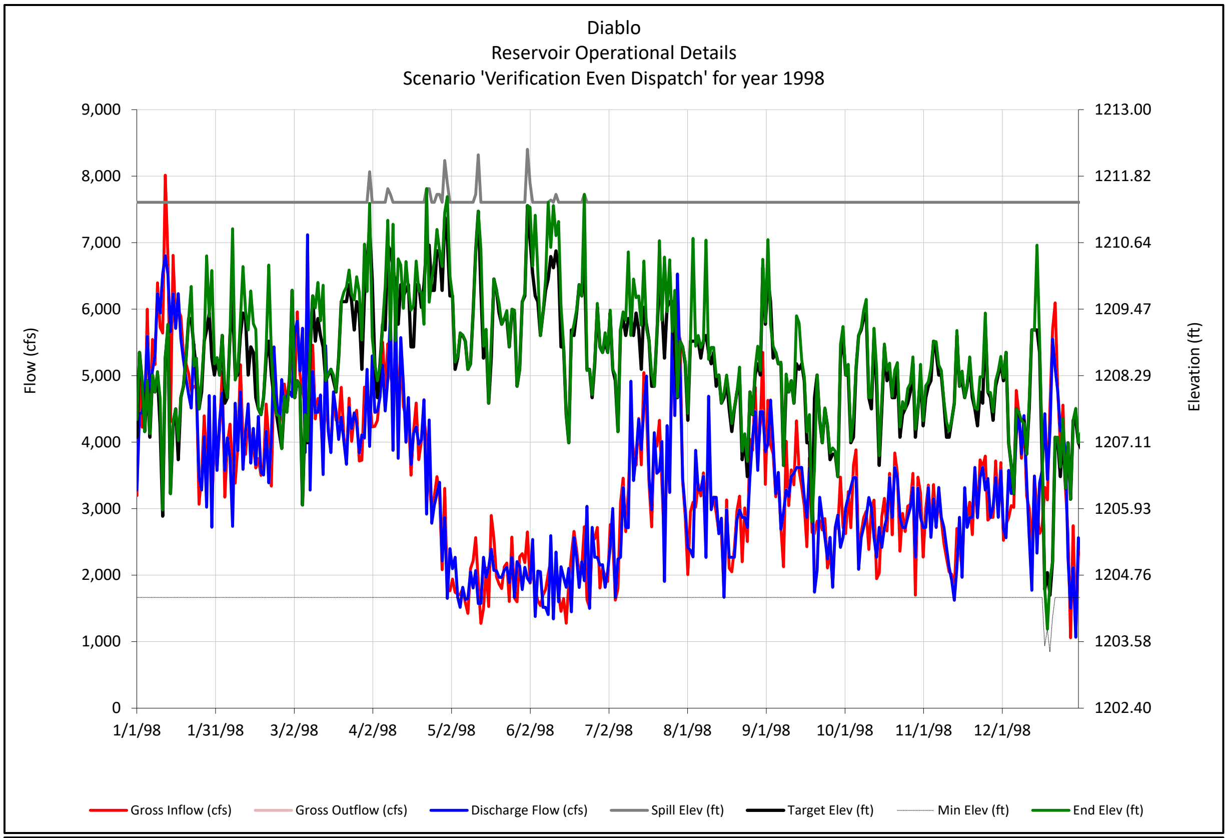
Verification Scenario with Even Dispatch

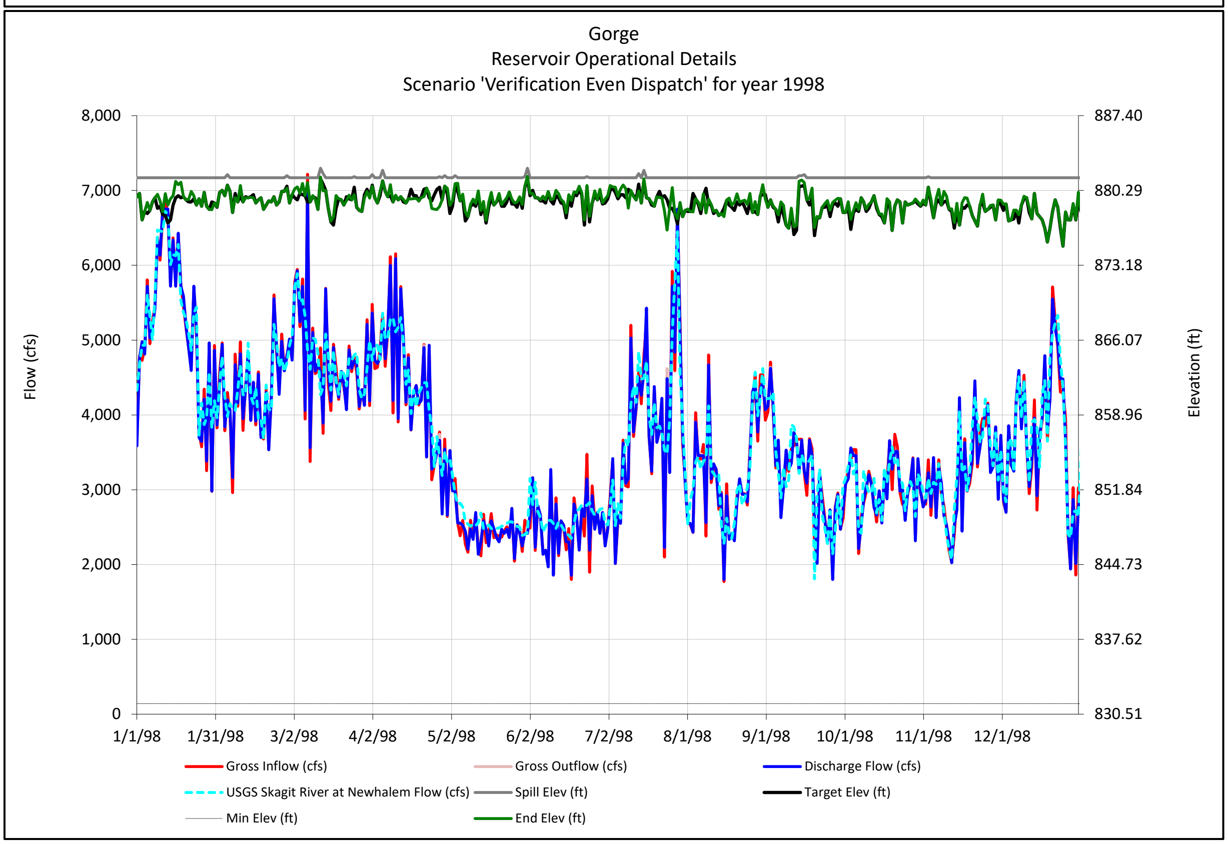


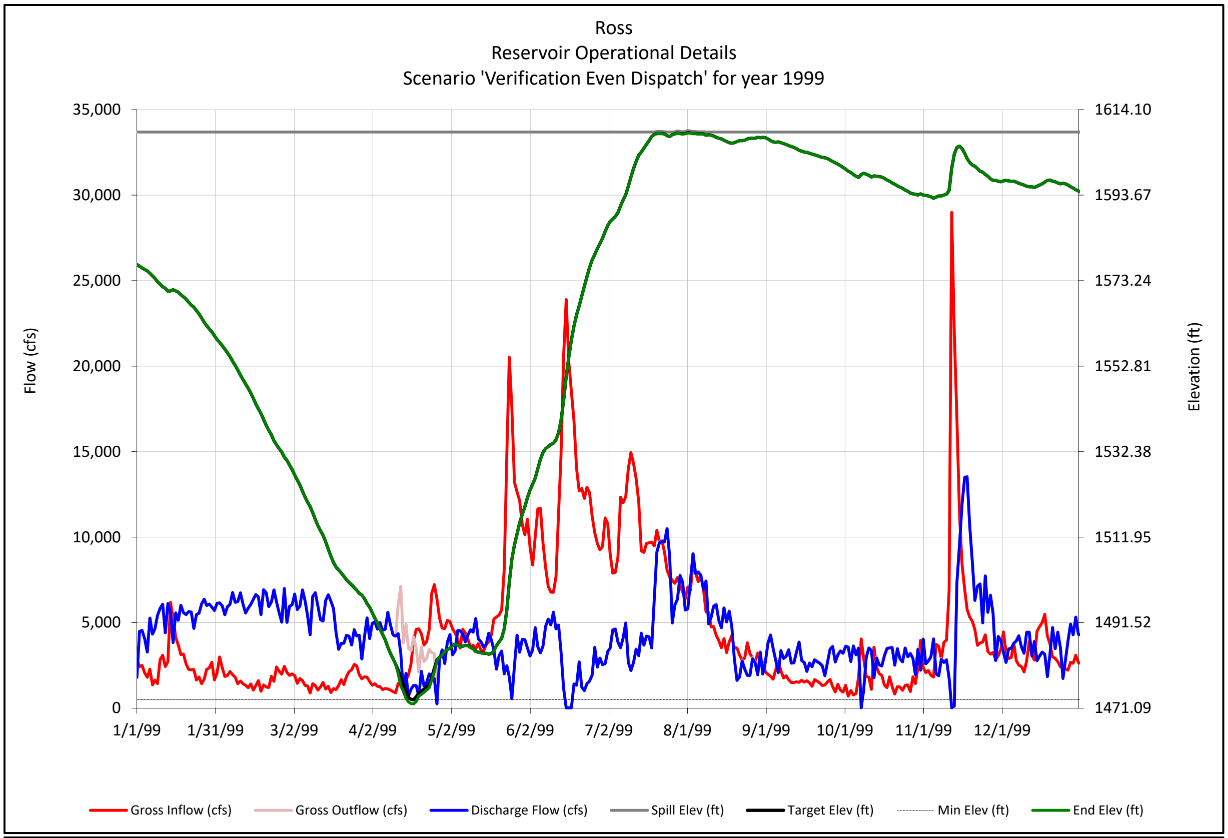


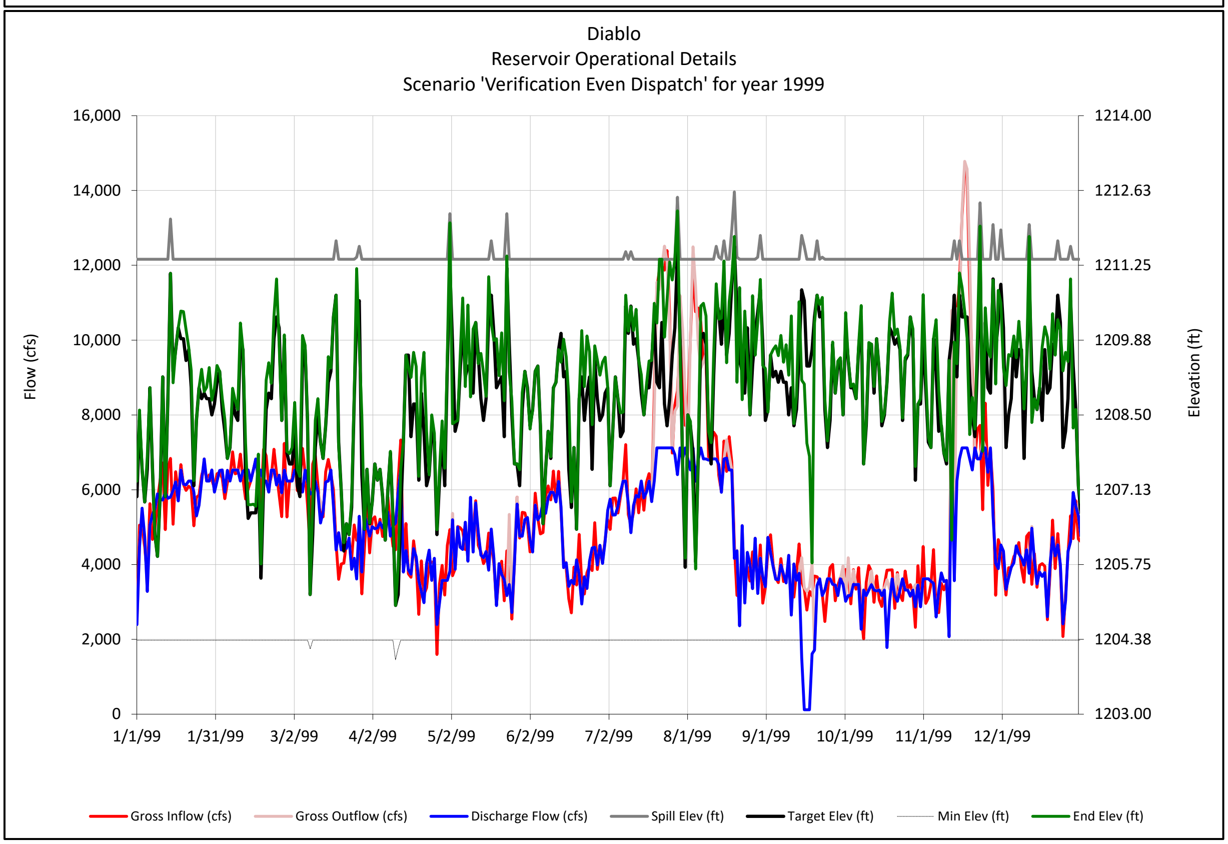

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 1997
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
891.00
870.10
849.20
828.30
807.40
786.50
1/1/97
1/31/97
3/2/97
4/2/97
5/2/97
6/2/97
7/2/97
8/1/97
9/1/97
10/1/97
11/1/97
12/1/97
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

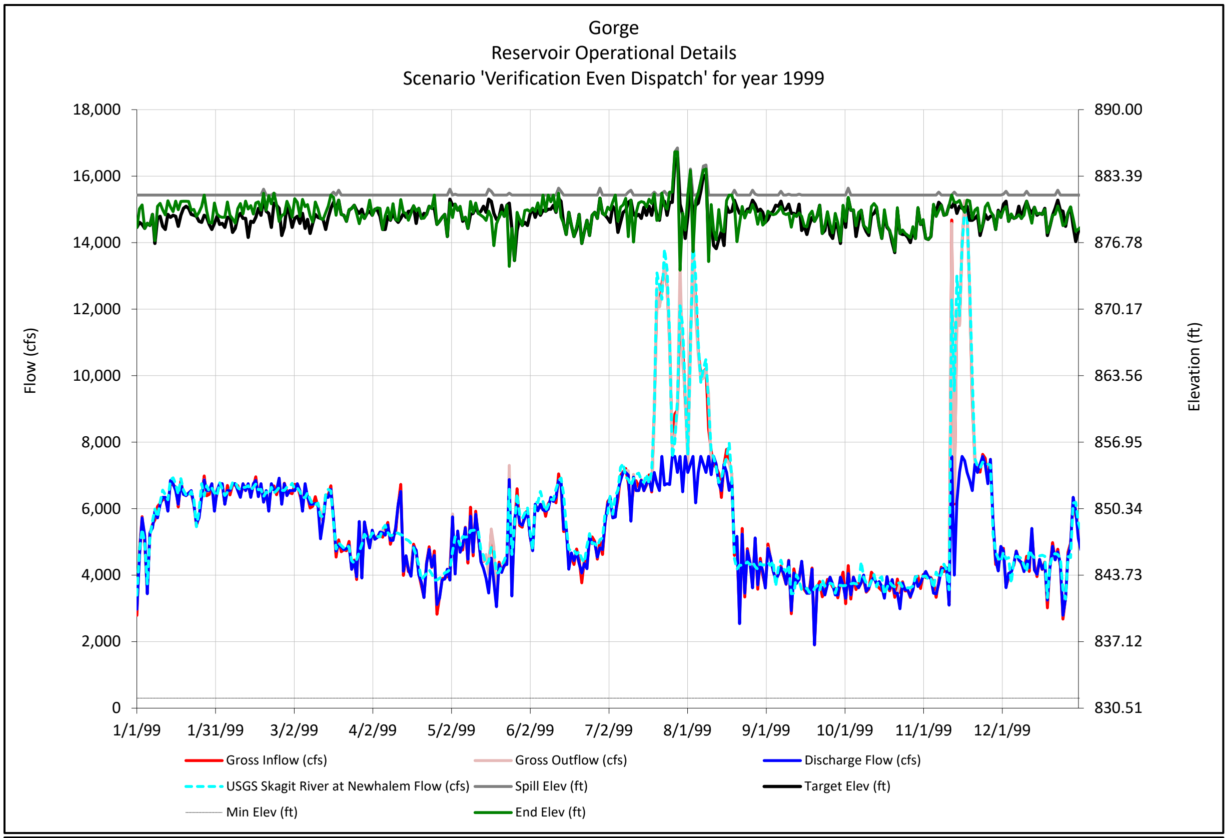

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 1998
Flow (cfs)
Elevation (ft)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1614.10
1593.81
1573.53
1553.24
1532.96
1512.67
1492.39
1472.10
1/1/98
1/31/98
3/2/98
4/2/98
5/2/98
6/2/98
7/2/98
8/1/98
9/1/98
10/1/98
11/1/98
12/1/98
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

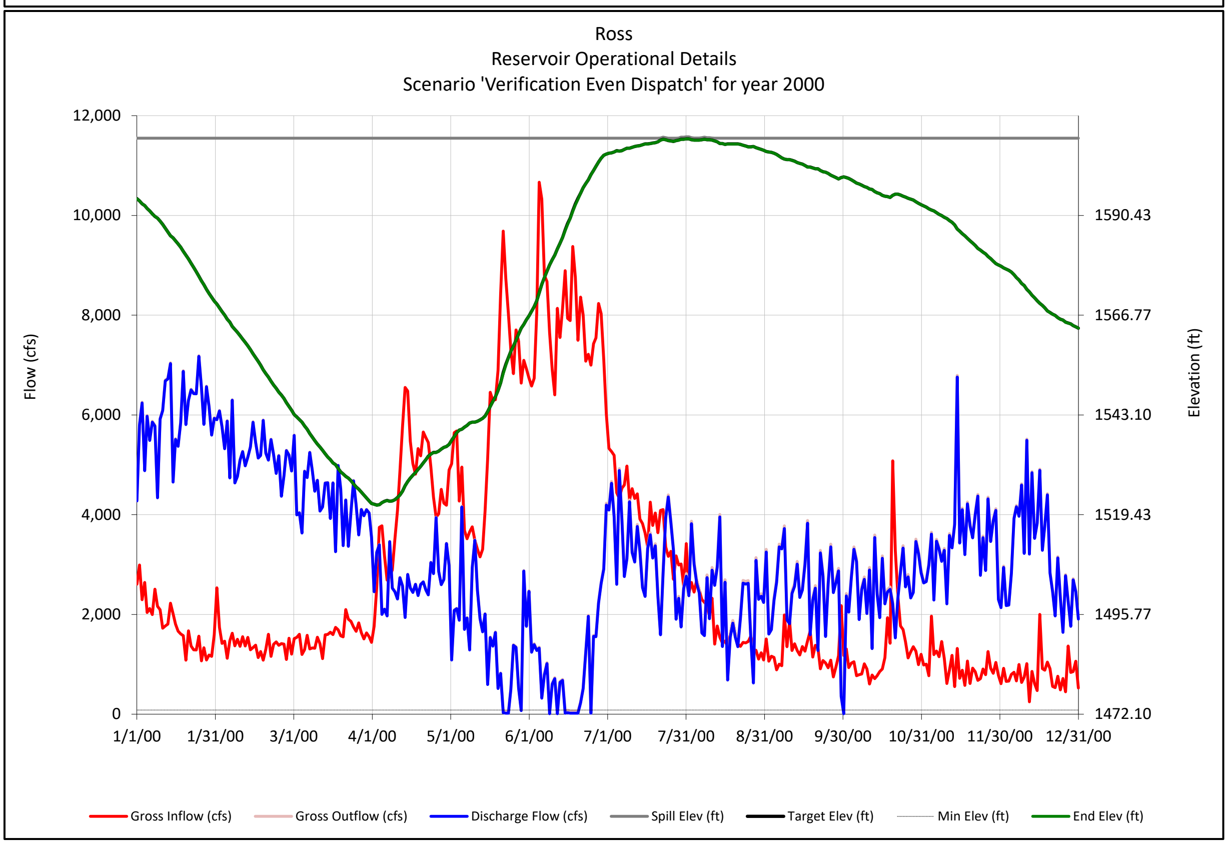

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 1998
Flow (cfs)
Elevation (ft)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1213.00
1211.82
1210.64
1209.47
1208.29
1207.11
1205.93
1204.76
1203.58
1202.40
1/1/98
1/31/98
3/2/98
4/2/98
5/2/98
6/2/98
7/2/98
8/1/98
9/1/98
10/1/98
11/1/98
12/1/98
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

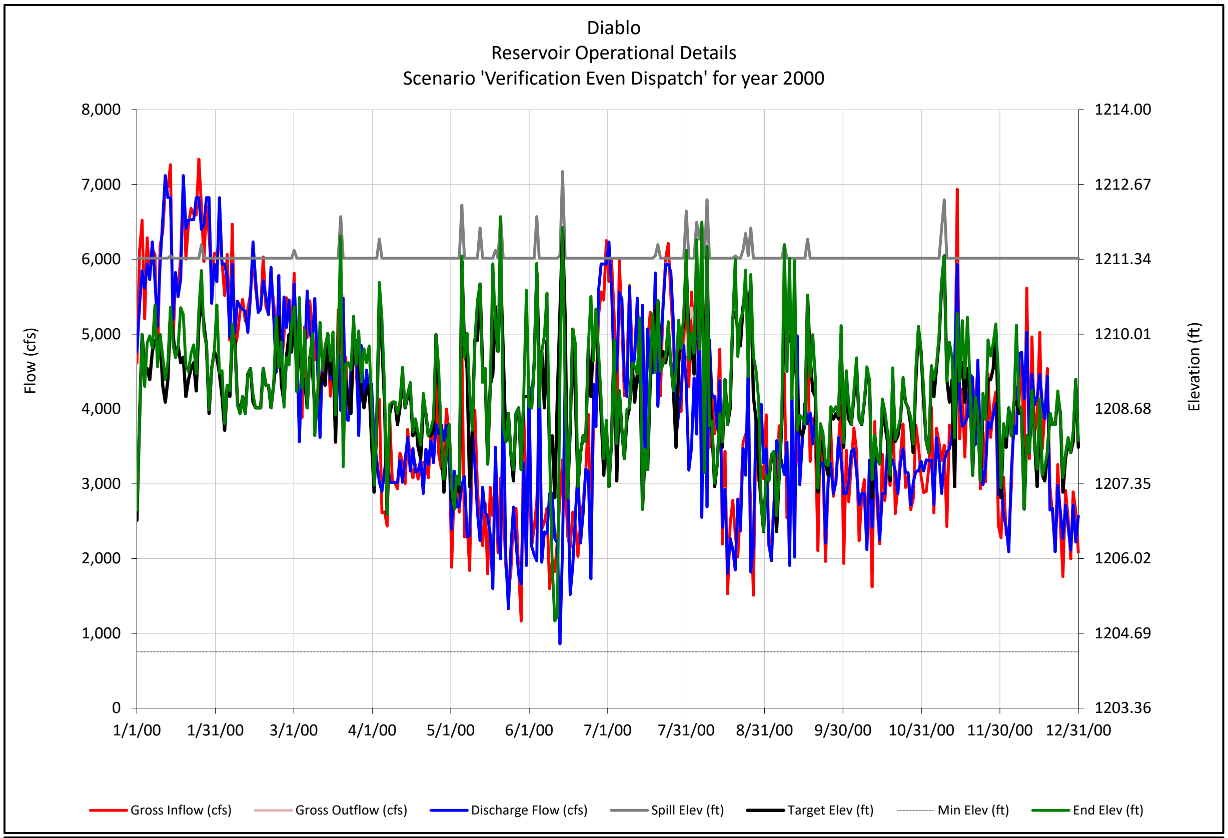

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 1998
Flow (cfs)
Elevation (ft)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
887.40
880.29
873.18
866.07
858.96
851.84
844.73
837.62
830.51
1/1/98
1/31/98
3/2/98
4/2/98
5/2/98
6/2/98
7/2/98
8/1/98
9/1/98
10/1/98
11/1/98
12/1/98
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

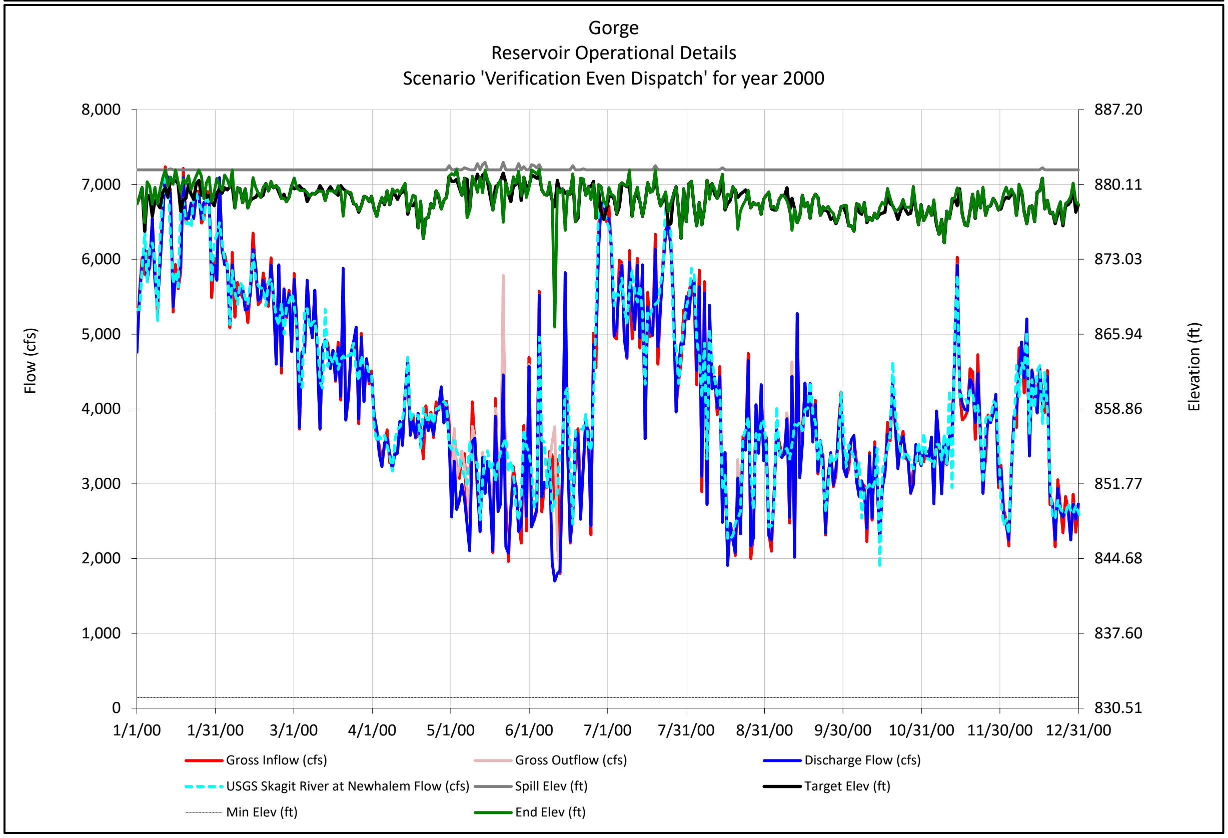

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 1999
Flow (cfs)
Elevation (ft)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1614.10
1593.67
1573.24
1552.81
1532.38
1511.95
1491.52
1471.09
1/1/99
1/31/99
3/2/99
4/2/99
5/2/99
6/2/99
7/2/99
8/1/99
9/1/99
10/1/99
11/1/99
12/1/99
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

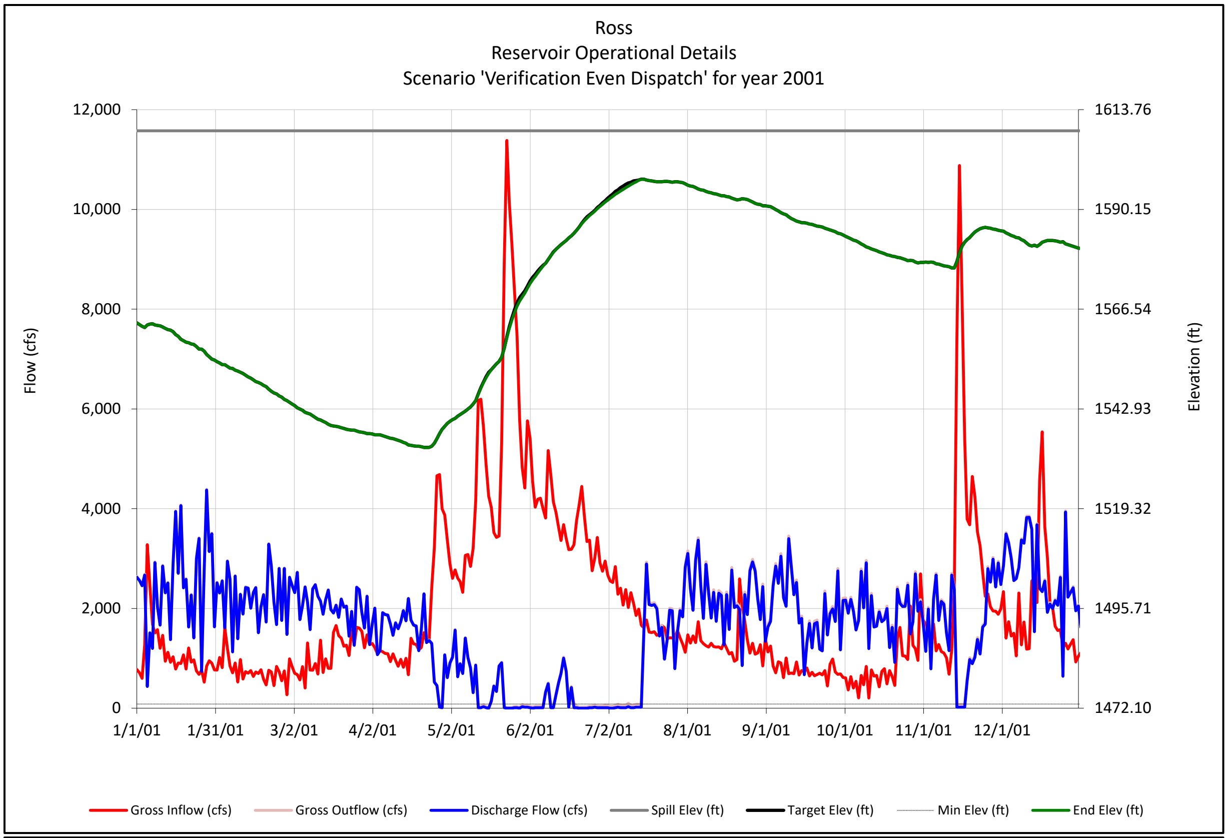

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 1999
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1214.00
1212.63
1211.25
1209.88
1208.50
1207.13
1205.75
1204.38
1203.00
1/1/99
1/31/99
3/2/99
4/2/99
5/2/99
6/2/99
7/2/99
8/1/99
9/1/99
10/1/99
11/1/99
12/1/99
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

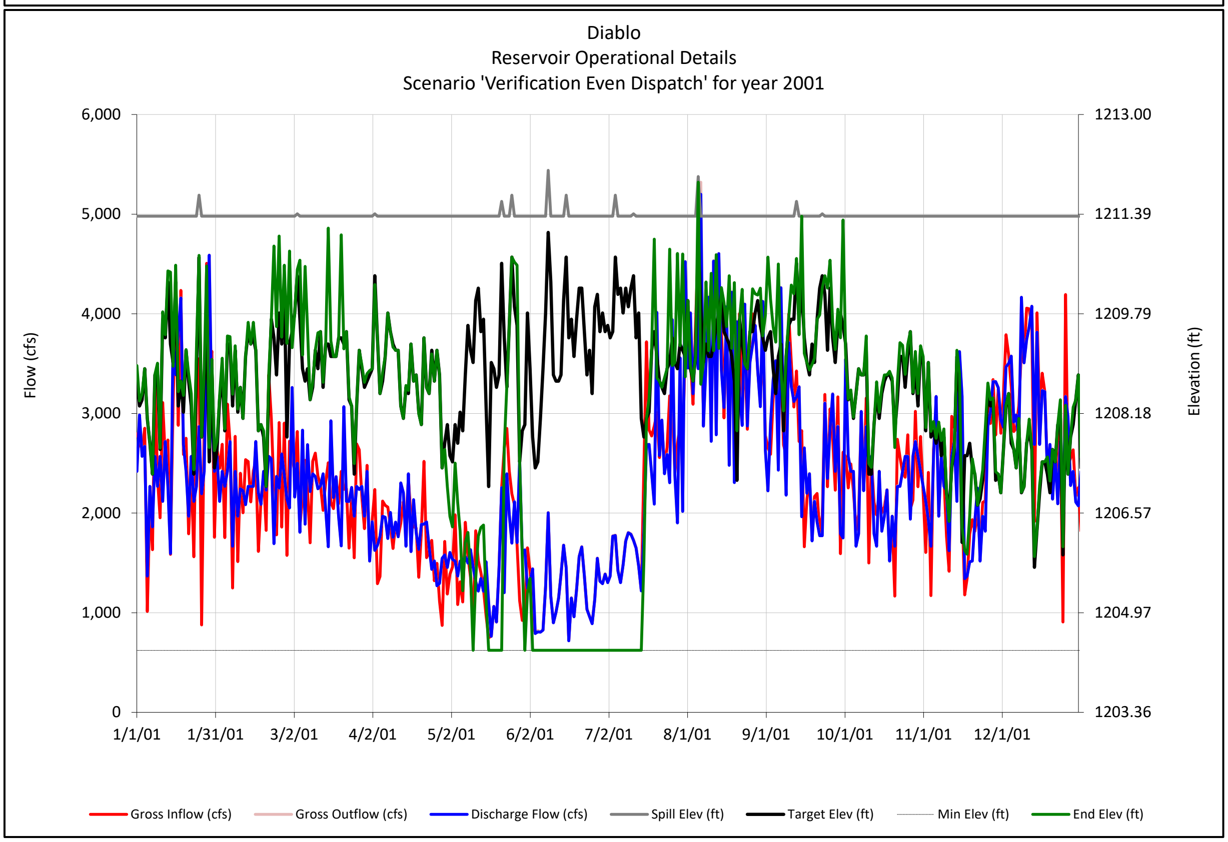

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 1999
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
890.00
883.39
876.78
870.17
863.56
856.95
850.34
843.73
837.12
830.51
1/1/99
1/31/99
3/2/99
4/2/99
5/2/99
6/2/99
7/2/99
8/1/99
9/1/99
10/1/99
11/1/99
12/1/99
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

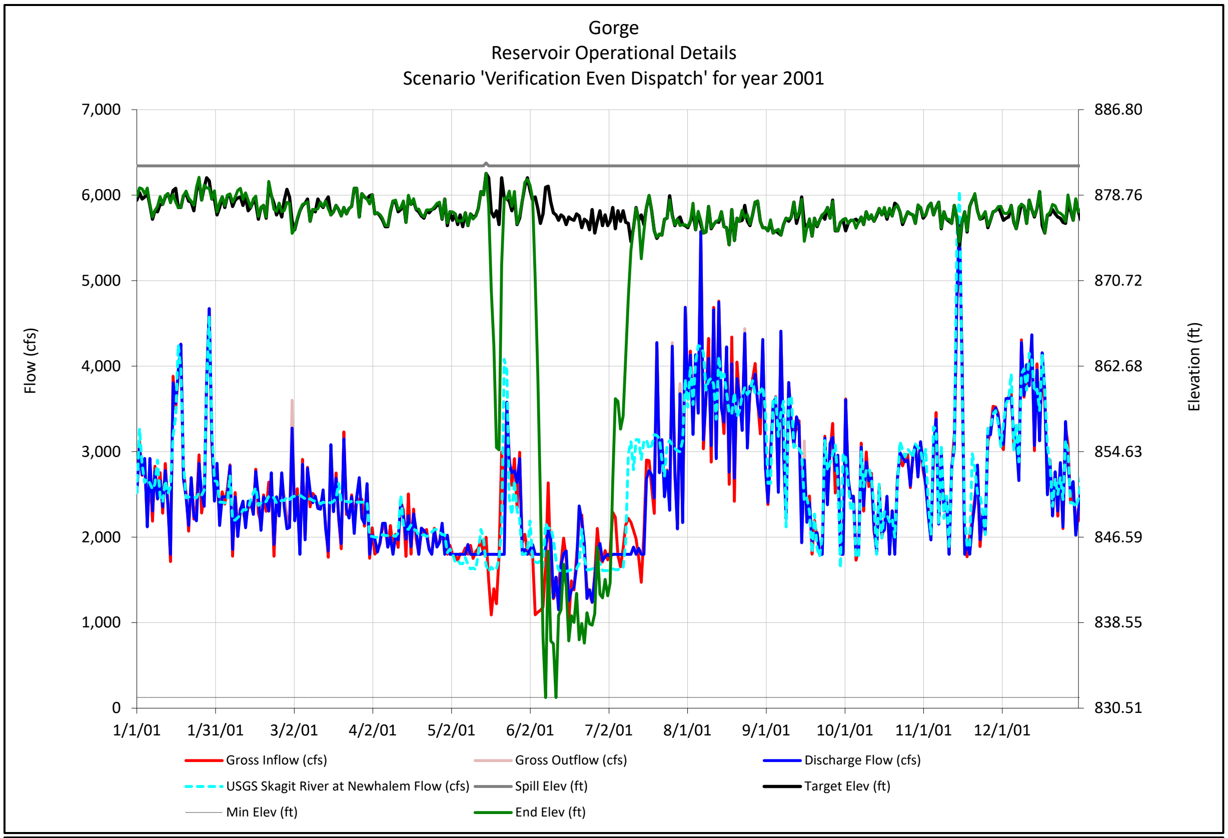

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2000
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1590.43
1566.77
1543.10
1519.43
1495.77
1472.10
1/1/00
1/31/00
3/1/00
4/1/00
5/1/00
6/1/00
7/1/00
7/31/00
8/31/00
9/30/00
10/31/00
11/30/00
12/31/00
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

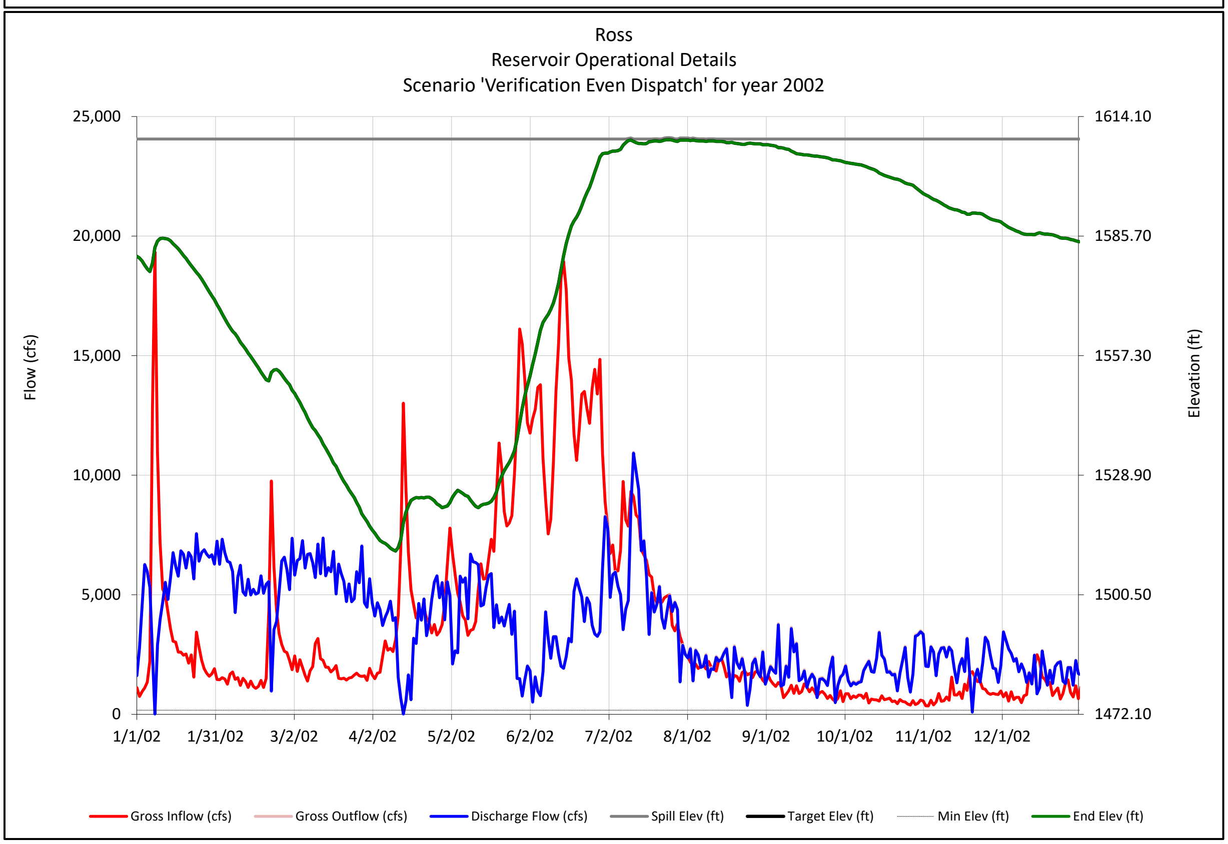

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2000
Flow (cfs)
Elevation (ft)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1214.00
1212.67
1211.34
1210.01
1208.68
1207.35
1206.02
1204.69
1203.36
1/1/00
1/31/00
3/1/00
4/1/00
5/1/00
6/1/00
7/1/00
7/31/00
8/31/00
9/30/00
10/31/00
11/30/00
12/31/00
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

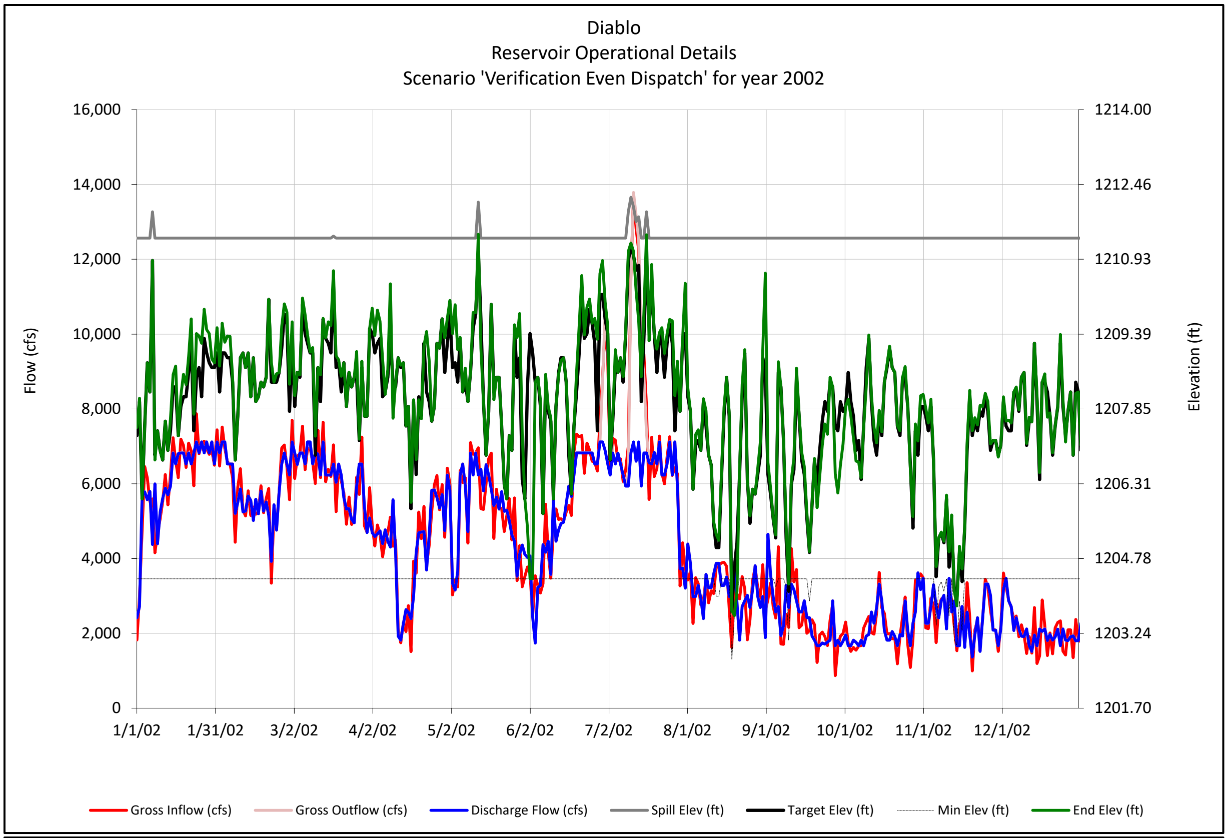

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2000
Flow (cfs)
Elevation (ft)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
887.20
880.11
873.03
865.94
858.86
851.77
844.68
837.60
830.51
1/1/00
1/31/00
3/1/00
4/1/00
5/1/00
6/1/00
7/1/00
7/31/00
8/31/00
9/30/00
10/31/00
11/30/00
12/31/00
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

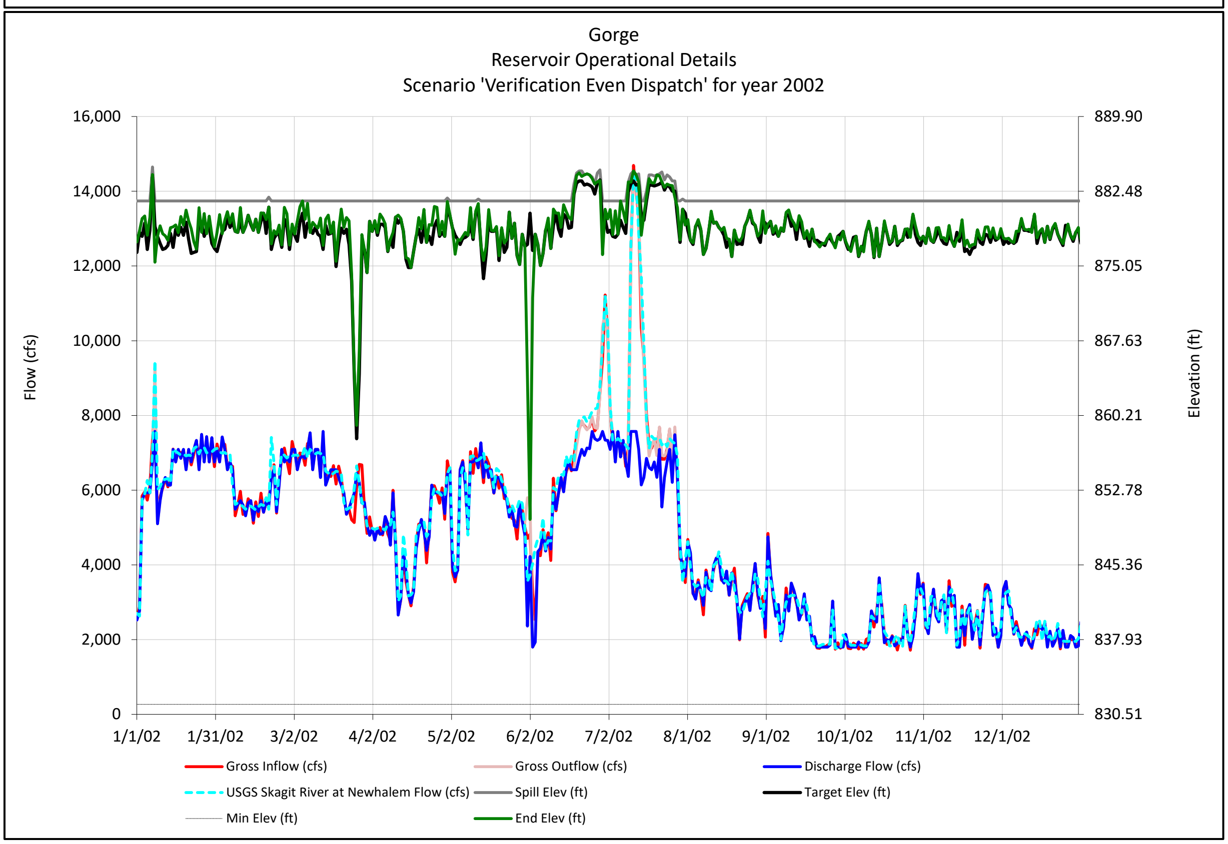

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2001
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1590.15
1566.54
1542.93
1519.32
1495.71
1472.10
1/1/01
1/31/01
3/2/01
4/2/01
5/2/01
6/2/01
7/2/01
8/1/01
9/1/01
10/1/01
11/1/01
12/1/01
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

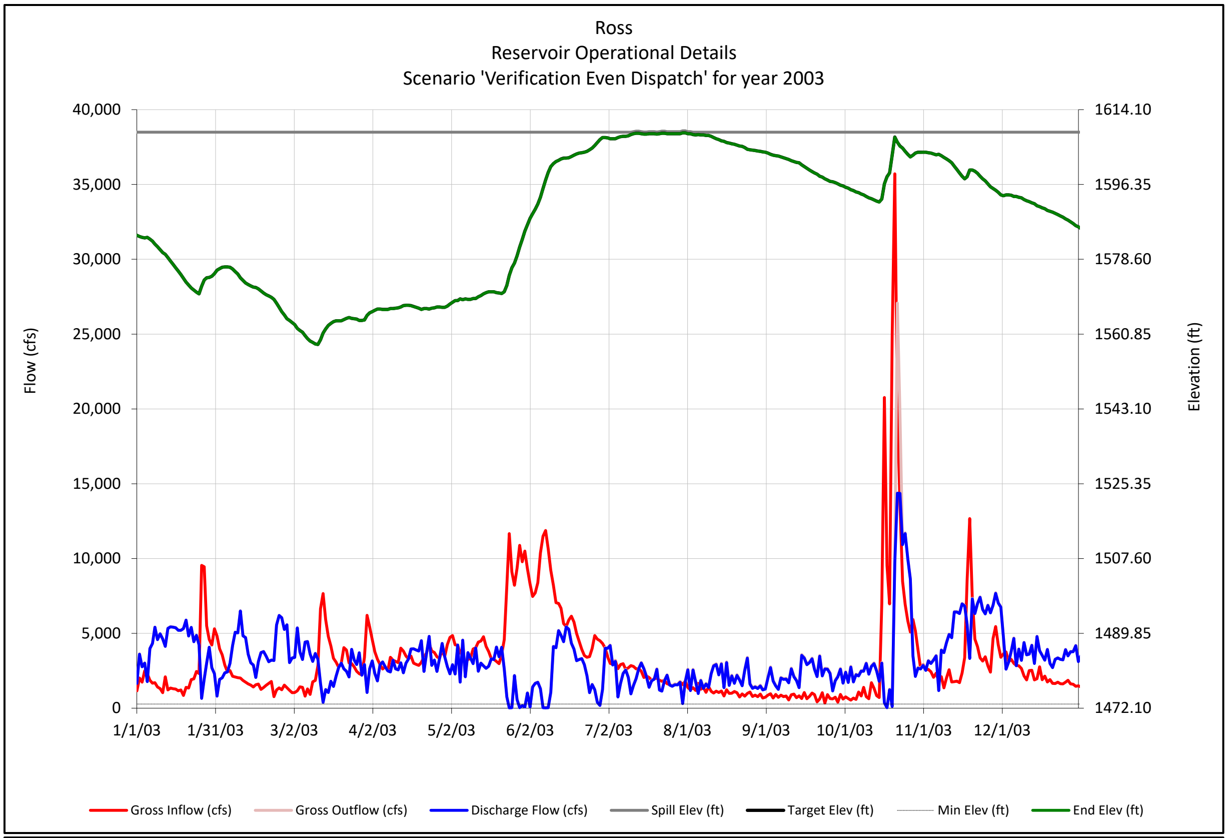

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2001
Flow (cfs)
Elevation (ft)
6,000
5,000
4,000
3,000
2,000
1,000
0
1213.00
1211.39
1209.79
1208.18
1206.57
1204.97
1203.36
1/1/01
1/31/01
3/2/01
4/2/01
5/2/01
6/2/01
7/2/01
8/1/01
9/1/01
10/1/01
11/1/01
12/1/01
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

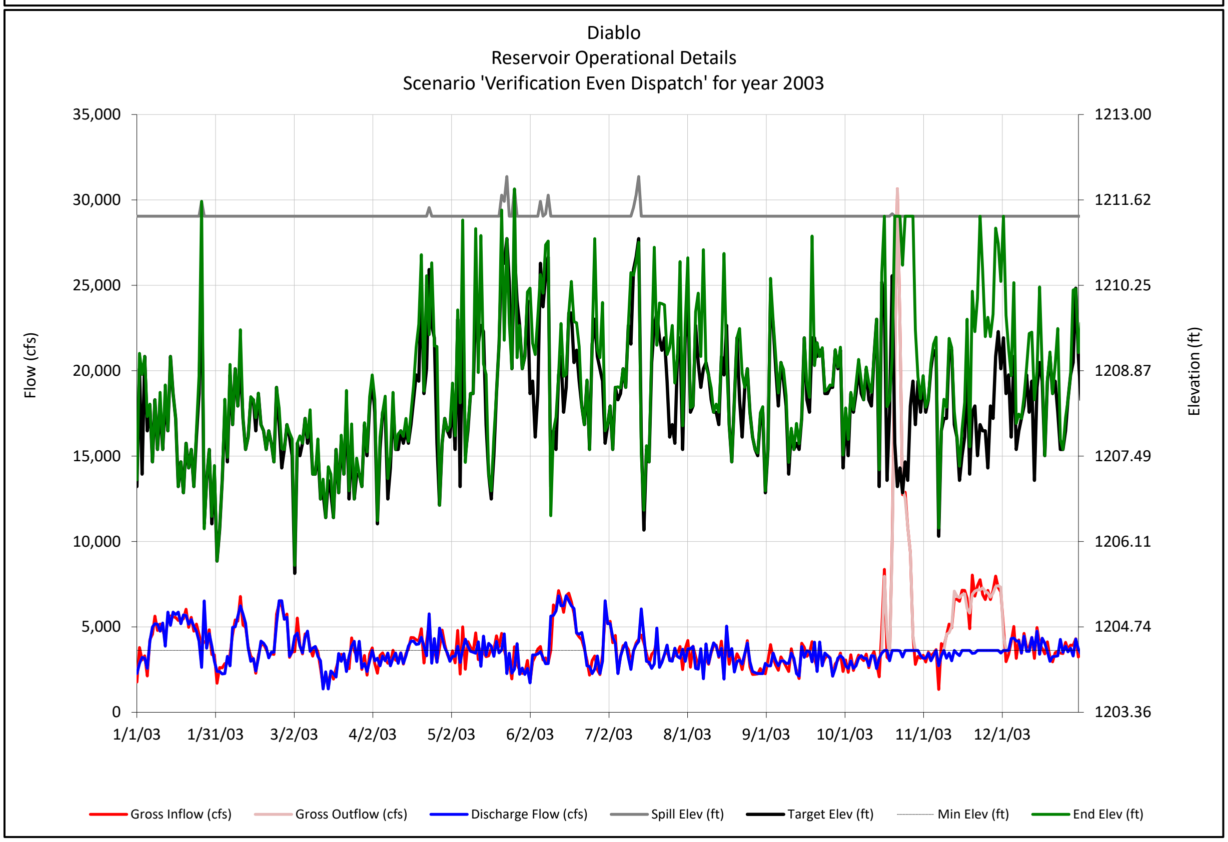

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2001
Flow (cfs)
Elevation (ft)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
886.80
878.76
870.72
862.68
854.63
846.59
838.55
830.51
1/1/01
1/31/01
3/2/01
4/2/01
5/2/01
6/2/01
7/2/01
8/1/01
9/1/01
10/1/01
11/1/01
12/1/01
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

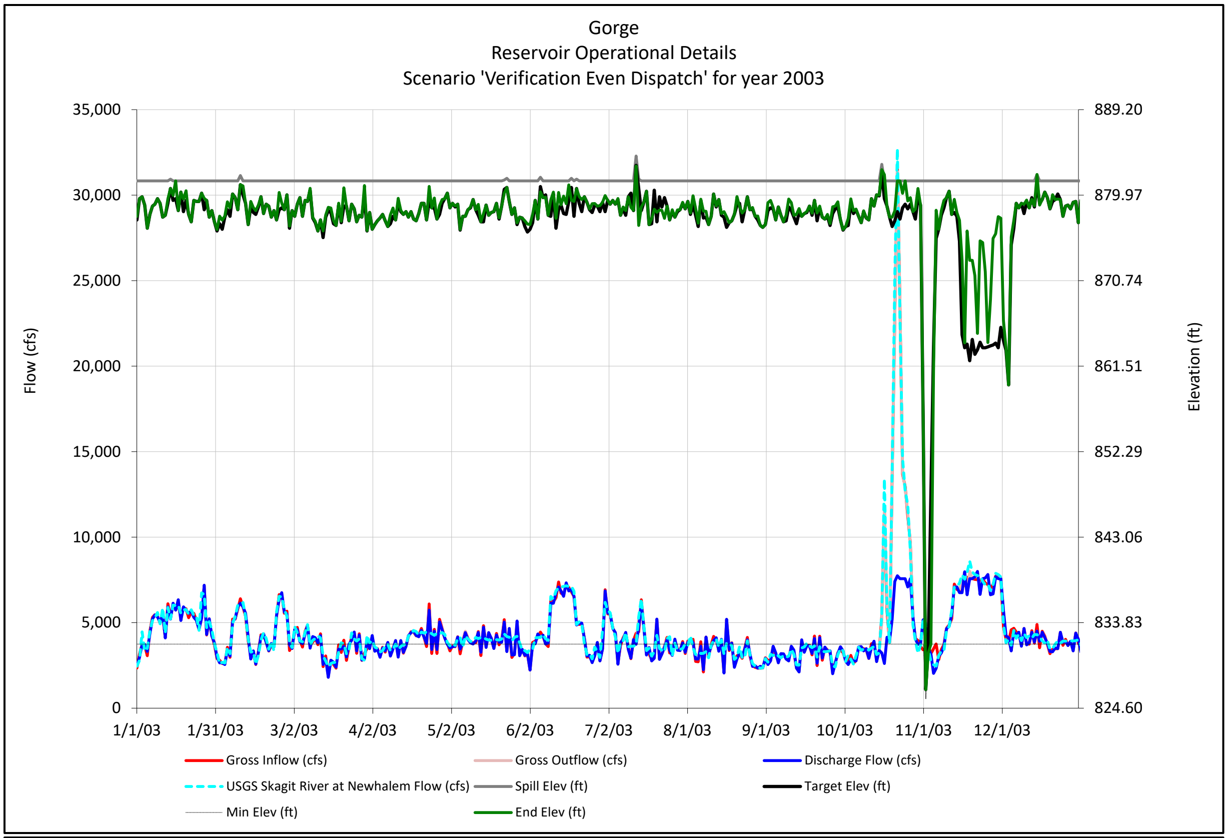

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2002
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
1614.10
1585.70
1557.30
1528.90
1500.50
1472.10
1/1/02
1/31/02
3/2/02
4/2/02
5/2/02
6/2/02
7/2/02
8/1/02
9/1/02
10/1/02
11/1/02
12/1/02
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

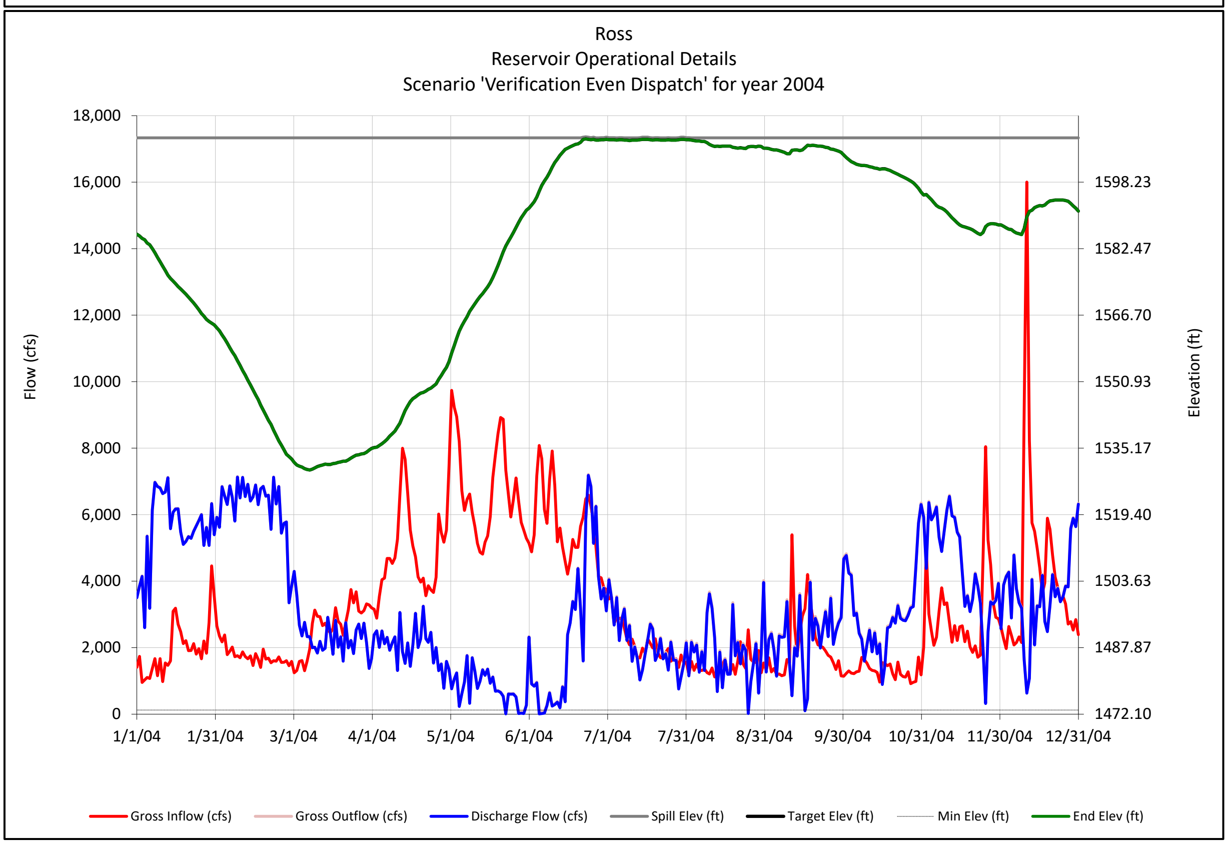

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2002
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1214.00
1212.46
1210.93
1209.39
1207.85
1206.31
1204.78
1203.24
1201.70
1/1/02
1/31/02
3/2/02
4/2/02
5/2/02
6/2/02
7/2/02
8/1/02
9/1/02
10/1/02
11/1/02
12/1/02
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

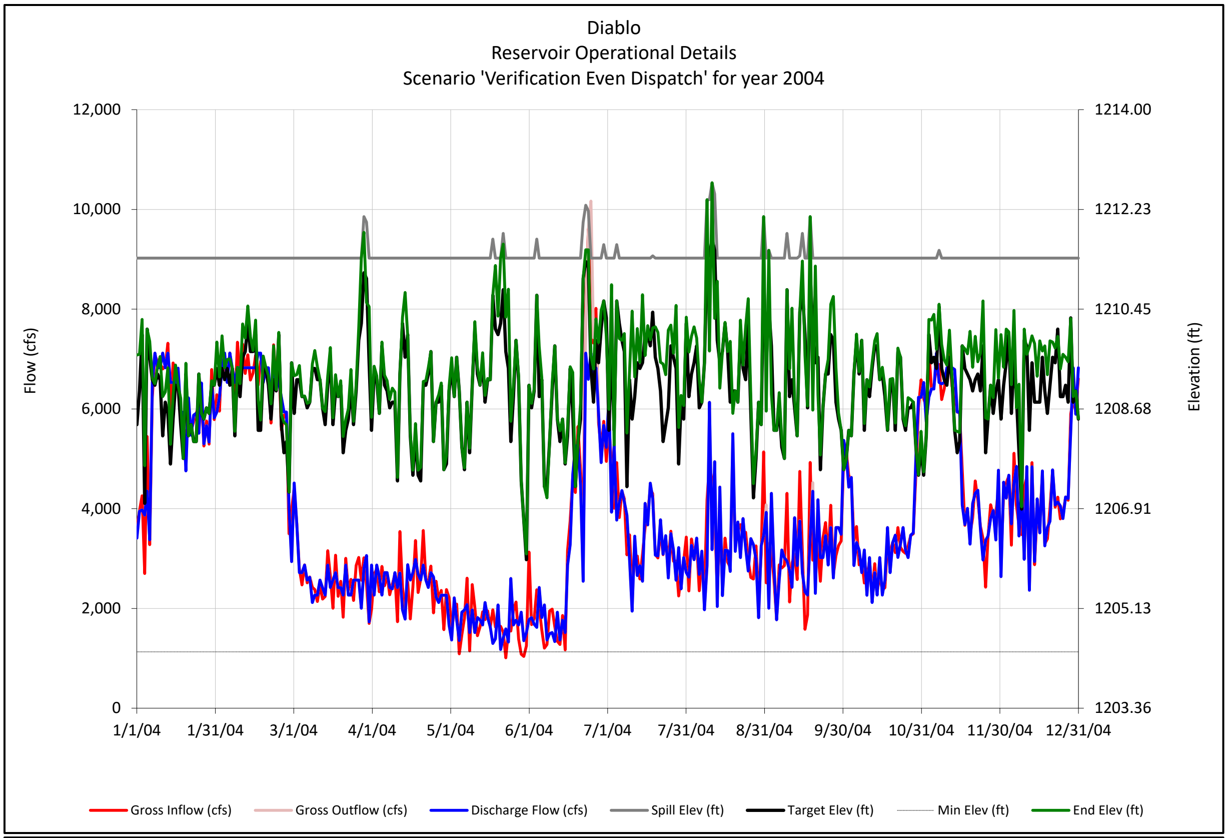

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2002
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
889.90
882.48
875.05
867.63
860.21
852.78
845.36
837.93
830.51
1/1/02
1/31/02
3/2/02
4/2/02
5/2/02
6/2/02
7/2/02
8/1/02
9/1/02
10/1/02
11/1/02
12/1/02
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

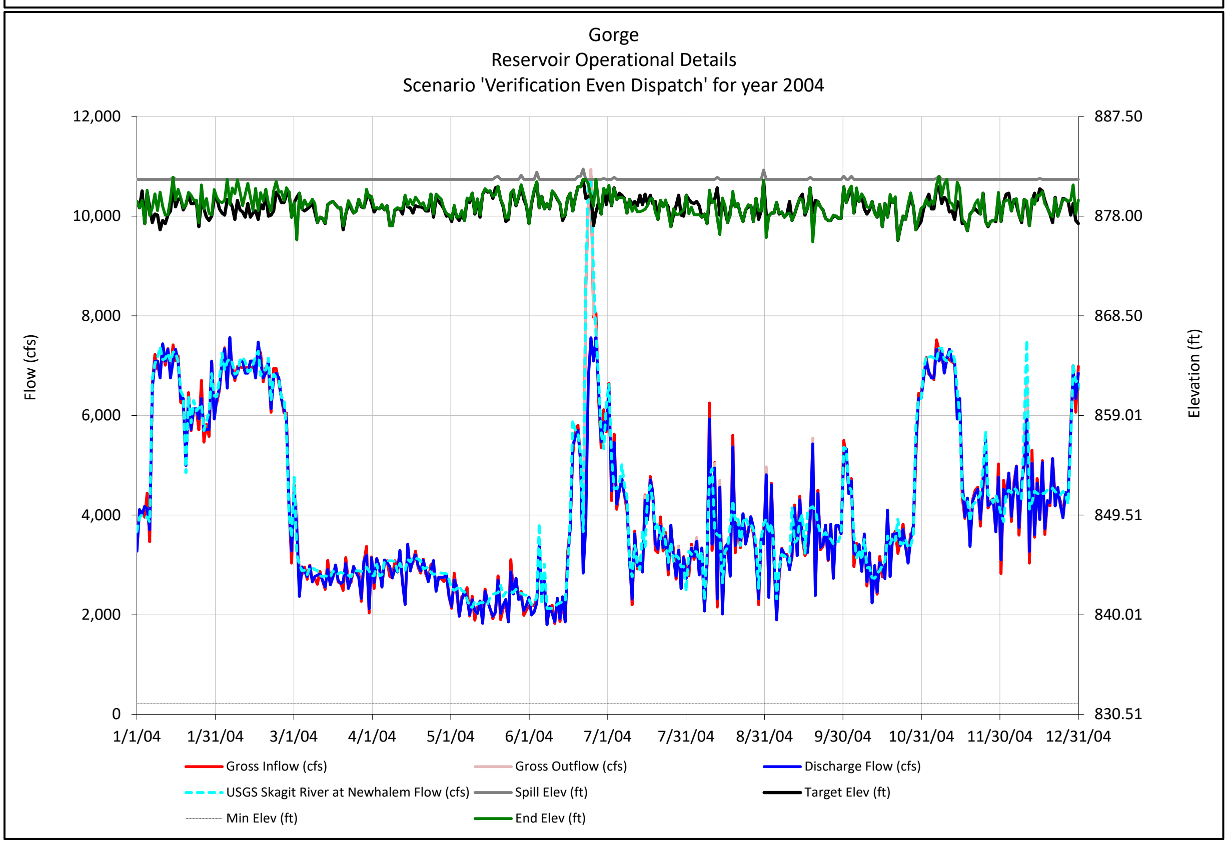

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2003
Flow (cfs)
Elevation (ft)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1614.10
1596.35
1578.60
1560.85
1543.10
1525.35
1507.60
1489.85
1472.10
1/1/03
1/31/03
3/2/03
4/2/03
5/2/03
6/2/03
7/2/03
8/1/03
9/1/03
10/1/03
11/1/03
12/1/03
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

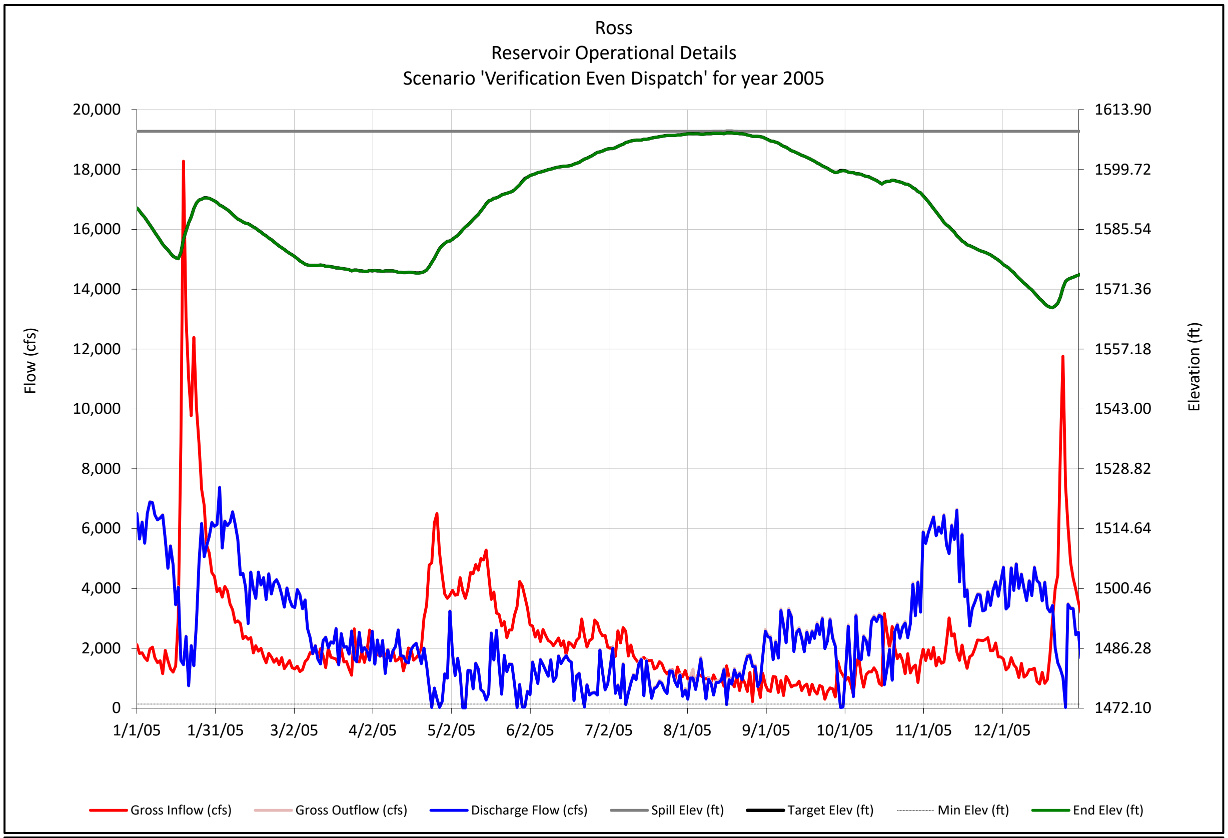

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2003
Flow (cfs)
Elevation (ft)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1213.00
1211.62
1210.25
1208.87
1207.49
1206.11
1204.74
1203.36
1/1/03
1/31/03
3/2/03
4/2/03
5/2/03
6/2/03
7/2/03
8/1/03
9/1/03
10/1/03
11/1/03
12/1/03
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

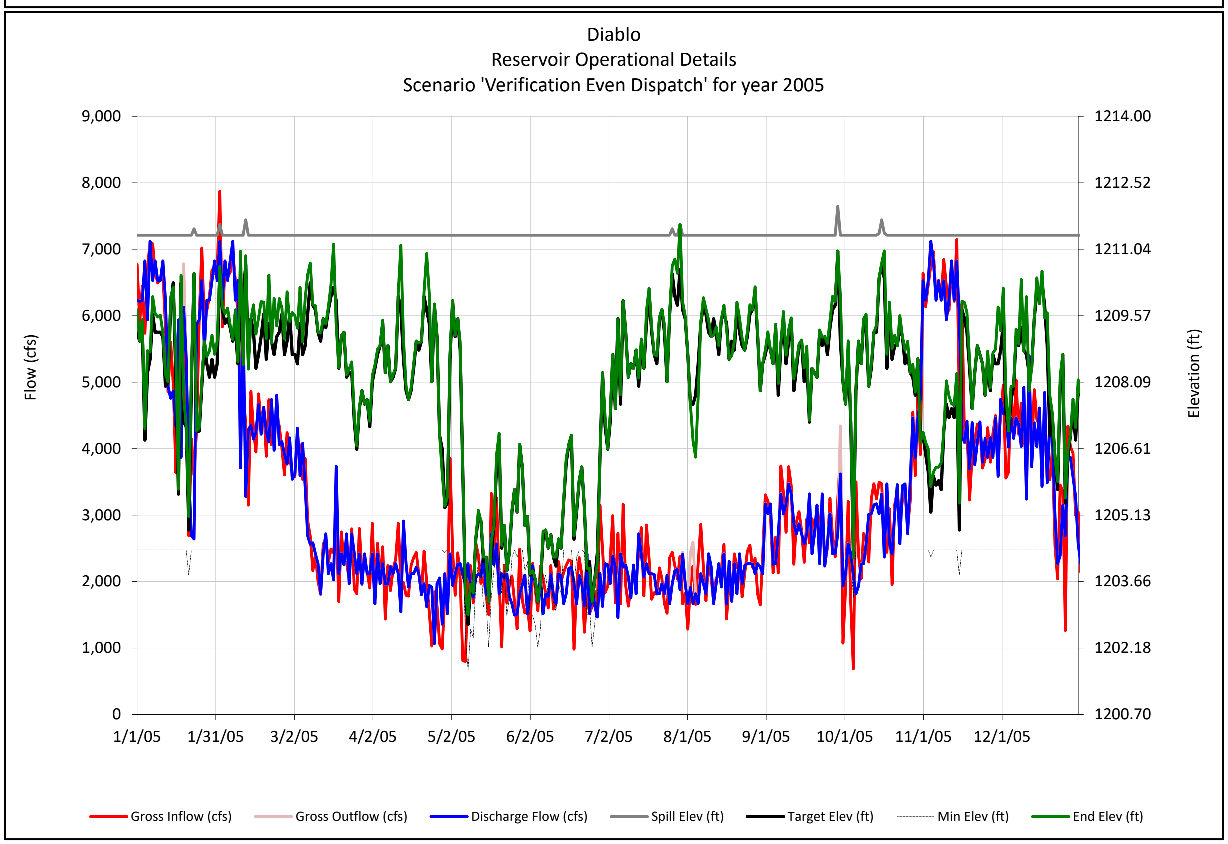

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2003
Flow (cfs)
Elevation (ft)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
889.20
879.97
870.74
861.51
852.29
843.06
833.83
824.60
1/1/03
1/31/03
3/2/03
4/2/03
5/2/03
6/2/03
7/2/03
8/1/03
9/1/03
10/1/03
11/1/03
12/1/03
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2004
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1598.23
1582.47
1566.70
1550.93
1535.17
1519.40
1503.63
1487.87
1472.10
1/1/04
1/31/04
3/1/04
4/1/04
5/1/04
6/1/04
7/1/04
7/31/04
8/31/04
9/30/04
10/31/04
11/30/04
12/31/04
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

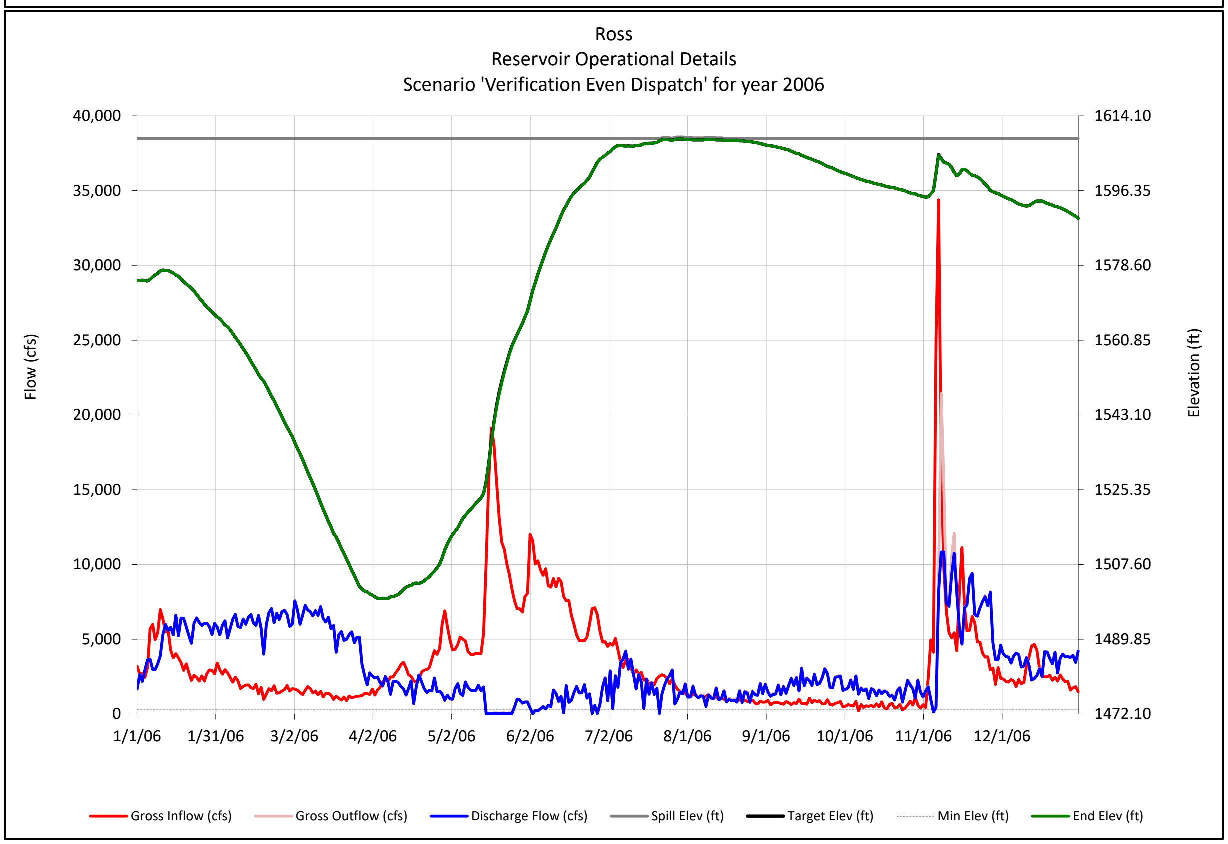

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2004
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1214.00
1212.23
1210.45
1208.68
1206.91
1205.13
1203.36
1/1/04
1/31/04
3/1/04
4/1/04
5/1/04
6/1/04
7/1/04
7/31/04
8/31/04
9/30/04
10/31/04
11/30/04
12/31/04
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

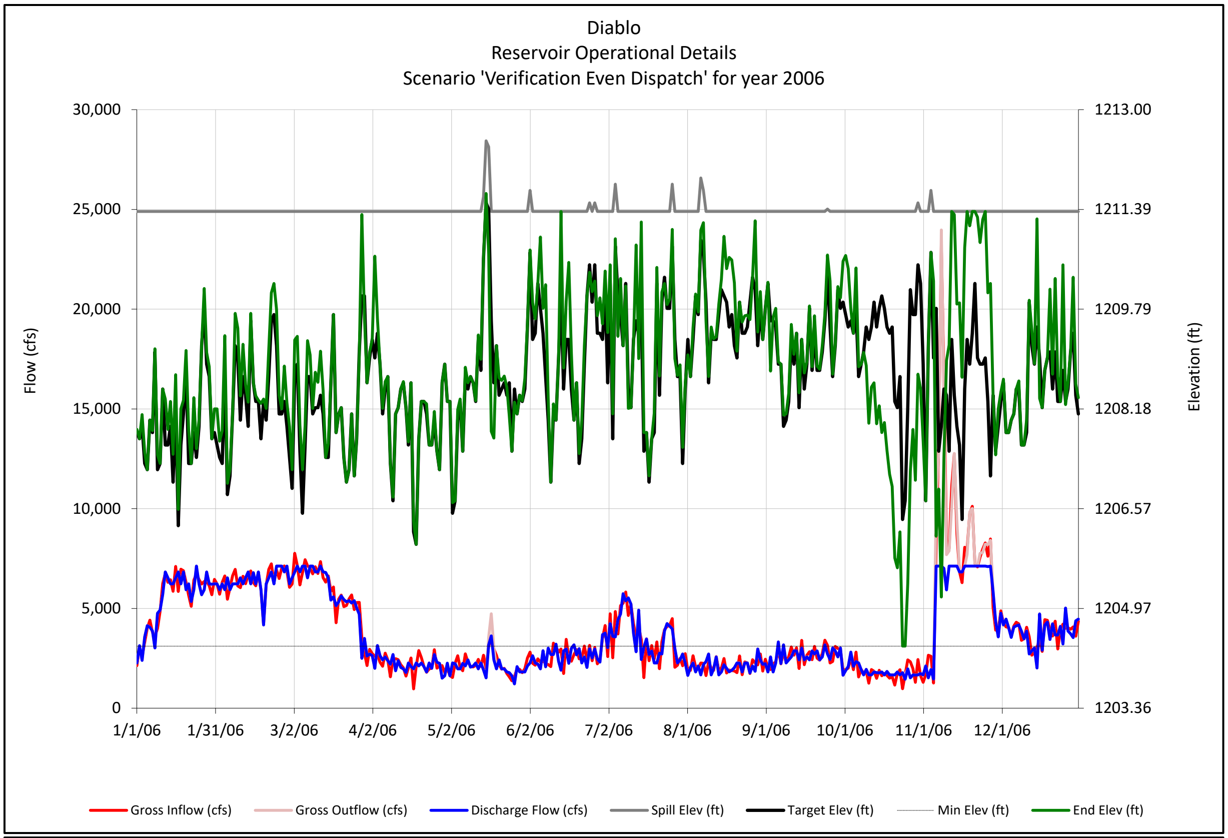

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2004
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
887.50
878.00
868.50
859.01
849.51
840.01
830.51
1/1/04
1/31/04
3/1/04
4/1/04
5/1/04
6/1/04
7/1/04
7/31/04
8/31/04
9/30/04
10/31/04
11/30/04
12/31/04
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

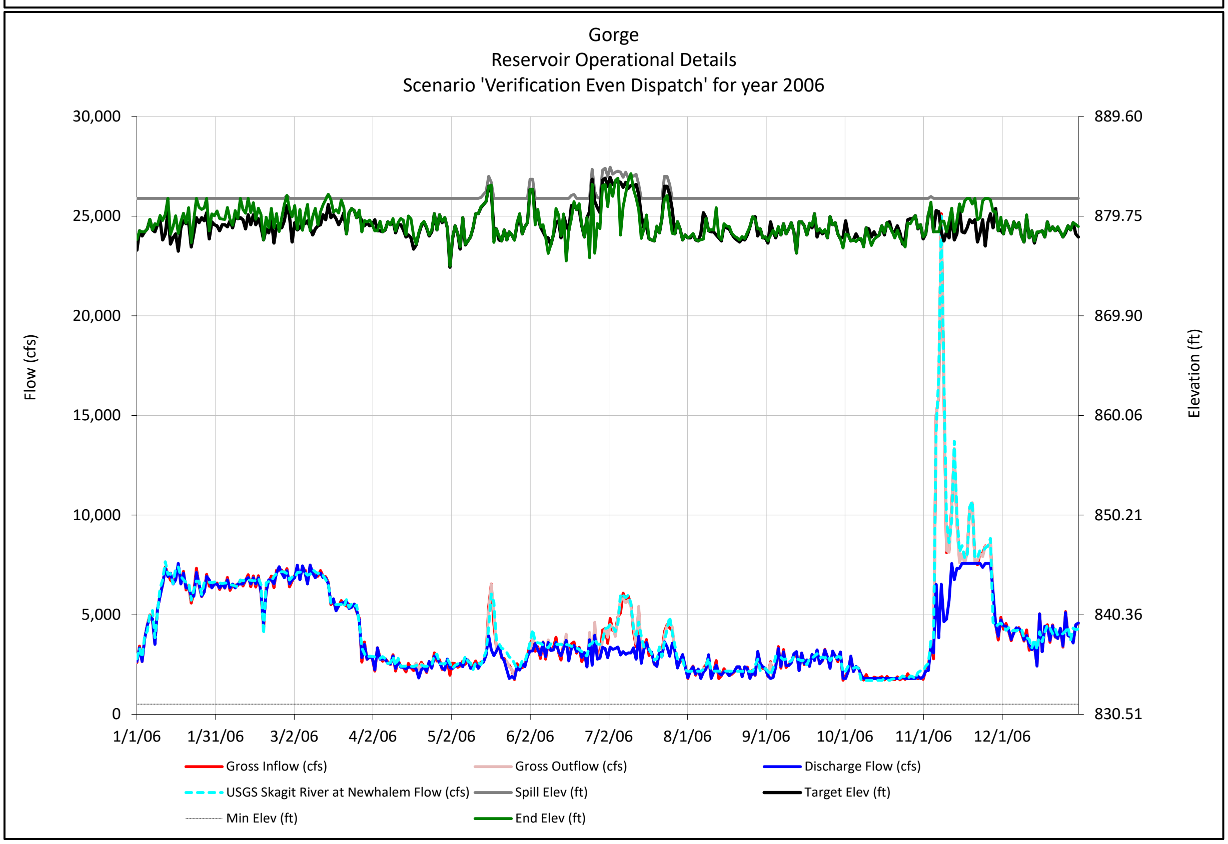

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2005
Flow (cfs)
Elevation (ft)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.90
1599.72
1585.54
1571.36
1557.18
1543.00
1528.82
1514.64
1500.46
1486.28
1472.10
1/1/05
1/31/05
3/2/05
4/2/05
5/2/05
6/2/05
7/2/05
8/1/05
9/1/05
10/1/05
11/1/05
12/1/05
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

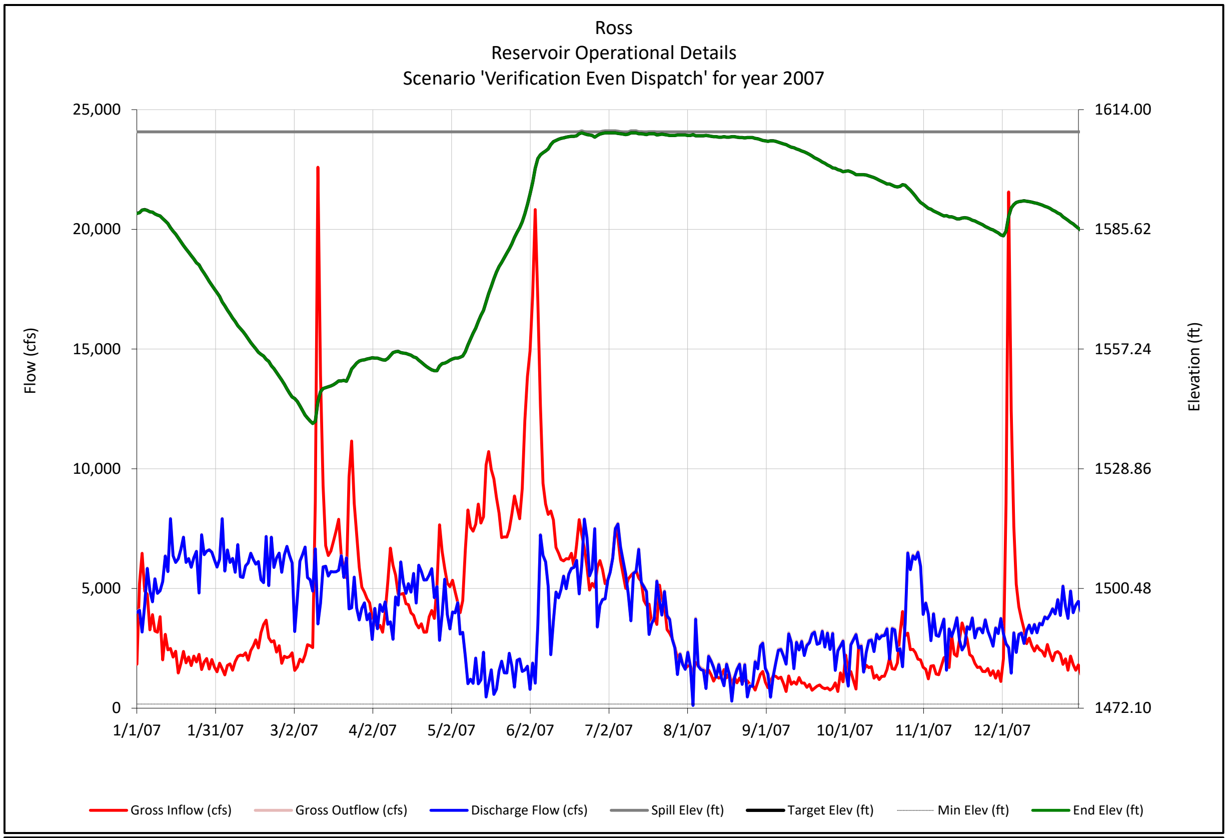

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2005
Flow (cfs)
Elevation (ft)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1214.00
1212.52
1211.04
1209.57
1208.09
1206.61
1205.13
1203.66
1202.18
1200.70
1/1/05
1/31/05
3/2/05
4/2/05
5/2/05
6/2/05
7/2/05
8/1/05
9/1/05
10/1/05
11/1/05
12/1/05
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

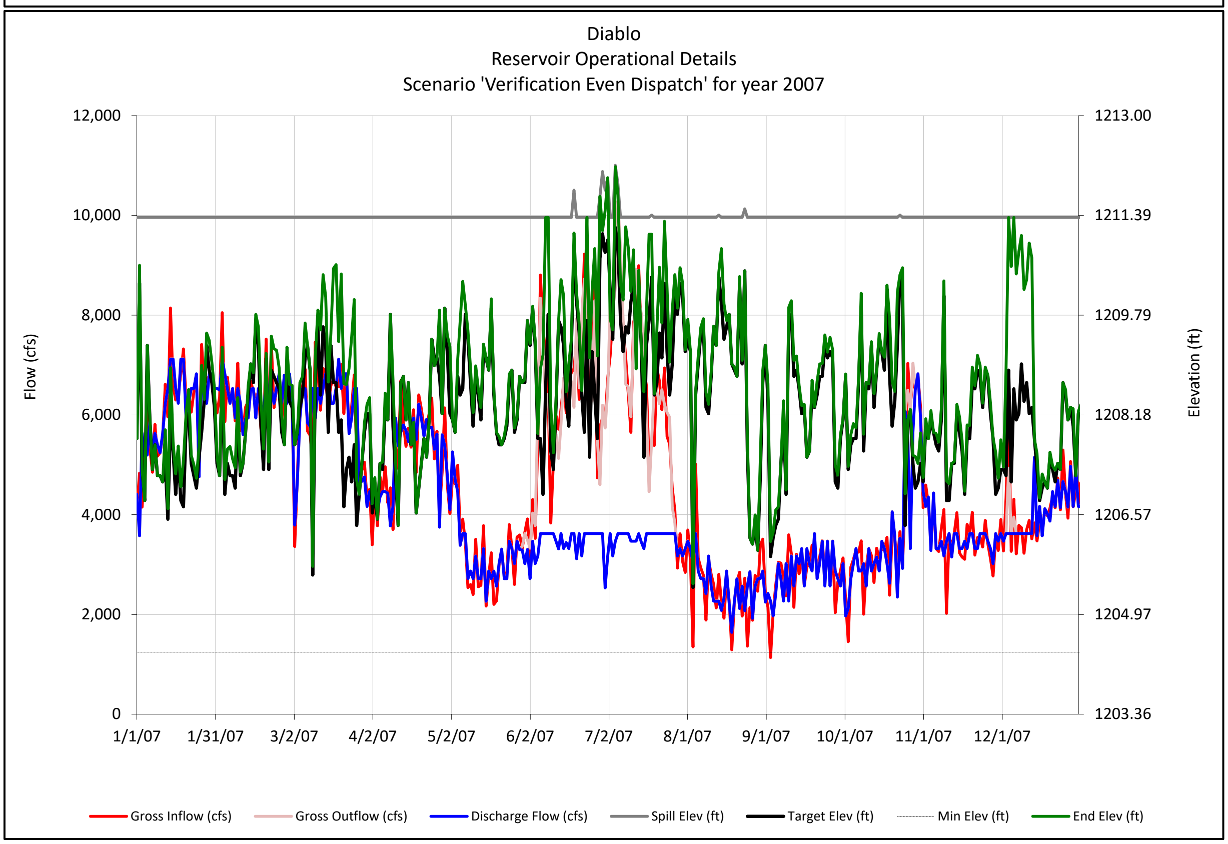

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2005
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
887.90
878.34
868.77
859.21
849.64
840.08
830.51
1/1/05
1/31/05
3/2/05
4/2/05
5/2/05
6/2/05
7/2/05
8/1/05
9/1/05
10/1/05
11/1/05
12/1/05
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

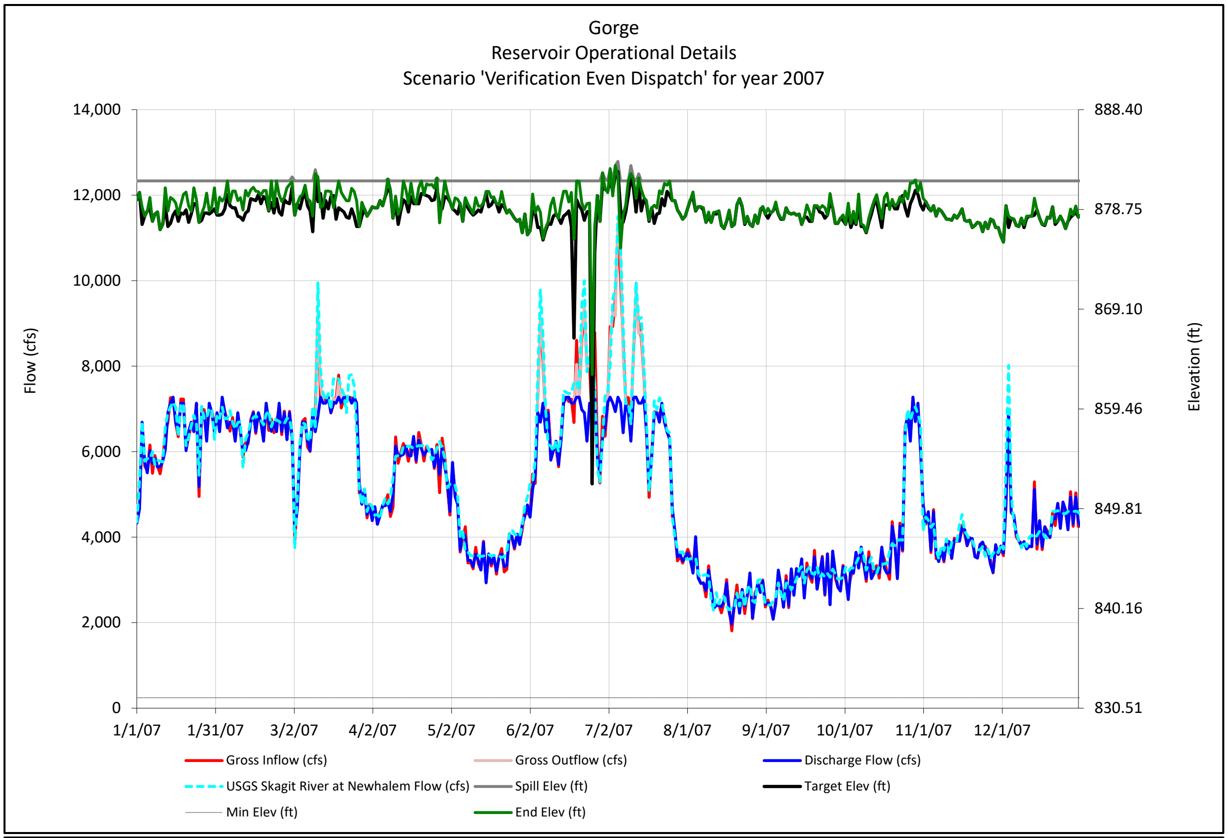

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2006
Flow (cfs)
Elevation (ft)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1614.10
1596.35
1578.60
1560.85
1543.10
1525.35
1507.60
1489.85
1472.10
1/1/06
1/31/06
3/2/06
4/2/06
5/2/06
6/2/06
7/2/06
8/1/06
9/1/06
10/1/06
11/1/06
12/1/06
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

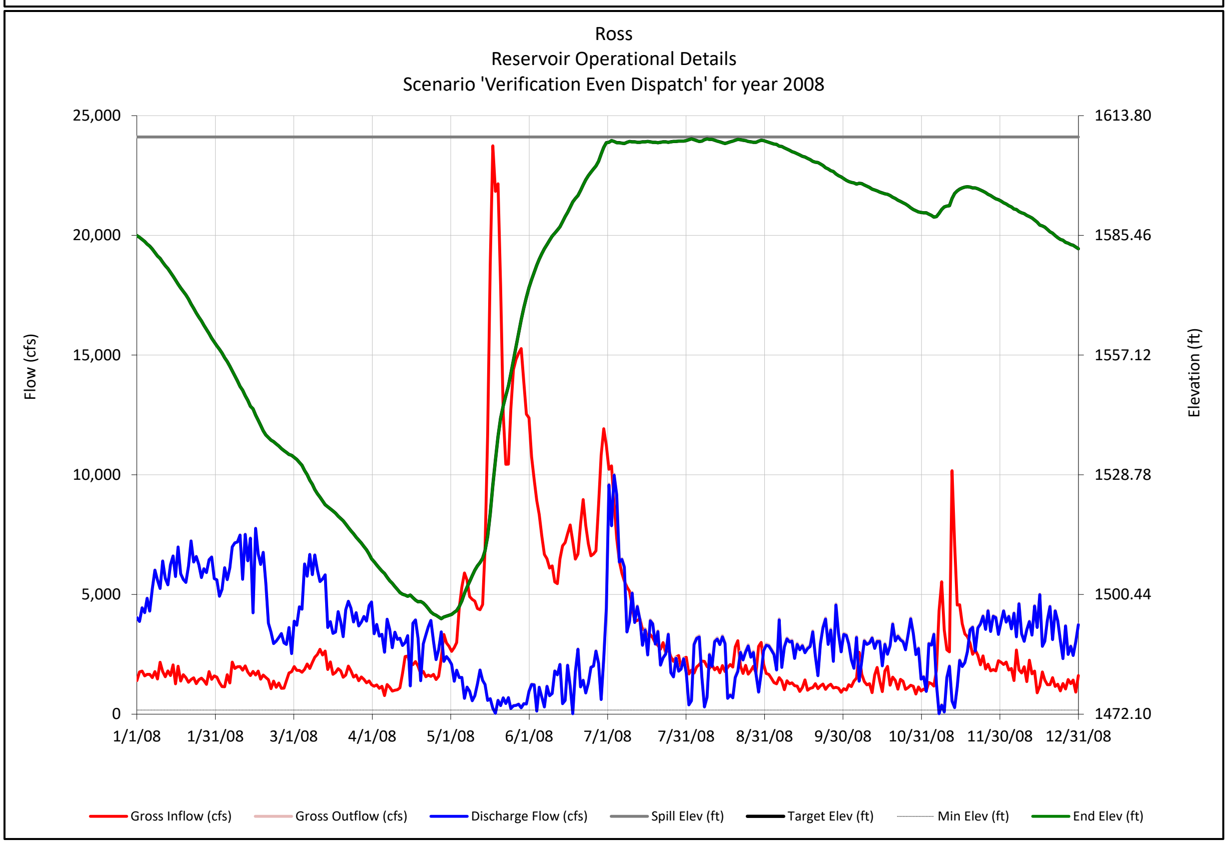

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2006
Flow (cfs)
Elevation (ft)
30,000
25,000
20,000
15,000
10,000
5,000
0
1213.00
1211.39
1209.79
1208.18
1206.57
1204.97
1203.36
1/1/06
1/31/06
3/2/06
4/2/06
5/2/06
6/2/06
7/2/06
8/1/06
9/1/06
10/1/06
11/1/06
12/1/06
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

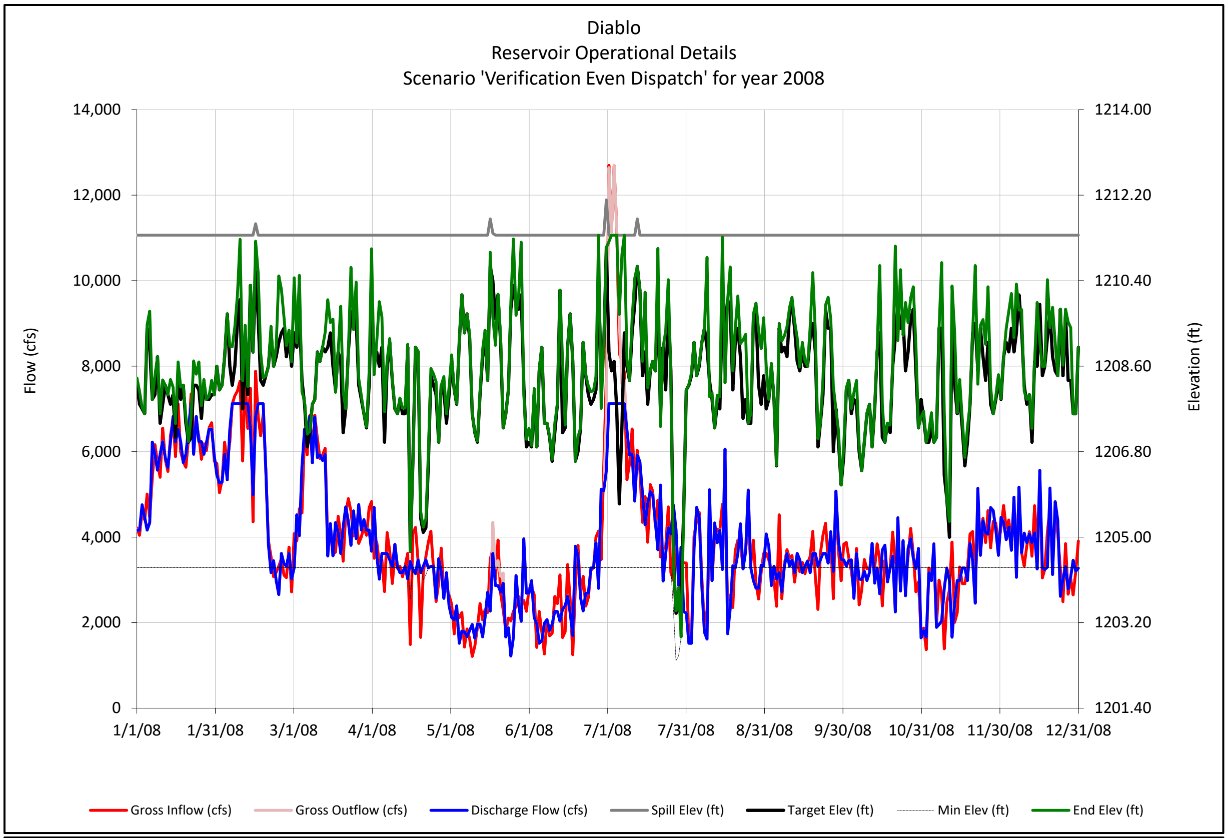

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2006
Flow (cfs)
Elevation (ft)
30,000
25,000
20,000
15,000
10,000
5,000
0
889.60
879.75
869.90
860.06
850.21
840.36
830.51
1/1/06
1/31/06
3/2/06
4/2/06
5/2/06
6/2/06
7/2/06
8/1/06
9/1/06
10/1/06
11/1/06
12/1/06
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

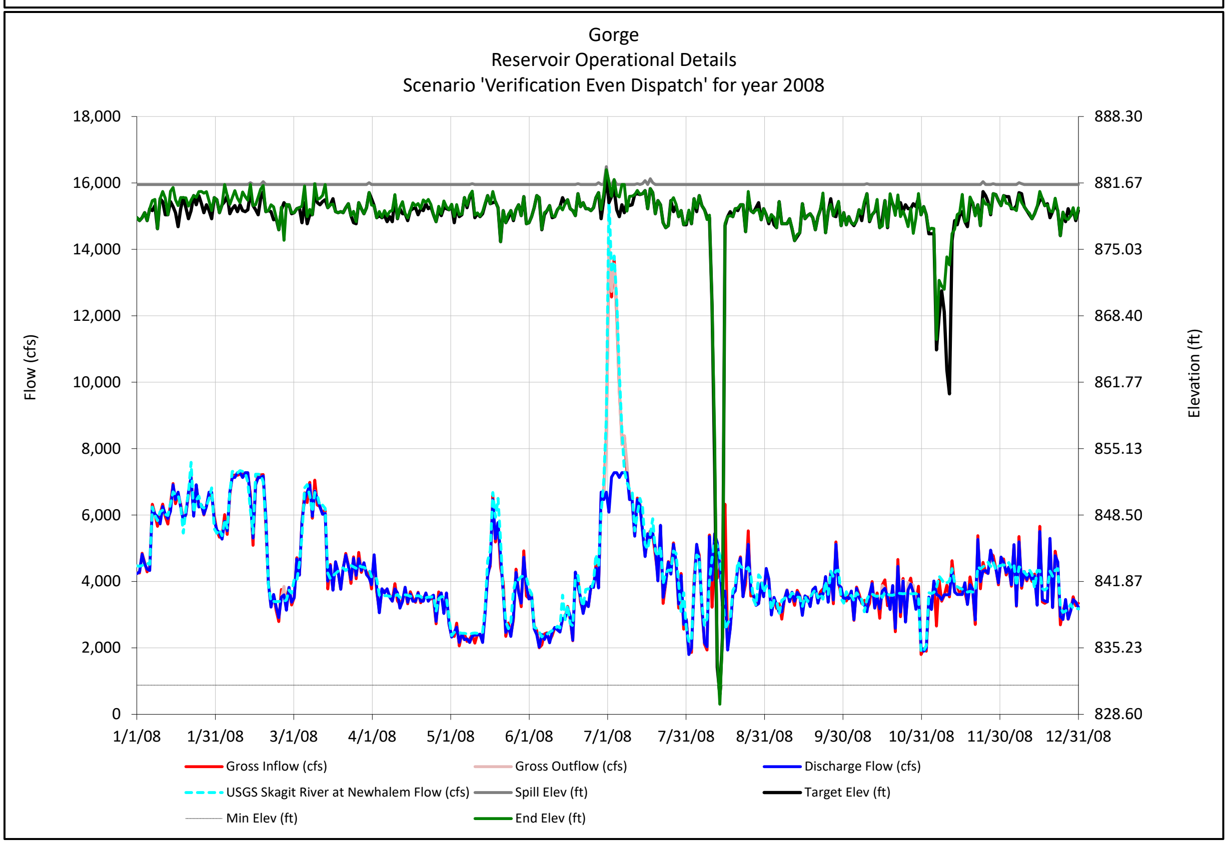

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2007
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
1614.00
1585.62
1557.24
1528.86
1500.48
1472.10
1/1/07
1/31/07
3/2/07
4/2/07
5/2/07
6/2/07
7/2/07
8/1/07
9/1/07
10/1/07
11/1/07
12/1/07
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

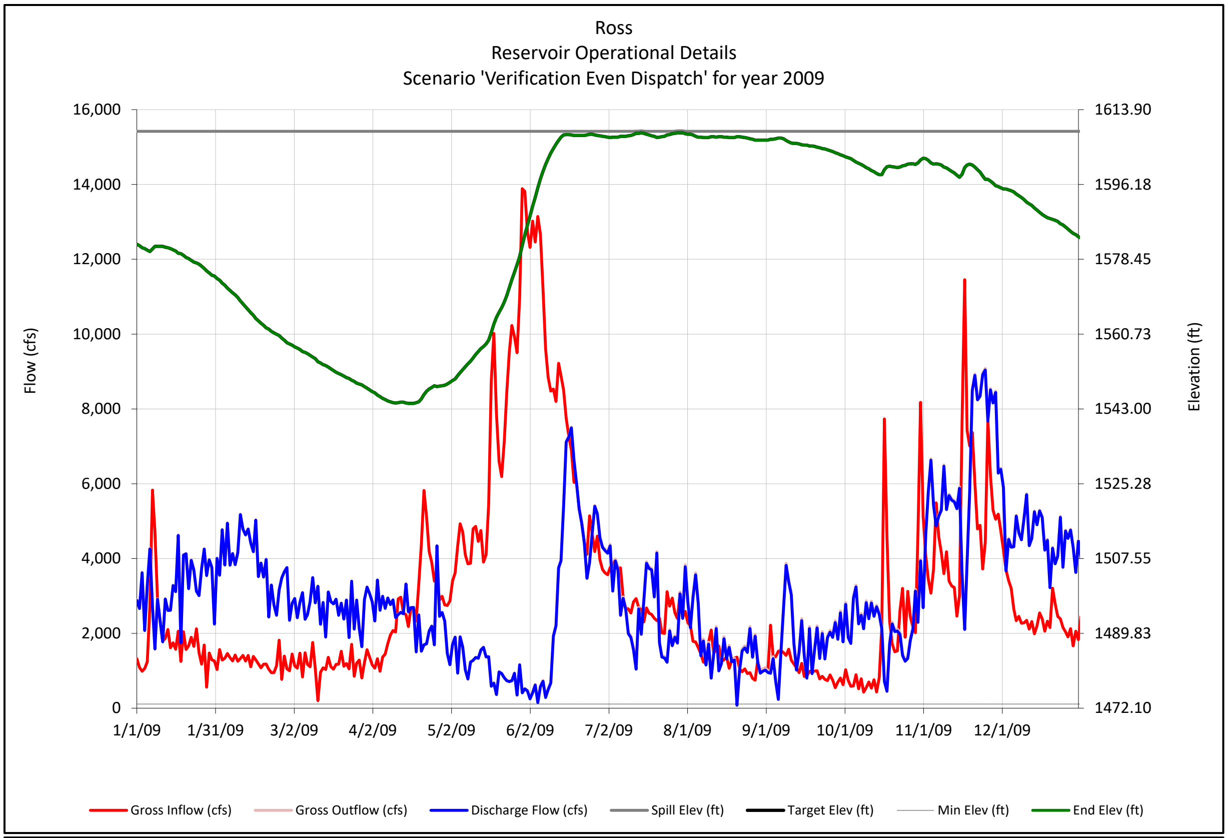

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2007
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1213.00
1211.39
1209.79
1208.18
1206.57
1204.97
1203.36
1/1/07
1/31/07
3/2/07
4/2/07
5/2/07
6/2/07
7/2/07
8/1/07
9/1/07
10/1/07
11/1/07
12/1/07
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

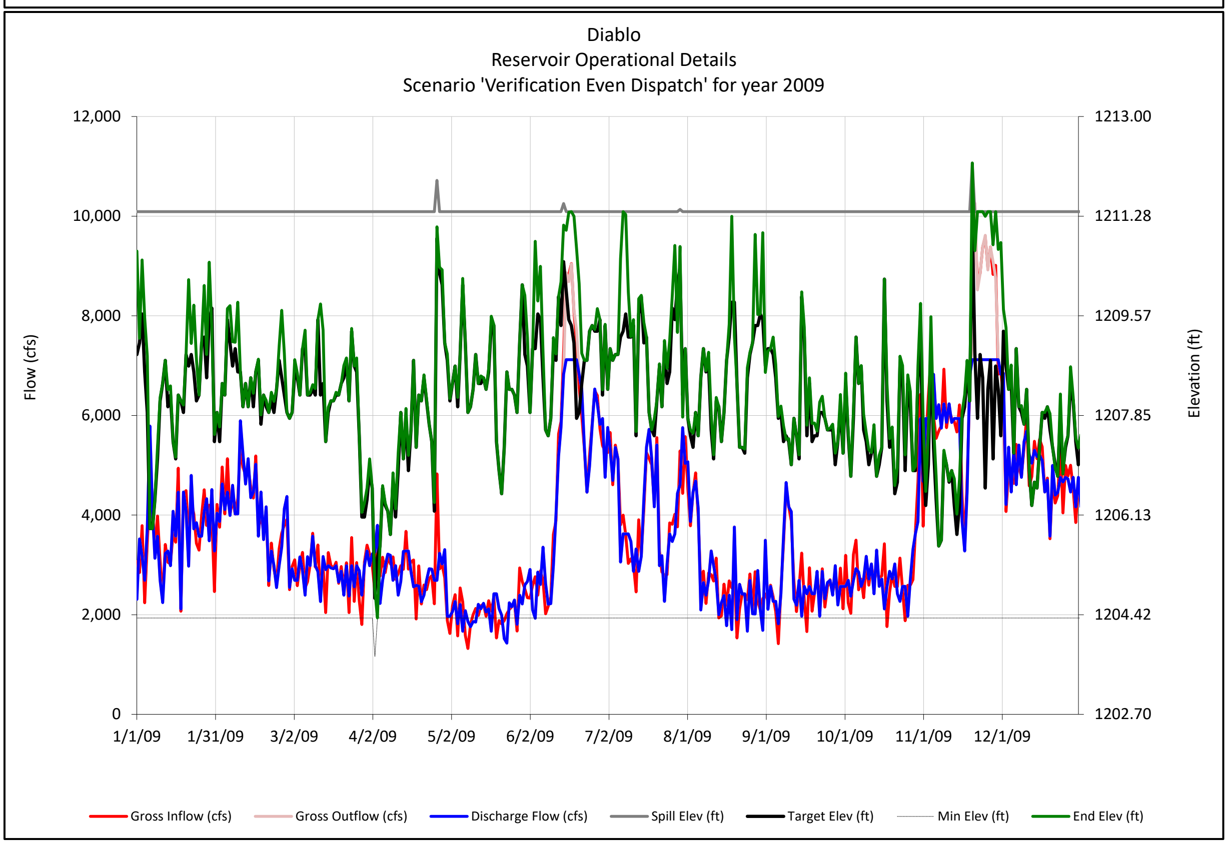

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2007
Flow (cfs)
Elevation (ft)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
888.40
878.75
869.10
859.46
849.81
840.16
830.51
1/1/07
1/31/07
3/2/07
4/2/07
5/2/07
6/2/07
7/2/07
8/1/07
9/1/07
10/1/07
11/1/07
12/1/07
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

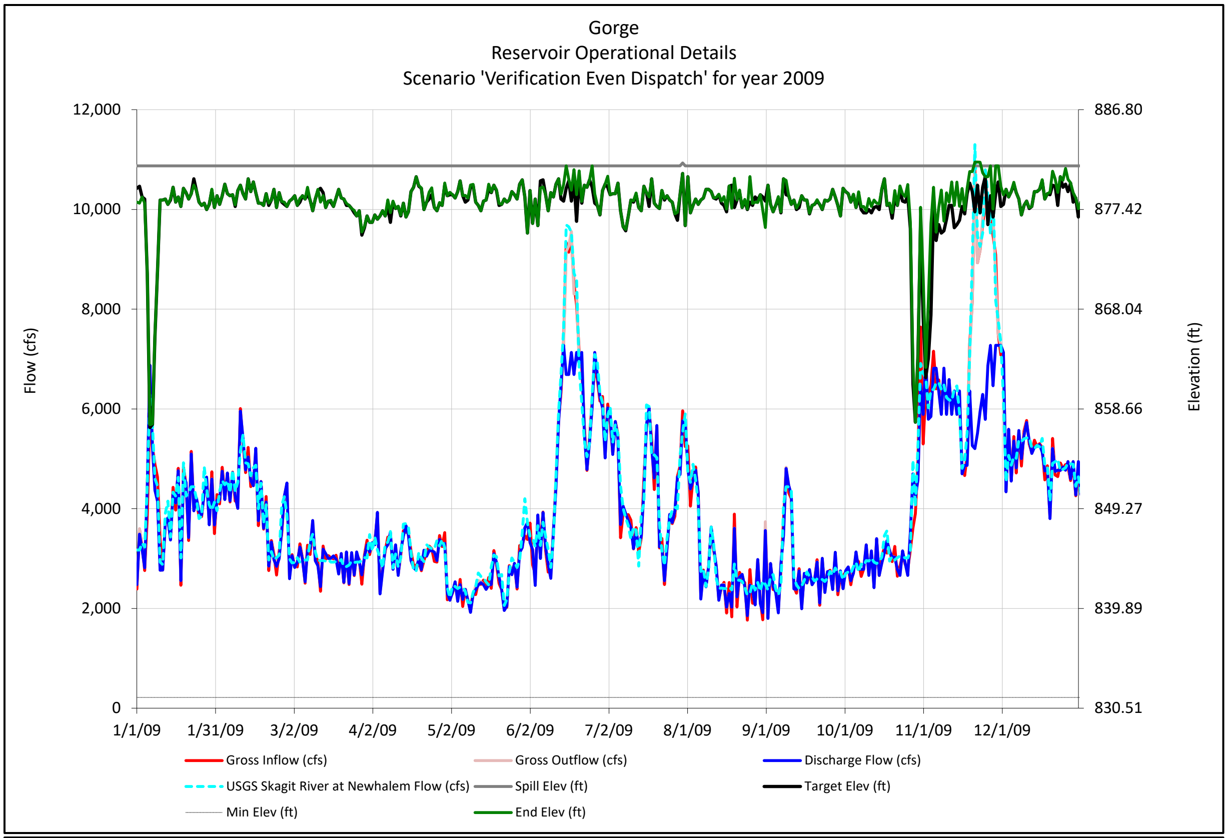

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2008
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
1613.80
1585.46
1557.12
1528.78
1500.44
1472.10
1/1/08
1/31/08
3/1/08
4/1/08
5/1/08
6/1/08
7/1/08
7/31/08
8/31/08
9/30/08
10/31/08
11/30/08
12/31/08
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

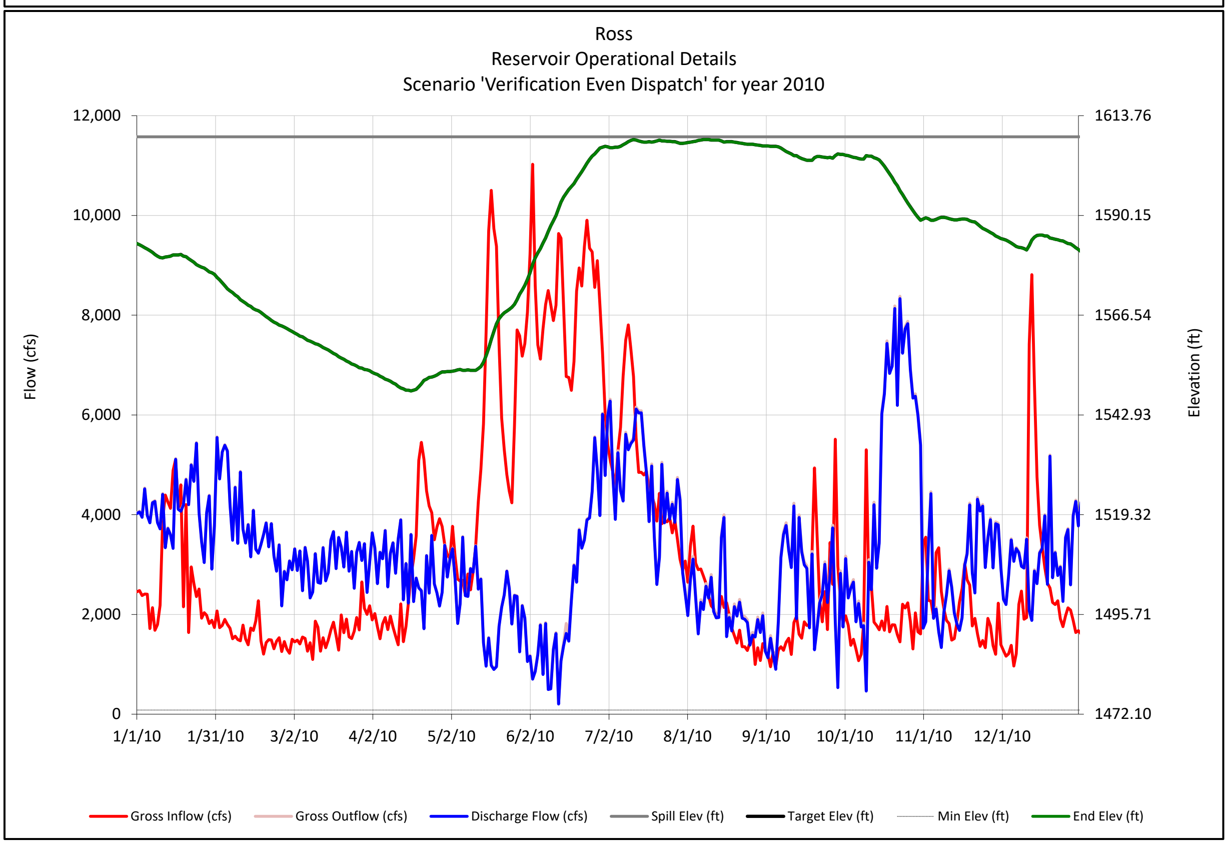

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2008
Flow (cfs)
Elevation (ft)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1214.00
1212.20
1210.40
1208.60
1206.80
1205.00
1203.20
1201.40
1/1/08
1/31/08
3/1/08
4/1/08
5/1/08
6/1/08
7/1/08
7/31/08
8/31/08
9/30/08
10/31/08
11/30/08
12/31/08
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

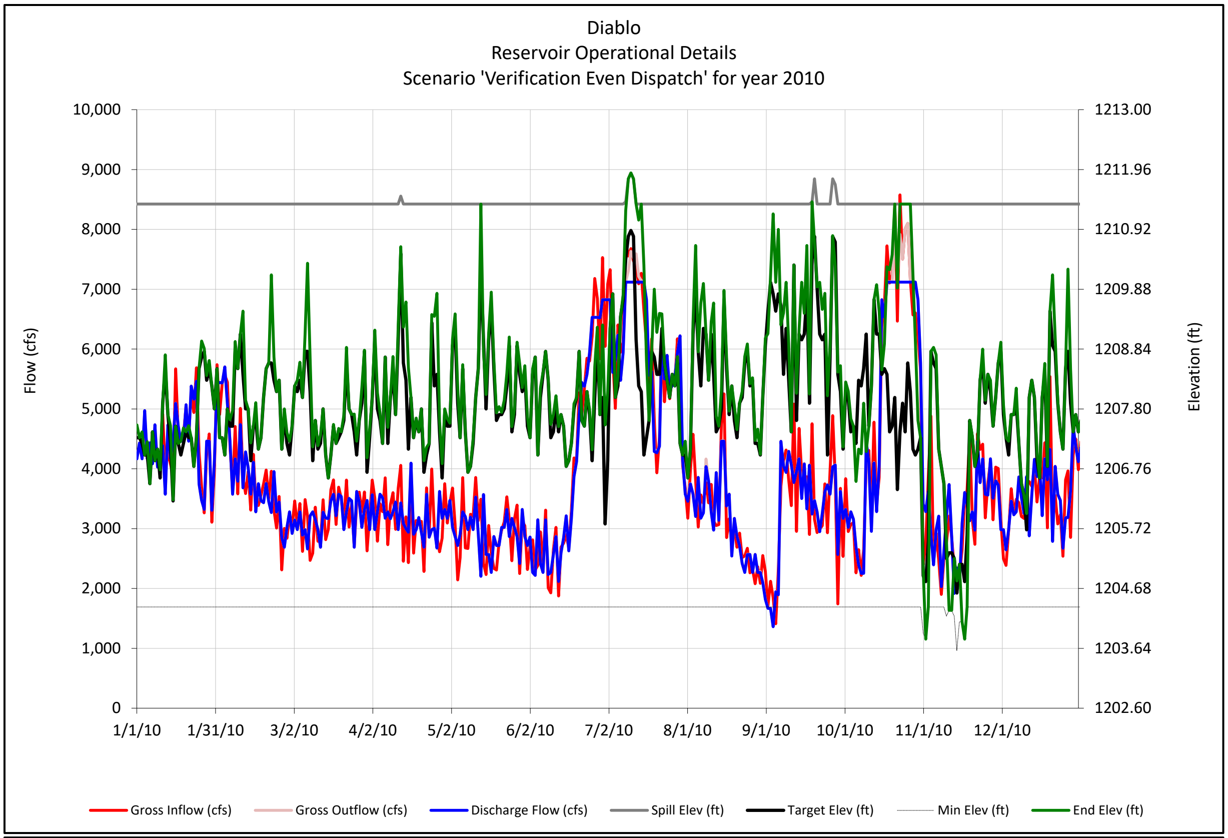

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2008
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
888.30
881.67
875.03
868.40
861.77
855.13
848.50
841.87
835.23
828.60
1/1/08
1/31/08
3/1/08
4/1/08
5/1/08
6/1/08
7/1/08
7/31/08
8/31/08
9/30/08
10/31/08
11/30/08
12/31/08
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

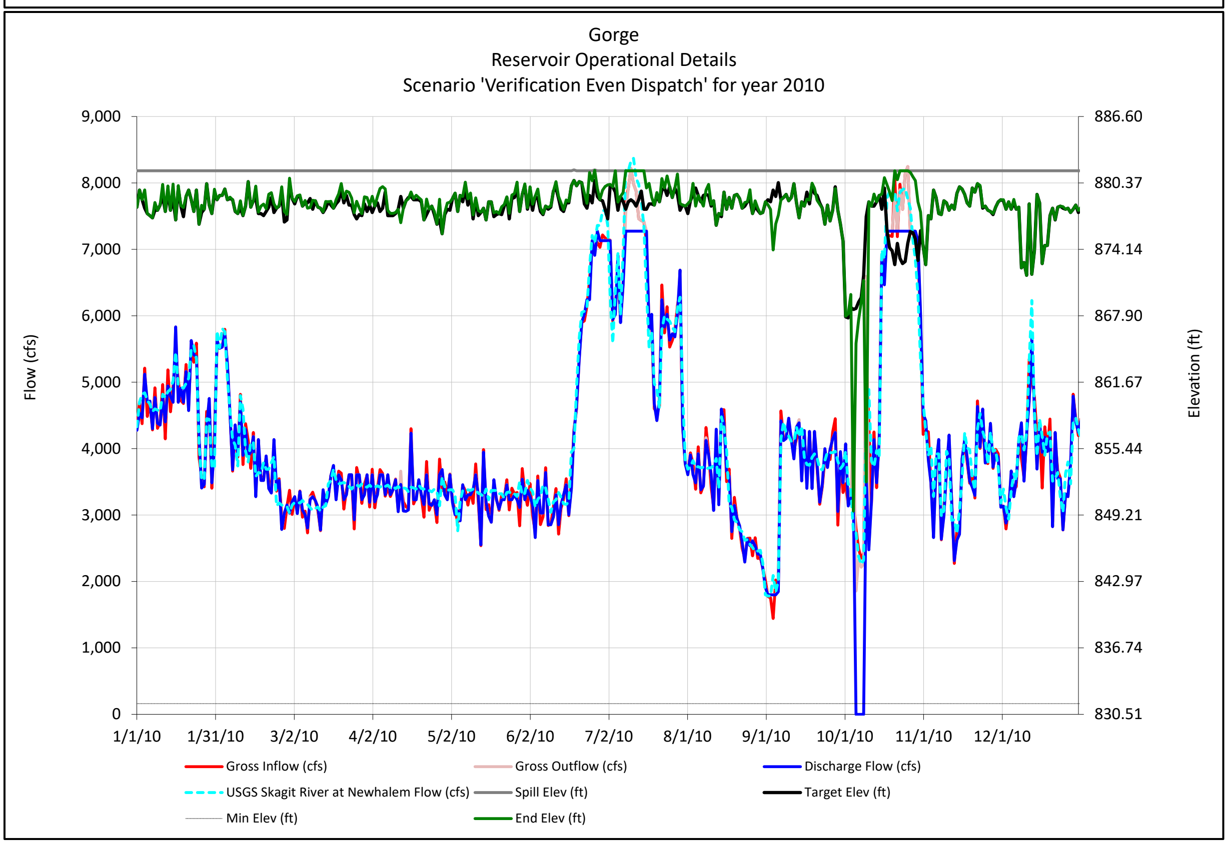

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2009
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.90
1596.18
1578.45
1560.73
1543.00
1525.28
1507.55
1489.83
1472.10
1/1/09
1/31/09
3/2/09
4/2/09
5/2/09
6/2/09
7/2/09
8/1/09
9/1/09
10/1/09
11/1/09
12/1/09
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

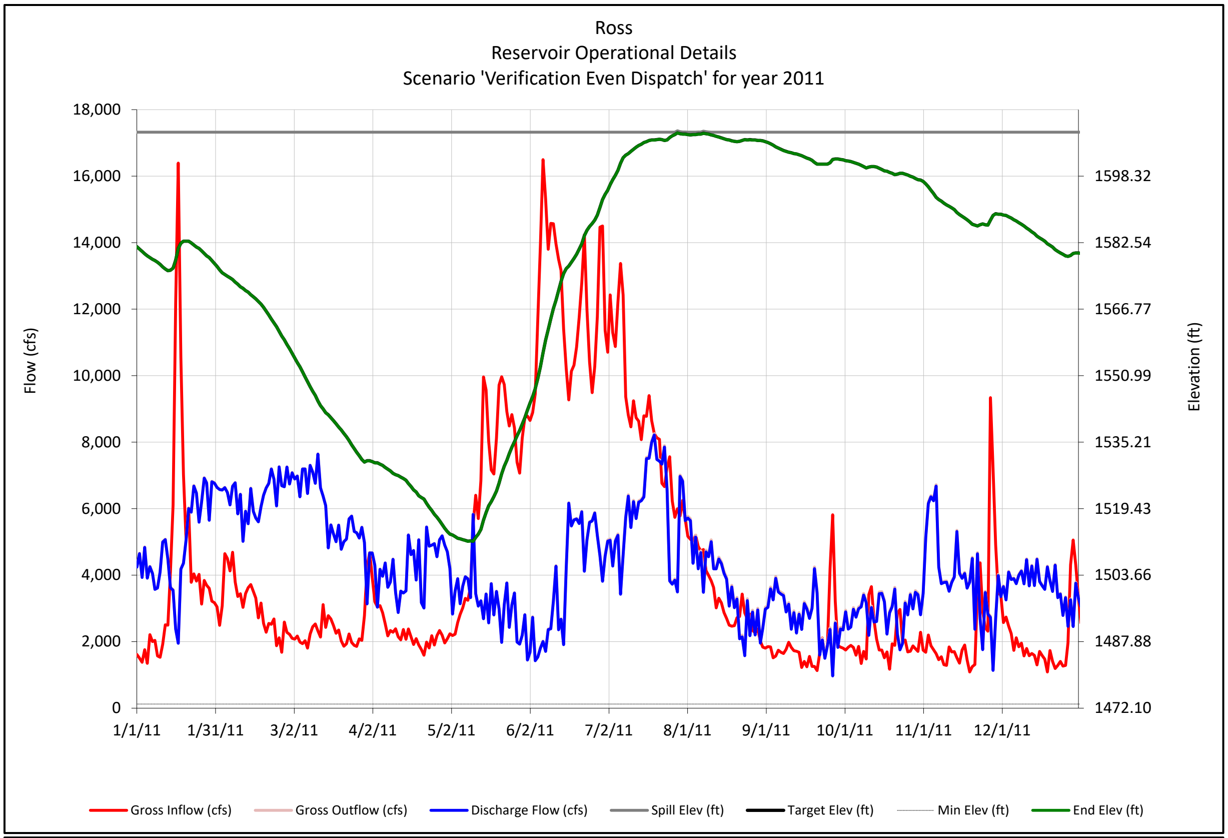

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2009
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1213.00
1211.28
1209.57
1207.85
1206.13
1204.42
1202.70
1/1/09
1/31/09
3/2/09
4/2/09
5/2/09
6/2/09
7/2/09
8/1/09
9/1/09
10/1/09
11/1/09
12/1/09
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

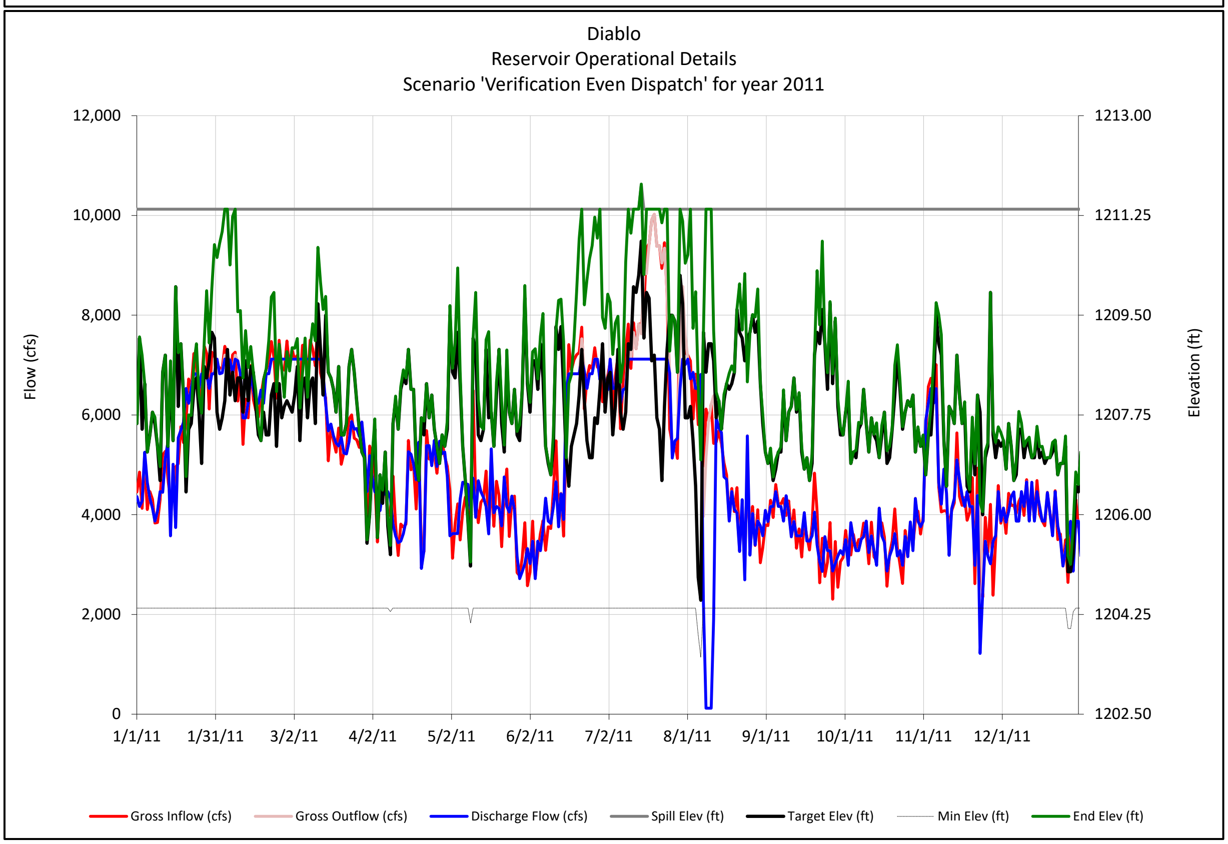

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2009
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
886.80
877.42
868.04
858.66
849.27
839.89
830.51
1/1/09
1/31/09
3/2/09
4/2/09
5/2/09
6/2/09
7/2/09
8/1/09
9/1/09
10/1/09
11/1/09
12/1/09
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

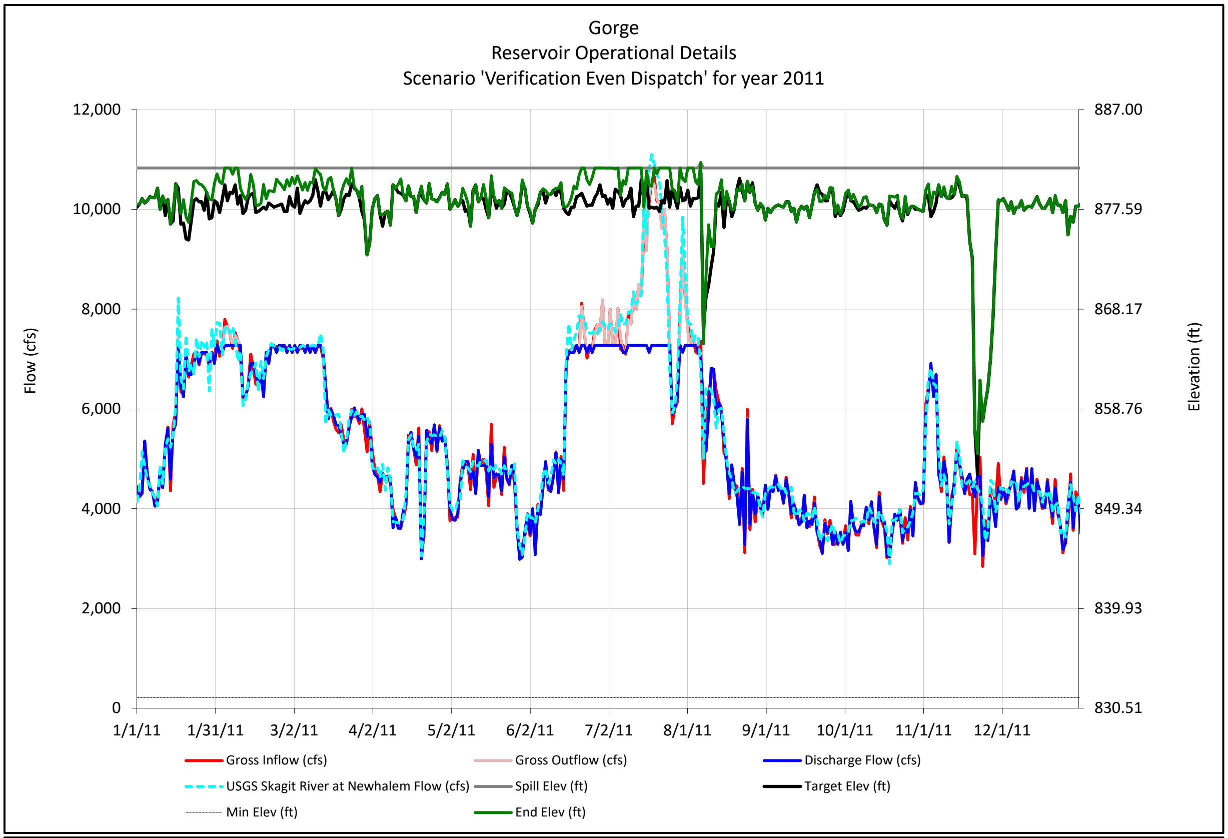

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2010
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1590.15
1566.54
1542.93
1519.32
1495.71
1472.10
1/1/10
1/31/10
3/2/10
4/2/10
5/2/10
6/2/10
7/2/10
8/1/10
9/1/10
10/1/10
11/1/10
12/1/10
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

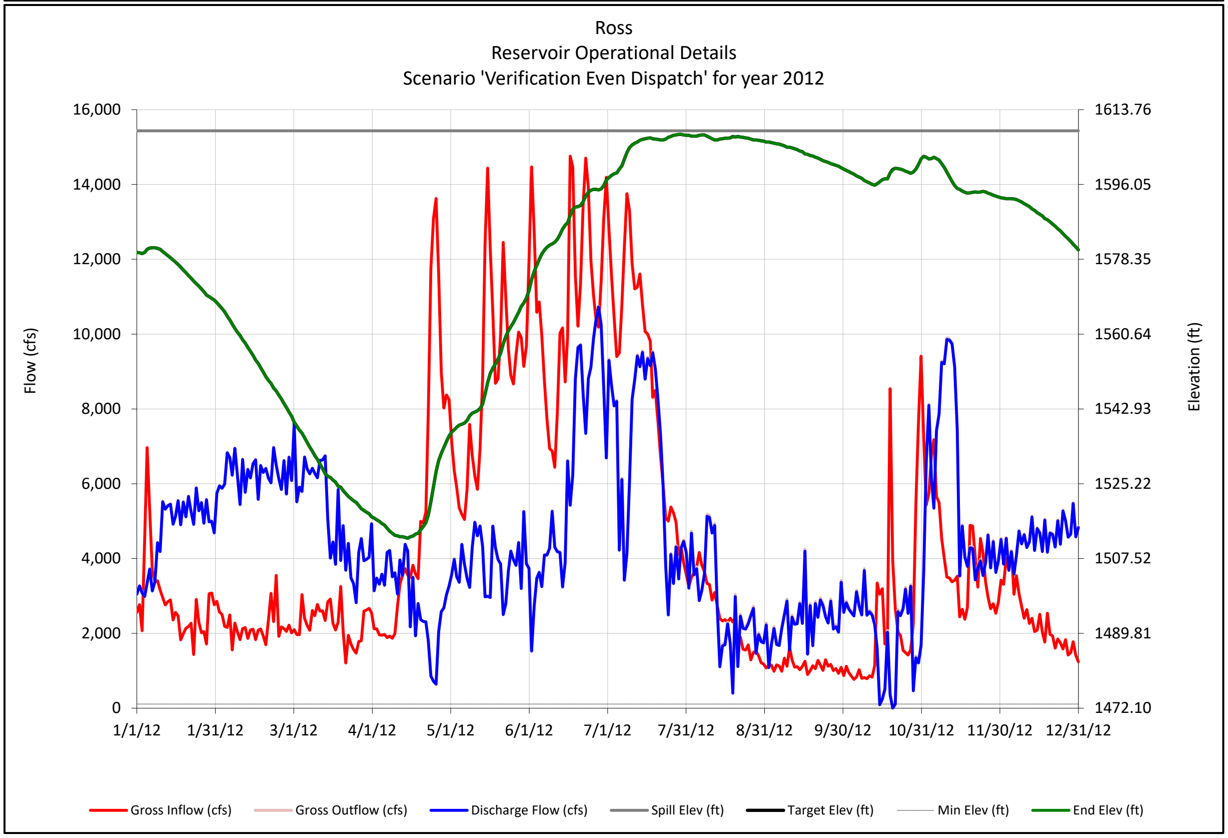

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2010
Flow (cfs)
Elevation (ft)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1213.00
1211.96
1210.92
1209.88
1208.84
1207.80
1206.76
1205.72
1204.68
1203.64
1202.60
1/1/10
1/31/10
3/2/10
4/2/10
5/2/10
6/2/10
7/2/10
8/1/10
9/1/10
10/1/10
11/1/10
12/1/10
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

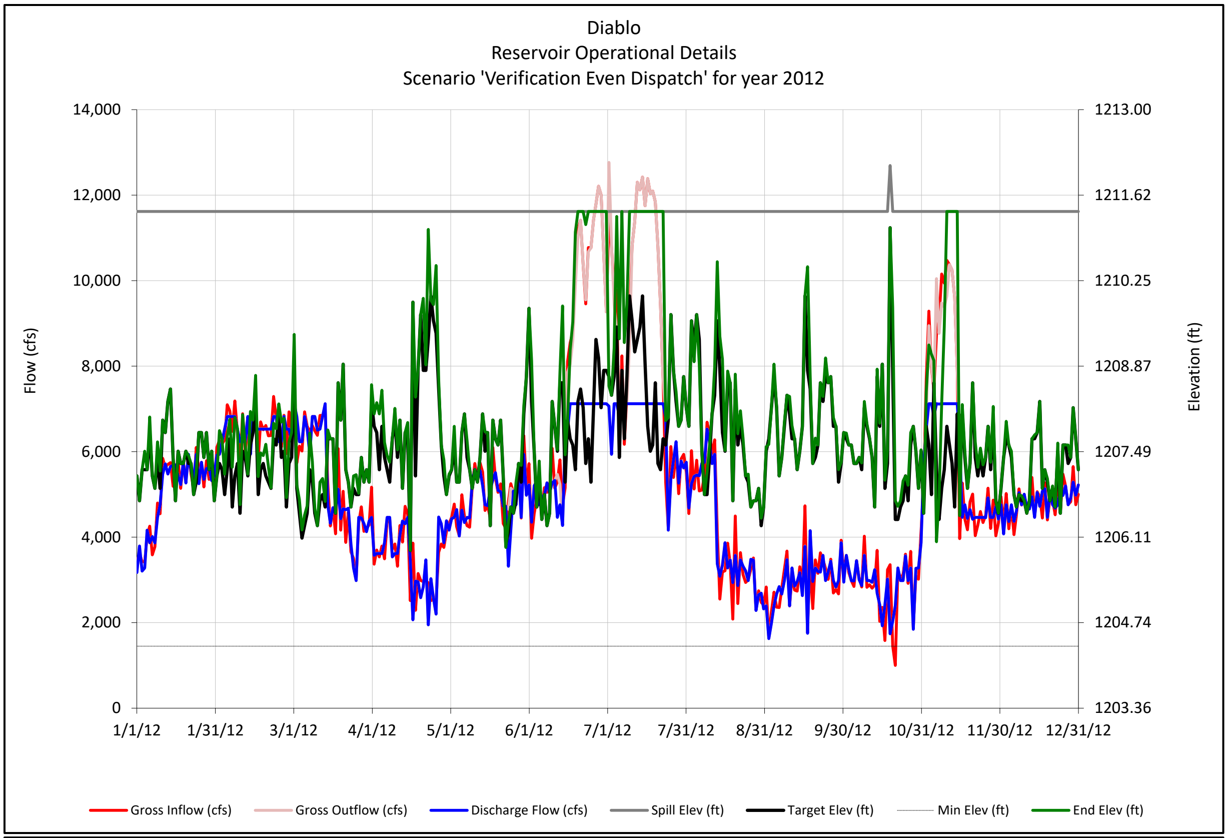

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2010
Flow (cfs)
Elevation (ft)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
886.60
880.37
874.14
867.90
861.67
855.44
849.21
842.97
836.74
830.51
1/1/10
1/31/10
3/2/10
4/2/10
5/2/10
6/2/10
7/2/10
8/1/10
9/1/10
10/1/10
11/1/10
12/1/10
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

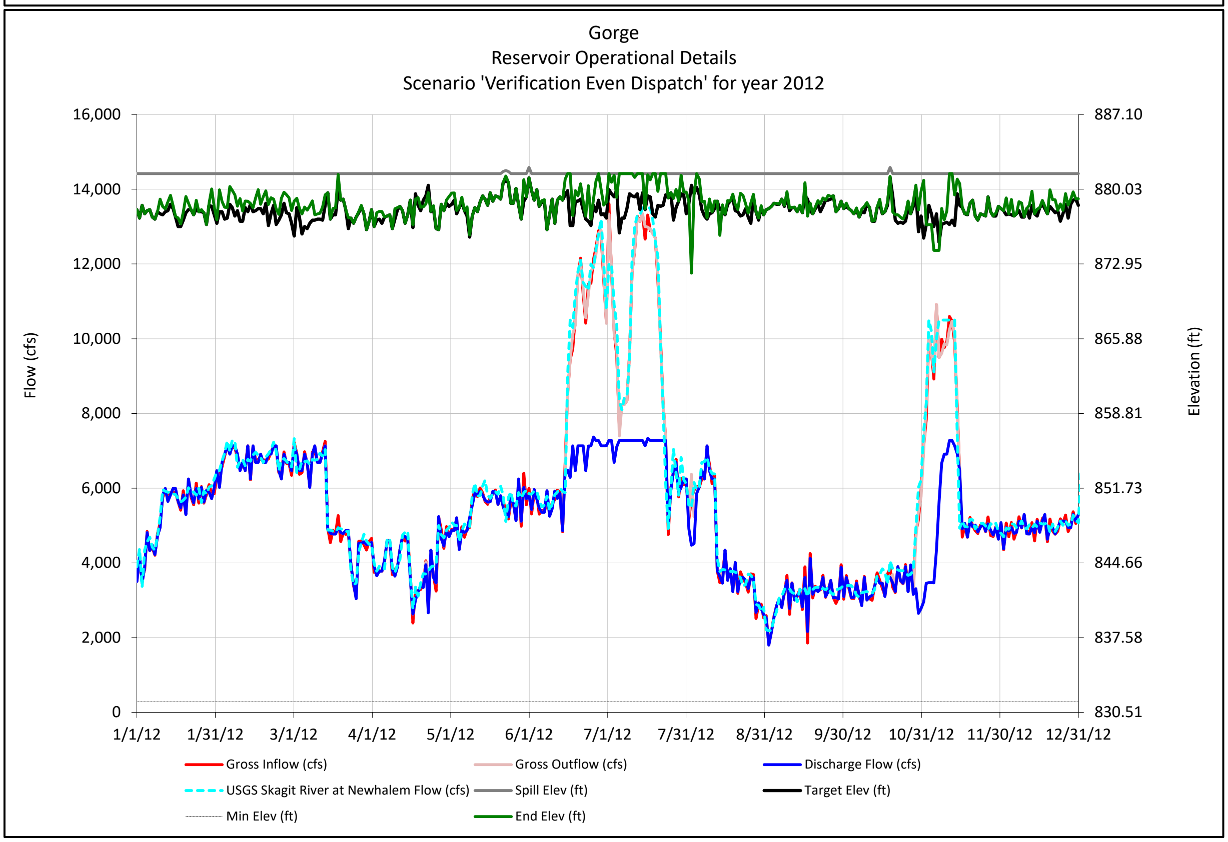

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2011
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1598.32
1582.54
1566.77
1550.99
1535.21
1519.43
1503.66
1487.88
1472.10
1/1/11
1/31/11
3/2/11
4/2/11
5/2/11
6/2/11
7/2/11
8/1/11
9/1/11
10/1/11
11/1/11
12/1/11
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

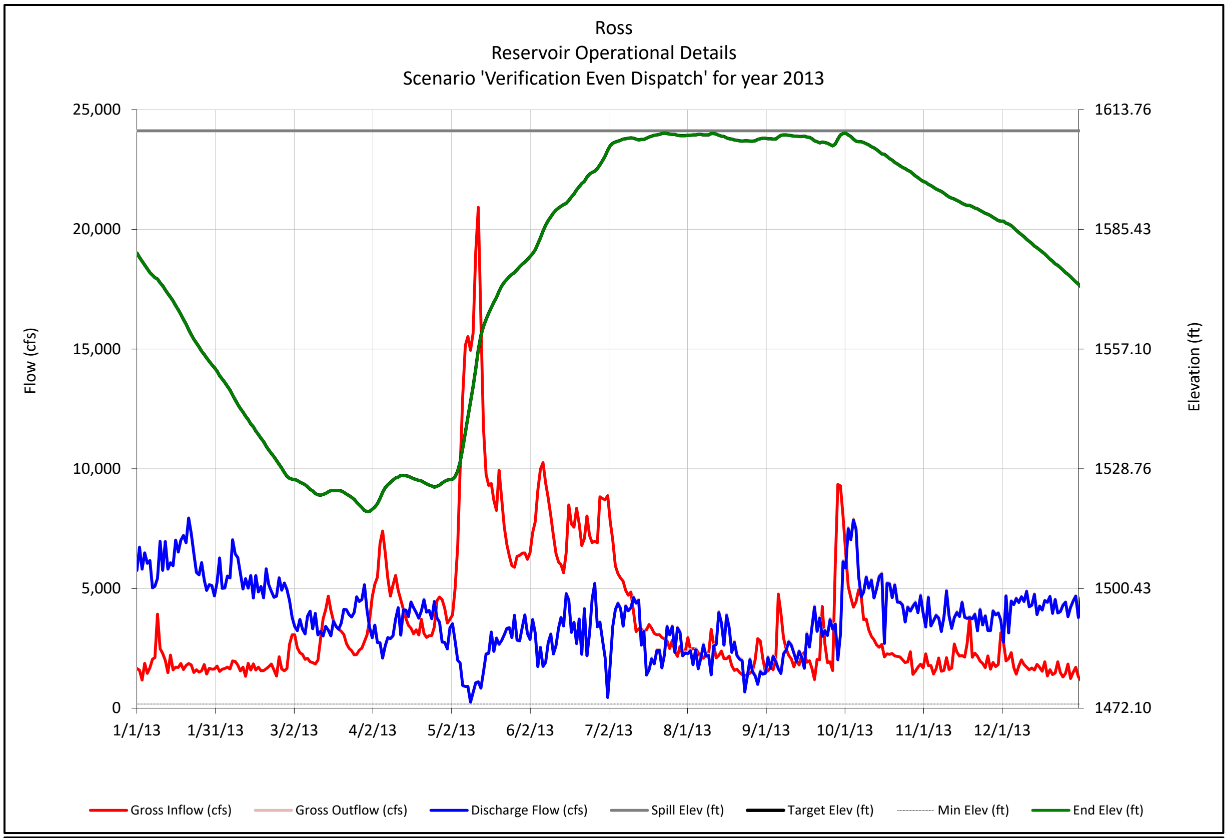

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2011
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1213.00
1211.25
1209.50
1207.75
1206.00
1204.25
1202.50
1/1/11
1/31/11
3/2/11
4/2/11
5/2/11
6/2/11
7/2/11
8/1/11
9/1/11
10/1/11
11/1/11
12/1/11
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

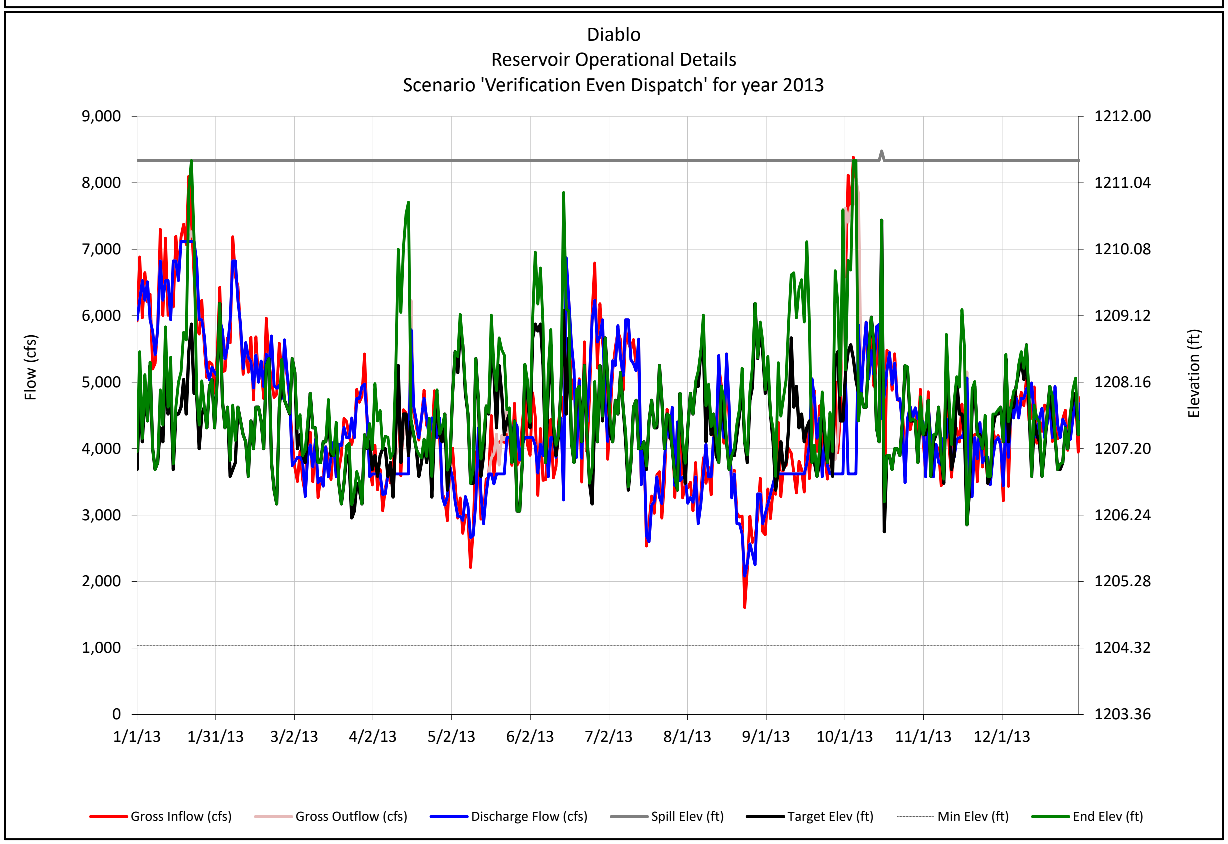

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2011
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
887.00
877.59
868.17
858.76
849.34
839.93
830.51
1/1/11
1/31/11
3/2/11
4/2/11
5/2/11
6/2/11
7/2/11
8/1/11
9/1/11
10/1/11
11/1/11
12/1/11
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

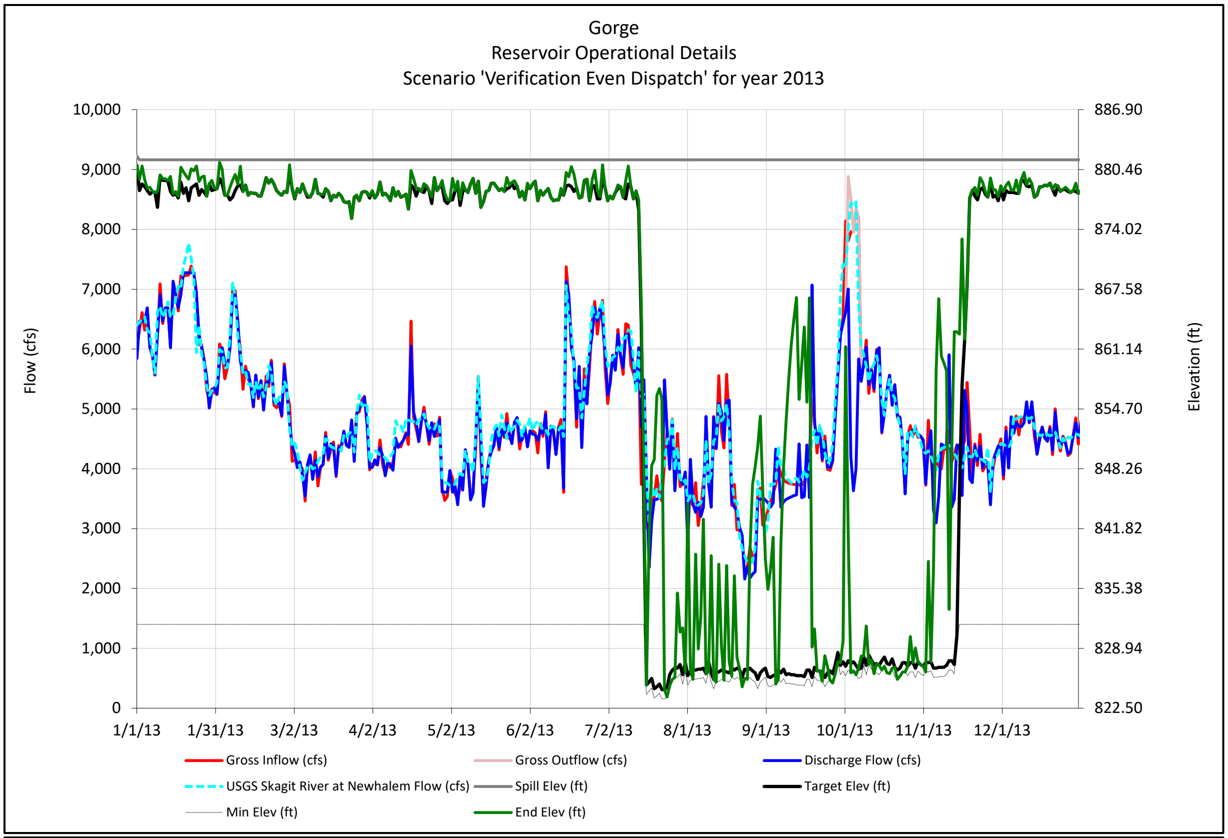

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2012
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1596.05
1578.35
1560.64
1542.93
1525.22
1507.52
1489.81
1472.10
1/1/12
1/31/12
3/1/12
4/1/12
5/1/12
6/1/12
7/1/12
7/31/12
8/31/12
9/30/12
10/31/12
11/30/12
12/31/12
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

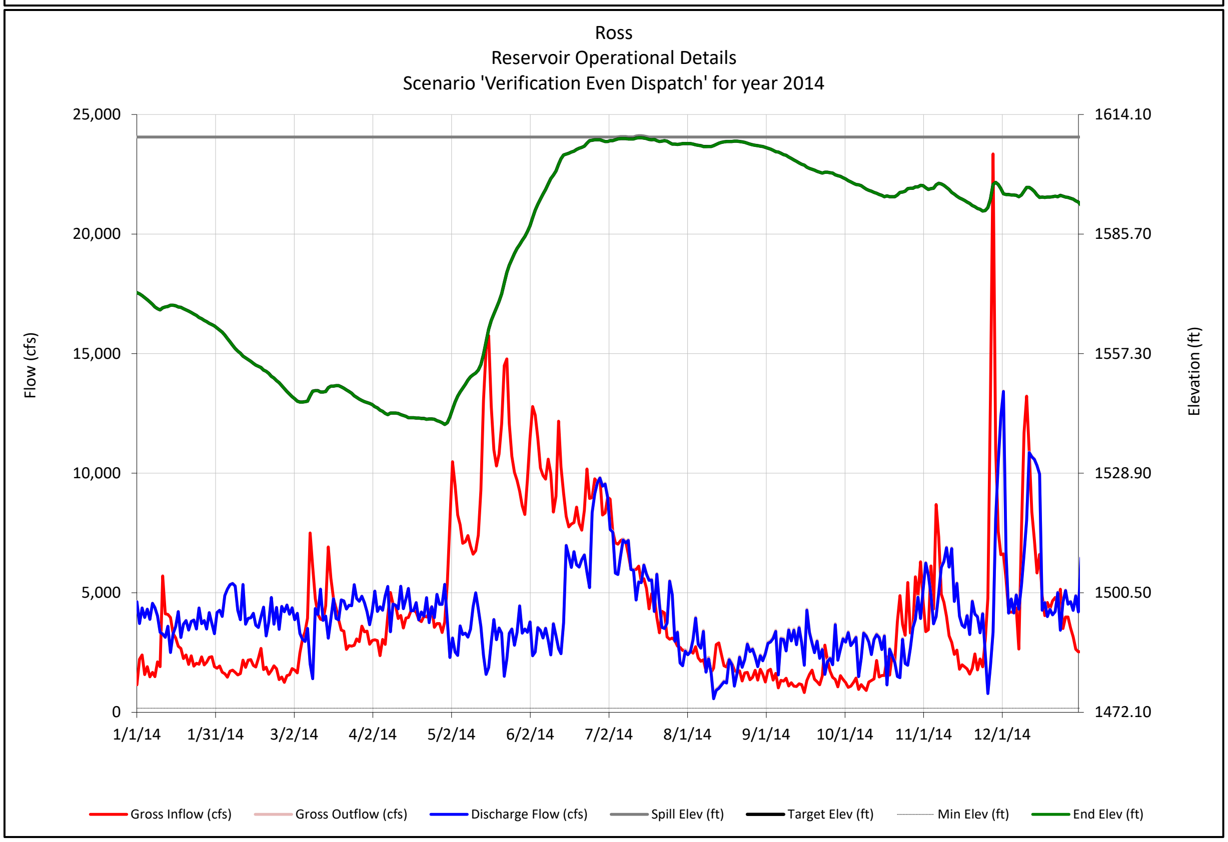

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2012
Flow (cfs)
Elevation (ft)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1213.00
1211.62
1210.25
1208.87
1207.49
1206.11
1204.74
1203.36
1/1/12
1/31/12
3/1/12
4/1/12
5/1/12
6/1/12
7/1/12
7/31/12
8/31/12
9/30/12
10/31/12
11/30/12
12/31/12
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

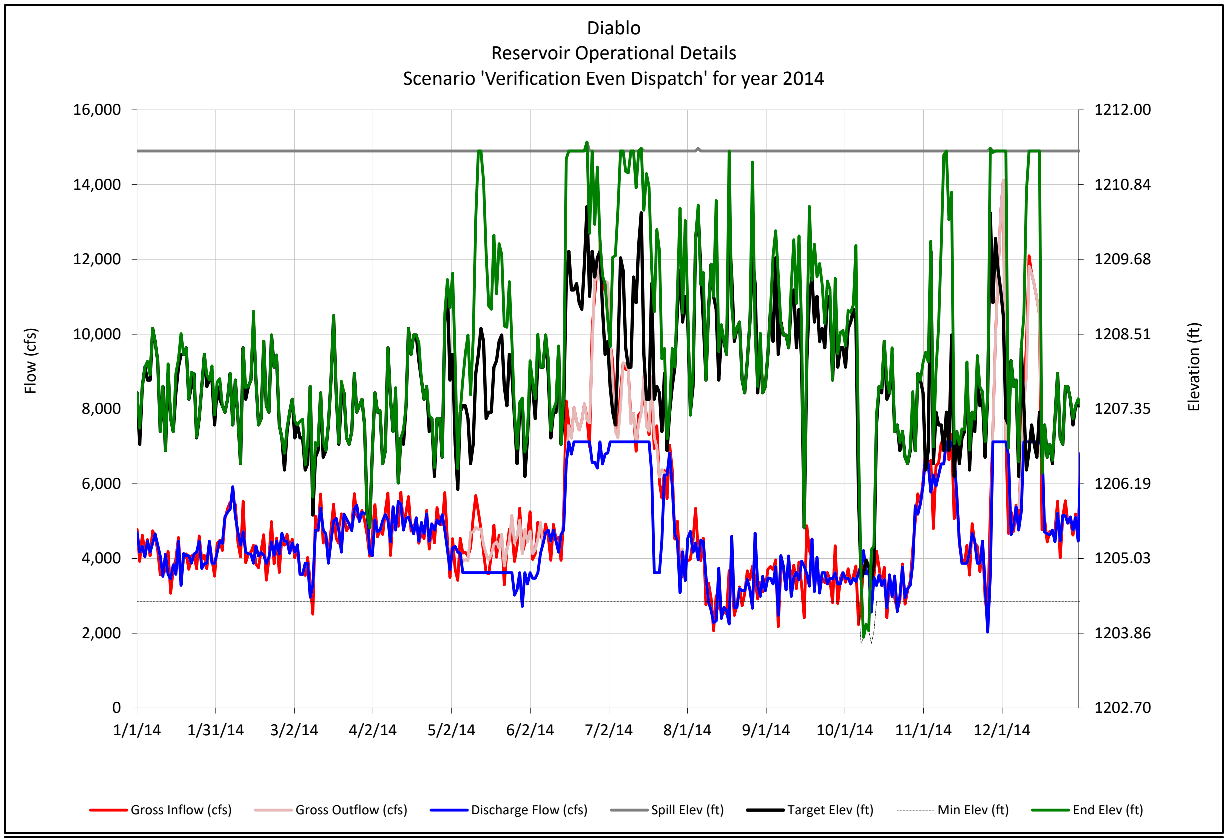

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2012
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
887.10
880.03
872.95
865.88
858.81
851.73
844.66
837.58
830.51
1/1/12
1/31/12
3/1/12
4/1/12
5/1/12
6/1/12
7/1/12
7/31/12
8/31/12
9/30/12
10/31/12
11/30/12
12/31/12
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

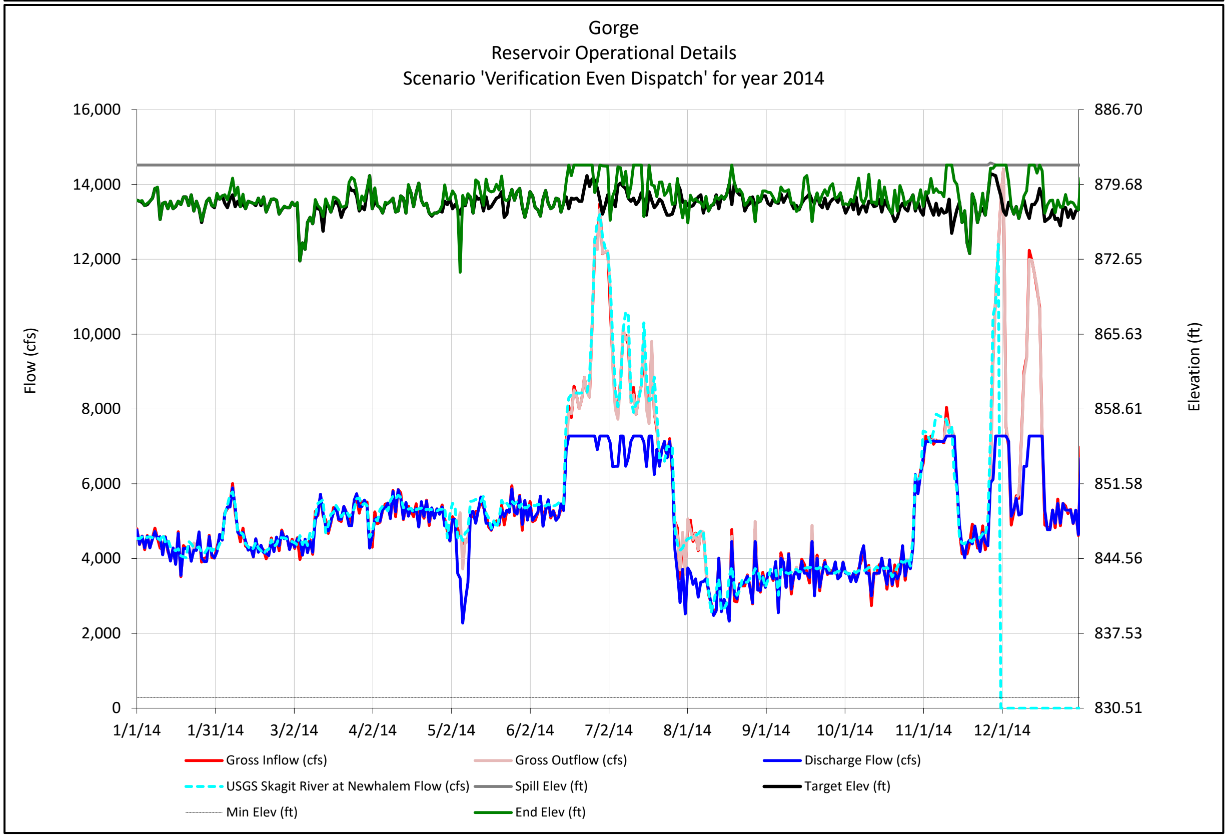

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2013
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
1613.76
1585.43
1557.10
1528.76
1500.43
1472.10
1/1/13
1/31/13
3/2/13
4/2/13
5/2/13
6/2/13
7/2/13
8/1/13
9/1/13
10/1/13
11/1/13
12/1/13
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

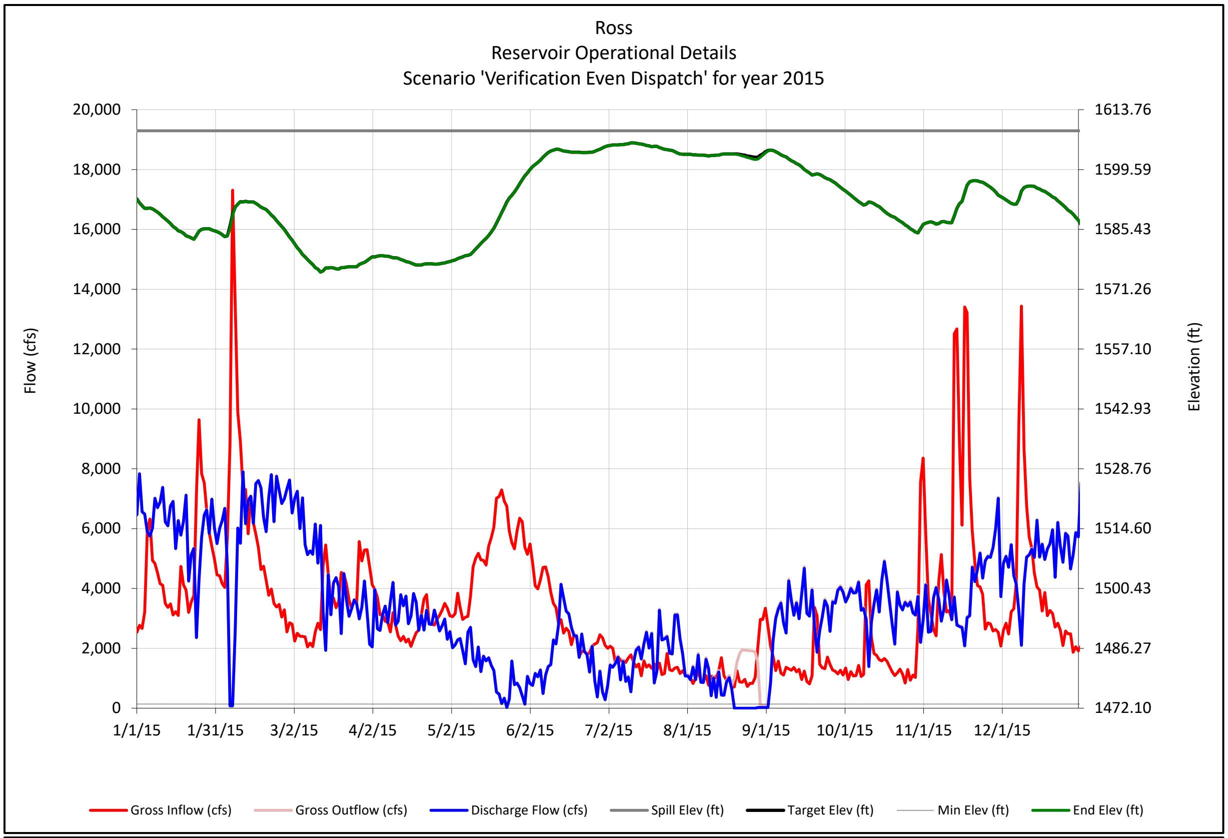

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2013
Flow (cfs)
Elevation (ft)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1212.00
1211.04
1210.08
1209.12
1208.16
1207.20
1206.24
1205.28
1204.32
1203.36
1/1/13
1/31/13
3/2/13
4/2/13
5/2/13
6/2/13
7/2/13
8/1/13
9/1/13
10/1/13
11/1/13
12/1/13
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

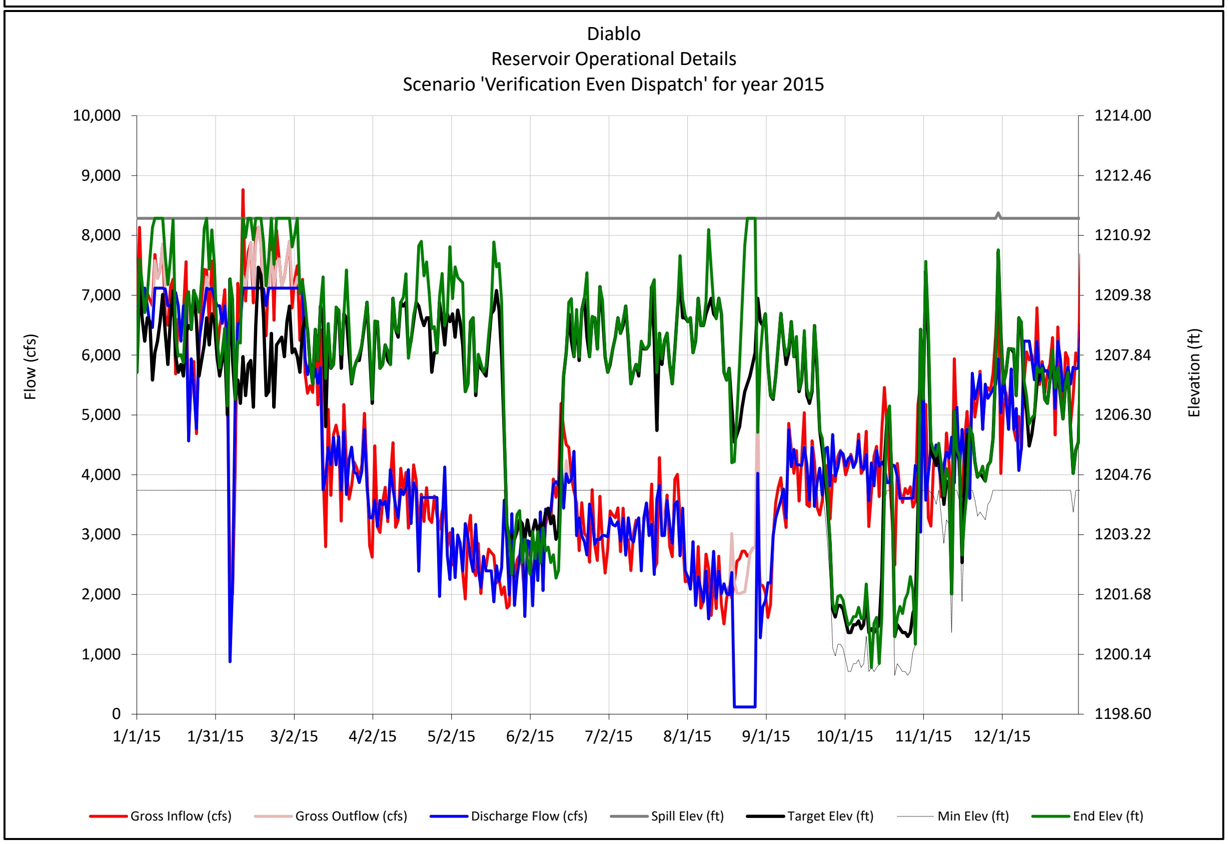

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2013
Flow (cfs)
Elevation (ft)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
886.90
880.46
874.02
867.58
861.14
854.70
848.26
841.82
835.38
828.94
822.50
1/1/13
1/31/13
3/2/13
4/2/13
5/2/13
6/2/13
7/2/13
8/1/13
9/1/13
10/1/13
11/1/13
12/1/13
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

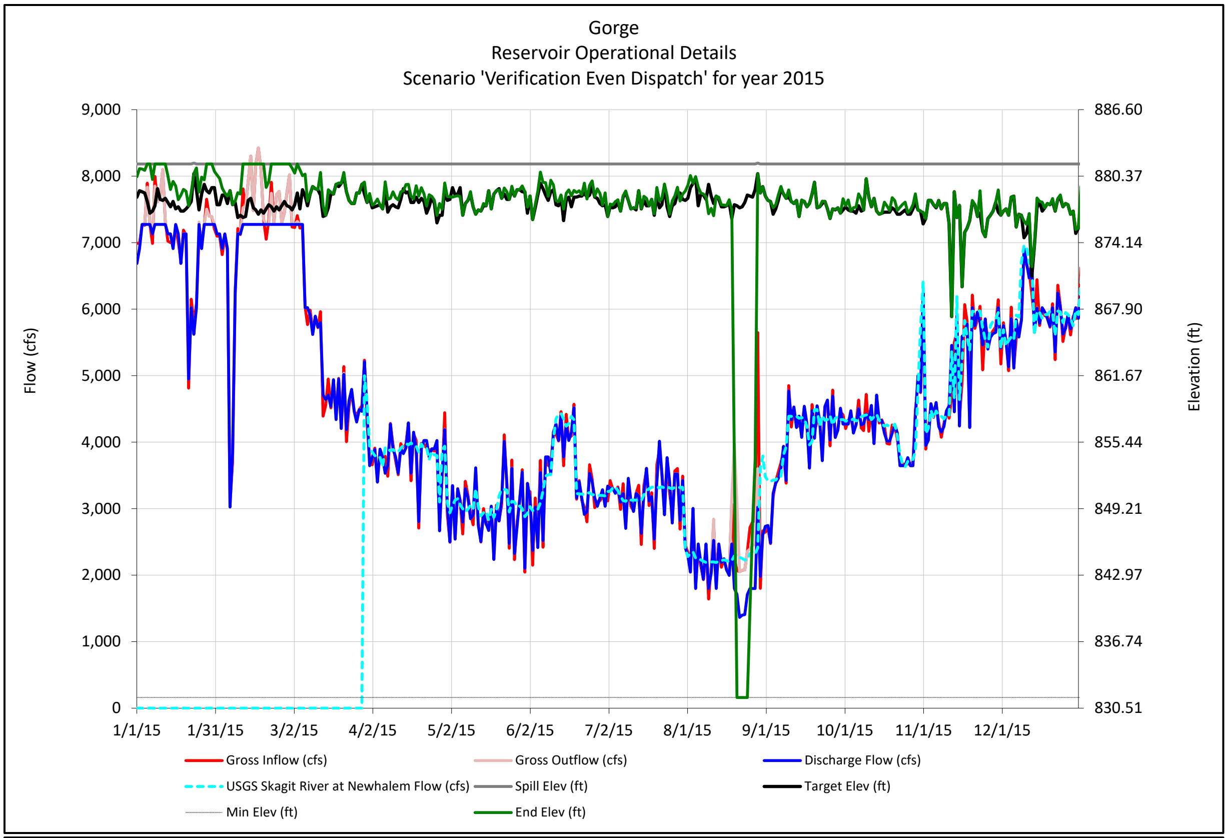

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2014
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
1614.10
1585.70
1557.30
1528.90
1500.50
1472.10
1/1/14
1/31/14
3/2/14
4/2/14
5/2/14
6/2/14
7/2/14
8/1/14
9/1/14
10/1/14
11/1/14
12/1/14
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

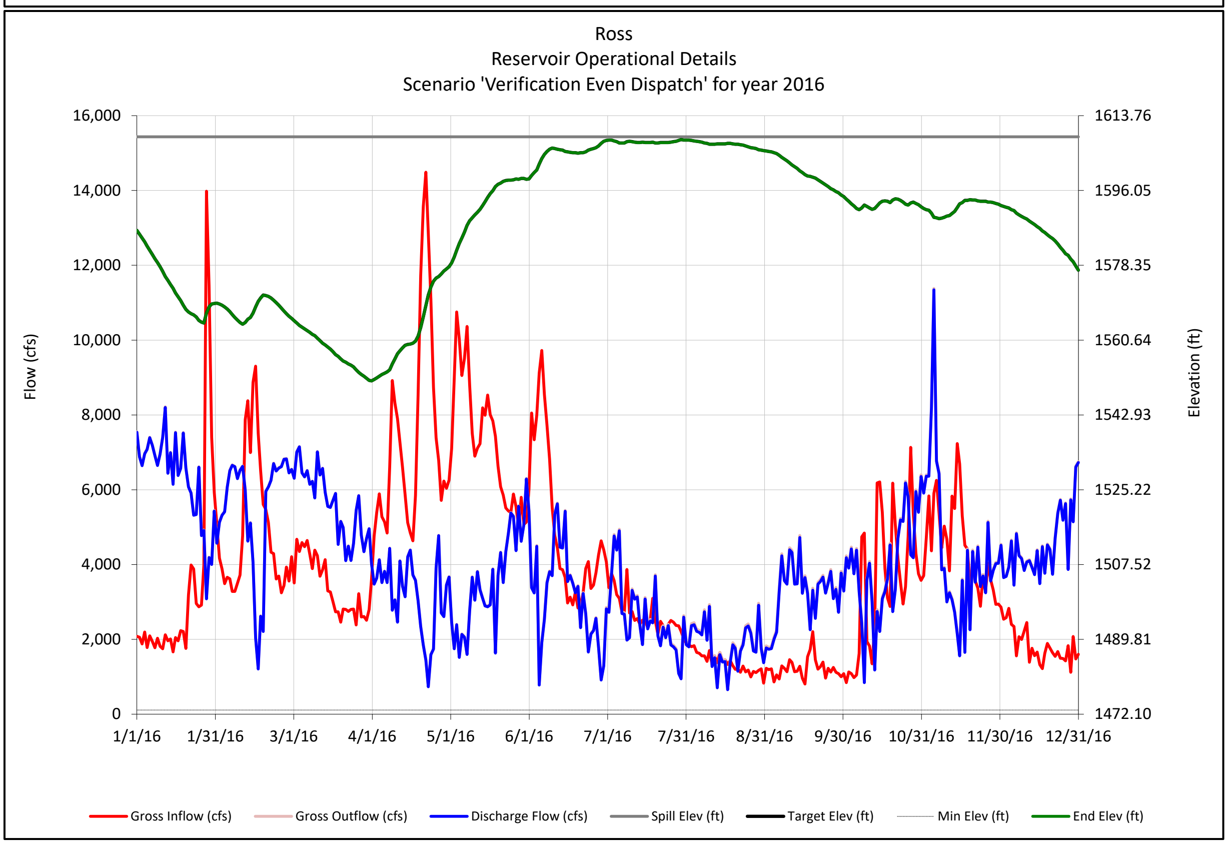

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2014
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1212.00
1210.84
1209.68
1208.51
1207.35
1206.19
1205.03
1203.86
1202.70
1/1/14
1/31/14
3/2/14
4/2/14
5/2/14
6/2/14
7/2/14
8/1/14
9/1/14
10/1/14
11/1/14
12/1/14
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2014
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
886.70
879.68
872.65
865.63
858.61
851.58
844.56
837.53
830.51
1/1/14
1/31/14
3/2/14
4/2/14
5/2/14
6/2/14
7/2/14
8/1/14
9/1/14
10/1/14
11/1/14
12/1/14
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2015
Flow (cfs)
Elevation (ft)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1599.59
1585.43
1571.26
1557.10
1542.93
1528.76
1514.60
1500.43
1486.27
1472.10
1/1/15
1/31/15
3/2/15
4/2/15
5/2/15
6/2/15
7/2/15
8/1/15
9/1/15
10/1/15
11/1/15
12/1/15
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2015
Flow (cfs)
Elevation (ft)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1214.00
1212.46
1210.92
1209.38
1207.84
1206.30
1204.76
1203.22
1201.68
1200.14
1198.60
1/1/15
1/31/15
3/2/15
4/2/15
5/2/15
6/2/15
7/2/15
8/1/15
9/1/15
10/1/15
11/1/15
12/1/15
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2015
Flow (cfs)
Elevation (ft)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
886.60
880.37
874.14
867.90
861.67
855.44
849.21
842.97
836.74
830.51
1/1/15
1/31/15
3/2/15
4/2/15
5/2/15
6/2/15
7/2/15
8/1/15
9/1/15
10/1/15
11/1/15
12/1/15
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2016
Flow (cfs)
Elevation (ft)
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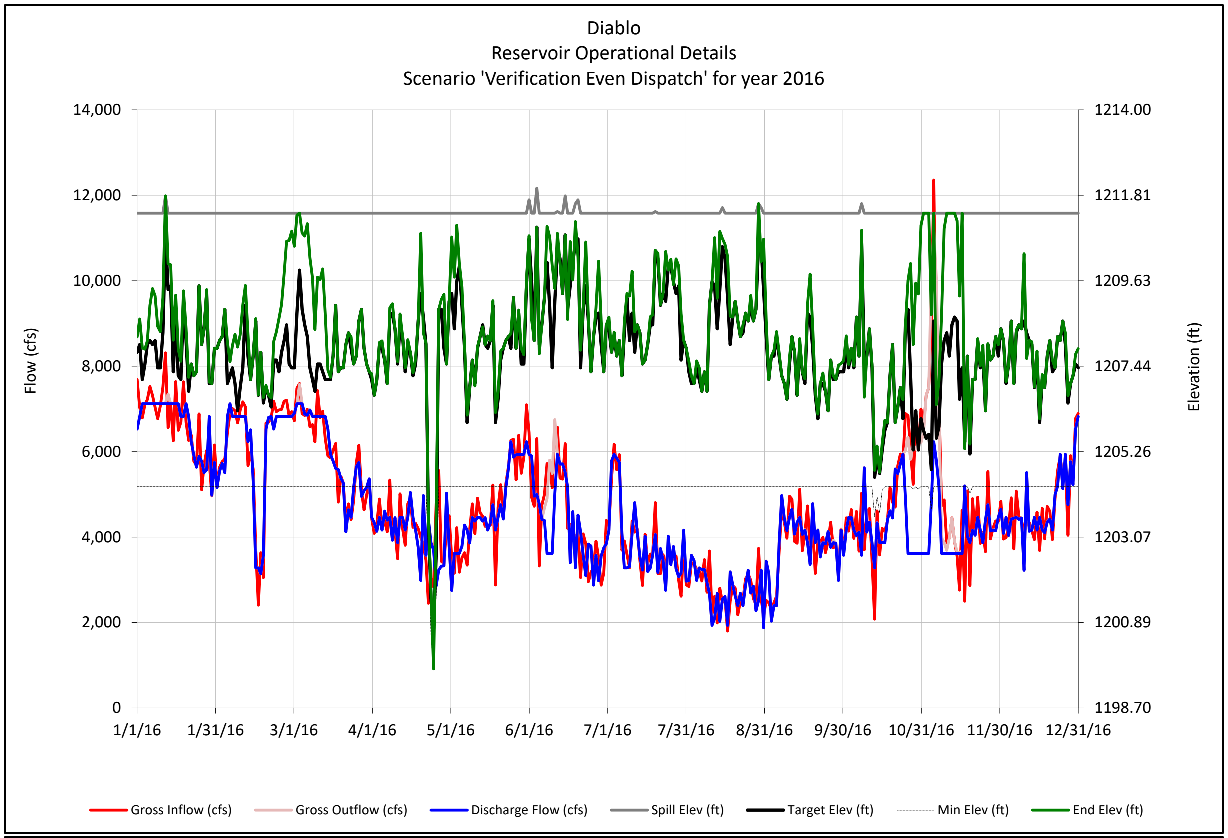
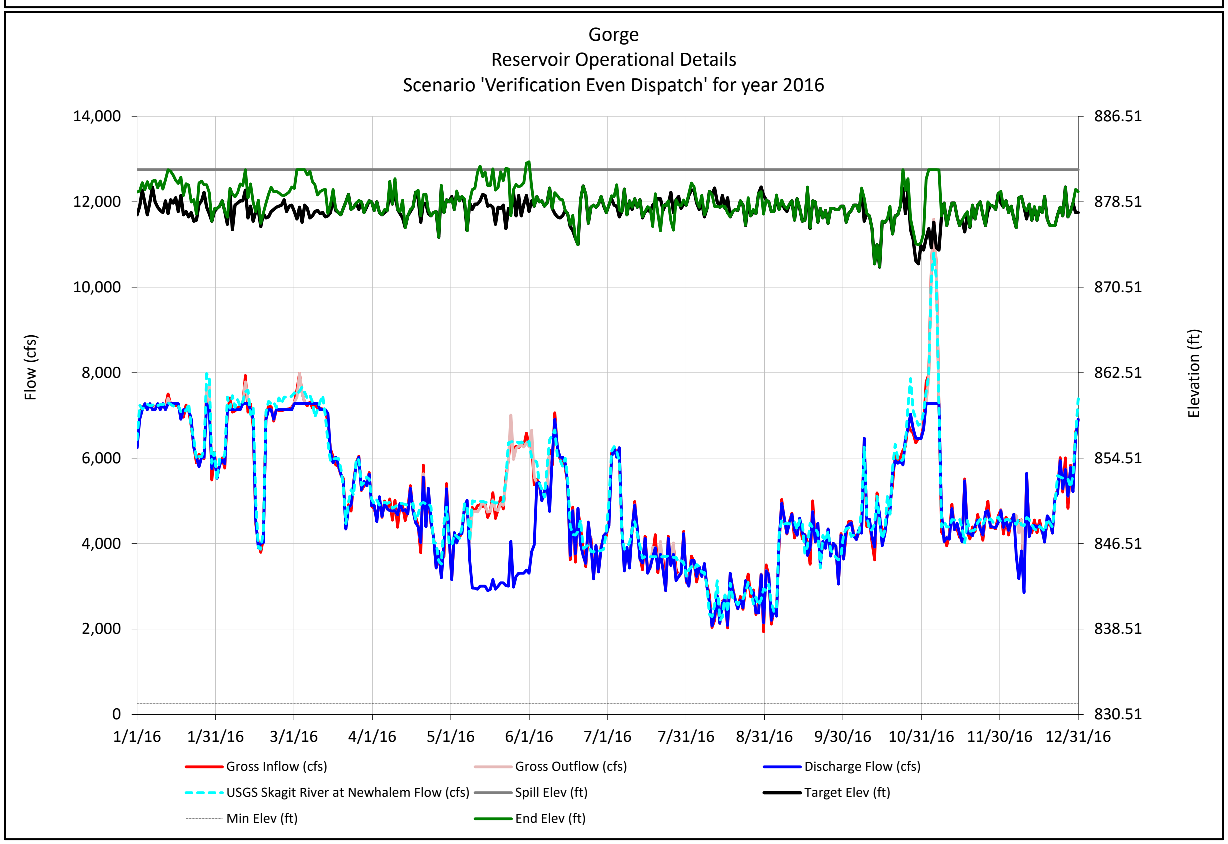
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1596.05
1578.35
1560.64
1542.93
1525.22
1507.52
1489.81
1472.10
1/1/16
1/31/16
3/1/16
4/1/16
5/1/16
6/1/16
7/1/16
7/31/16
8/31/16
9/30/16
10/31/16
11/30/16
12/31/16
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2016
Flow (cfs)
Elevation (ft)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1214.00
1211.81
1209.63
1207.44
1205.26
1203.07
1200.89
1198.70
1/1/16
1/31/16
3/1/16
4/1/16
5/1/16
6/1/16
7/1/16
7/31/16
8/31/16
9/30/16
10/31/16
11/30/16
12/31/16
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2016
Flow (cfs)
Elevation (ft)
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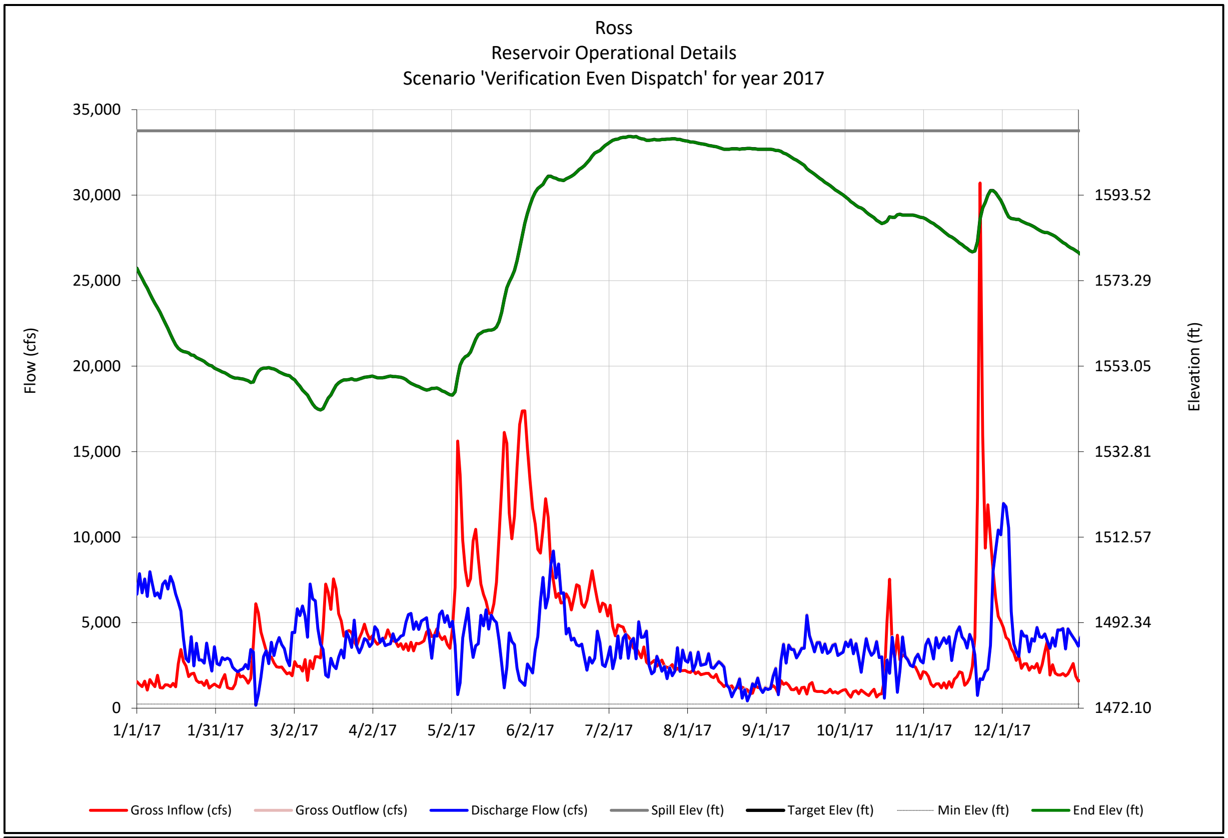
10,000
8,000
6,000
4,000
2,000
0
886.51
878.51
870.51
862.51
854.51
846.51
838.51
830.51
1/1/16
1/31/16
3/1/16
4/1/16
5/1/16
6/1/16
7/1/16
7/31/16
8/31/16
9/30/16
10/31/16
11/30/16
12/31/16
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2017
Flow (cfs)
Elevation (ft)
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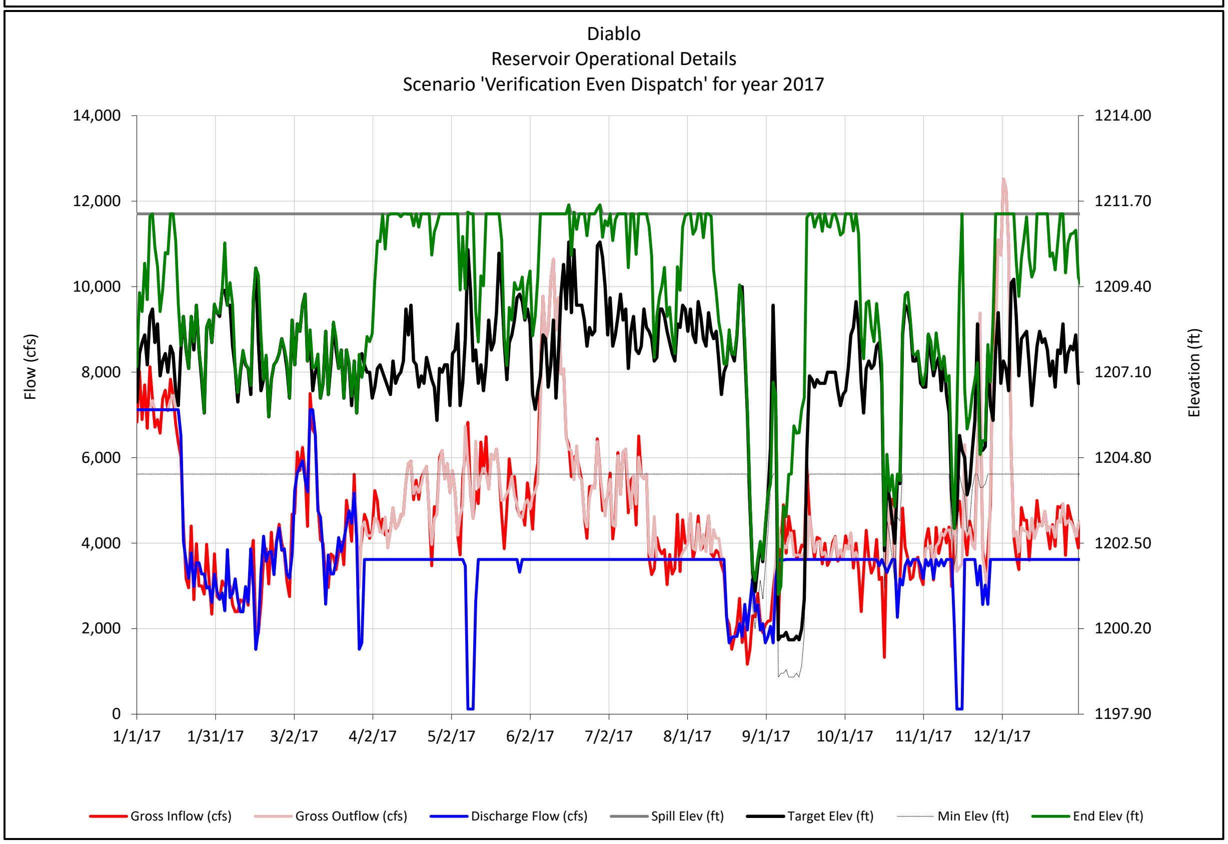
25,000
20,000
15,000
10,000
5,000
0
1593.52
1573.29
1553.05
1532.81
1512.57
1492.34
1472.10
1/1/17
1/31/17
3/2/17
4/2/17
5/2/17
6/2/17
7/2/17
8/1/17
9/1/17
10/1/17
11/1/17
12/1/17
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2017
Flow (cfs)
Elevation (ft)
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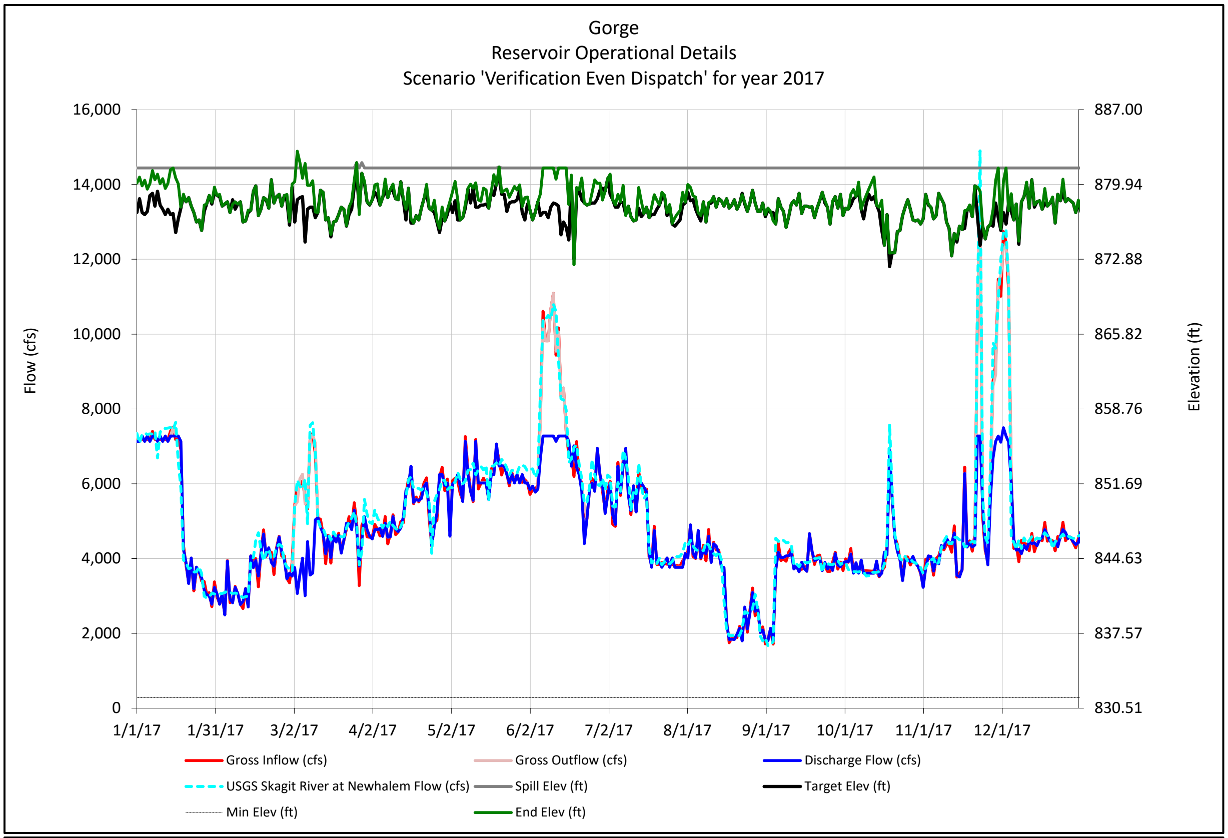
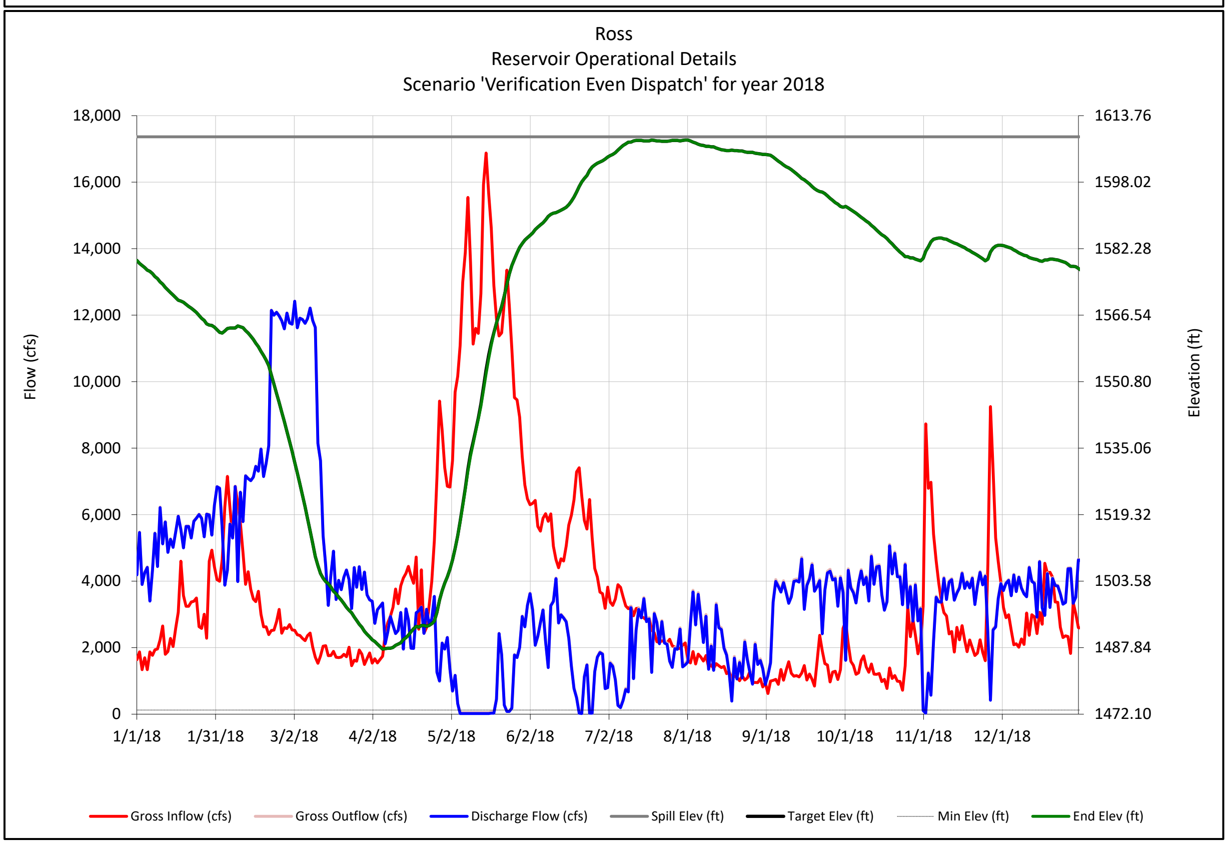
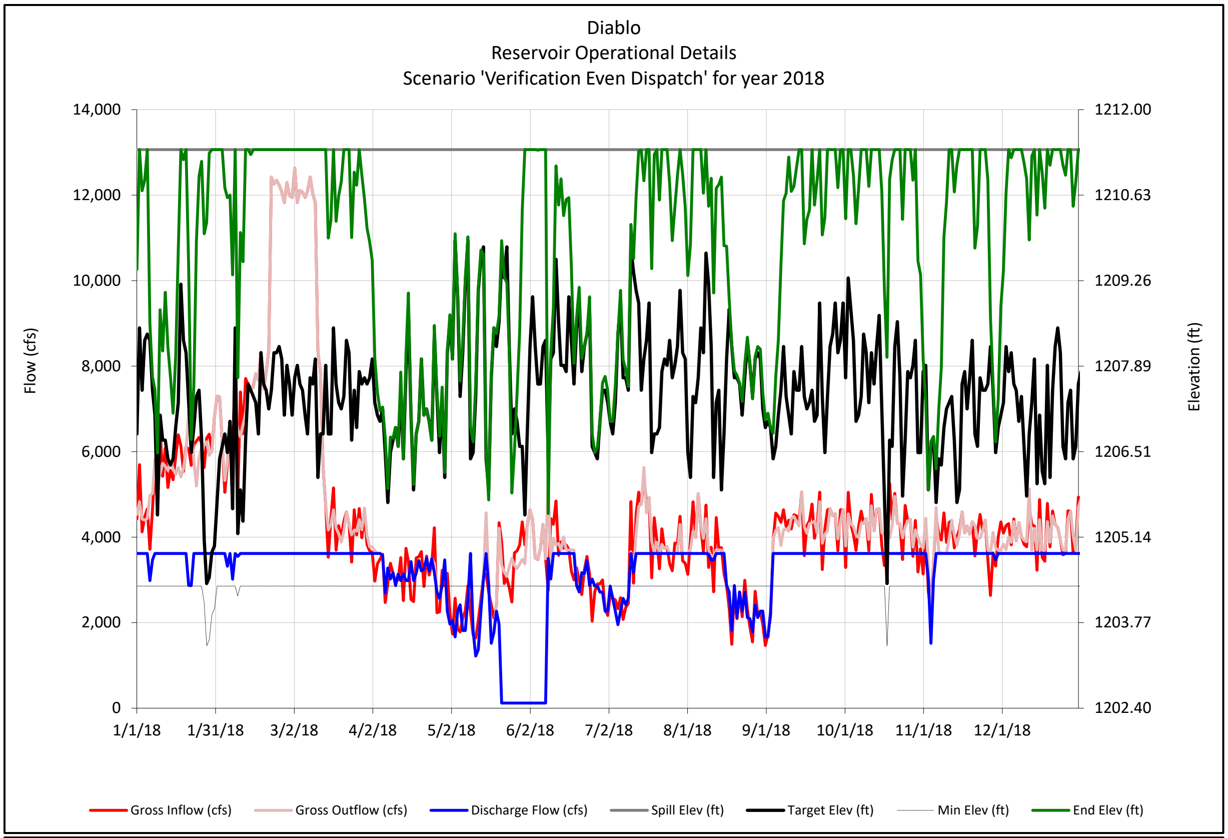
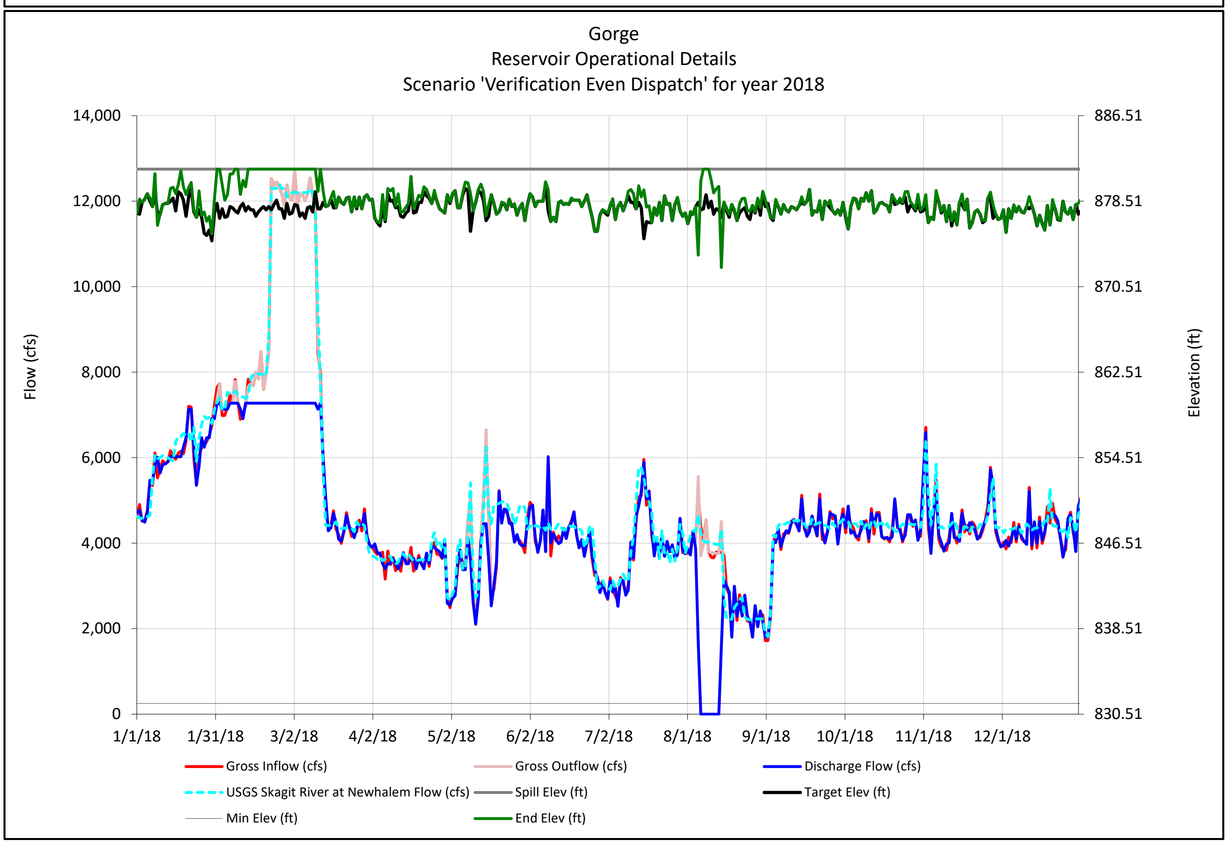
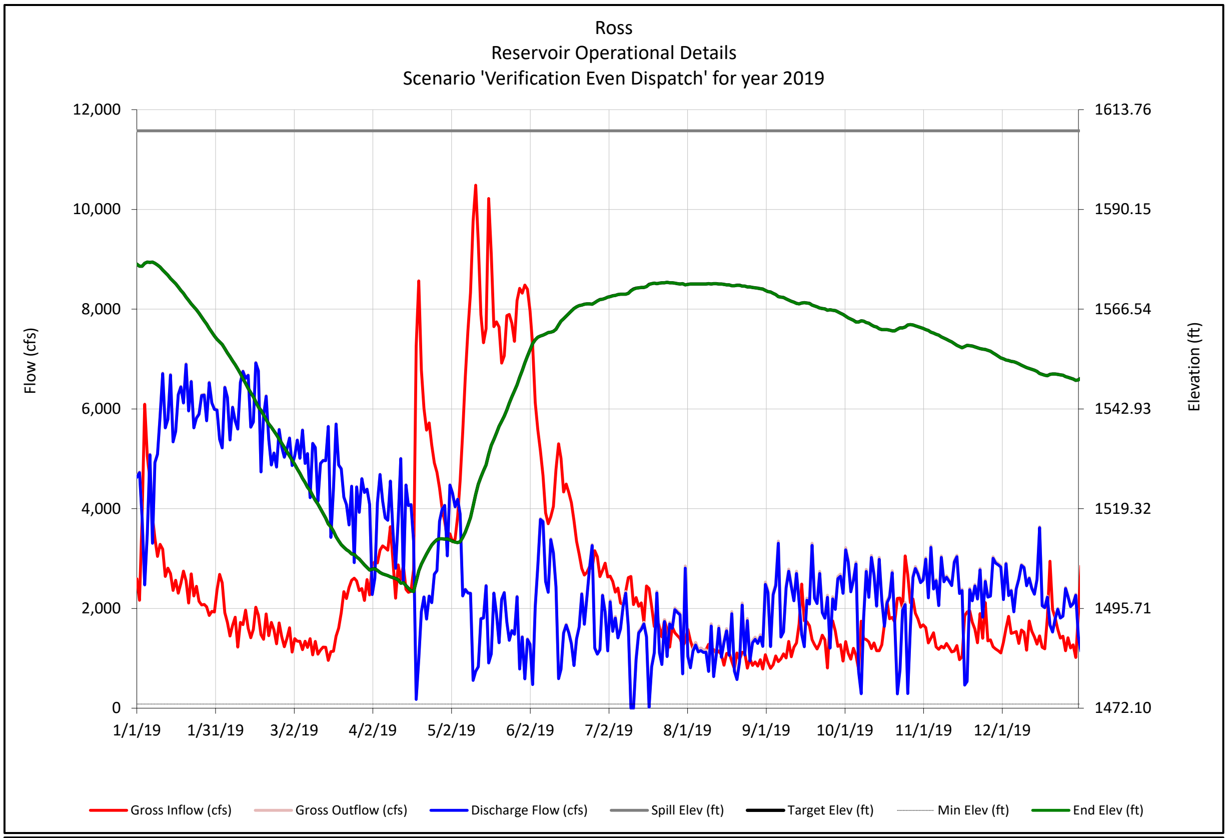
12,000
10,000
8,000
6,000
4,000
2,000
0
1214.00
1211.70
1209.40
1207.10
1204.80
1202.50
1200.20
1197.90
1/1/17
1/31/17
3/2/17
4/2/17
5/2/17
6/2/17
7/2/17
8/1/17
9/1/17
10/1/17
11/1/17
12/1/17
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

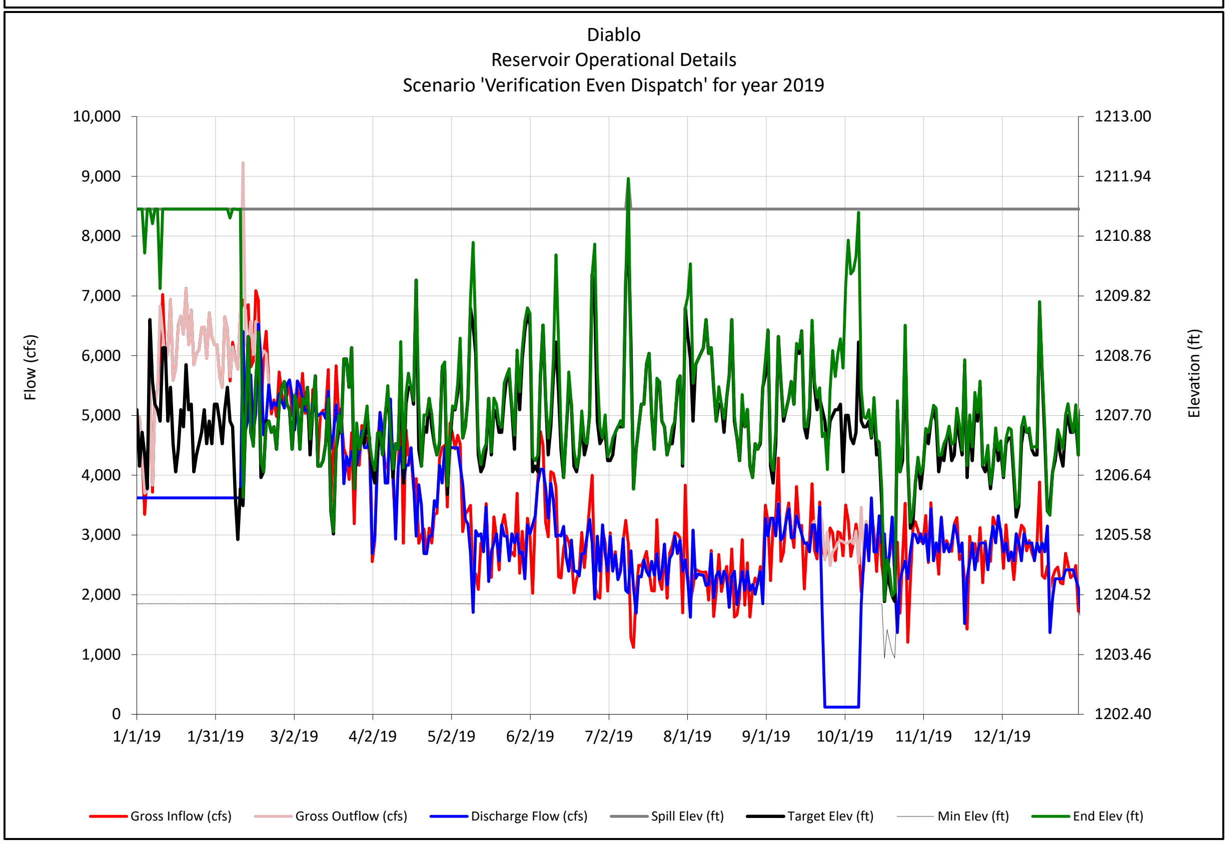

Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2017
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
887.00
879.94
872.88
865.82
858.76
851.69
844.63
837.57
830.51
1/1/17
1/31/17
3/2/17
4/2/17
5/2/17
6/2/17
7/2/17
8/1/17
9/1/17
10/1/17
11/1/17
12/1/17
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

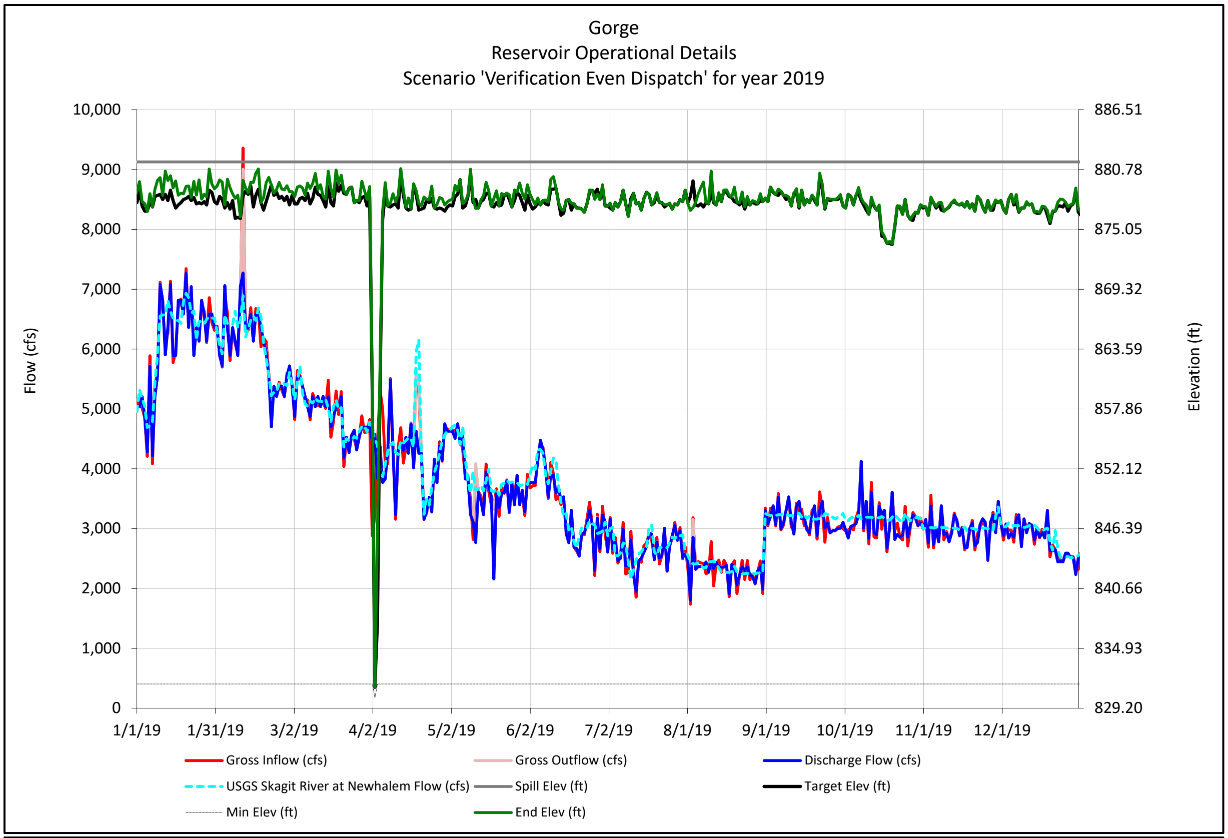

Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2018
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1598.02
1582.28
1566.54
1550.80
1535.06
1519.32
1503.58
1487.84
1472.10
1/1/18
1/31/18
3/2/18
4/2/18
5/2/18
6/2/18
7/2/18
8/1/18
9/1/18
10/1/18
11/1/18
12/1/18
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

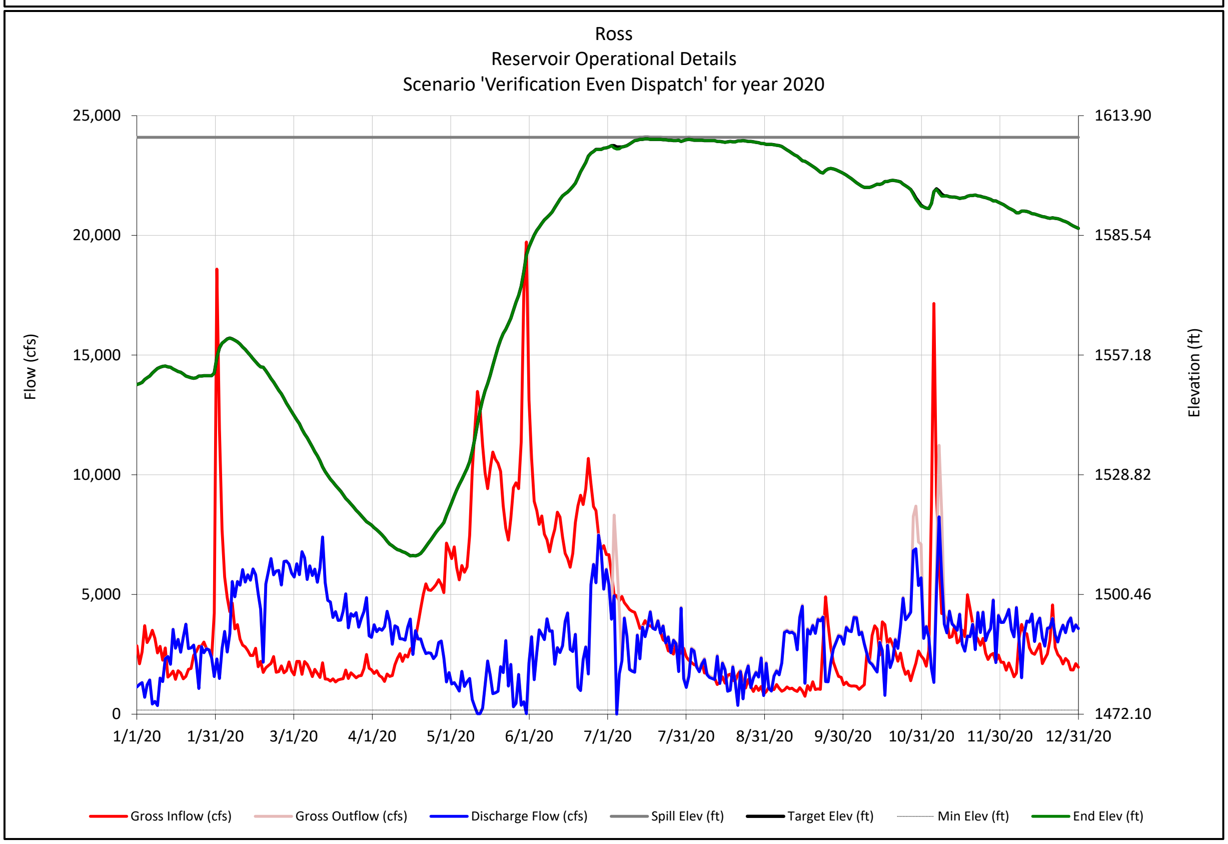

Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2018
Flow (cfs)
Elevation (ft)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1212.00
1210.63
1209.26
1207.89
1206.51
1205.14
1203.77
1202.40
1/1/18
1/31/18
3/2/18
4/2/18
5/2/18
6/2/18
7/2/18
8/1/18
9/1/18
10/1/18
11/1/18
12/1/18
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2018
Flow (cfs)
Elevation (ft)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
886.51
878.51
870.51
862.51
854.51
846.51
838.51
830.51
1/1/18
1/31/18
3/2/18
4/2/18
5/2/18
6/2/18
7/2/18
8/1/18
9/1/18
10/1/18
11/1/18
12/1/18
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2019
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1590.15
1566.54
1542.93
1519.32
1495.71
1472.10
1/1/19
1/31/19
3/2/19
4/2/19
5/2/19
6/2/19
7/2/19
8/1/19
9/1/19
10/1/19
11/1/19
12/1/19
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2019
Flow (cfs)
Elevation (ft)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1213.00
1211.94
1210.88
1209.82
1208.76
1207.70
1206.64
1205.58
1204.52
1203.46
1202.40
1/1/19
1/31/19
3/2/19
4/2/19
5/2/19
6/2/19
7/2/19
8/1/19
9/1/19
10/1/19
11/1/19
12/1/19
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2019
Flow (cfs)
Elevation (ft)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
886.51
880.78
875.05
869.32
863.59
857.86
852.12
846.39
840.66
834.93
829.20
1/1/19
1/31/19
3/2/19
4/2/19
5/2/19
6/2/19
7/2/19
8/1/19
9/1/19
10/1/19
11/1/19
12/1/19
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Ross
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2020
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
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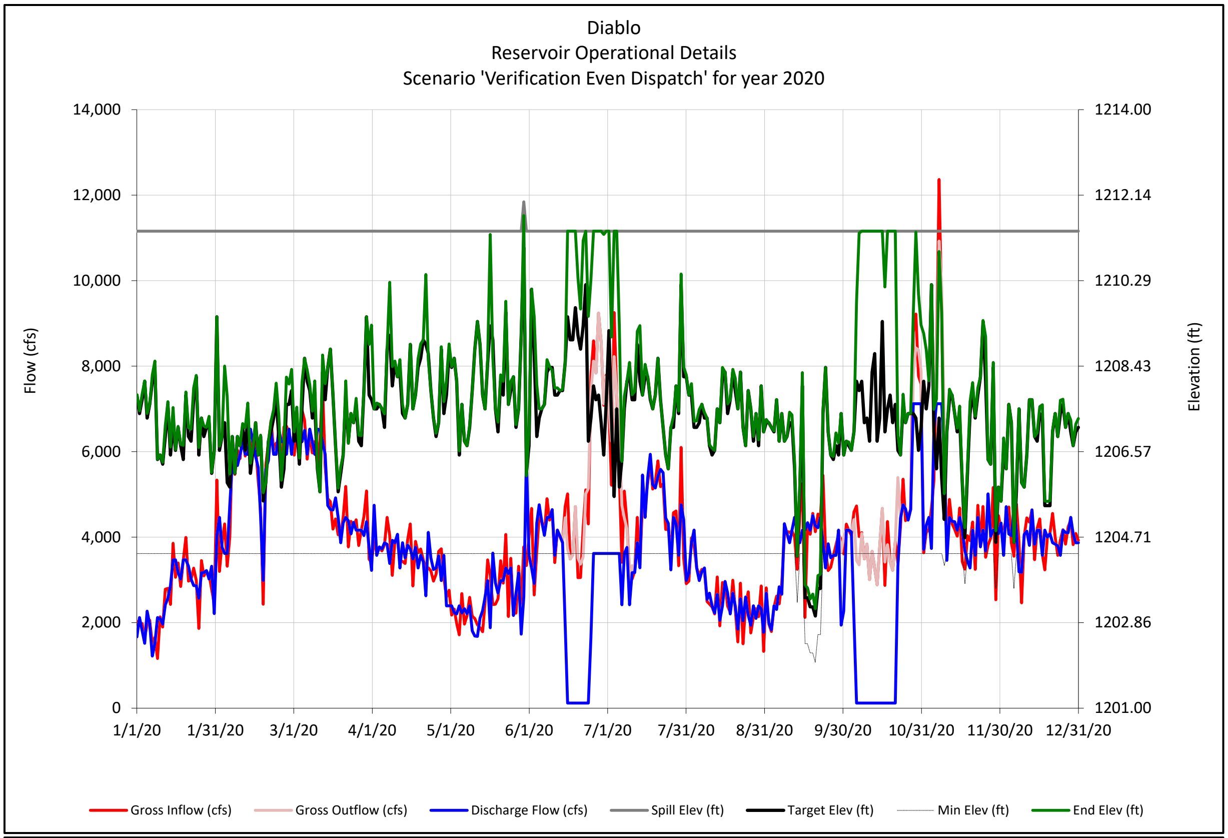
1585.54
1557.18
1528.82
1500.46
1472.10
1/1/20
1/31/20
3/1/20
4/1/20
5/1/20
6/1/20
7/1/20
7/31/20
8/31/20
9/30/20
10/31/20
11/30/20
12/31/20
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Diablo
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2020
Flow (cfs)
Elevation (ft)
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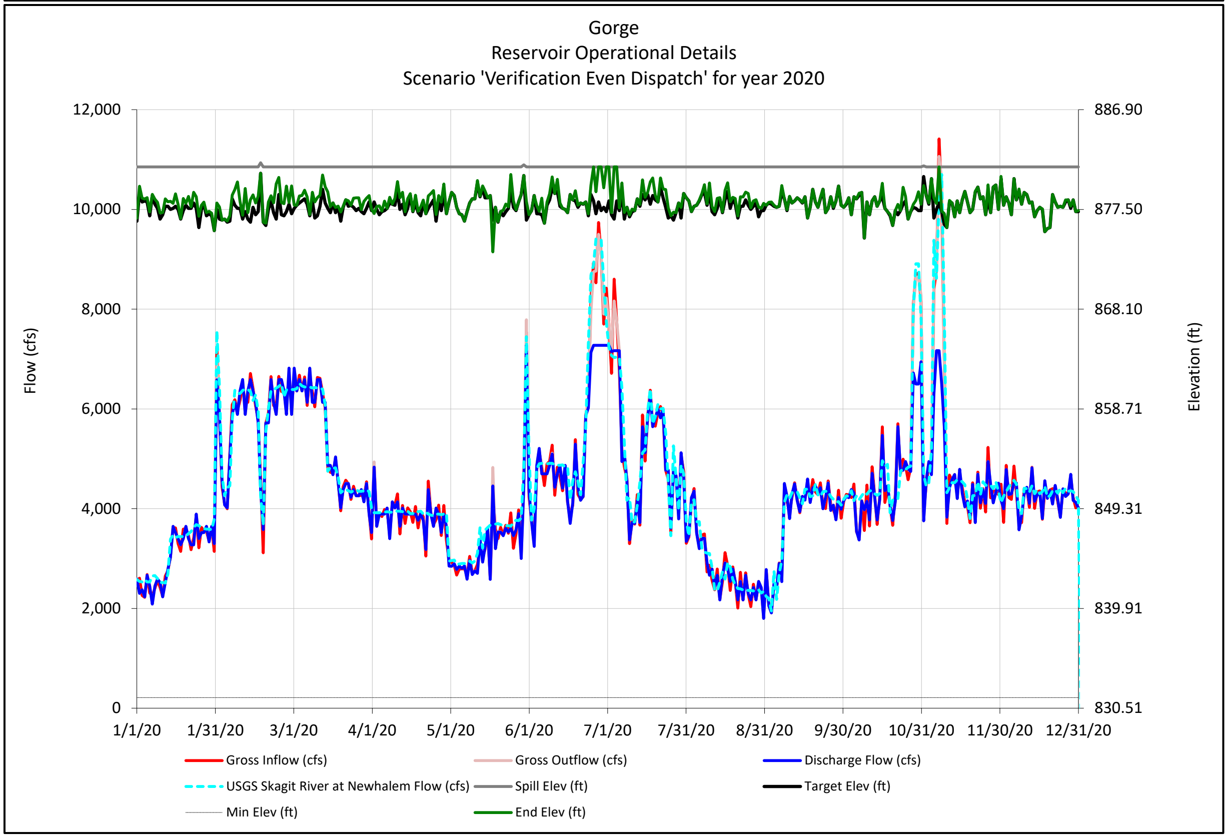
12,000
10,000
8,000
6,000
4,000
2,000
0
1214.00
1212.14
1210.29
1208.43
1206.57
1204.71
1202.86
1201.00
1/1/20
1/31/20
3/1/20
4/1/20
5/1/20
6/1/20
7/1/20
7/31/20
8/31/20
9/30/20
10/31/20
11/30/20
12/31/20
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)


Gorge
Reservoir Operational Details
Scenario 'Verification Even Dispatch' for year 2020
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
886.90
877.50
868.10
858.71
849.31
839.91
830.51
1/1/20
1/31/20
3/1/20
4/1/20
5/1/20
6/1/20
7/1/20
7/31/20
8/31/20
9/30/20
10/31/20
11/30/20
12/31/20
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)

OPERATIONS MODEL STUDY
SKAGIT OPERATIONS MODEL LOGIC AND VALIDATION REPORT

APPENDIX 4

CURRENT OPERATIONS BASELINE SCENARIO
GRAPHICAL RESULTS

Current Operations Baseline Scenarios Graphical Results

Scenario Presented

Current Operations Baseline (Baseline) Scenario with Default Dispatch

Data Presented:

Gross Inflow (cfs) – represents the simulated daily average total inflow to the reservoir, including incremental inflow from the hydrology inflow dataset; and, if applicable, simulated discharge and spills from the upstream plant.

Gross Outflow (cfs) – represents the simulated daily average total outflow from the reservoir, which includes powerhouse discharge, spillway flows and evaporative losses. This time series is only visible on the plots when spillway flow occurs, all other times the time series follows the powerhouse discharge (Discharge Flow).

Discharge Flow (cfs) – represents the simulated daily average powerhouse discharge.

Spill Elev (ft) – represents the elevation in feet, NAVD 88 datum, at which the model will begin to calculate spill.

Target Elev (ft) – this is the water surface elevation in feet, NAVD 88 datum, the model attempts to meet at the end of each day. For the Current Operations Baseline Scenarios, as part of the custom logic, this time series at Ross is based on the model forecasted inflows and outflows for creation of the Spawning Control Curve (SCC). This time series is only visible on the plots when the model is unable to meet this elevation and the End Elev deviates from the target elevation either due to insufficient inflows, releases to support downstream flow requirements, or to prevent spill at a downstream reservoir; otherwise, the time series follows the End Elev series. For the Baseline scenario, target elevations for Ross outside of the SCC period, and target elevations for Diablo and Gorge are based on median historical month beginning elevations for the period 1997 to 2020 from the historical operations database converted to NAVD 88.

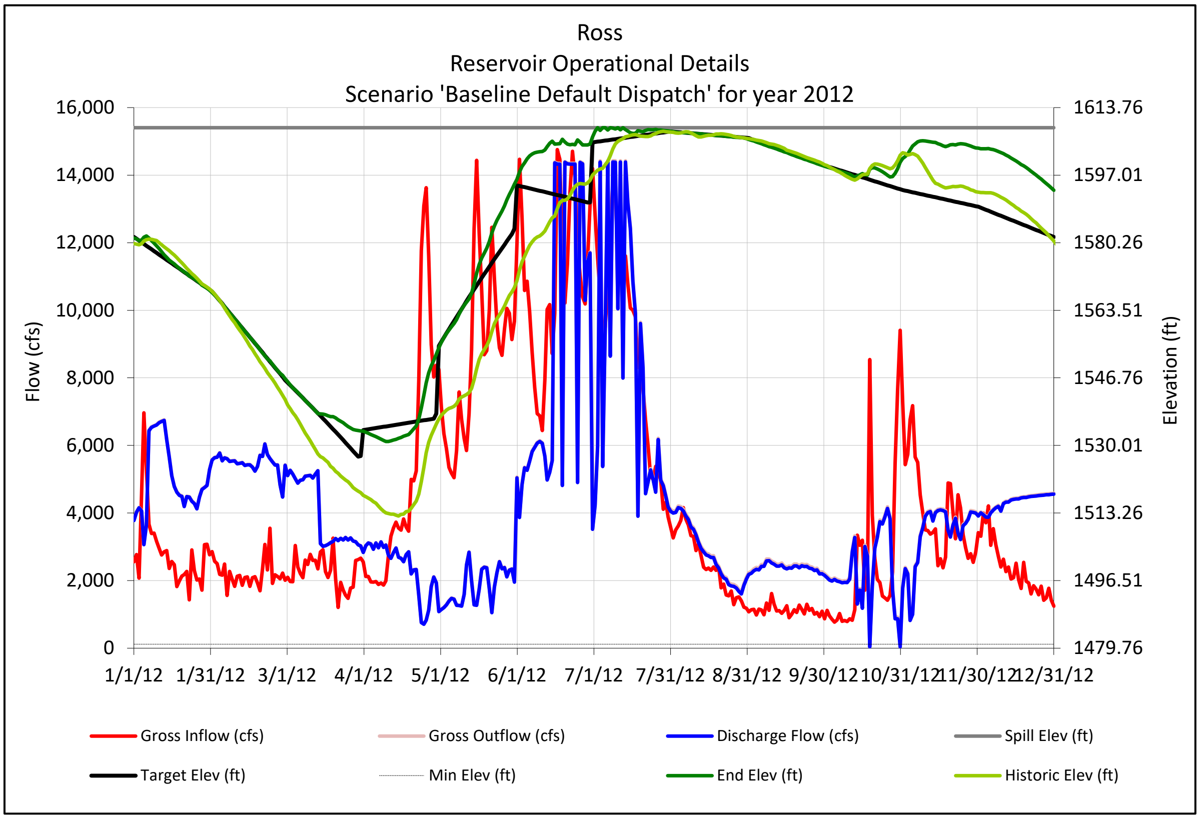
Min Elev (ft) – represents the elevation in feet, NAVD 88 datum, at which the model will cease powerhouse discharge.

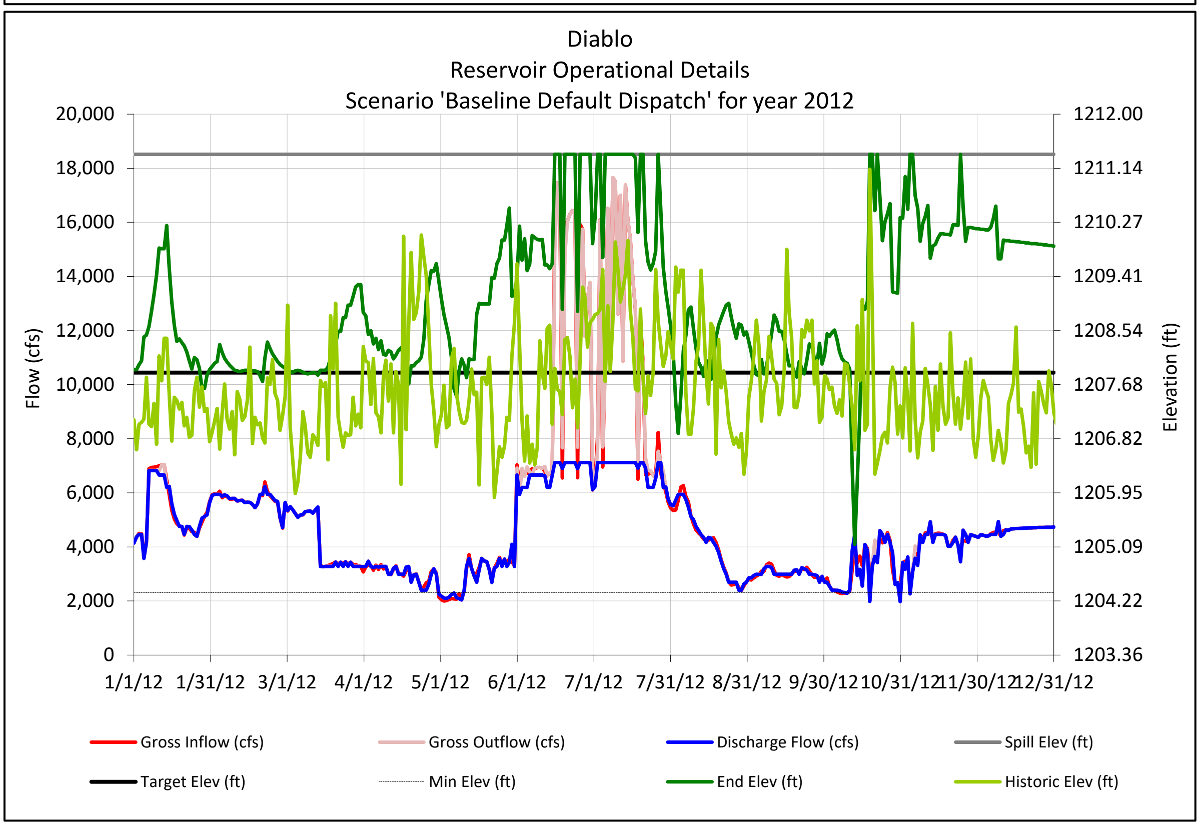
End Elev (ft) – represents the simulated end of day elevation in feet, NAVD 88 datum.

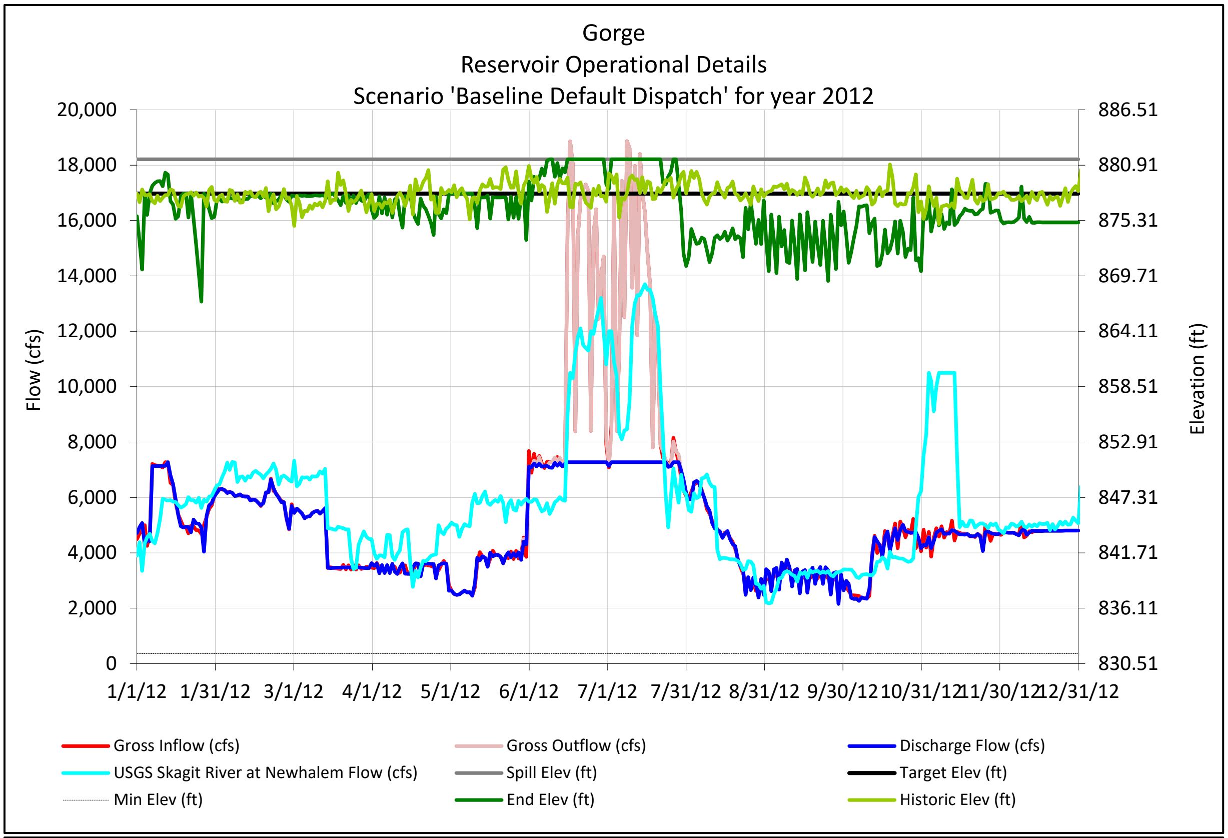
Historical Elev (ft) – represents the historical City Light reported end of day elevation in feet, converted to NAVD 88 datum.

USGS Skagit River at Newhalem Flow (cfs) – represents the historical flows reported by the USGS. Note the gage is missing data for the period 12/1/2014 through 3/29/2015.

Current Operations Baseline Scenario with Default Dispatch






Gorge
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2012
Flow (cfs)
Elevation (ft)
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18,000
16,000
14,000
12,000
10,000
8,000
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880.91
875.31
869.71
864.11
858.51
852.91
847.31
841.71
836.11
830.51
1/1/12
1/31/12
3/1/12
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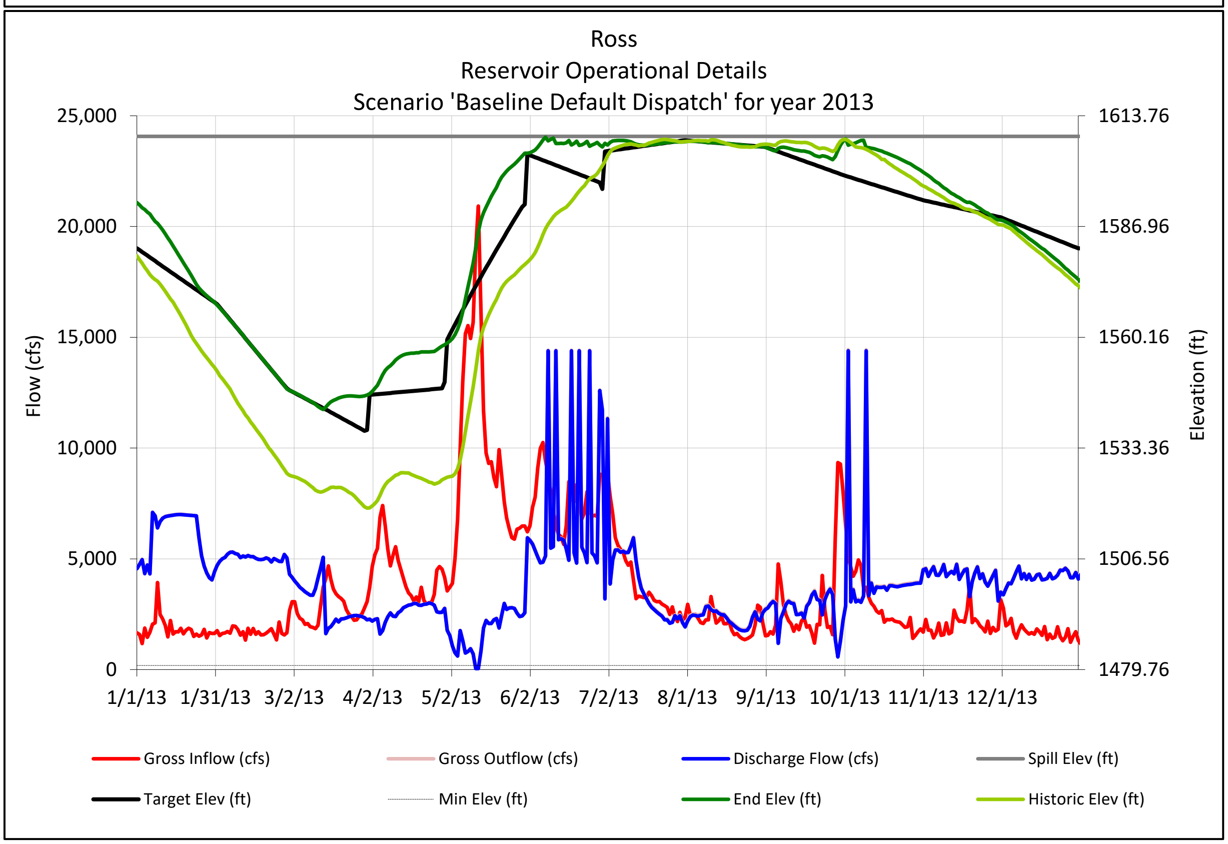
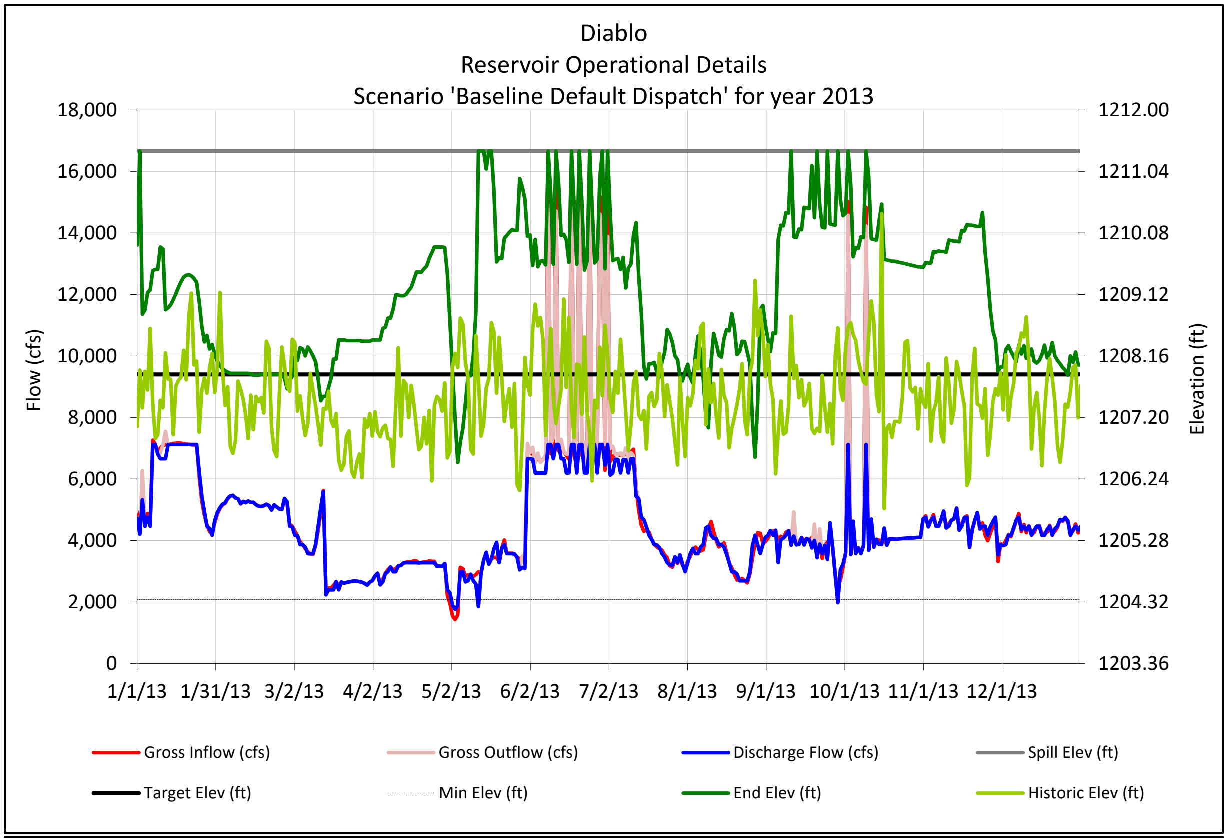
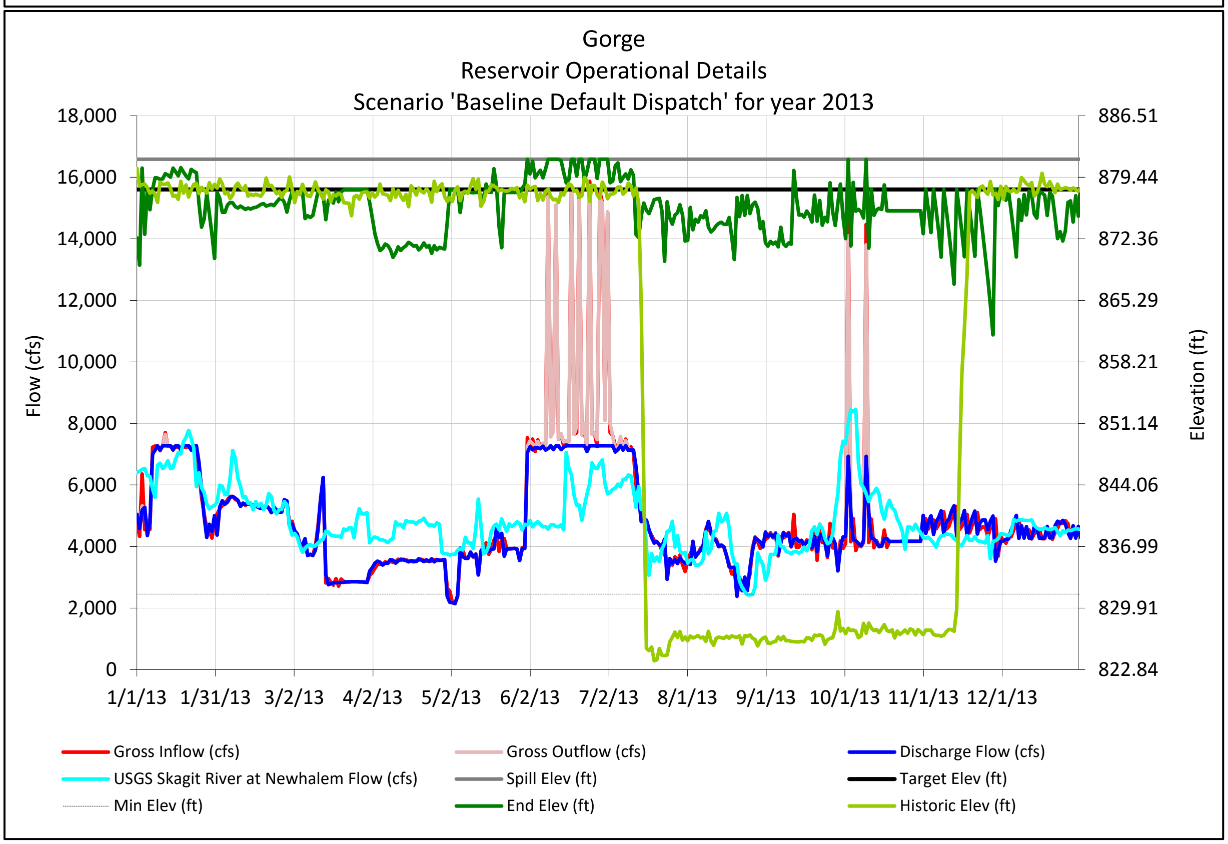
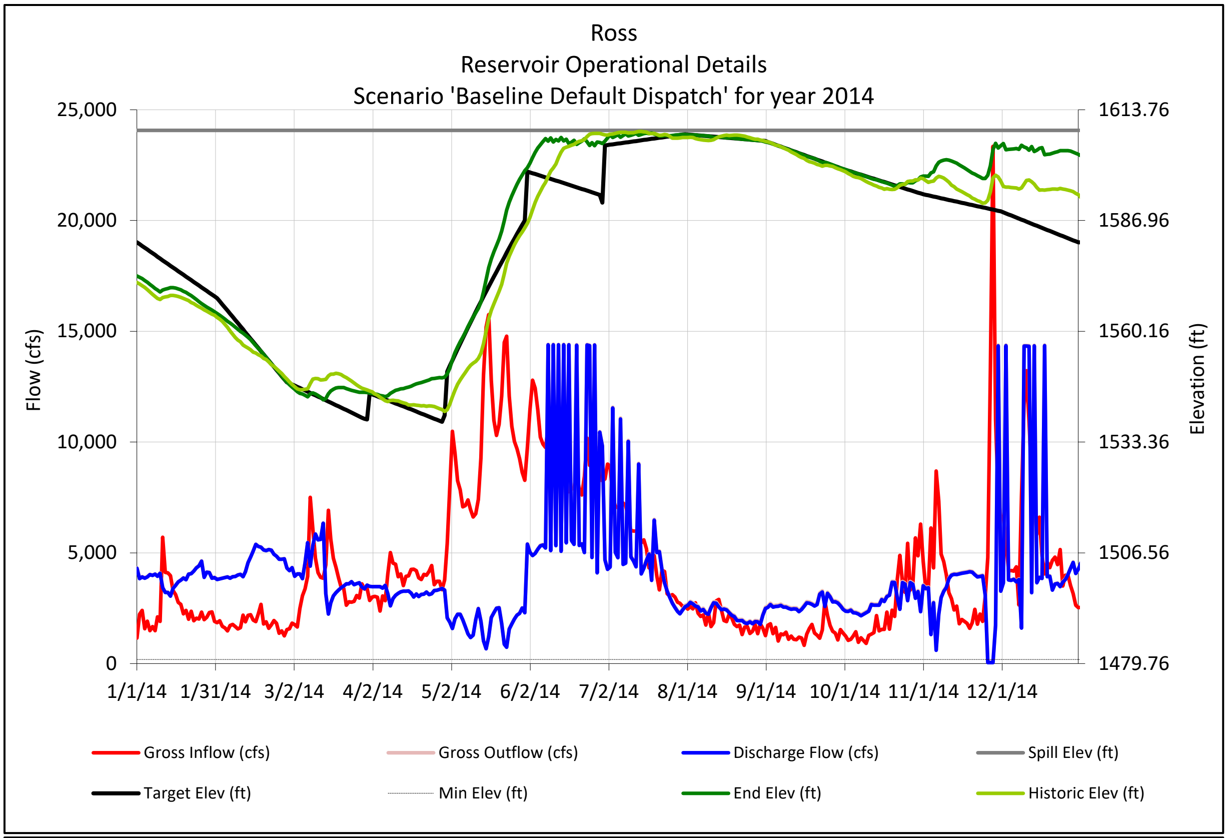
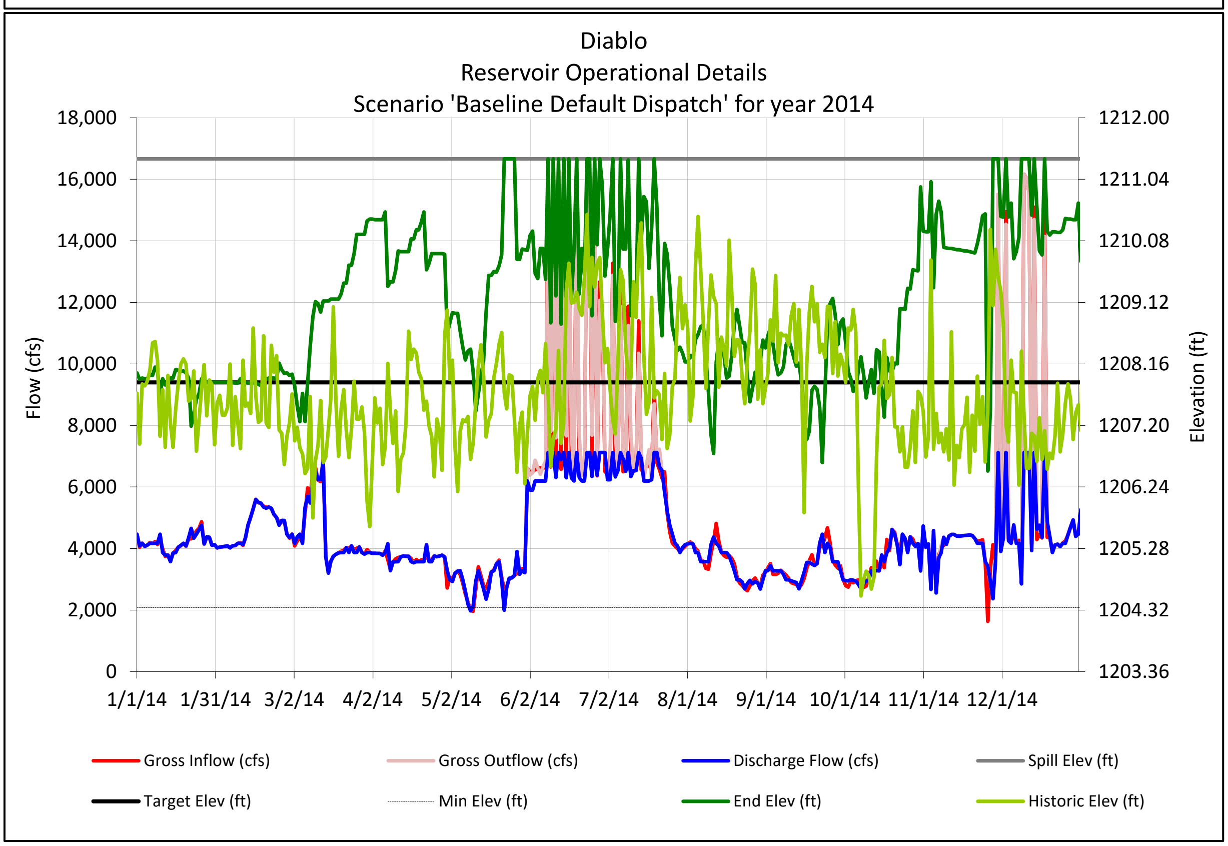
5/1/12
6/1/12
7/1/12
7/31/12
8/31/12
9/30/12
10/31/12
11/30/12
12/31/12
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)

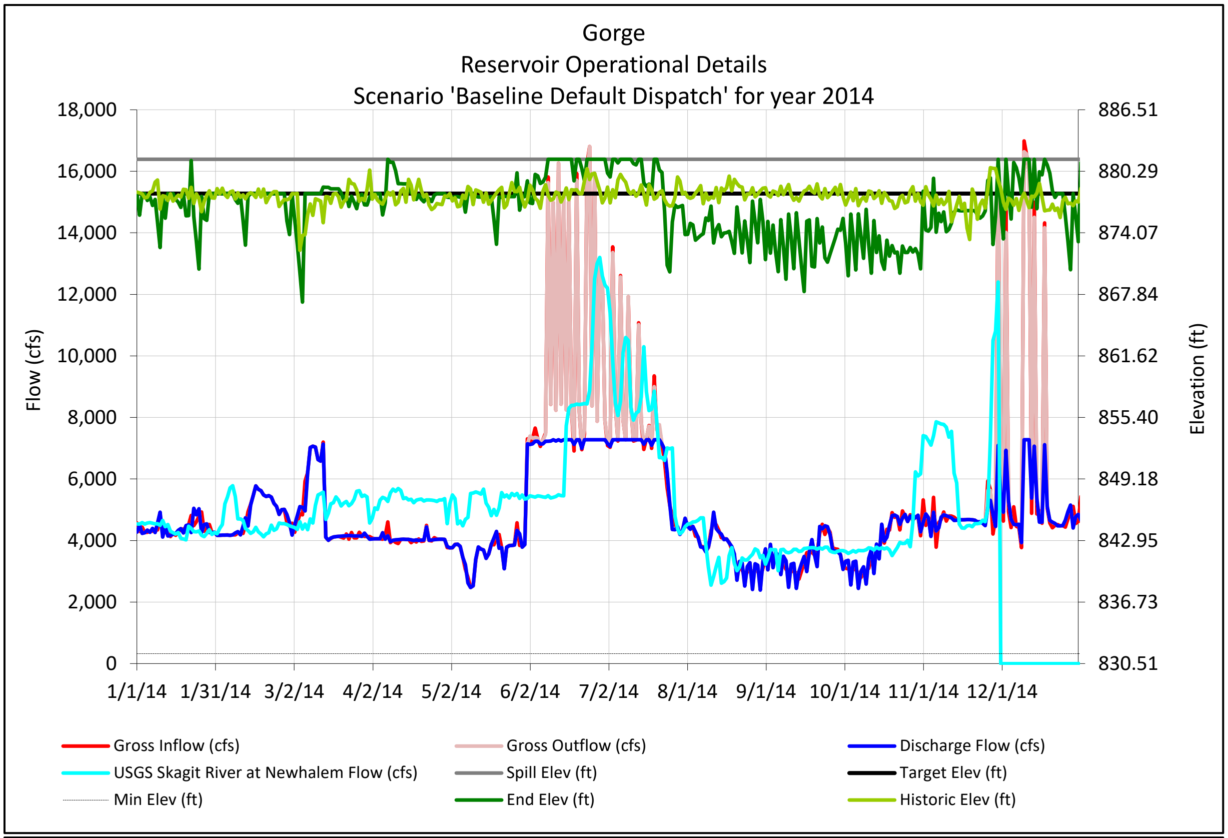

Ross
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2013
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
1613.76
1586.96
1560.16
1533.36
1506.56
1479.76
1/1/13
1/31/13
3/2/13
4/2/13
5/2/13
6/2/13
7/2/13
8/1/13
9/1/13
10/1/13
11/1/13
12/1/13
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)

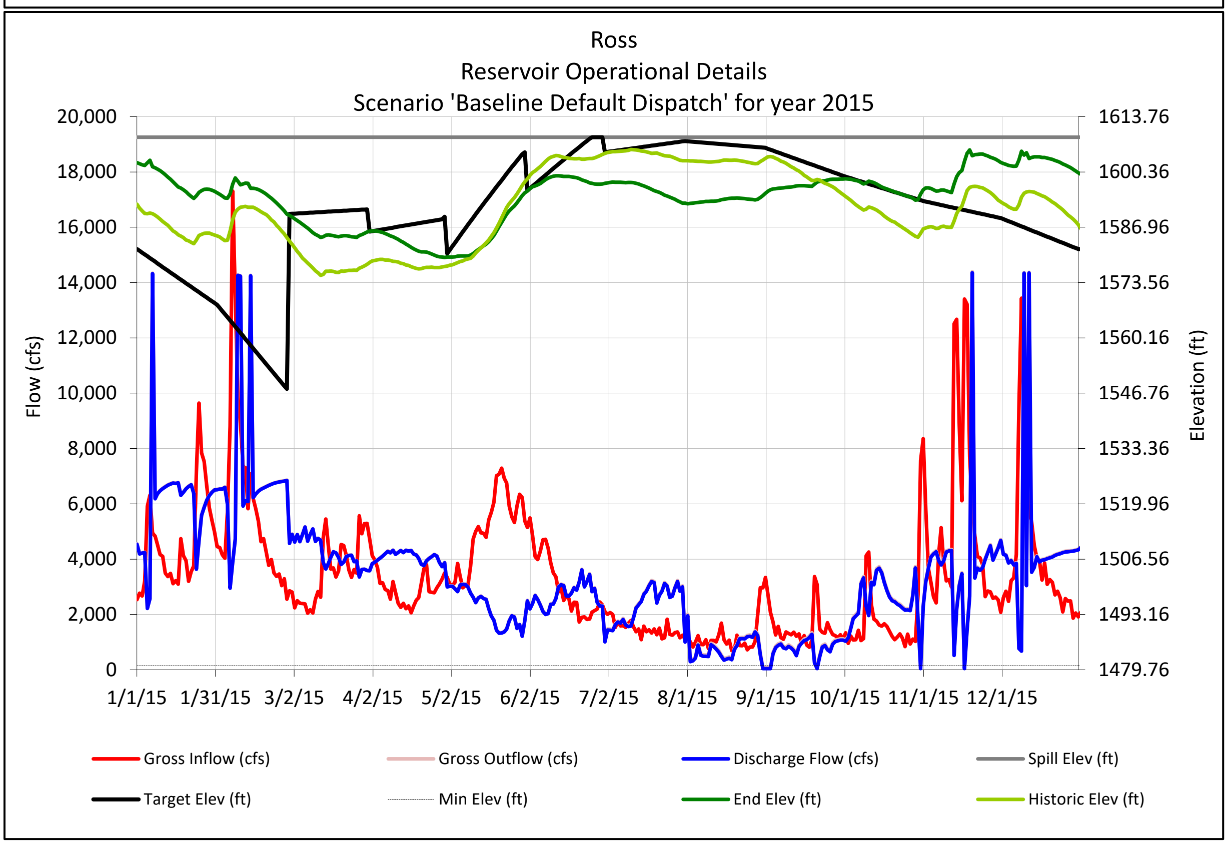

Diablo
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2013
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1212.00
1211.04
1210.08
1209.12
1208.16
1207.20
1206.24
1205.28
1204.32
1203.36
1/1/13 1/31/13 3/2/13 4/2/13 5/2/13 6/2/13 7/2/13 8/1/13 9/1/13 10/1/13 11/1/13 12/1/13
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)

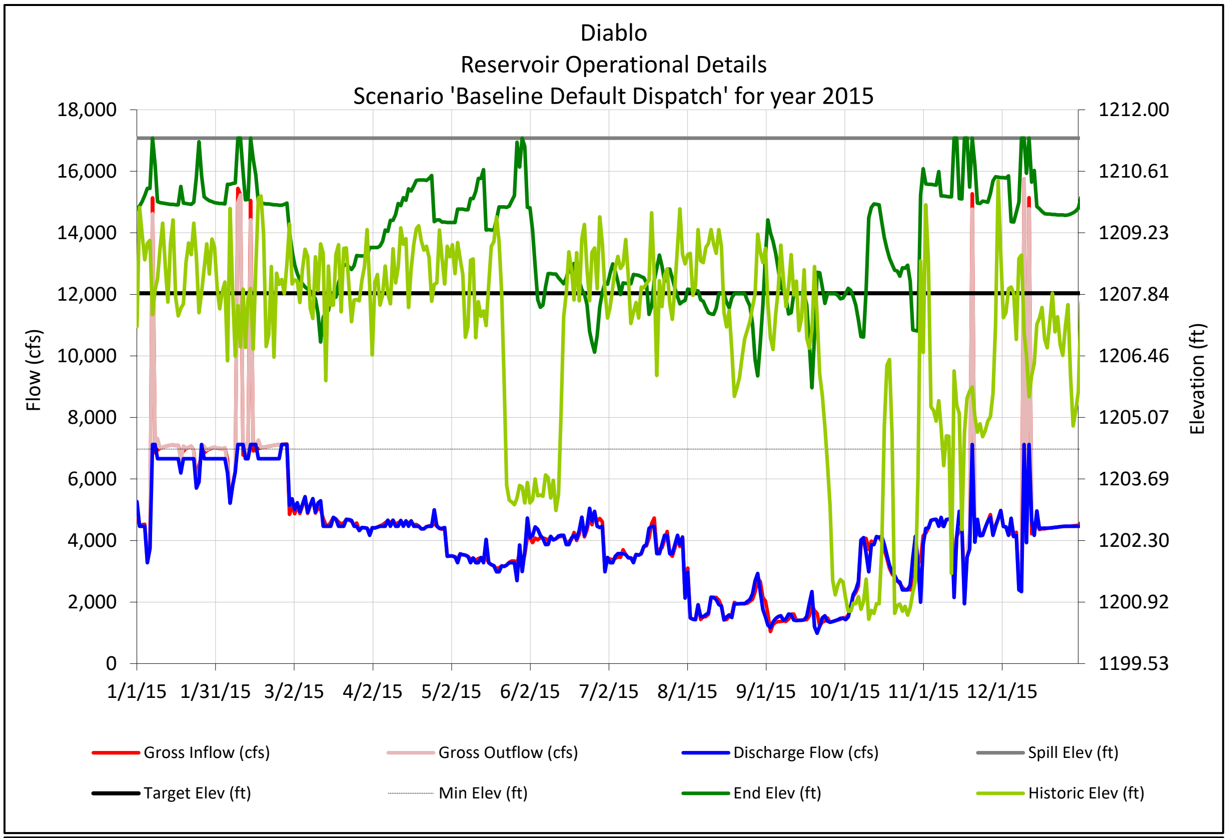

Gorge
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2013
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
886.51
879.44
872.36
865.29
858.21
851.14
844.06
836.99
829.91
822.84
1/1/13 1/31/13 3/2/13 4/2/13 5/2/13 6/2/13 7/2/13 8/1/13 9/1/13 10/1/13 11/1/13 12/1/13
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)

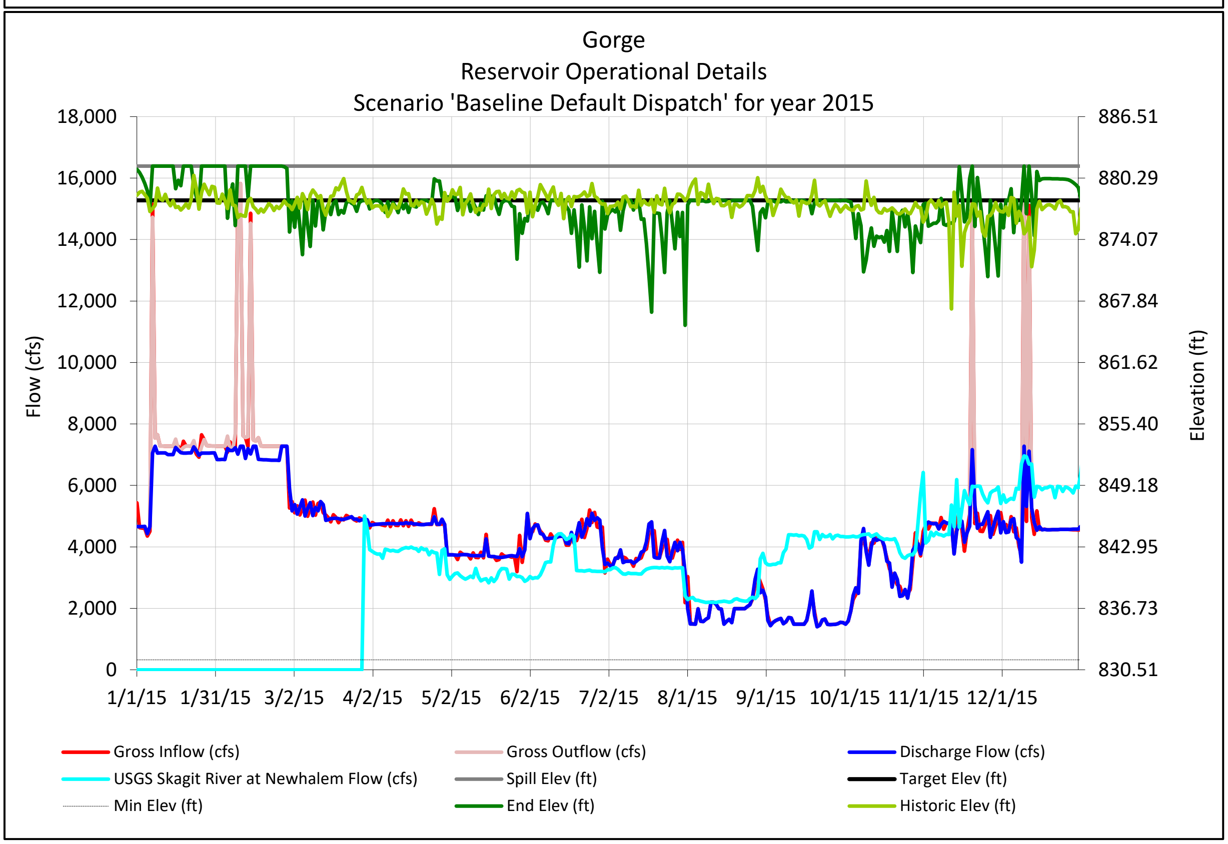

Ross
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2014
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
1613.76
1586.96
1560.16
1533.36
1506.56
1479.76
1/1/14
1/31/14
3/2/14
4/2/14
5/2/14
6/2/14
7/2/14
8/1/14
9/1/14
10/1/14
11/1/14
12/1/14
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)

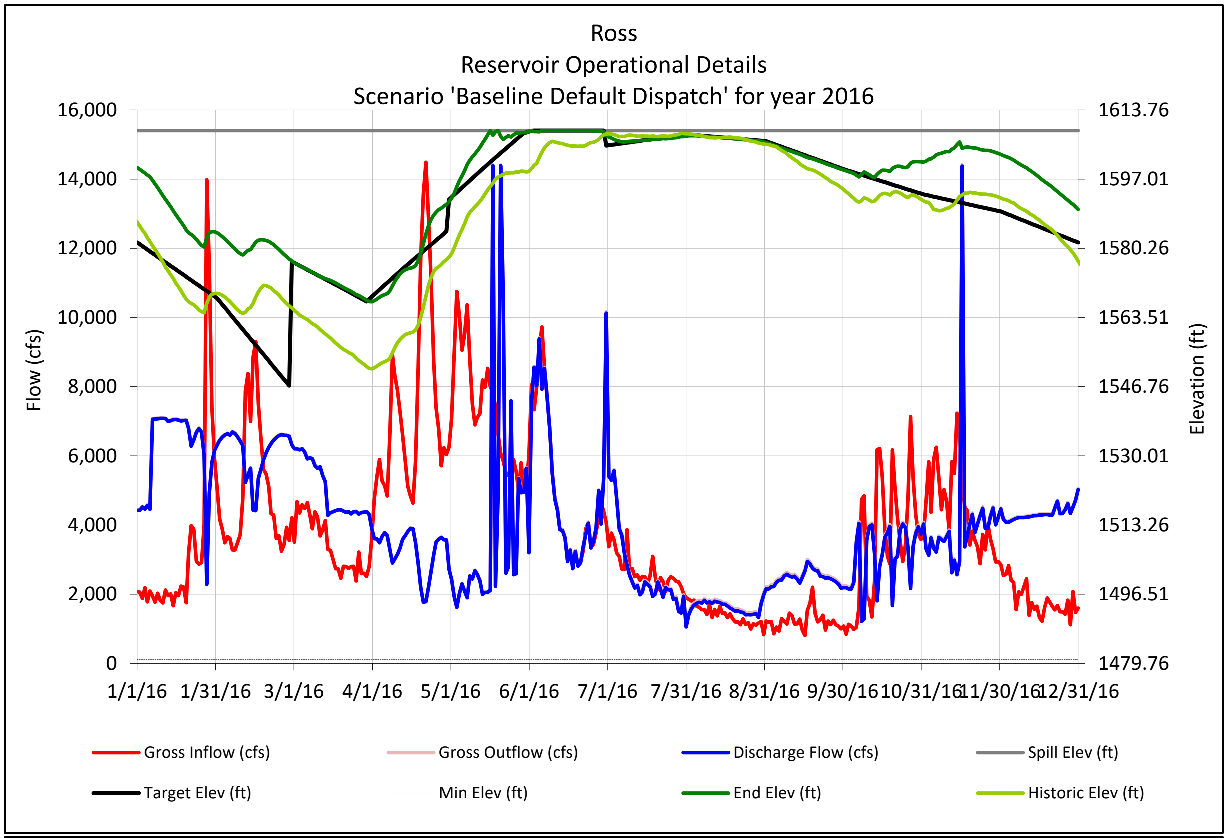

Diablo
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2014
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1212.00
1211.04
1210.08
1209.12
1208.16
1207.20
1206.24
1205.28
1204.32
1203.36
1/1/14
1/31/14
3/2/14
4/2/14
5/2/14
6/2/14
7/2/14
8/1/14
9/1/14
10/1/14
11/1/14
12/1/14
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)

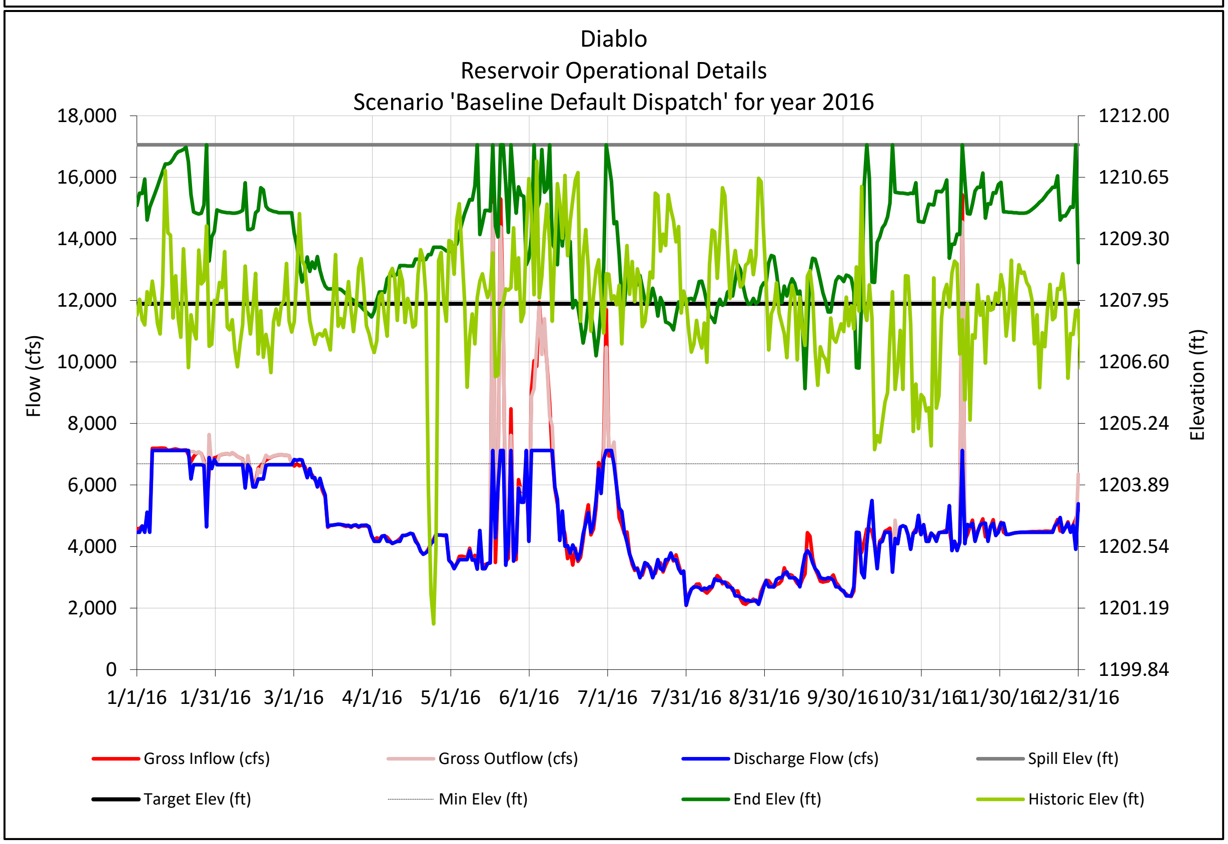

Gorge
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2014
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
886.51
880.29
874.07
867.84
861.62
855.40
849.18
842.95
836.73
830.51
1/1/14 1/31/14 3/2/14 4/2/14 5/2/14 6/2/14 7/2/14 8/1/14 9/1/14 10/1/14 11/1/14 12/1/14
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)

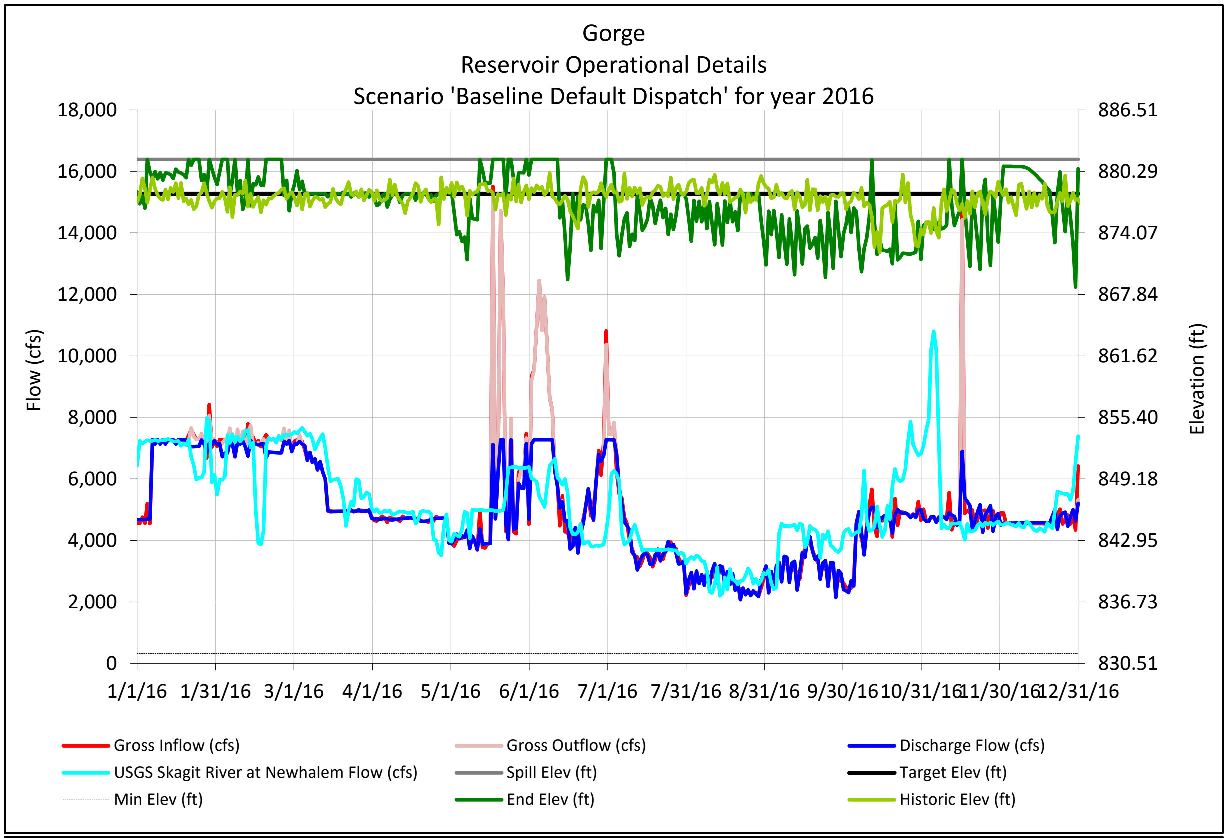

Ross
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2015
Flow (cfs)
Elevation (ft)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1600.36
1586.96
1573.56
1560.16
1546.76
1533.36
1519.96
1506.56
1493.16
1479.76
1/1/15 1/31/15 3/2/15 4/2/15 5/2/15 6/2/15 7/2/15 8/1/15 9/1/15 10/1/15 11/1/15 12/1/15
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)

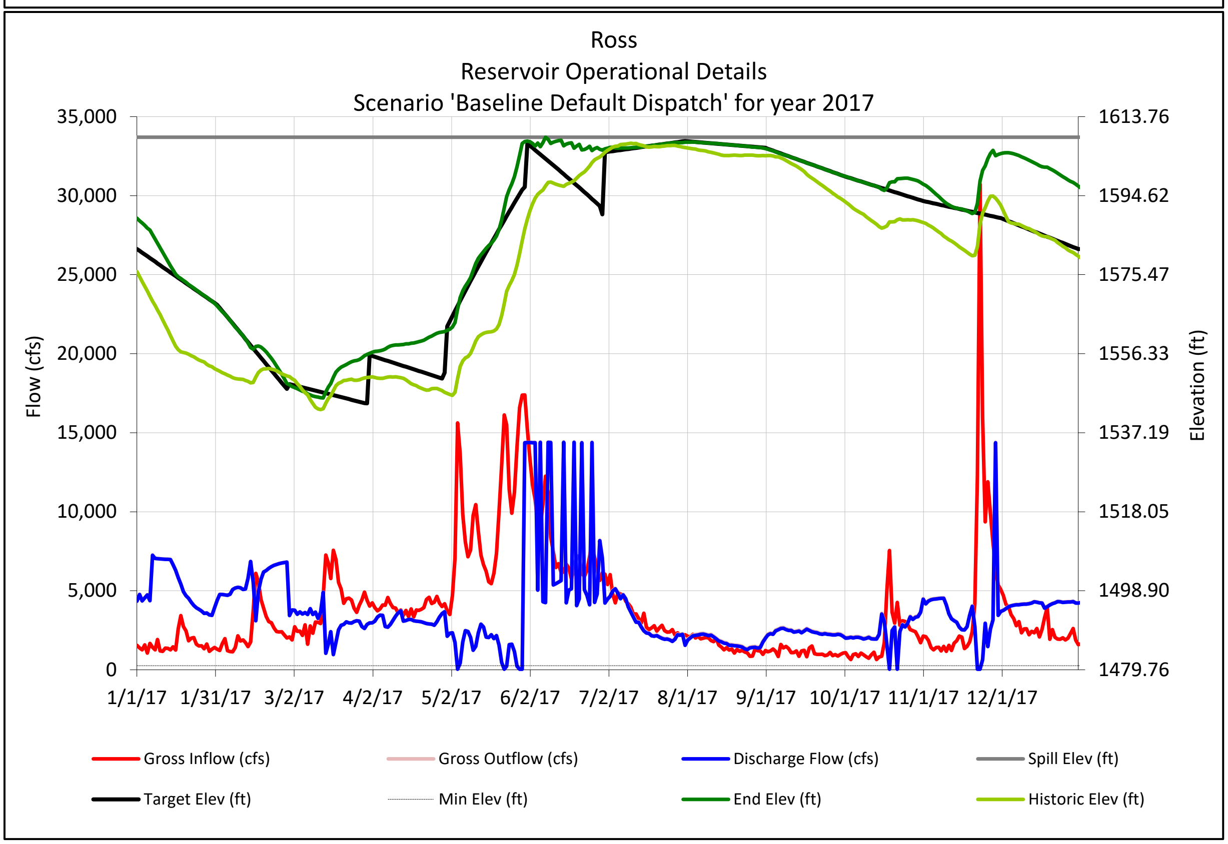

Diablo
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2015
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1212.00
1210.61
1209.23
1207.84
1206.46
1205.07
1203.69
1202.30
1200.92
1199.53
1/1/15
1/31/15
3/2/15
4/2/15
5/2/15
6/2/15
7/2/15
8/1/15
9/1/15
10/1/15
11/1/15
12/1/15
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)


Gorge
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2015
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
886.51
880.29
874.07
867.84
861.62
855.40
849.18
842.95
836.73
830.51
1/1/15
1/31/15
3/2/15
4/2/15
5/2/15
6/2/15
7/2/15
8/1/15
9/1/15
10/1/15
11/1/15
12/1/15
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)


Ross
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2016
Flow (cfs)
Elevation (ft)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1597.01
1580.26
1563.51
1546.76
1530.01
1513.26
1496.51
1479.76
1/1/16
1/31/16
3/1/16
4/1/16
5/1/16
6/1/16
7/1/16
7/31/16
8/31/16
9/30/16
10/31/16
11/30/16
12/31/16
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)


Diablo
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2016
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1212.00
1210.65
1209.30
1207.95
1206.60
1205.24
1203.89
1202.54
1201.19
1199.84
1/1/16
1/31/16
3/1/16
4/1/16
5/1/16
6/1/16
7/1/16
7/31/16
8/31/16
9/30/16
10/31/16
11/30/16
12/31/16
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)


Gorge
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2016
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
886.51
880.29
874.07
867.84
861.62
855.40
849.18
842.95
836.73
830.51
1/1/16
1/31/16
3/1/16
4/1/16
5/1/16
6/1/16
7/1/16
7/31/16
8/31/16
9/30/16
10/31/16
11/30/16
12/31/16
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)


Ross
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2017
Flow (cfs)
Elevation (ft)
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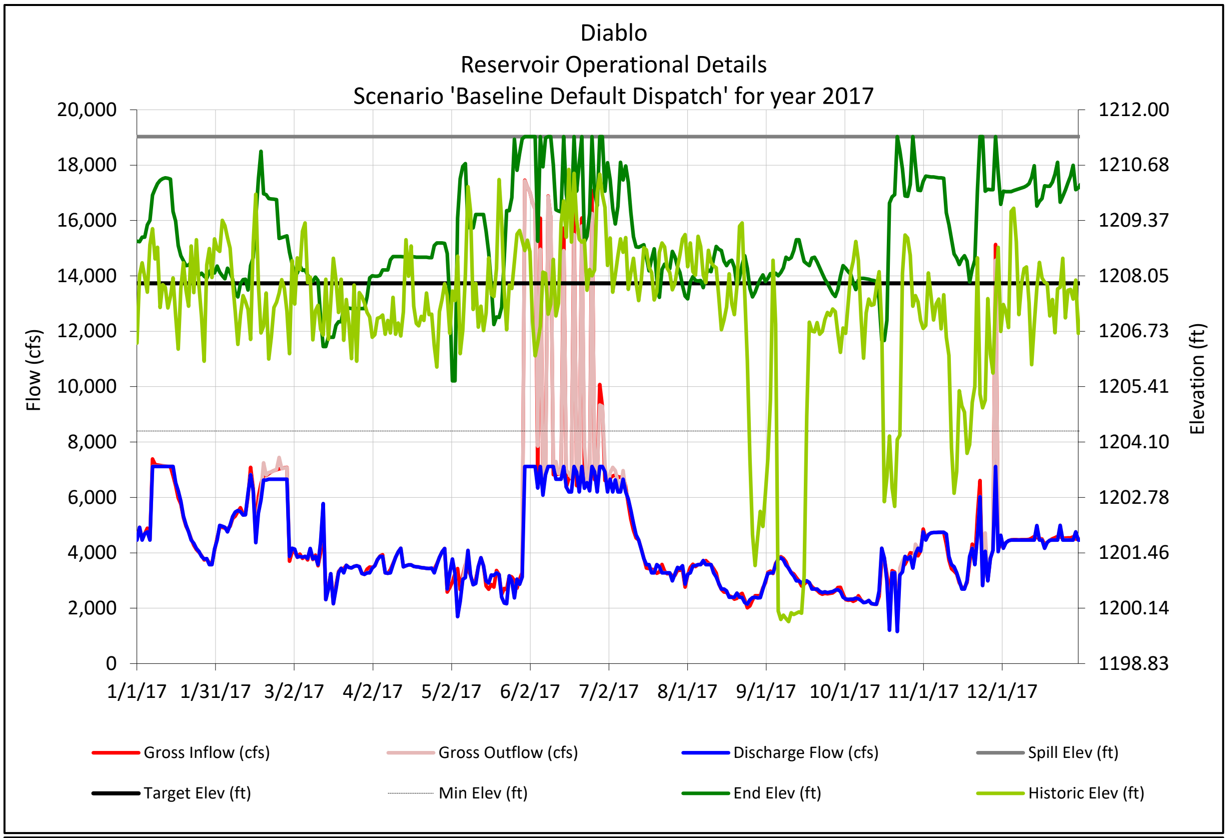
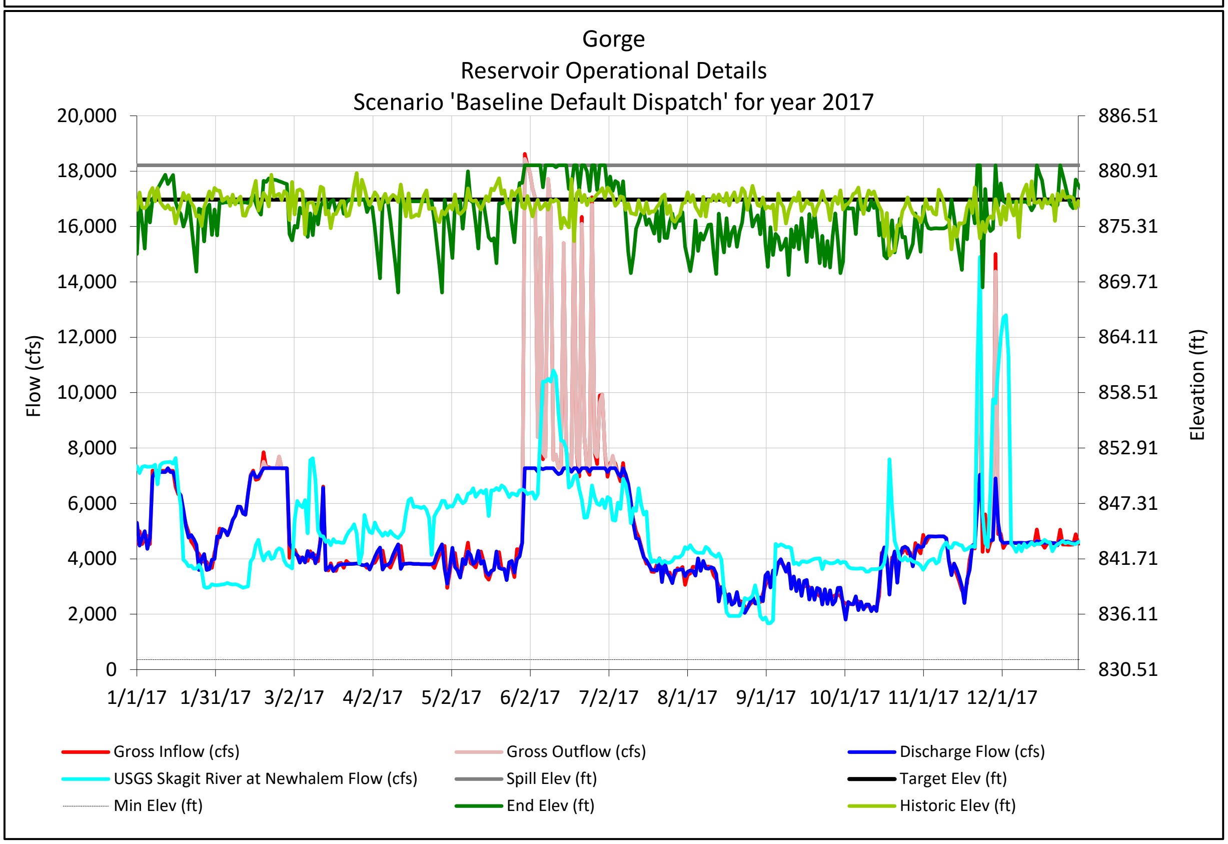
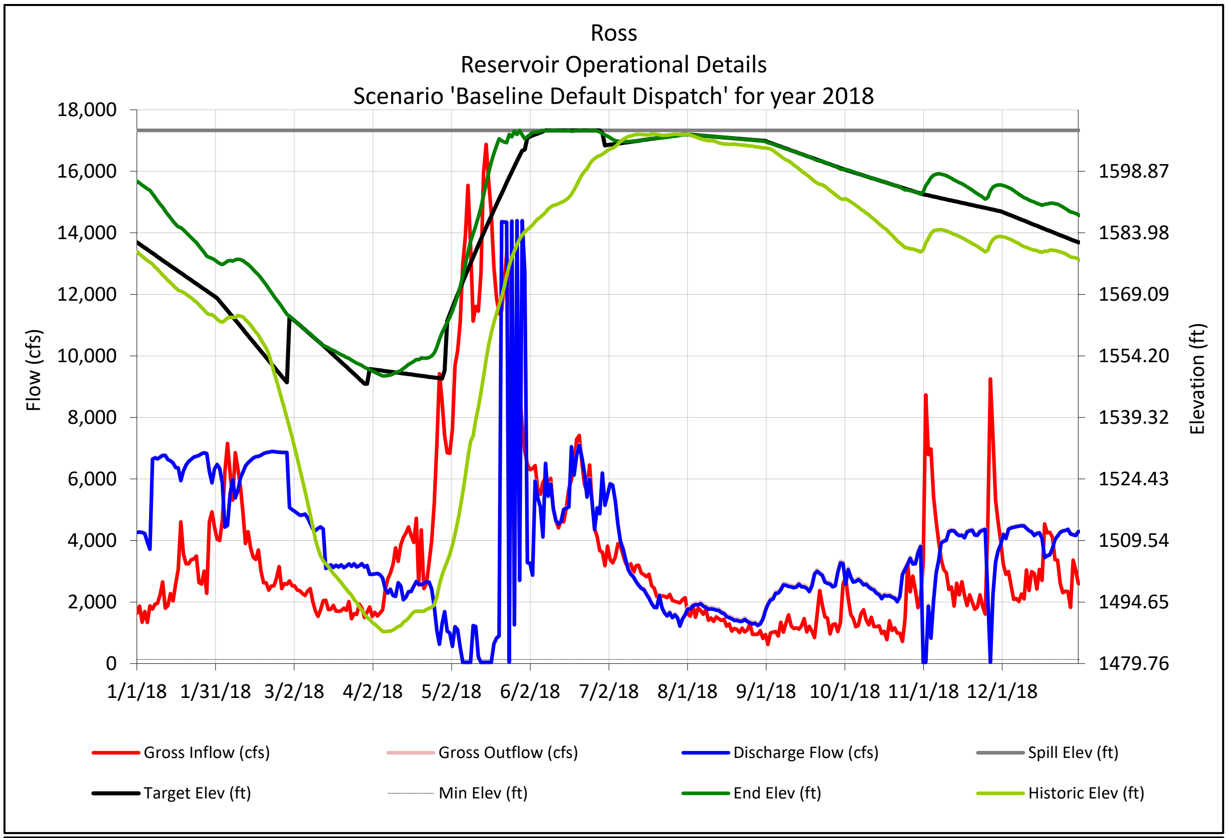
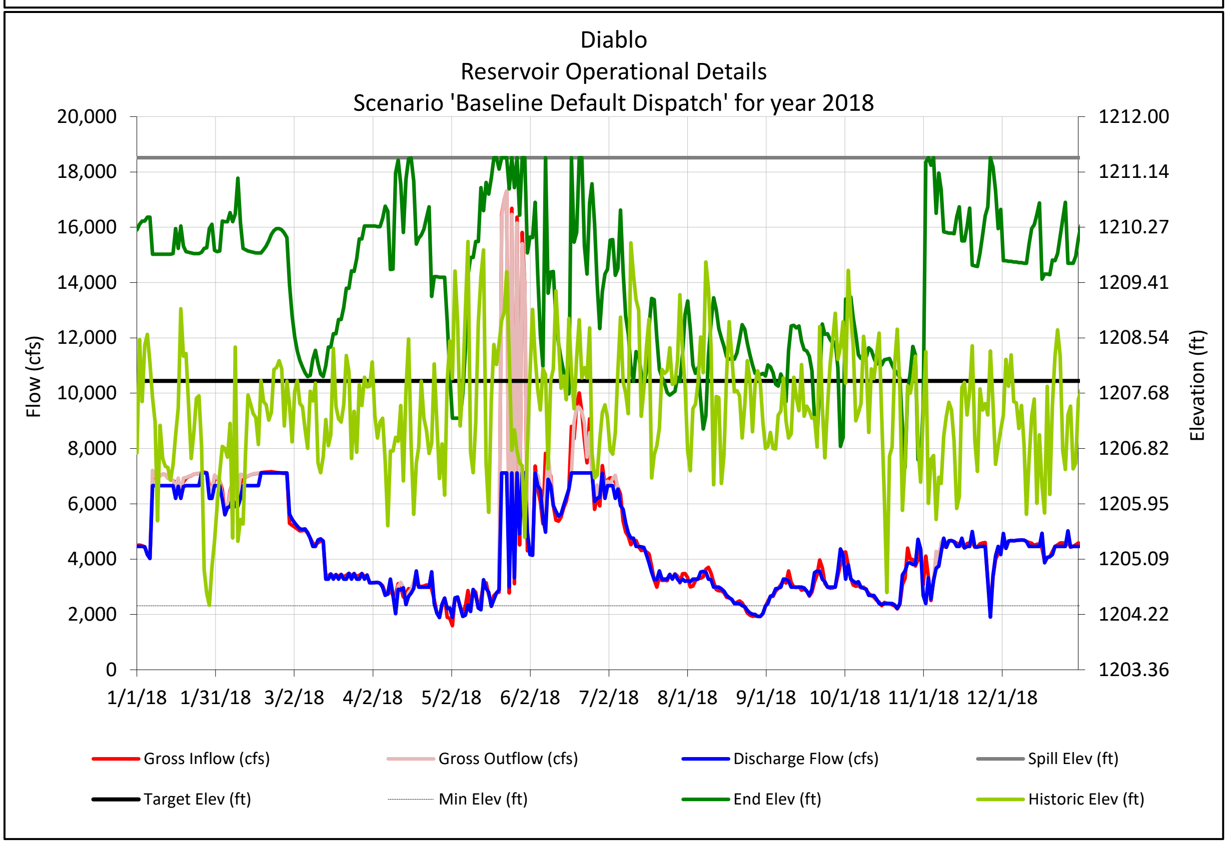
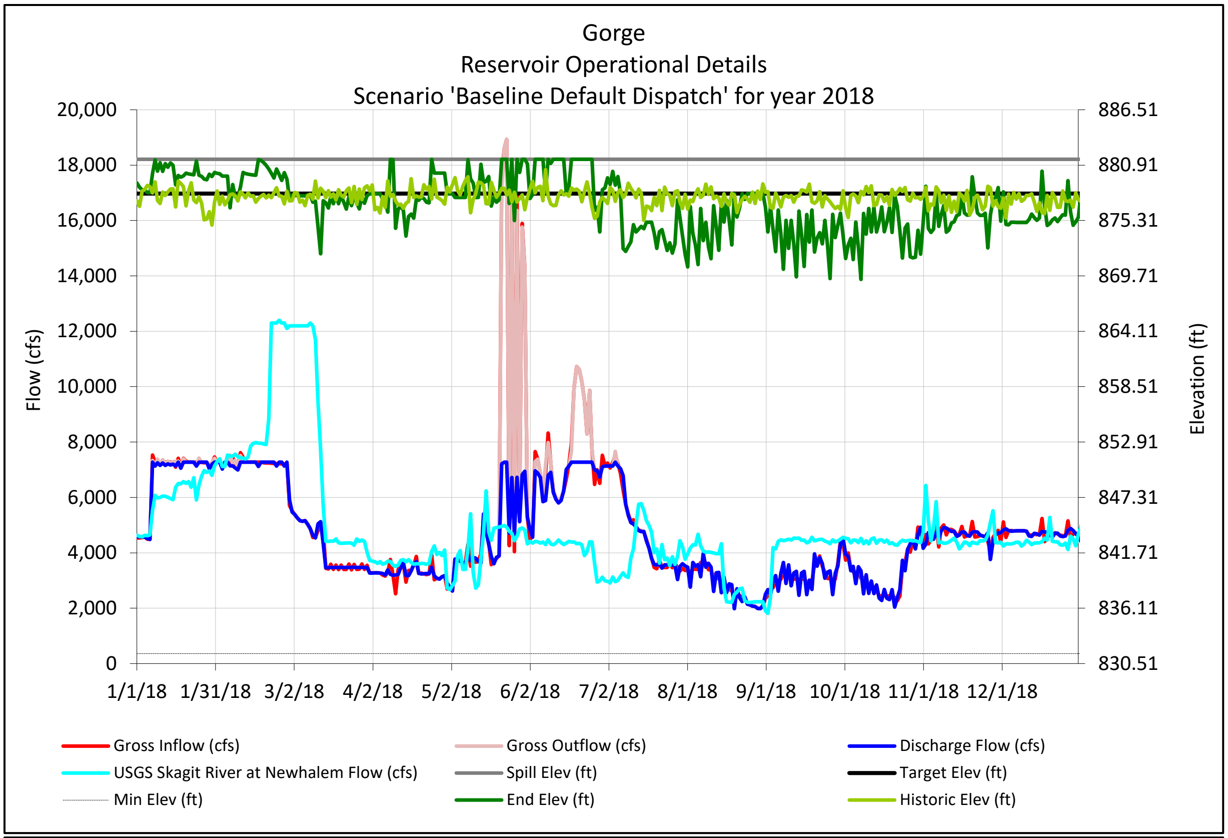
30,000
25,000
20,000
15,000
10,000
5,000
0
1613.76
1594.62
1575.47
1556.33
1537.19
1518.05
1498.90
1479.76
1/1/17
1/31/17
3/2/17
4/2/17
5/2/17
6/2/17
7/2/17
8/1/17
9/1/17
10/1/17
11/1/17
12/1/17
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)


Diablo
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2017
Flow (cfs)
Elevation (ft)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1212.00
1210.68
1209.37
1208.05
1206.73
1205.41
1204.10
1202.78
1201.46
1200.14
1198.83
1/1/17
1/31/17
3/2/17
4/2/17
5/2/17
6/2/17
7/2/17
8/1/17
9/1/17
10/1/17
11/1/17
12/1/17
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)

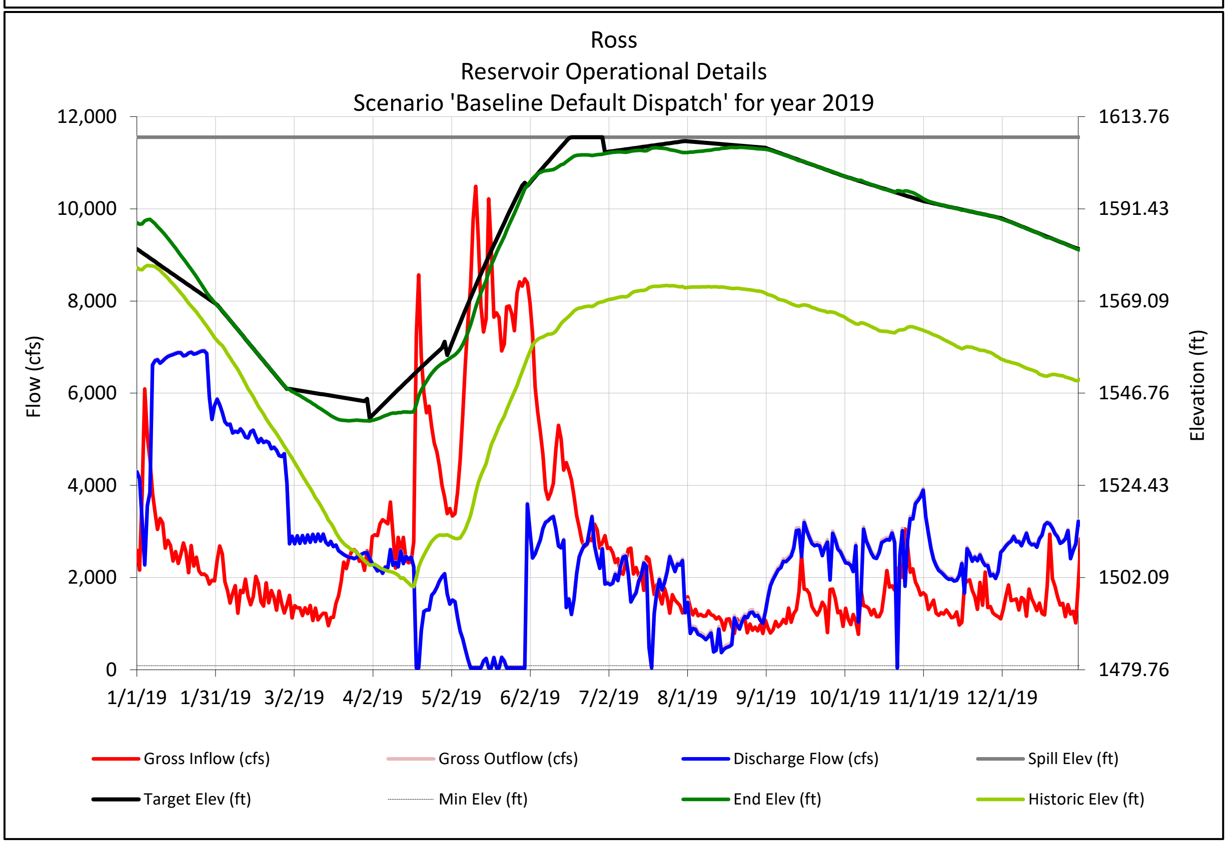

Gorge
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2017
Flow (cfs)
Elevation (ft)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
886.51
880.91
875.31
869.71
864.11
858.51
852.91
847.31
841.71
836.11
830.51
1/1/17
1/31/17
3/2/17
4/2/17
5/2/17
6/2/17
7/2/17
8/1/17
9/1/17
10/1/17
11/1/17
12/1/17
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)


Ross
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2018
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1598.87
1583.98
1569.09
1554.20
1539.32
1524.43
1509.54
1494.65
1479.76
1/1/18 1/31/18 3/2/18 4/2/18 5/2/18 6/2/18 7/2/18 8/1/18 9/1/18 10/1/18 11/1/18 12/1/18
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)

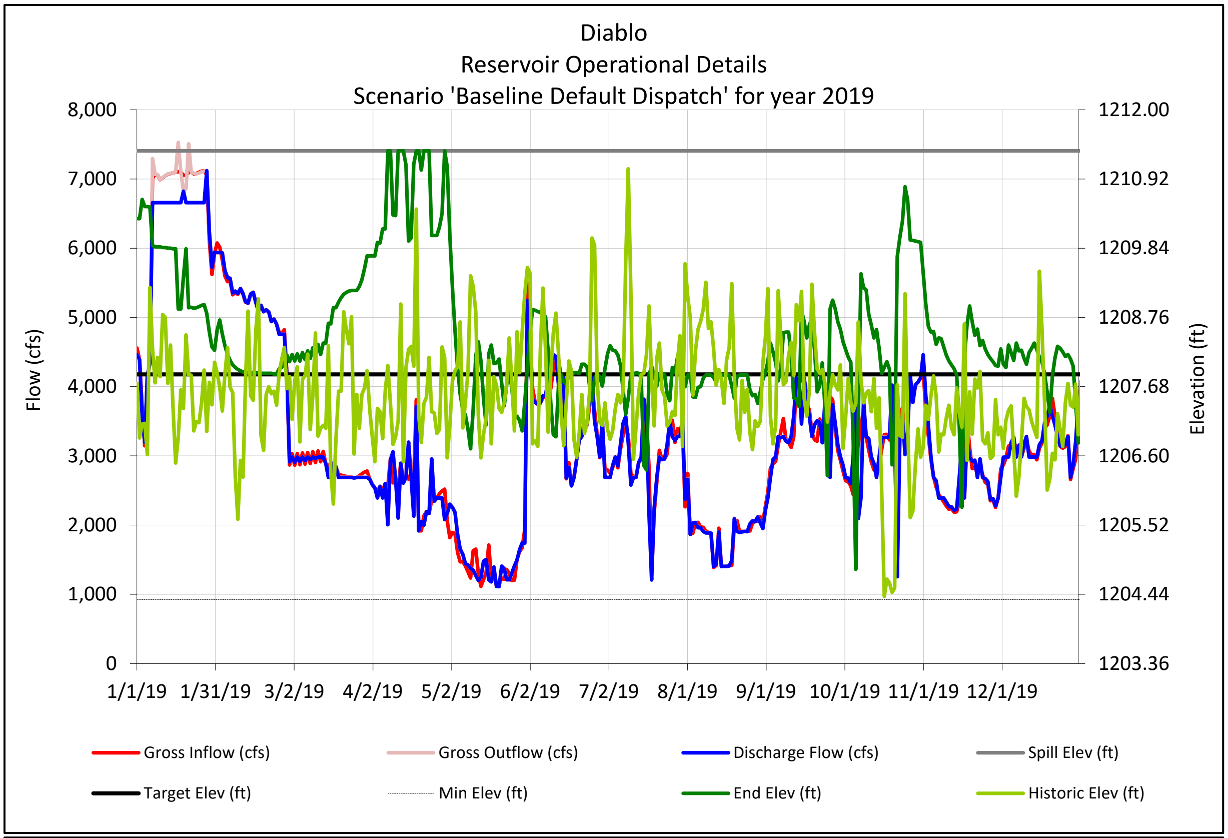

Diablo
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2018
Flow (cfs)
Elevation (ft)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1212.00
1211.14
1210.27
1209.41
1208.54
1207.68
1206.82
1205.95
1205.09
1204.22
1203.36
1/1/18 1/31/18 3/2/18 4/2/18 5/2/18 6/2/18 7/2/18 8/1/18 9/1/18 10/1/18 11/1/18 12/1/18
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)

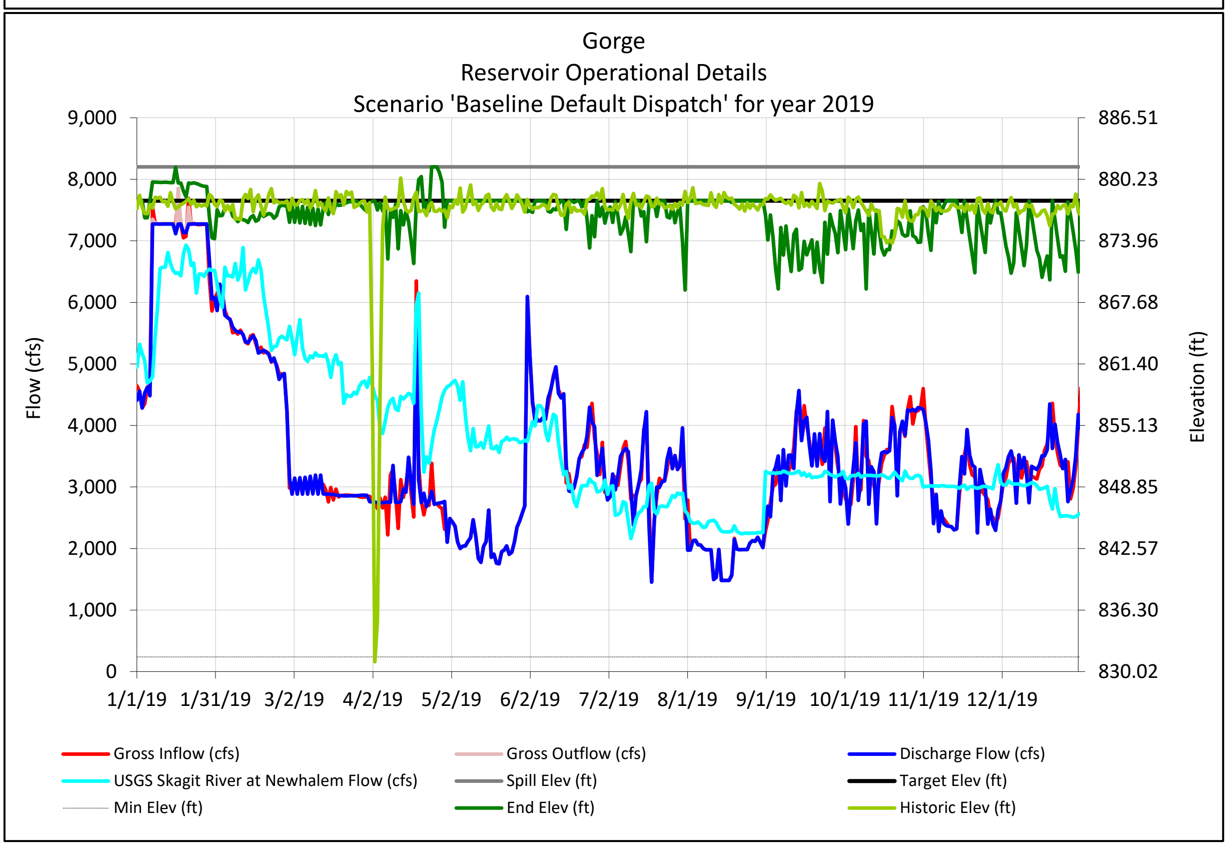


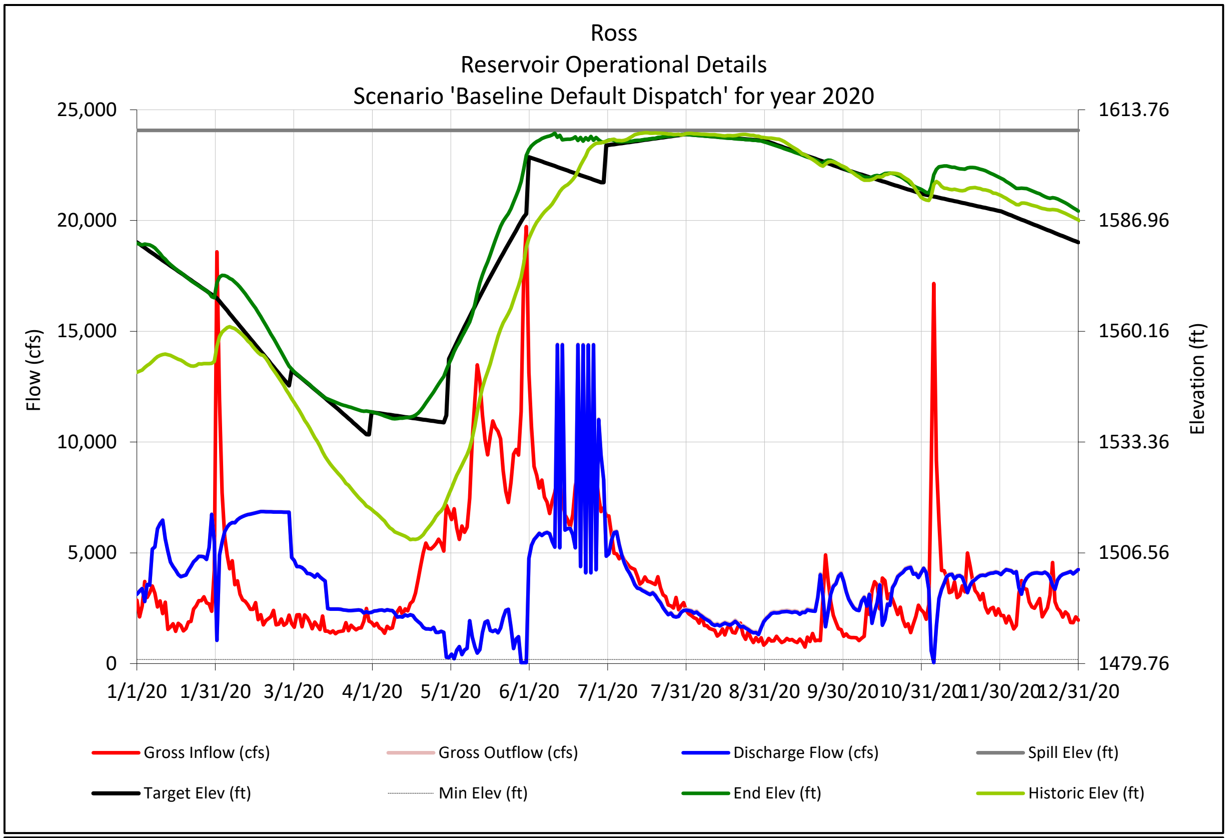
Gorge
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2018
Flow (cfs)
Elevation (ft)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
886.51
880.91
875.31
869.71
864.11
858.51
852.91
847.31
841.71
836.11
830.51
1/1/18 1/31/18 3/2/18 4/2/18 5/2/18 6/2/18 7/2/18 8/1/18 9/1/18 10/1/18 11/1/18 12/1/18
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)

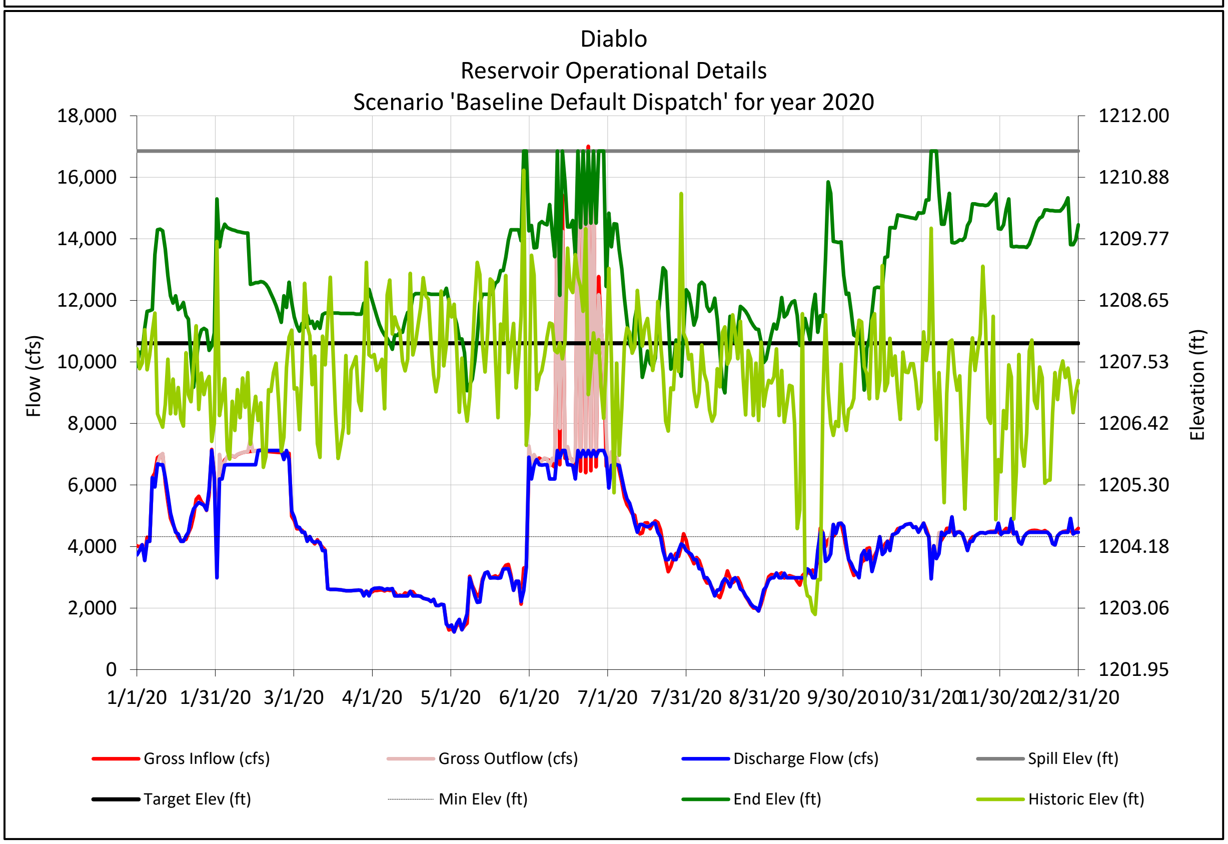


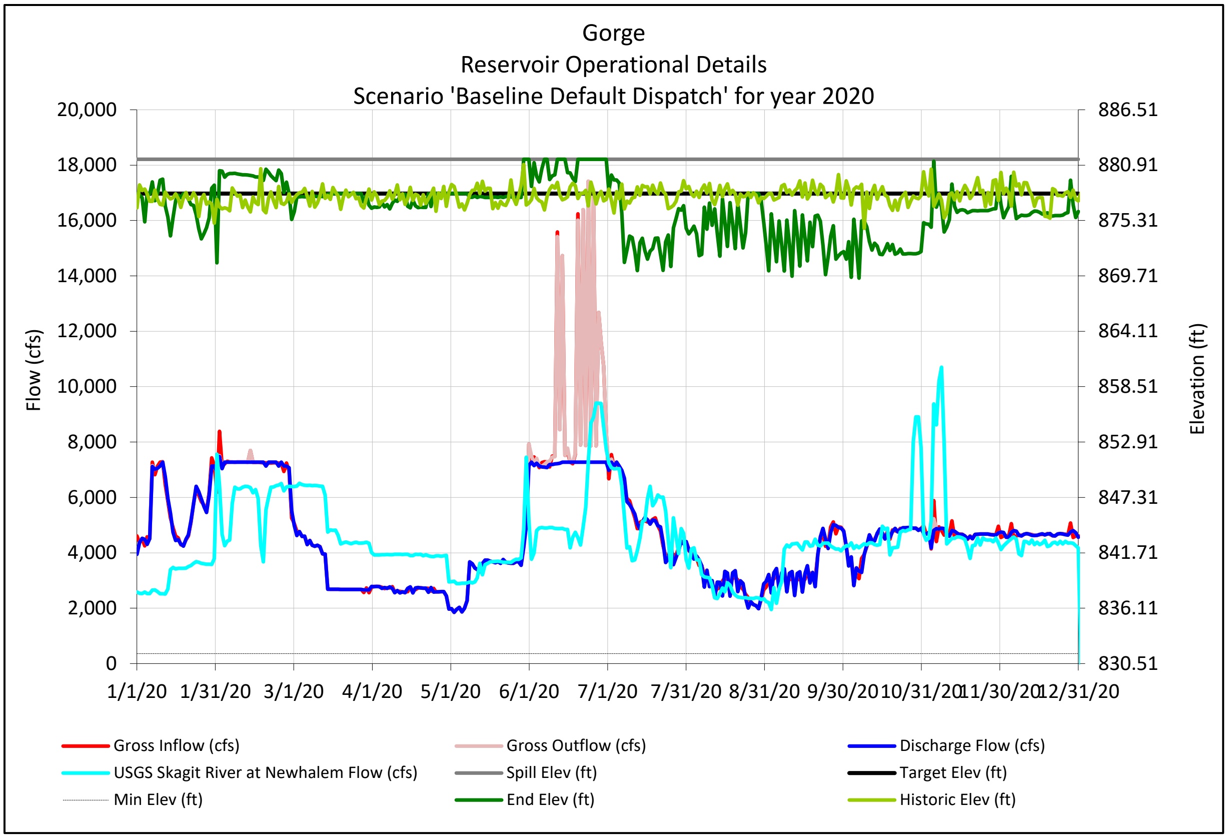
Ross
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2019
Flow (cfs)
Elevation (ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
1613.76
1591.43
1569.09
1546.76
1524.43
1502.09
1479.76
1/1/19 1/31/19 3/2/19 4/2/19 5/2/19 6/2/19 7/2/19 8/1/19 9/1/19 10/1/19 11/1/19 12/1/19
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)


Diablo
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2019
Flow (cfs)
Elevation (ft)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1212.00
1210.92
1209.84
1208.76
1207.68
1206.60
1205.52
1204.44
1203.36
1/1/19
1/31/19
3/2/19
4/2/19
5/2/19
6/2/19
7/2/19
8/1/19
9/1/19
10/1/19
11/1/19
12/1/19
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)


Gorge
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2019
Flow (cfs)
Elevation (ft)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
886.51
880.23
873.96
867.68
861.40
855.13
848.85
842.57
836.30
830.02
1/1/19
1/31/19
3/2/19
4/2/19
5/2/19
6/2/19
7/2/19
8/1/19
9/1/19
10/1/19
11/1/19
12/1/19
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)


Ross
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2020
Flow (cfs)
Elevation (ft)
25,000
20,000
15,000
10,000
5,000
0
1613.76
1586.96
1560.16
1533.36
1506.56
1479.76
1/1/20
1/31/20
3/1/20
4/1/20
5/1/20
6/1/20
7/1/20
7/31/20
8/31/20
9/30/20
10/31/20
11/30/20
12/31/20
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)


Diablo
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2020
Flow (cfs)
Elevation (ft)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1212.00
1210.88
1209.77
1208.65
1207.53
1206.42
1205.30
1204.18
1203.06
1201.95
1/1/20
1/31/20
3/1/20
4/1/20
5/1/20
6/1/20
7/1/20
7/31/20
8/31/20
9/30/20
10/31/20
11/30/20
12/31/20
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)


Gorge
Reservoir Operational Details
Scenario 'Baseline Default Dispatch' for year 2020
Flow (cfs)
Elevation (ft)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
886.51
880.91
875.31
869.71
864.11
858.51
852.91
847.31
841.71
836.11
830.51
1/1/20
1/31/20
3/1/20
4/1/20
5/1/20
6/1/20
7/1/20
7/31/20
8/31/20
9/30/20
10/31/20
11/30/20
12/31/20
Gross Inflow (cfs)
Gross Outflow (cfs)
Discharge Flow (cfs)
USGS Skagit River at Newhalem Flow (cfs)
Spill Elev (ft)
Target Elev (ft)
Min Elev (ft)
End Elev (ft)
Historic Elev (ft)