

**SACRAMENTO MUNICIPAL UTILITY DISTRICT
UPPER AMERICAN RIVER PROJECT
(FERC NO. 2101)**

**WATER BALANCE MODEL
TECHNICAL REPORT**

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EXECUTIVE SUMMARY

This report describes the computer program used to model the operation of the Upper American River Project (UARP) and the Chili Bar Project. The Water Balance Model for the UARP and Chili Bar Project is based on a commercial deterministic model that was customized by SMUD specifically for this purpose.

The Water Balance Model is a planning tool that uses the historical hydrologic record and the operational characteristics of the reservoirs, powerhouses, and other facilities to define and assess the typical operation of the UARP and Chili Bar Project from 1975 to 2001 and the proposed operation of the Iowa Hill Development. This makes the model well suited to analyze questions about monthly, seasonal, or inter-annual operation of the project. For example, the Water Balance Model can evaluate the feasibility of maintaining carryover storage targets at Union Valley, estimate monthly on-peak energy generation, and compare annual energy production for multiple flow regime proposals.

Pacific Gas & Electric's (PG&E) participation in the model development process has been limited to primarily the Chili Bar Project portion of the model. PG&E's participation in the UARP's Water Balance Model Subcommittee does not constitute acceptance or agreement of model results with respect to any contractual agreements between SMUD and PG&E.

The program requires extensive input data. This document describes energy demand periods, facility characteristics, operating practices, and details the values of many of the parameters that were used in the so-called Base Cases. The parameters are listed in an appendix to this report, and can be cross-referenced with other reports that include more detailed listings of program inputs.

1.0 INTRODUCTION

Sacramento Municipal Utility District (SMUD) owns and operates the Upper American River Project (UARP), which is located on South Fork of the American River, Silver Creek, and branches of the Rubicon River. Pacific Gas and Electric Company (PG&E) owns and operates the Chili Bar Project, which is located on South Fork of the American River immediately downstream of the UARP.

Under contract with SMUD, Devine Tarbell & Associates' (DTA) adapted their CHEOPS™ (Computerized Hydroelectric Operations Planning Software) Water Balance Model computer program to model the operations of the UARP and Chili Bar Project. SMUD and PG&E entered into a trilateral contract with DTA as the primary means of incorporating Chili Bar Project parameters into the Water Balance Model.

This document describes the Water Balance Model, including data input and model computations. A detailed listing of all input data is provided in Appendix A. A description of the model configuration and solution algorithm is provided in Appendix B.

1.1 Overview of Water Balance Model

The Water Balance Model takes as input hydrologic data and operating parameters. The hydrologic data consist of mean daily inflow to each of the UARP and Chili Bar Project reservoirs. The operating parameters include details of data summarized in this document, including powerhouse characteristics and reservoir physical and operational limits. The model simulates the real-world operation of the hydraulic features of the UARP, constrained by these inputs. The simulation focuses on water allocation and flow; energy generation is an output and not explicitly constrained by system load.

The model was developed to operate over a 26-year-long period of record from 1975 through 2000, based on the recommendation of the UARP relicensing process Water Balance Subcommittee. This period of record covers a variety of different water year types from the back-to-back very dry water years of 1976 and 1977 to very wet water years in the late 1990s.

To simulate UARP operation, the Water Balance Model steps sequentially through each day in the period of record. It allocates water through tunnels and powerhouses each day, and then shapes the daily volume in 15-minute increments according to the operating parameters. The output consists of time series of flow, reservoir storage, and energy generated at each location in the UARP and in the Chili Bar Project.

PG&E's participation in the model development process has been limited to primarily the Chili Bar Project portion of the model. PG&E's participation in the UARP's Water Balance Model Subcommittee does not constitute acceptance or agreement of model results with respect to any contractual agreements between SMUD and PG&E.

1.2 Base Case Specification

This document includes a description of the existing projects, operated within the constraints of the current licenses. This is called the *base case*.

Two separate base cases area specified in the model to deal with the two alternatives considered by SMUD in its License Application for the UARP:

1. The existing UARP and Chili Bar Project (“UARP/CB-Only Base Case”).
2. The existing projects with the addition of the Iowa Hill Development proposed by SMUD (“UARP/CB with Iowa Hill Base Case”).

This document describes both base cases. All project features except inclusion of Iowa Hill Development are identical in both.

2.0 OVERARCHING CONSTRAINTS

This section describes the general constraints incorporated into the Water Balance Model. The Water Balance Model employs logic that attempts to represent the considerations made in the day-to-day operation of the projects. Because no planning model can capture the diverse circumstances and dynamic real-time operating conditions of the projects, the Water Balance Model is designed to model their long term operation. This depiction is forward-looking and does not reflect historical operations.

2.1 Physical Operation Constraints

2.1.1 Existing UARP and Chili Bar

The Water Balance Model utilizes the following information for each reservoir and powerhouse in the model:

- Storage-elevation relationship
- Area-elevation relationship
- Evaporation rate
- Spillway flow-elevation relationship, with and without flashboards
- Tunnel flow-head relationship
- Powerhouse head loss, turbine performance, and generator performance

Subsequent to the publication of the Initial Information Package and First Stage Consultation documents, numerous detailed analyses conducted during the relicensing process resulted in updates to this information. The data shown in the tables in Appendix A reflect the operational and physical constraints built into the Water Balance Model base case.

2.1.2 Iowa Hill Development

Iowa Hill Development is a proposed project that consists of a pumping/generation powerhouse adjacent to Slab Creek Reservoir and a 6,500 ac-ft reservoir. There are three individually dispatched units. Data for Iowa Hill Development are presented in Appendix A, Line 67. Because this project is in the conceptual design stage, these data may change.

2.2 Daily Operation Constraints

SMUD’s operation of the UARP is guided by several factors. These include: 1) following power demand and control-area regulation and reliability requirements; 2) meeting FERC license requirements; and 3) meeting dam safety requirements.

PG&E’s operation of Chili Bar Reservoir is guided by the need to meet FERC license requirements and dam safety requirements. When possible, operations also follow power demand.

In the model, flows through UARP and Chili Bar Project powerhouses and reservoirs are scheduled on an hourly basis. Discharge and powerhouse operations are evaluated on a 15-minute basis. The various powerhouses in the UARP and Chili Bar Project are used to fulfill different needs (Table 2.2-1).

Table 2.2-1. Summary of powerhouse operation modes.		
Powerhouse	Operational Mode	Notes
Loon Lake, Jones Fork, Jaybird, Camino, White Rock, Union Valley	Peaking	These are generally operated in a true peaking mode, with limited constraints on minimum powerhouse flows and sufficient storage for daily and weekly peaking cycles.
Robbs Peak	Run-of-the-river	The Gerle Creek–Robbs Peak system has only nominal storage. Robbs Peak Powerhouse provides significant peaking power benefits, as its primary inflow during most of the year is the Loon Lake Powerhouse discharge.
Chili Bar	Peaking Hourly schedule Ramping rates	Generation may be shifted away from the assumed load curve to accommodate whitewater boating and ramping rate restrictions.
Iowa Hill	Hourly schedule	Pump/generation units operated to fulfill two purposes: (1) pump off-peak and generate on-peak; and (2) generate as needed to support regulation and reliability.

In actual practice, the operation of the UARP and the Chili Bar Project is constantly reacting to changes in hydrology, customer demand, system needs and energy market conditions. However, the UARP and the Chili Bar Project operate within an envelope of over-arching objectives and constraints that have evolved over time. These are:

- Load Shape
- Preferred Reservoir Storage Objectives

- Monthly Energy Reliability Objective
- Operating Reserve
- Minimum Reservoir Releases
- Maintenance and Ramping
- Hydrology

These objectives and constraints are described in the sections that follow.

2.2.1 Load Shape

The Water Balance Model uses a daily volume of water to generate power according to an hourly schedule. The power demand (“load”) varies substantially during the different hours of the day. The Water Balance Model distributes the daily generation among the hours of the day to prioritize power production when the load is greatest (“peak” hours). Some additional generation is modeled during off-peak hours to provide system regulation.

Each day is defined as 24 hours beginning at midnight (the hour ending at 1:00 AM, designated HE01) to midnight (the hour ending at midnight, designated HE24). Moreover, the demand for power is markedly different on weekdays compared to weekends.

As depicted in the Figure 2.2-1, the load shape varies by day of the week:

- For weekdays, shown on the lower half of the figure, Monday through Saturday, the load shape depicts a peak demand period from HE07 through HE22. Energy production is further prioritized to the period including HE15 through HE20.
- On Sundays, energy production is prioritized during a peak period that occurs from HE09 through HE22.

The depiction shown in Figure 2.2-1 is an example. Line 3 in Appendix A shows the load shape for each month that was used in the Water Balance Model.

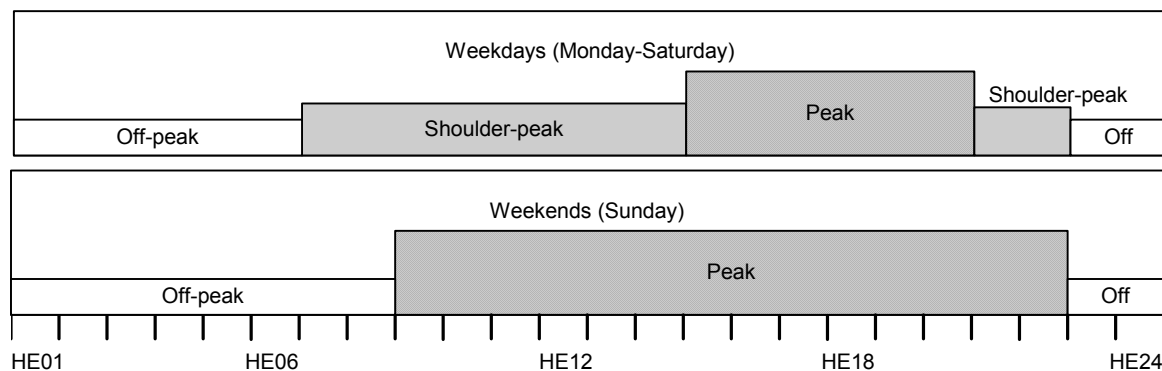


Figure 2.2.1-1. Example load shapes for weekdays and for weekends.

At every 1-day time step, the program allocates a volume of water. Then, with this daily volume:

- The program first allocates water for non-generation objectives uniformly among the hours of the day.
- The remaining water is available for generation. The program allocates his daily volume among the hours of the day using the load shape to maximize the amount of on-peak generation.
- The program will first allocate water to hours in the peak periods. If shoulder peak periods are identified, it allocates water to those periods next.
- Finally, it allocates any remaining water volume, to the hours in the off-peak periods.

The efficiency with which powerhouses generate power varies with the rate of flow. The Water Balance Model attempts to operate the turbines at or near peak efficiency. It optimizes generation by distributing the water in 15-minute intervals. This is done starting in the last hour of each of the periods mentioned, then working backward to earlier hours in the period.

2.2.2 Preferred Reservoir Storage Objectives

Typical of mixed-elevation Sierra Nevada watersheds, the pattern of natural runoff to UARP and Chili Bar Project reservoirs is shaped by a combination of rainfall and snowmelt. The significant precipitation season occurs between November and April, and typically occurs as rainfall in lower elevations and snow in upper elevations.

Rainfall runoff occurs during rainfall events while accumulated snow typically runs off during the spring and early summer, April through July. During the summer and early fall natural runoff is minimal, and often zero at the higher elevations.

Three UARP reservoirs (Loon Lake, Ice House, and Union Valley) are operated to store water during the winter and spring and release it for power generation during the summer and fall.

In actual practice, the selection and application of reservoir storage objectives during the course of a year requires the anticipation of future runoff within the year. In the Water Balance Model, the preferred reservoir storage objectives guide the program to draw down reservoir storage during the summer and to maintain storage during the winter and spring, in anticipation of a dry year. This provides:

- **Spill avoidance:** the preferred reservoir storage objectives provide sufficient available reservoir space to regulate runoff with generation capability and avoid spill during the winter and spring.
- **Carry over storage:** the preferred reservoir storage objectives guide the use of stored water for generation during the summer to meet system needs while also drawing down the reservoirs for the subsequent year's runoff.

The preferred reservoir storage objectives are modeled as sets of reservoir elevations that serve as operating targets. At each point in the simulation, each reservoir elevation target is determined by the snowmelt runoff expected and the season within the year. In actual operation of the UARP, these elevations are fine tuned throughout the developing water year as runoff forecasts are updated and electricity needs unfold as a function of summer conditions, primarily air temperatures in Sacramento.

These preferred reservoir storage curves were developed through the testing and review of multiple iterations of the model, through events that have occurred, with an attempt made to balance the criteria of spill avoidance and seasonal carry over of reservoir storage. They are represented as a set of daily elevation values, one for each reservoir and wetness index. The program uses these sets of reservoir elevations as a form of constraints that are considered when arriving at a simulated operation for a year.

During development of the Water Balance Model, the elevations were adjusted until they resulted in a simulated operation that efficiently manages the reservoirs (reasonably avoids spills) while also reasonably capturing runoff into storage for the summer season.

Five sets of preferred reservoir storage objectives were defined for each of the three major reservoirs (Loon Lake, Ice House and Union Valley). They are plotted in Figures 2.2.2-1 through 2.2.2-3, and tabulated in Appendix A, Lines 12, 26, and 32.

The choice of which of the five sets to use for a particular water year is made using a “wetness index” equal to an anticipated runoff condition for the basin. This index is the April-July unimpaired runoff at American River at Fair Oaks gage as computed by the Snow Surveys section of California Department of Water Resources (DWR). This is equivalent to the computed natural inflow to Folsom Reservoir. It is a value expressed as a water volume in units of thousands of acre-feet (TAF). Table 2.2.2-1 illustrates the range of unimpaired runoff associated with each preferred reservoir storage objective year type. It is important to note that this index is different from the criterion used to determine minimum flow releases as described later in Table 2.2.2-4.

Table 2.2.2-1. Preferred reservoir storage objective wetness index designations and range of applicability.	
Designation in Water Balance Model	Minimum index value (TAF)
A	0
B	500
C	1,000
D	1,500
E	2,000

The program establishes the wetness index in October of a water year and it remains unchanged during the remainder of the water year.

The objectives are consistent with the conditions stated on the DWR Division of Safety of Dams (DSOD) dam certificates.

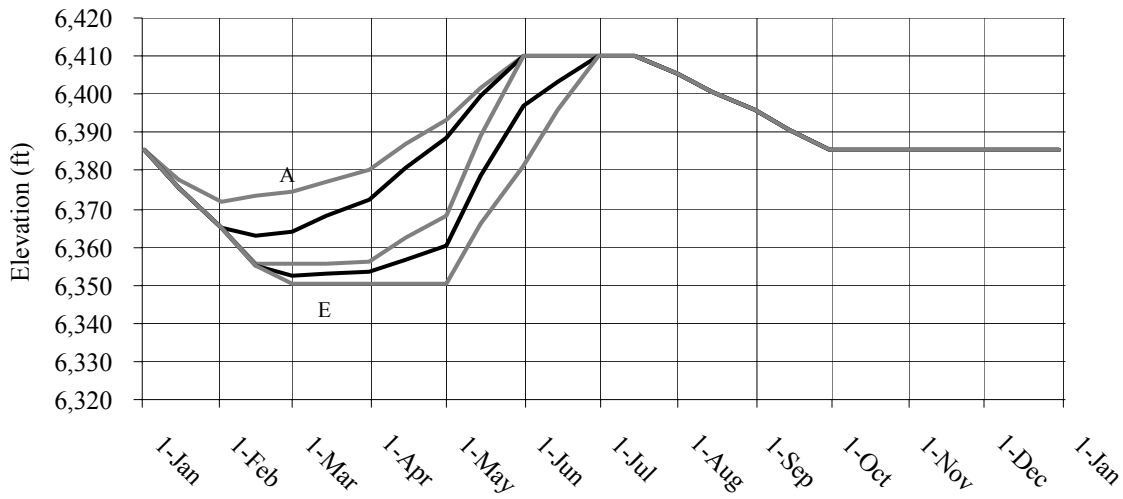


Figure 2.2.2-1. Loon Lake Reservoir preferred storage objective.

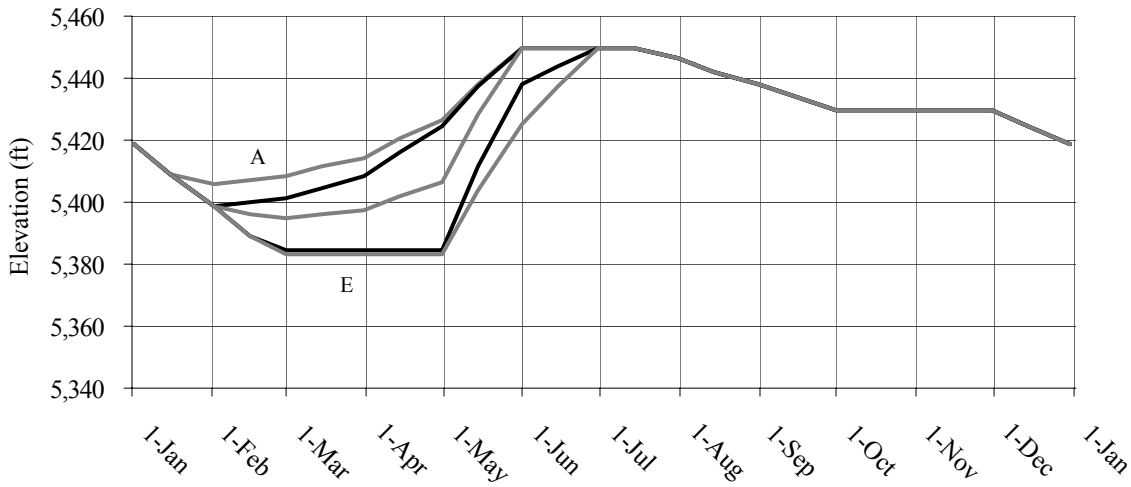


Figure 2.2.2-2. Ice House Reservoir preferred storage objective.

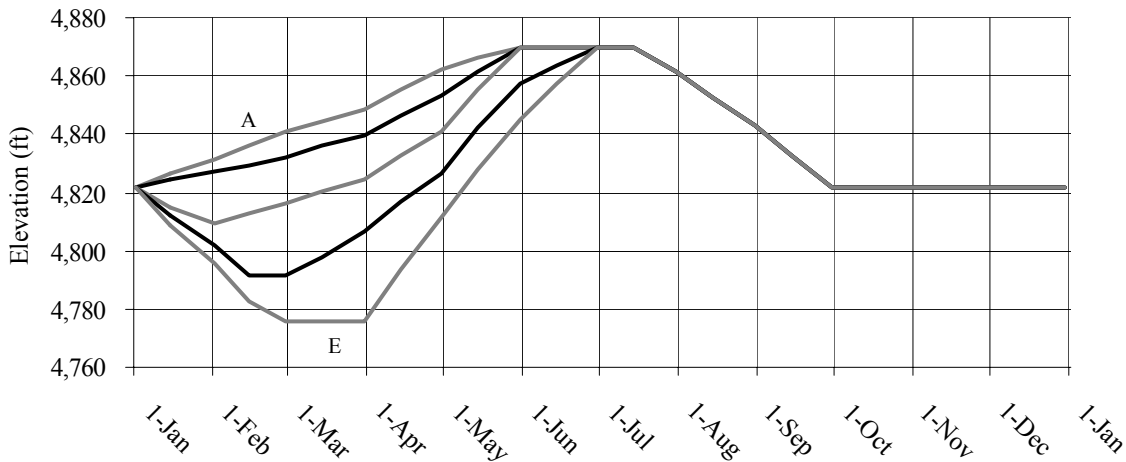


Figure 2.2.2-3. Union Valley Reservoir preferred storage objective.

2.2.3 Monthly Energy Reliability Objective

The monthly energy reliability objective guides the Water Balance Model to manage water to generate at least the minimum amount of energy needed meet system regulation and reliability needs.

The monthly energy reliability objective defines an amount of minimum monthly generation from the project that will be produced. In actual project operation and system planning, this generation is anticipated to be that amount minimally required by the UARP to meet control area needs. Control area needs are mandated external to SMUD and include the instantaneous balancing of loads and resources, ramping to follow load, and stabilizing the variability in other resources such as solar and wind projects.

However, a “minimum” generation objective provides only limited guidance for the management of reservoir storage. Great flexibility exists in utilizing stored water from the UARP:

- UARP reservoirs could be heavily drawn upon during a season or a year at the expense of having stored water available in subsequent periods.
- Stored water could be retained in anticipation of a prolonged drought.

To guide the management of its resource, SMUD developed a planning principle for the UARP that recognizes the value of assuring the availability of UARP generation during drought. The underpinning of this principle a generation plan that does not impair the UARP’s ability to provide a minimum sustained generation during a recurrence of the worst drought of record.

The monthly energy reliability objective has been modeled to accomplish two goals of long-term operation planning:

1. **Reliability and demand.** In a year when the preferred reservoir storage objectives result in insufficient generation to meet reliability and demand needs, the monthly energy reliability objective will call for additional generation. Additional water from Union Valley, Loon Lake, and Ice House reservoirs will be drawn to generate more power.
2. **Drought protection.** In general, achieving the first goal will draw reservoirs down below the preferred reservoir storage objectives. The monthly energy reliability objective values were established by a review of historical operations. They were adjusted and simulated until the monthly energy reliability objective was achieved every year of the simulation including the worst drought in the period of record.

For modeling purposes, the energy reliability objective is expressed in terms of power releases from Union Valley Reservoir. These releases are given in Appendix A, Line 2.

This volume of water for power generation will be allocated as follows:

1. When the energy reliability objective controls the release from Union Valley Reservoir, part of the incremental volume will be released during the on-peak period. The on-peak fraction can vary by month and is listed in Appendix A, Line 2.
2. All of the water needed to meet the energy reliability objective will be drawn from Union Valley Reservoir except when its usable capacity falls below 25%. Usable capacity is defined as the water volume between flood elevation and minimum elevation.
3. If sufficient water is not available from Union Valley Reservoir, additional water will be drawn from Ice House Reservoir and Loon Lake into Union Valley Reservoir to provide sufficient water for the release. The relative contribution of these two reservoirs is shown in Table 2.2.3-1.

Reservoir	Apportionment (percent)
Ice House Reservoir	40
Loon Lake Reservoir	60

2.2.4 Operating Reserve

SMUD’s status as a control area requires it to maintain operating reserve or “spinning reserve” based on its load, generation, and transmission resources. SMUD normally obtains about half of its system operating reserve from the UARP during the summer, and all of its operating reserve from the UARP during the winter.

For the base case models, the operating reserve requirement is labeled as spinning reserve, as shown in Line 2 of Appendix A. A separate value is provided for each of the UARP reservoirs. The model uses this capacity to avoid spill during periods such as large-runoff storm events.

2.2.5 Minimum Reservoir Releases

The Water Balance Model includes the existing FERC license conditions for minimum flow releases at all UARP reservoirs and at Chili Bar Reservoir. These requirements are shown for each reservoir in Appendix A under the Bypass Flows and Minimum Flows tables. The flow requirements at several dams are uniform across water year types. At other locations the flow requirements vary by water year type. For these locations, up to four different release schedules can occur associated with four water year types. The index for the water year is the forecasted unimpaired runoff at the Fair Oaks gage on the American River as published by the California Department of Water Resources (DWR) in Bulletin 120. This runoff is essentially equivalent to the basin inflow to Folsom Lake. The four classifications are listed in Table 2.2.5-1.

Common designation	Designation in Water Balance Model	Minimum threshold TAF
Water year type 1	A	0
Water year type 2	B	1000
Water year type 3	C	1500
Water year type 4	D	2000

It is important to note that this index is different from the criterion used to determine the preferred storage objective, described in Table 2.2.2-1. The Water Balance Model is capable of handling five water year types. The model was configured to allow five water year types because the Water Balance Subcommittee of the UARP relicensing process determined that five water year types were more appropriate for the operation of the UARP.

The unimpaired runoff forecast is published by DWR at various times of the year. For many of the locations where minimum stream flow requirements are identified, the April 1 forecast is used to identify the schedule of flows to be implemented during April for the ensuing twelve months. At other locations, either an earlier forecast initiates the current year’s schedule or a subsequent forecast updates the current year’s schedule. Entries of an “X” in Table 2.2.5-2 designate when these forecast updates apply. The model uses these criteria to adjust minimum releases over different water year types and different months within a given water year.

Location	March update	April update	May update
Rubicon Reservoir		X	
Buck Island Reservoir		X	
Loon Lake Reservoir		X	
Gerle Creek Reservoir		X	
Robbs Peak Reservoir		X	
Ice House Reservoir		X	X
Union Valley Reservoir		X	
Junction Reservoir		X	
Camino Reservoir		X	
Brush Creek Reservoir	X	X	X
Slab Creek Reservoir	X	X	X
Chili Bar Reservoir		X	

2.2.6 Maintenance and Ramping

Two additional operational constraints are imposed on certain powerhouses within the model. Each powerhouse is typically taken out of service for a period of weeks in the autumn. Also, there are regulatory restrictions on certain powerhouse’s discharge rate of change. The program enforces this through ramping rate restrictions, which can vary during each year.

Maintenance schedules and ramping rate restrictions are specified in Appendix A under the headings for each reservoir with an associated powerhouse.

2.2.7 Hydrology

Rainfall and snowmelt supply water to each of the reservoirs in the UARP and to Chili Bar Reservoir. This information is specified in the Water Balance Model in the form of daily time series of flow. Each reservoir has a time series that includes the sum of natural tributary stream flows, and local shoreline inflow, and accretions along each stream up leading to the next reservoir. The *Hydrology Technical Report* prepared for this relicensing describes how these values were developed for the period of record, 1975-2000. These values are used in the base case.

FERC Project 184 regulates flow along the South Fork American River upstream of the UARP. This regulation is included in the base case Slab Creek Reservoir inflow.

3.0 **SPECIFIC CONSTRAINTS**

3.1 **Slab Creek Powerhouse**

The 400 kW Slab Creek Powerhouse is part of the UARP but it is not in the Water Balance Model.

3.2 **Chili Bar Reservoir**

3.2.1 Scheduling Chili Bar Project Operations and Whitewater Boating Flows

Chili Bar Powerhouse is operated during times of peak power demand to the extent possible, dependent on the timing and quantity of water provided during White Rock Powerhouse operations. While peak power demands vary seasonally, the highest demands are typically between 4:00 PM and 10:00 PM.

Recent Chili Bar Project operations have reflected non-license, annual agreements between SMUD, PG&E, and whitewater boating interests. These operations have scheduled releases of approximately 1,200 cfs between 9 am and noon from Tuesday through Sunday to accommodate whitewater boating in the Reach Downstream of Chili Bar during normal and wet water years. Considerable volumes of water may also be released at other times of the day, but the timing of these other releases is based on unpredictable power demand. If recreational flow magnitudes and durations increase, the flexibility of SMUD and PG&E to meet variable power demand is believed to decrease. In wetter years, release magnitude and duration are generally larger and longer. In drier years, releases are generally smaller, more variable and less predictable.

3.2.2 Chili Bar Project Operation Restrictions

The existing license imposes a minimum streamflow requirement of 100 cfs, but 200 cfs is the low end of the operating range of Chili Bar Powerhouse. As inflow to Chili Bar Reservoir decreases, Chili Bar Powerhouse draft is reduced to 200 cfs to meet the reservoir target elevation of approximately 994 feet. This target elevation has been based on the need to retain adequate storage in the reservoir to maintain the base flow for several days if minimal inflow occurs.

Ramping restrictions in the current Chili Bar Project license require Chili Bar Powerhouse to take 2-3 hours to go from a base flow of 200 cfs to full flow and from full load to base flow.

3.3.3 Chili Bar Project Operation Modes

The hourly discharge pattern from Chili Bar Powerhouse is modeled to follow the load shape used with reservoirs in the UARP. Optionally, this schedule can be adjusted so that additional water is provided at times suitable for whitewater boating. To provide the daily volume to support the minimum instream flow or the whitewater boating flow, there are three modes of operation:

1. **Delinked mode.** There is no flow volume support from Slab Creek Reservoir for whitewater boating or for minimum flow requirements. Chili Bar Reservoir outflow is shaped for power demand and adjusted if possible to accommodate the whitewater boating demand.
2. **Linked mode.** Releases will be made from Slab Creek Reservoir the day before as needed to provide sufficient volume for minimum streamflow releases, if possible, but without reoperating the UARP upstream.
3. **Linked mode with raft flow support.** The volume of water in excess of incremental accretion that is required to support whitewater boating flows is discharged from Slab Creek Reservoir (if available) on the day prior to the whitewater boating flow.

Furthermore, the following options can be set:

- **Raft flow support up UARP option.** This option is available when the “linked with raft flow support” mode is selected. The volume of water, in excess of available storage in Slab Creek Reservoir and incremental accretion, which is required to support whitewater boating flows will be discharged from UARP reservoirs upstream of Slab Creek Reservoir on the day prior to the whitewater boating flow.
- **Spill prevention option.** This option is available when either the “linked” or “linked with raft flow support” mode is selected. White Rock Powerhouse discharge schedules may be reduced to avoid spills at Chili Bar Reservoir.

Calculation of a daily discharge from Chili Bar Reservoir is based upon inflow plus the change in storage. If a scenario is specified that includes whitewater boating flows, the volume is calculated and entered as a daily average requirement. If no whitewater boating flow is specified, the daily discharge is bounded by a minimum instantaneous flow limit (required minimum streamflow). These data are listed in Appendix A, Line 63.

3.3.4 Operation Mode Selected

For the base cases, the whitewater boating flow release schedule is as listed in Appendix A, Line 64. The reservoir is modeled in delinked mode.

In SMUD's analyses used for its license application, the reservoir is modeled in linked mode.

3.3.5 Computation of Inflow to Chili Bar Reservoir

The program calculates reservoir inflow based on White Rock Powerhouse discharge and Slab Creek bypass flow plus incremental accretion. Then:

- If **delinked** mode is selected, inflows are modified to calculate today's White Rock powerhouse discharge as an average of today's discharge and yesterday's discharge.
- If **linked** is selected, inflows are estimated and averaged based upon a forecast period of two days. The program checks calculated inflow and start-of-day elevation against storage criteria. Then:
- If **raft flow support** is selected, the program schedules sufficient White Rock Powerhouse draft to augment Slab Creek Reservoir instream release and accretion flow to meet the whitewater boating flow.
- If **raft flow support** is not selected, then if the sum of the usable storage and inflow volume is inadequate, the whitewater boating volume requirement may be abandoned, or the minimum discharge may be decreased below the desired minimum to the license-required minimum. These values are listed in Appendix A, Line 63.

3.3.6 Detailed Daily Scheduling

Detailed daily scheduling depends upon whitewater boating requirements.

- If a period to be scheduled is during a whitewater boating flow period and on a whitewater boating flow day, the program schedules a ramp up to the whitewater boating flow for the whitewater boating period duration. The program then schedules the remaining available volume during the peak power demand period.
- If the day is not during a whitewater boating flow period, the schedule is set for the peak demand power generation period.

Detailed reservoir elevations are calculated from inflow versus outflow during each day after referring to the starting day's storage and elevation, as follows:

- If **Spill Prevention** is selected, then White Rock Powerhouse draft will be rescheduled to attempt to modify total discharge to avoid the spill.
- If **Spill Prevention** is not selected, then if spill occurs and total discharge is below capacity, the program increases scheduled discharge and recalculates available volume.
- If a minimum elevation violation occurs, the program reduces total daily discharge down to no lower than minimum instantaneous flow, then reduces set generation to zero and continues to calculate inflow and reservoir storage.

UARP facility discharges are then scheduled as follows:

- If the program option **linked** is selected, then Chili Bar Project's bypass flows and minimum instantaneous flows (less incremental accretion) are built into the upstream reservoir's daily discharge volume up to Union Valley.
- If the option **raft support** is checked, tomorrow's whitewater boating flow volume, less Chili Bar incremental accretion, is set as a daily average requirement for White Rock's discharge for today.
- If **raft flow up UARP** is selected, then each reservoir from Union Valley to Slab Creek may be re-operated so that sufficient volume will be provided to deliver the next day's whitewater boating flows to Chili Bar Reservoir.

3.3 Iowa Hill Development

Iowa Hill Powerhouse is modeled with an hourly schedule that varies by the day of the week and the month of the year. Generally, the powerhouse would be operated to pump during off-peak hours and to generate during on-peak hours. The Water Balance Model can schedule this in one of two modes for each month of the year:

1. **Not linked.** Iowa Hill is scheduled as specified, independently of Slab Creek Reservoir and White Rock Powerhouse.
2. **Linked.** Iowa Hill and Slab Creek Reservoir are evaluated conjunctively.

For the UARP with Iowa Hill Base Case, the linked option is specified. This means that the program will operate these reservoirs conjunctively.

The hourly schedule modeled for the base case is a weekly pattern that varies by month. It is specified in Appendix A, Lines 70-72.

APPENDIX A

WATER BALANCE MODEL INPUT

- System Settings
- Rubicon Reservoir
- Buck Island Reservoir
- Loon Lake Reservoir
- Gerle Creek Reservoir
- Robbs Peak Reservoir
- Ice House Reservoir
- Union Valley Reservoir
- Junction Reservoir
- Camino Reservoir
- Brush Creek Reservoir
- Slab Creek Reservoir
- Chili Bar Reservoir (Pacific Gas and Electric Co.)
- Iowa Hill Development
- Addenda

APPENDIX A

WATER BALANCE MODEL INPUT

The tables in this appendix summarize the inputs to the Water Balance Model for the two base cases. The UARP/CB-only base case includes operational features that deal with all UARP developments and Chili Bar Project but not including the Iowa Hill Development. The UARP/CB + Iowa Hill base case includes all input data provided in this appendix for UARP, Chili Bar Project, and the proposed Iowa Hill Development.

Due to their quantity, the individual tables are not numbered. Instead, line numbers have been included along the left margin. The line numbers here correspond to line numbers in the input data report. A program external to the Water Balance Model generates this report.

Several of the tables are listed in abridged form at their proper line number. This is indicated with a notation at the bottom of the table. The full content of such tables is listed in the Addenda, at the bottom of this Appendix.

System settings

1	<u>System settings</u>	<u>General options</u>	<u>Summary of plant settings</u>			
	Name: HRBC5RCNOFORS	Carry over elevations: Yes	Reservoir	Physical	Operational	Generating
	Desc: mah14jan04	Forecast nbr of days: 2	Rubicon	HRBC	HRBC	Base Case
	<u>Water year type profile</u>	Forecast accuracy: 1	Buck Island	HRBC	HRBC	Base Case
	Name: Base Case	<u>Hydrology</u>	Loon Lake	HRBC	HRBC	Base Case
	Filename:	Filename: inflow.dat	Gerle Creek	HRBC	HRBC	Base Case
	WaterYearTypes1.xls	Size: 1207.4 kB (1236426 bytes)	Robbs Peak	HRBC	HRBC	HRBC
	Modified: 16-Jan-04 13:54	Modified: 18-Mar-04	Ice House	HRBC	HRBC	HRBC
	Preferred Storage Obj. Name: BasecaseSmooth	09:26	Union Valley	HRBC	HRBC	HRBC
	Filename: RCBasecase.xls	Tagline:	Junction	HRBC-1	HRBC	HRBC
	Modified: 17-Jun-04 15:20		Camino	HRBC	HRBC	HRBC
			Brush Creek	HRBC	HRBC	Base Case
			Slab Creek	HRBC	HRBC	HRBC
			Chili Bar	Base Case	Base Case	HRBC
			Iowa Hill	Base Case Generating	Dommer1	Base Case

2	<u>Energy Reliability Objective (HRBC)</u>	<u>Spinning Reserve (HRBC)</u>			
	Month	Vol, af	Peak	Plant	Reserve, MW
	Jan	19500	0.95	Loon Lake	2
	Feb	5000	0.95	Robbs Peak	0
	Mar	5000	0.95	Jones Fork	0
	Apr	5000	0.95	Union Valley	0
	May	5000	0.95	Jaybird	28
	Jun	25000	0.95	Camino	50
	Jul	25000	0.95	White Rock	28
	Aug	25000	0.95		
	Sep	19500	0.95		
	Oct	19500	0.95		
	Nov	19500	0.95		
	Dec	19500	0.95		

3 Monthly load shape, durations in hours beginning 0000 (HRBC6x16Super) 6x16 with 6 hour of super peak every month

January	Off	Sec	Pri	Sec	Off	Pri	Sec	Off	July	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2	Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2	Weekend	8		14		0		0	2
February	Off	Sec	Pri	Sec	Off	Pri	Sec	Off	August	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2	Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2	Weekend	8		14		0		0	2
March	Off	Sec	Pri	Sec	Off	Pri	Sec	Off	September	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2	Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2	Weekend	8		14		0		0	2
April	Off	Sec	Pri	Sec	Off	Pri	Sec	Off	October	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2	Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2	Weekend	8		14		0		0	2
May	Off	Sec	Pri	Sec	Off	Pri	Sec	Off	November	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2	Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2	Weekend	8		14		0		0	2
June	Off	Sec	Pri	Sec	Off	Pri	Sec	Off	December	Off	Sec	Pri	Sec	Off	Pri	Sec	Off
Weekday	6	8	6	2		0	0	2	Weekday	6	8	6	2		0	0	2
Weekend	8		14		0		0	2	Weekend	8		14		0		0	2

Rubicon Reservoir (1)

4	Storage (HRBC)		Area (HRBC)		Evaporation (HRBC)		Spillway (HRBC)		Tunnel/plant flow (HRBCnew)	
	Elev, ft	Vol, af	Elev, ft	Area, ac	Mon	Evp, in/d	Elev, ft	Flow, cfs	Elev, ft	Flow, cfs
	6550.0	2016	6550.0	122.0	Jan	0.000	6552.0	43775.0	6546.0	910.0
	6549.0	1894	6548.0	116.0	Feb	0.000	6551.0	32731.0	6545.1	819.7
	6548.0	1774	6546.0	110.0	Mar	0.065	6550.0	24533.0	6544.3	741.9
	6546.0	1545	6544.0	103.0	Apr	0.095	6548.2	12125.0	6543.4	657.4
	6545.0	1435	6542.0	95.0	May	0.169	6548.1	11333.0	6542.6	585.1
	6544.0	1329	6540.0	87.0	Jun	0.197	6548.0	10737.0	6541.8	515.4
	6543.0	1226	6538.0	80.0	Jul	0.259	6547.8	9294.0	6541.4	481.1
	6542.0	1127	6536.0	72.0	Aug	0.242	6547.5	7922.0	6540.7	420.7
	6541.0	1032	6534.0	63.0	Sep	0.208	6547.3	6627.0	6540.1	371.1
	6540.0	940	6532.0	54.0	Oct	0.107	6547.0	5412.0	6539.4	316.2
	6539.0	853	6530.0	45.0	Nov	0.029	6546.8	4284.0	6538.8	271.6
	6538.0	769	6528.0	36.0	Dec	0.000	6546.5	3250.0	6538.2	229.5
	6537.0	689	6526.0	26.0			6546.3	2305.0	6537.4	174.9
	6535.0	541	6524.0	15.0			6546.0	1507.0	6536.9	143.4
	6533.2	425	6522.0	5.0			6545.8	818.2	6536.4	114.3
	6532.0	352	6520.0	0.0			6545.5	360.8	6535.7	77.2
	6530.0	248					6545.3	159.5	6535.3	58.2
	6527.0	127					6545.2	83.6	6534.7	33.0
	6525.0	71					6545.1	23.6	6534.3	18.6
	6522.0	24					6545.0	0.0	6533.9	6.2
	6520.0	19							6533.7	1.9
									6533.5	0.0

5	Node options		Flood elevations (Base Case)		Target elevations (HRBC)		Minimum elevations (Base Case)	
	Date	Elev, ft	Date	Elev, ft	Date	Elev, ft	Date	Elev, ft
	01-Jan	6545.0	01-Jan	6533.8	01-Jan	6533.0		
	31-Dec	6545.0	30-Apr	6533.8	31-Dec	6533.0		
			01-May	6539.2				
			09-May	6539.2				
			09-Sep	6539.2				
			10-Sep	6533.8				
			31-Dec	6533.8				

6	Bypass flows, cfs (HRBC)							Gate		Diversion with gate down	
	Date	A	B	C	D	E	Inflow	Setting name: HRBCnew	Elev, ft	Flow, cfs	
	01-Jan	6	6	6	6	0	Yes	Desc: Data from Randy 10-10-03	6545.4	681.2	
	01-Feb	6	6	6	6	0	Yes	Install: 1000 cfs	6545.2	642.4	
	01-Mar	6	6	6	6	0	Yes	Remove: 10-Sep	6544.8	579.9	
	01-Apr	6	6	6	6	0	Yes	Average days: 3	6544.4	518.4	
	01-May	6	6	6	6	0	Yes	Volume date: 22-Jul	6544.0	459.1	
	01-Jun	6	6	6	6	0	Yes	Volume remain: 2 taf	6543.6	401.9	
	01-Jul	6	6	6	6	0	Yes		6543.2	347.1	
	01-Aug	6	6	6	6	0	Yes		6542.8	294.7	
	01-Sep	6	6	6	6	0	Yes		6542.4	245.0	
	01-Oct	6	6	6	6	0	Yes		6542.0	198.2	
	01-Nov	6	6	6	6	0	Yes		6541.6	154.4	
	01-Dec	6	6	6	6	0	Yes		6541.3	123.8	
	31-Dec	6	6	6	6	0	Yes		6540.9	86.3	
									6540.5	53.3	
									6540.1	26.7	
									6539.7	7.9	
									6539.6	0.6	
									6539.5	0.0	

Buck Island Reservoir (2)

Storage (HRBC)		Area (HRBC)		Evaporation (HRBC)		Spillway (HRBC)		Tunnel/plant flow (HRBCnew)	
Elev, ft	Vol, af	Elev, ft	Area, ac	Mon	Evp, in/d	Elev, ft	Flow, cfs	Elev, ft	Flow, cfs
6446.0	1700	6446.0	114.0	Jan	0.000	6449.0	57283.0	6437.6	1160.0
6440.0	1400	6444.0	100.0	Feb	0.000	6447.0	41656.0	6437.0	1078.0
6436.0	1077	6440.0	86.0	Mar	0.065	6443.0	16834.0	6436.4	998.0
6432.0	808	6436.0	72.0	Apr	0.095	6441.0	9427.0	6435.8	919.0
6428.0	587	6432.0	60.0	May	0.169	6439.0	4147.0	6435.1	828.5
6425.0	450	6428.0	48.0	Jun	0.197	6438.8	3594.0	6434.5	752.6
6424.0	410	6424.0	38.0	Jul	0.259	6438.5	3068.0	6433.8	666.0
6420.0	272	6420.0	29.0	Aug	0.242	6438.3	2571.0	6433.2	593.7
6416.0	169	6416.0	21.0	Sep	0.208	6438.0	2105.0	6432.5	511.5
6412.0	95	6412.0	14.0	Oct	0.107	6437.8	1671.0	6431.8	432.0
6408.0	46	6408.0	9.0	Nov	0.029	6437.5	1273.0	6431.2	366.2
6404.0	17	6404.0	4.0	Dec	0.000	6437.3	915.0	6430.6	302.8
6400.0	4	6400.0	0.0			6437.0	580.0	6430.0	242.1
						6436.8	334.0	6429.4	184.5
						6436.5	152.0	6428.8	128.6
						6436.3	70.0	6428.2	71.7
						6436.2	37.0	6427.6	24.5
						6436.1	12.0	6427.0	0.1
						6436.0	0.0		

Note: Table abridged; full printout in addenda

Node options	Flood elevations (Base Case)		Target elevations (Base Case)		Minimum elevations (HRBC)	
Name: Base case	Date	Elev, ft	Date	Elev, ft	Date	Elev, ft
Min flow: 0 cfs	01-Jan	6436.0	01-Jan	6427.0	01-Jan	6424.5
Capacity: unlimited	31-Dec	6436.0	31-Mar	6427.0	31-Dec	6424.5
Op type: Diversion			01-Apr	6433.0		
			01-Oct	6433.0		
			02-Oct	6427.0		
			31-Dec	6427.0		

Bypass flows, cfs (HRBC)							Gate	Diversion with gate down	
Date	A	B	C	D	E	Inflow	Setting name: HRBCnew	Elev, ft	Flow, cfs
01-Jan	1	1	1	1	0	No	Desc: Data from Randy 10-10-03	6435.0	137.0
01-Feb	1	1	1	1	0	No	Install: 31-Dec	6434.9	126.5
01-Mar	1	1	1	1	0	No	Remove: 31-Dec	6434.8	116.7
01-Apr	1	1	1	1	0	No	Average days: 3	6434.7	107.5
01-May	1	1	1	1	0	No	Volume date: 31-Dec	6434.6	99.0
01-Jun	1	1	1	1	0	No	Volume remain: 0 taf	6434.5	91.0
01-Jul	1	1	1	1	0	No		6434.4	81.3
01-Aug	1	1	1	1	0	No		6434.3	72.5
01-Sep	1	1	1	1	0	No		6434.2	64.6
01-Oct	1	1	1	1	0	No		6434.1	57.4
01-Nov	1	1	1	1	0	No		6434.0	51.0
01-Dec	1	1	1	1	0	No		6433.9	43.8
31-Dec	1	1	1	1	0	No		6433.8	37.5
								6433.7	31.0
								6433.6	25.5
								6433.5	18.8
								6433.4	13.7
								6433.3	10.0
								6433.2	5.6
								6433.1	3.0
								6433.0	1.3
								6433.0	0.0

Loon Lake Reservoir (3)

Storage (HRBC)		Area (HRBC)		Evaporation (Base Case)		Spillway (HRBC)		Tailwater (Base Case)	
Elev, ft	Vol, af	Elev, ft	Area, ac	Mon	Evp, in/d	Elev, ft	Flow, cfs	Flow, cfs	Elev, ft
6430.0	97318	6420.0	1574.0	Jan	0.000	6418.0	15243.0	1	5270
6420.0	82646	6410.0	1419.0	Feb	0.000	6417.0	12476.0		
6410.0	69308	6400.0	1264.0	Mar	0.065	6416.0	9901.0		
6400.0	55970	6390.0	1124.0	Apr	0.095	6415.0	7532.0		
6390.0	44009	6380.0	992.0	May	0.169	6414.0	5389.0		
6380.0	33472	6370.0	863.0	Jun	0.197	6413.0	3500.0		
6370.0	24151	6360.0	712.0	Jul	0.259	6412.0	1905.0		
6360.0	16247	6350.0	567.0	Aug	0.242	6411.0	674.0		
6350.0	9856	6340.0	372.0	Sep	0.208	6410.0	0.0		
6340.0	5124	6330.0	176.0	Oct	0.107				
6330.0	2420	6320.0	90.0	Nov	0.029				
6325.5	0	6310.0	35.0	Dec	0.000				

Node options Name: Base Case Min flow: 0 cfs Capacity: 1178 cfs Op type: Strictly peaking	Flood elevations (Base Case)		Minimum elevations (HRBC)	
	Date	Elev, ft	Date	Elev, ft
	01-Jan	6410.0	01-Jan	6348.5
31-Dec	6410.0	31-Mar	6348.5	
		01-Apr	6335.0	
		31-Oct	6335.0	
		01-Dec	6348.5	
		31-Dec	6348.5	

Bypass flows, cfs (HRBC)							Preferred storage objective (elevation), ft (BasecaseSmooth)					
Date	A	B	C	D	E	Inflow	Day	A	B	C	D	E
01-Jan	8	8	8	8	0	No	Jan 01	6385.3	6385.3	6385.3	6385.3	6385.3
01-Feb	8	8	8	8	0	No	Jan 15	6377.5	6375.3	6375.3	6375.3	6375.3
01-Mar	8	8	8	8	0	No	Feb 01	6372.0	6365.3	6365.3	6365.3	6365.3
01-Apr	8	8	8	8	0	No	Feb 15	6373.2	6362.7	6355.5	6355.3	6355.3
01-May	8	8	8	8	0	No	Mar 01	6374.3	6364.0	6355.5	6352.3	6350.2
01-Jun	8	8	8	8	0	No	Mar 15	6377.3	6368.1	6355.5	6352.8	6350.2
01-Jul	8	8	8	8	0	No	Apr 01	6380.3	6372.2	6356.3	6353.3	6350.2
01-Aug	8	8	8	8	0	No	Apr 15	6386.8	6380.5	6362.2	6356.7	6350.2
01-Sep	8	8	8	8	0	No	May 01	6393.3	6388.8	6368.0	6360.1	6350.2
01-Oct	8	8	8	8	0	No	May 15	6401.7	6399.4	6389.0	6378.4	6365.8
01-Nov	8	8	8	8	0	No	Jun 01	6410.0	6410.0	6410.0	6396.8	6381.5
01-Dec	8	8	8	8	0	No	Jun 15	6410.0	6410.0	6410.0	6403.4	6395.7
31-Dec	8	8	8	8	0	No	Jul 01	6410.0	6410.0	6410.0	6410.0	6410.0
							Jul 15	6410.0	6410.0	6410.0	6410.0	6410.0
							Aug 01	6405.3	6405.3	6405.3	6405.3	6405.3
							Aug 15	6400.6	6400.6	6400.6	6400.6	6400.6
							Sep 01	6395.8	6395.8	6395.8	6395.8	6395.8
							Sep 15	6390.5	6390.5	6390.5	6390.5	6390.5
							Oct 01	6385.2	6385.2	6385.2	6385.2	6385.2
							Oct 15	6385.2	6385.2	6385.2	6385.2	6385.2
							Nov 01	6385.2	6385.2	6385.2	6385.2	6385.2
							Nov 15	6385.2	6385.2	6385.2	6385.2	6385.2
							Dec 01	6385.2	6385.2	6385.2	6385.2	6385.2
							Dec 15	6385.2	6385.2	6385.2	6385.2	6385.2
							Dec 31	6385.2	6385.2	6385.2	6385.2	6385.2

Sacramento Municipal Utility District
 Upper American River Project
 FERC Project No. 2101

13 Powerhouse settings summary - Loon Lake
 (Base Case)

				Maintenance (Maintenance)		Peak/max schedule (Peak All Year)	
Unit	Headloss	Generator	Turbine	Date	Units	Date	Setting
1	Base Case	Base Case U1	Base Case U1	01-Jan	0	01-Jan	1.00
				20-Sep	1	31-Dec	1.00
				30-Sep	0		
				31-Dec	0		

14 Head loss coefficients, ft/cfs²
 (Base Case)

					Generator performance, unit 1 (Base Case U1)		
Unit	Unit loss	Common loss	Max unit	Com2?	Output, MWh	Eff	Cap
1	0.000000000	0.000000000	1	No	1.0	1.00	80.0
					80.0	1.00	80.0

15 Turbine performance, unit 1
 (Base Case U1), Gate leakage: 0.0 cfs

Head 1060.0 ft		Head 1100.0 ft		Head 1115.0 ft		Head 1125.0 ft		Head 1140.0 ft	
Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
28.0	0.3982	28.0	0.3838	28.0	0.3786	28.0	0.3752	28.0	0.3703
67.0	0.4993	65.0	0.4959	65.0	0.4893	64.0	0.4925	64.0	0.4860
92.0	0.7272	90.0	0.7164	89.0	0.7147	88.0	0.7164	87.0	0.7151
246.0	0.8159	238.0	0.8127	235.0	0.8120	233.0	0.8117	230.0	0.8114
320.0	0.8363	310.0	0.8319	307.0	0.8287	304.0	0.8295	301.0	0.8267
344.0	0.8428	333.0	0.8390	329.0	0.8378	327.0	0.8354	323.0	0.8346
368.0	0.8484	356.0	0.8451	352.0	0.8433	350.0	0.8405	346.0	0.8391
551.0	0.8500	531.0	0.8499	523.0	0.8513	518.0	0.8519	511.0	0.8522
600.0	0.8549	580.0	0.8522	573.0	0.8510	569.0	0.8494	562.0	0.8487
624.0	0.8578	604.0	0.8539	596.0	0.8538	592.0	0.8519	585.0	0.8507
648.0	0.8604	627.0	0.8569	619.0	0.8563	614.0	0.8556	607.0	0.8541
675.0	0.8590	651.0	0.8583	643.0	0.8573	637.0	0.8577	630.0	0.8558
702.0	0.8578	675.0	0.8596	666.0	0.8595	660.0	0.8596	652.0	0.8587
811.0	0.8525	780.0	0.8541	769.0	0.8547	761.0	0.8560	751.0	0.8560
838.0	0.8516	806.0	0.8532	794.0	0.8545	787.0	0.8544	776.0	0.8551
866.0	0.8498	832.0	0.8524	820.0	0.8532	813.0	0.8529	801.0	0.8543
893.0	0.8491	858.0	0.8516	846.0	0.8521	838.0	0.8526	827.0	0.8525
920.0	0.8484	885.0	0.8499	872.0	0.8510	864.0	0.8512	852.0	0.8519
963.0	0.8479	974.5	0.8490	978.5	0.8495	982.0	0.8496	987.0	0.8498
1006.0	0.8474	1064.0	0.8481	1085.0	0.8481	1100.0	0.8480	1122.0	0.8477

Gerle Creek Reservoir (4)

16	Storage (HRBC)		Spillway (HRBC)		Tunnel/plant flow (HRBC)		Tailwater (Base Case)	
	Elev, ft	Vol, af	Elev, ft	Flow, cfs	Elev, ft	Flow, cfs	Flow, cfs	Elev, ft
	5253.0	3385	5246.0	55223.0	5246.0	1025.0	1	1
	5249.0	2494	5241.5	23696.0	5229.3	1025.0		
	5245.0	1876	5237.0	9379.0	5228.4	907.6		
	5237.0	1148	5235.0	4951.0	5227.5	786.7		
	5235.0	1035	5234.0	3084.0	5226.6	671.7		
	5230.0	784	5233.5	2255.0	5225.8	562.9		
	5225.0	564	5233.0	1487.0	5224.9	460.7		
	5220.0	383	5232.5	952.0	5224.0	365.6		
	5215.0	248	5232.0	438.0	5223.1	278.1		
	5210.0	143	5231.8	258.0	5222.3	199.0		
	5205.0	69	5231.5	130.0	5221.4	129.3		
	5200.0	25	5231.5	127.0	5220.5	70.4		
	5195.0	5	5231.3	71.0	5219.6	24.9		
	5190.0	0	5231.2	45.0	5218.8	0.0		
			5231.1	21.0				
			5231.0	0.0				

17	Node options Name: Base Case Min flow: 0 cfs Capacity: unlimited Op type: Non-generating	Flood elevations (Base Case)		Target elevations (Base Case)		Minimum elevations (Base Case)	
		Date	Elev, ft	Date	Elev, ft	Date	Elev, ft
		01-Jan	5231.0	01-Jan	5225.0	01-Jan	5219.0
		31-Dec	5231.0	31-Dec	5225.0	31-Dec	5219.0

18	Bypass flows, cfs (HRBC)						
	Date	A	B	C	D	E	Inflow
	01-Jan	4	4	4	4	0	No
	01-Feb	4	4	4	4	0	No
	01-Mar	4	4	4	4	0	No
	01-Apr	4	4	4	4	0	No
	01-May	4	4	7	7	0	No
	01-Jun	4	4	7	7	0	No
	01-Jul	4	4	7	7	0	No
	01-Aug	4	4	7	7	0	No
	01-Sep	4	4	7	7	0	No
	01-Oct	4	4	7	7	0	No
	01-Nov	4	4	4	4	0	No
	01-Dec	4	4	4	4	0	No
	31-Dec	4	4	4	4	0	No

Robbs Peak Reservoir (5)

19	Storage (HRBC)		Spillway (HRBC)		Tailwater (Base Case)	
	Elev, ft	Vol, af	Elev, ft	Flow, cfs	Flow, cfs	Elev, ft
	5247.0	860	5244.0	88206.0	1	4821
	5241.0	390	5242.0	70237.0		
	5232.0	148	5240.0	53846.0		
	5231.0	136	5238.0	39232.0		
	5230.0	123	5236.0	26717.0		
	5229.0	110	5234.0	17127.0		
	5228.0	98	5233.0	13953.0		
	5227.0	88	5232.0	11004.0		
	5226.0	78	5231.0	8298.0		
	5225.0	70	5230.0	5861.0		
	5224.0	61	5229.0	3725.0		
	5222.0	47	5228.0	1885.0		
	5220.0	35	5227.0	517.0		
	5218.0	26	5226.0	0.0		
	5216.0	20				
	5214.0	17				
	5206.0	11				

20	Node options		Flood elevations (Base Case)		Target elevations (HRBC)		Minimum elevations (Base Case)	
	Name: Base Case	Min flow: 0 cfs	Date	Elev, ft	Date	Elev, ft	Date	Elev, ft
	Capacity: 1250 cfs		01-Jan	5225.6	01-Jan	5225.6	01-Jan	5224.0
	Op type: Pure run of river		31-Dec	5225.6	31-May	5225.6	31-Dec	5224.0
					01-Jun	5230.0		
					27-Sep	5229.0		
					28-Sep	5228.0		
					29-Sep	5227.0		
					30-Sep	5226.0		
					01-Oct	5225.6		
					31-Dec	5225.6		

21	Bypass flows, cfs (HRBC)							Flashboards		Spillway with flashboards	
	Date	A	B	C	D	E	Inflow	Setting name: HRBC	Elev, ft	Flow, cfs	
	01-Jan	1	1	1	1	0	No	Desc: Developed from MAHs sheet	5246.0	84006.0	
	01-Feb	1	1	1	1	0	No	RobbsPeakSWRatinfMAH.xls	5244.0	66000.0	
	01-Mar	1	1	1	1	0	No	Install: 31-May	5242.0	49528.0	
	01-Apr	1	1	1	1	0	No	Remove: 01-Oct	5240.0	34753.0	
	01-May	1	1	3	3	0	No	Average days: 1	5238.0	21907.0	
	01-Jun	1	1	3	3	0	No	Volume date: 31-Dec	5236.0	11368.0	
	01-Jul	1	1	3	3	0	No	Volume remain: 0 taf	5234.0	4063.0	
	01-Aug	1	1	3	3	0	No		5233.0	2147.0	
	01-Sep	1	1	3	3	0	No		5232.0	667.0	
	01-Oct	1	1	3	3	0	No		5231.0	0.0	
	01-Nov	1	1	1	1	0	No				
	01-Dec	1	1	1	1	0	No				
	31-Dec	1	1	1	1	0	No				

22	Powerhouse settings summary - Robbs Peak (HRBC)				Maintenance (Maintenance)		Peak/max schedule (Peak All Year)	
	Unit	Headloss	Generator	Turbine	Date	Units	Date	Setting
	1	Base Case	Base Case U1	Base Case U1	01-Jan	0	01-Jan	1.00
					20-Sep	1	31-Dec	1.00
					30-Sep	0		
					31-Dec	0		

23	Head loss coefficients, ft/cfs ² (Base Case)					Generator performance, unit 1 (Base Case U1)		
	Unit	Unit loss	Common loss	Max unit	Com2?	Output, MWh	Eff	Cap
	1	5.6230e-005	0.000000000	1	No	1.0	1.00	26.0
						26.0	1.00	26.0

24	Turbine performance, unit 1 (Base Case U1), Gate leakage: 0.0 cfs									
	Head 275.0 ft		Head 310.0 ft		Head 340.0 ft		Head 370.0 ft		Head 400.0 ft	
	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
	97.0	0.2530	103.0	0.2530	107.9	0.2530	112.5	0.2530	117.0	0.2530
	131.0	0.4476	139.1	0.4476	145.7	0.4476	152.0	0.4476	158.0	0.4476
	179.1	0.5903	190.1	0.5903	199.1	0.5903	207.7	0.5903	216.0	0.5903
	290.2	0.6875	308.1	0.6875	322.7	0.6875	336.6	0.6875	350.0	0.6875
	401.3	0.7587	426.1	0.7587	446.2	0.7587	465.5	0.7587	484.0	0.7587
	446.1	0.7752	473.6	0.7752	496.0	0.7752	517.4	0.7752	538.0	0.7752
	509.1	0.8212	540.5	0.8212	566.1	0.8212	590.5	0.8212	614.0	0.8212
	562.2	0.8531	596.9	0.8531	625.1	0.8531	652.1	0.8531	678.0	0.8531
	611.9	0.8692	649.7	0.8692	680.4	0.8692	709.8	0.8692	738.0	0.8692
	688.2	0.8974	730.7	0.8974	765.2	0.8974	798.3	0.8974	830.0	0.8974
	801.8	0.8924	851.3	0.8924	891.5	0.8924	930.0	0.8924	967.0	0.8924
	917.9	0.9339	974.5	0.9339	1020.6	0.9339	1064.7	0.9339	1107.0	0.9339
	1195.6	0.9002	1269.4	0.9002	1329.5	0.9002	1386.9	0.9002	1442.0	0.9002

Ice House Reservoir (6)

25	Storage (HRBC)		Area (HRBC)		Evaporation (Base Case)		Spillway (HRBC)		Tailwater (Base Case)	
	Elev, ft	Vol, af	Elev, ft	Area, ac	Mon	Evp, in/d	Elev, ft	Flow, cfs	Flow, cfs	Elev, ft
	5480.0	65672	5460.0	732.0	Jan	0.000	5454.5	23827.0	1	4838
	5460.0	50024	5450.0	675.0	Feb	0.000	5453.5	21869.0		
	5450.0	43504	5440.0	618.0	Mar	0.022	5452.5	19968.0		
	5440.0	36984	5430.0	571.0	Apr	0.061	5451.5	18126.0		
	5430.0	31038	5420.0	526.0	May	0.111	5450.5	16344.0		
	5420.0	25551	5410.0	475.0	Jun	0.178	5450.0	15476.0		
	5410.0	20537	5400.0	426.0	Jul	0.215	5448.5	12970.0		
	5400.0	16026	5390.0	379.0	Aug	0.195	5446.5	9866.0		
	5390.0	12000	5380.0	330.0	Sep	0.138	5444.5	7060.0		
	5380.0	8439	5370.0	271.0	Oct	0.065	5442.5	4585.0		
	5370.0	5420	5360.0	200.0	Nov	0.016	5440.5	2496.0		
	5360.0	3053	5350.0	126.0	Dec	0.000	5438.5	882.0		
	5350.0	1407	5340.0	65.0			5436.5	0.0		
	5327.5	0	5330.0	18.0						

26	Node options	Flood elevations (HRBC)		Minimum elevations (Base Case)		Preferred storage objective (elevation), ft (BasecaseSmooth)					
	Name: Base Case	Date	Elev, ft	Date	Elev, ft	Day	A	B	C	D	E
	Min flow: 0 cfs	01-Jan	5436.6	01-Jan	5380.0	Jan 01	5418.9	5418.9	5418.9	5418.9	5418.9
	Capacity: 291 cfs	31-Mar	5436.6	31-Dec	5380.0	Jan 15	5408.9	5408.9	5408.9	5408.9	5408.9
	Op type: Strictly peaking	01-Apr	5436.6			Feb 01	5405.7	5398.9	5398.9	5398.9	5398.9
		02-Apr	5445.0			Feb 15	5407.0	5400.0	5396.3	5388.9	5388.9
		15-Apr	5445.0			Mar 01	5408.4	5401.3	5394.8	5384.4	5383.0
		16-Apr	5447.0			Mar 15	5411.3	5404.8	5396.0	5384.4	5383.0
		30-Apr	5450.0			Apr 01	5414.3	5408.4	5397.2	5384.4	5383.0
		31-Oct	5450.0			Apr 15	5420.4	5416.4	5401.9	5384.4	5383.0
		01-Nov	5450.0			May 01	5426.5	5424.5	5406.6	5384.4	5383.0
		02-Nov	5436.6			May 15	5438.2	5437.2	5428.3	5411.4	5404.2
		31-Dec	5436.6			Jun 01	5450.0	5450.0	5450.0	5438.3	5425.4
						Jun 15	5450.0	5450.0	5450.0	5444.2	5437.7
						Jul 01	5450.0	5450.0	5450.0	5450.0	5450.0
						Jul 15	5450.0	5450.0	5450.0	5450.0	5450.0
						Aug 01	5446.2	5446.2	5446.2	5446.2	5446.2
						Aug 15	5442.3	5442.3	5442.3	5442.3	5442.3
						Sep 01	5438.3	5438.3	5438.3	5438.3	5438.3
						Sep 15	5434.1	5434.1	5434.1	5434.1	5434.1
						Oct 01	5429.9	5429.9	5429.9	5429.9	5429.9
						Oct 15	5429.9	5429.9	5429.9	5429.9	5429.9
						Nov 01	5429.9	5429.9	5429.9	5429.9	5429.9
						Nov 15	5429.9	5429.9	5429.9	5429.9	5429.9
						Dec 01	5429.9	5429.9	5429.9	5429.9	5429.9
						Dec 15	5424.4	5424.4	5424.4	5424.4	5424.4
						Dec 31	5418.9	5418.9	5418.9	5418.9	5418.9

27	Bypass flows, cfs (HRBC)						<u>Flashboards</u>	Spillway with		Minimum mean daily release			
		<u>Date</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>	<u>Inflow</u>	<u>Setting name: HRBC</u>	<u>flashboards</u>	<u>Date</u>	<u>Flow, cfs</u>	<u>Inflow</u>
		01-Jan	5	5	3	3	0	No	Desc: to Simulate gate closure	<u>Elev, ft</u>	<u>Flow, cfs</u>		
		01-Feb	5	5	3	3	0	No	Install: 01-Apr	5454.5	2520.0	01-Jan	11 No
		01-Mar	5	5	3	3	0	No	Remove: 01-Nov	5453.5	1729.0	31-Mar	11 No
		01-Apr	5	5	3	3	0	No	Average days: 1	5452.5	1044.0	01-Apr	0 No
		01-May	5	5	8	8	0	No	Volume date: 31-Dec	5451.5	485.0	30-Nov	0 No
		01-Jun	5	5	8	8	0	No	Volume remain: 0 taf	5450.5	93.0	01-Dec	11 No
		01-Jul	5	5	15	15	0	No		5450.0	0.0	31-Dec	11 No
		01-Aug	5	5	15	15	0	No					
		01-Sep	5	5	15	15	0	No					
		01-Oct	5	5	12	12	0	No					
		01-Nov	5	5	10	10	0	No					
		16-Nov	5	5	4	4	0	No					
		01-Dec	5	5	4	4	0	No					
		31-Dec	5	5	4	4	0	No					

28	Powerhouse settings summary - Jones Fork (HRBC)				<u>Maintenance</u>	Peak/max schedule			
		<u>Unit</u>	<u>Headloss</u>	<u>Generator</u>	<u>Turbine</u>	<u>(Maintenance)</u>	<u>(Peak All Year)</u>		
		1	Base Case U1	Base Case	Base Case U1	<u>Date</u>	<u>Units</u>	<u>Date</u>	<u>Setting</u>
						01-Jan	0	01-Jan	1.00
						02-Oct	1	31-Dec	1.00
						12-Oct	0		
						31-Dec	0		

29	Head loss coefficients, ft/cfs ² (Base Case U1)					Generator performance, unit 1			
		<u>Unit</u>	<u>Unit loss</u>	<u>Common loss</u>	<u>Max unit</u>	<u>Com2?</u>	<u>Output, MWh</u>	<u>Eff</u>	<u>Cap</u>
		1	0.000538100	0.000000000	1	No	1.0	1.00	11.5
							11.5	1.00	11.5

30	Turbine performance, unit 1 (Base Case U1), Gate leakage: 0.0 cfs	Head 465.0 ft		Head 510.0 ft		Head 550.0 ft		Head 580.0 ft		Head 610.0 ft	
		<u>Flow, cfs</u>	<u>Eff</u>	<u>Flow, cfs</u>	<u>Eff</u>	<u>Flow, cfs</u>	<u>Eff</u>	<u>Flow, cfs</u>	<u>Eff</u>	<u>Flow, cfs</u>	<u>Eff</u>
		31.9	0.1937	33.4	0.1937	34.7	0.1937	35.6	0.1937	36.5	0.1937
		43.4	0.4602	45.5	0.4602	47.2	0.4602	48.5	0.4602	49.7	0.4602
		49.4	0.5091	51.7	0.5091	53.7	0.5091	55.1	0.5091	56.5	0.5091
		60.1	0.5880	62.9	0.5880	65.4	0.5880	67.1	0.5880	68.8	0.5880
		70.1	0.6342	73.4	0.6342	76.3	0.6342	78.3	0.6342	80.3	0.6342
		81.8	0.6748	85.7	0.6748	89.0	0.6748	91.4	0.6748	93.8	0.6748
		90.3	0.7028	94.6	0.7028	98.2	0.7028	100.8	0.7028	103.4	0.7028
		102.5	0.7340	107.4	0.7340	111.5	0.7340	114.5	0.7340	117.4	0.7340
		117.2	0.7766	122.7	0.7766	127.4	0.7766	130.9	0.7766	134.2	0.7766
		138.6	0.8038	145.1	0.8038	150.7	0.8038	154.8	0.8038	158.7	0.8038
		157.5	0.8252	164.9	0.8252	171.3	0.8252	175.9	0.8252	180.4	0.8252
		179.0	0.8408	187.4	0.8408	194.6	0.8408	199.9	0.8408	205.0	0.8408
		205.6	0.8465	215.3	0.8465	223.6	0.8465	229.6	0.8465	235.5	0.8465
		232.8	0.8490	243.8	0.8490	253.2	0.8490	260.0	0.8490	266.6	0.8490
		267.6	0.8477	280.2	0.8477	291.0	0.8477	298.8	0.8477	306.5	0.8477

Union Valley Reservoir (7)

31	Storage (HRBC)		Area (HRBC)		Evaporation (Base Case)		Spillway (HRBC)		Tailwater (Base Case)	
	Elev, ft	Vol, af	Elev, ft	Area, ac	Mon	Evp, in/d	Elev, ft	Flow, cfs	Flow, cfs	Elev, ft
4890.0	327920	4880.0	3022.0	Jan	0.000	4882.5	41533.0	3000	4448	
4880.0	294311	4870.0	2847.0	Feb	0.000	4880.0	36000.0	2500	4448	
4870.0	266303	4860.0	2672.0	Mar	0.022	4877.5	30737.0	2000	4447	
4860.0	238295	4850.0	2479.0	Apr	0.061	4875.0	25760.0	1750	4446	
4850.0	212354	4840.0	2294.0	May	0.111	4872.5	21084.0	1250	4446	
4840.0	188501	4830.0	2108.0	Jun	0.178	4870.0	16731.0	1000	4445	
4830.0	166439	4820.0	1936.0	Jul	0.215	4867.5	12728.0	750	4445	
4820.0	146237	4810.0	1749.0	Aug	0.195	4865.0	9107.0	500	4445	
4810.0	127757	4800.0	1569.0	Sep	0.138	4862.5	5900.0	250	4444	
4800.0	111204	4790.0	1414.0	Oct	0.065	4860.0	3220.0	100	4444	
4790.0	96282	4780.0	1265.0	Nov	0.016	4857.5	1138.0	1	4444	
4780.0	82875	4770.0	1130.0	Dec	0.000	4855.0	0.0			
4770.0	70892	4760.0	1014.0							
4760.0	60171	4750.0	894.0							
4750.0	50621	4740.0	770.0							
4740.0	42310	4730.0	661.0							
4730.0	35147	4720.0	568.0							
4720.0	29018	4710.0	487.0							
4710.0	23761	4700.0	414.0							
4700.0	19245	4690.0	349.0							
4690.0	15439	4680.0	290.0							
4680.0	12250	4670.0	241.0							
4670.0	9610	4660.0	199.0							
4660.0	7417	4650.0	161.0							
4650.0	5615									
4640.0	4199									
4630.0	3090									
4628.0	0									

32	Node options Name: Base Case Min flow: 0 cfs Capacity: 1838 cfs Op type: Strictly peaking	Flood elevations (HRBC)		Minimum elevations (Base Case)		Preferred storage objective (elevation), ft (BasecaseSmooth)				
		Date	Elev, ft	Date	Elev, ft	Day	A	B	C	D
01-Jan	4855.0	01-Jan	4645.0	Jan 01	4821.9	4821.9	4821.9	4821.9	4821.9	4821.9
31-Mar	4855.0	31-Dec	4645.0	Jan 15	4826.7	4824.5	4815.0	4811.9	4808.9	4808.9
01-Apr	4855.0			Feb 01	4831.6	4827.1	4809.1	4801.9	4795.9	4795.9
02-Apr	4855.0			Feb 15	4836.1	4829.6	4812.6	4791.9	4782.9	4782.9
15-Apr	4865.0			Mar 01	4840.6	4832.1	4816.1	4791.7	4775.9	4775.9
30-Apr	4867.0			Mar 15	4844.6	4835.9	4820.2	4798.0	4775.9	4775.9
15-May	4870.0			Apr 01	4848.6	4839.8	4824.3	4806.5	4775.9	4775.9
31-Oct	4870.0			Apr 15	4855.3	4846.6	4832.5	4816.7	4793.6	4793.6
01-Nov	4855.0			May 01	4862.0	4853.3	4840.6	4826.8	4811.2	4811.2
31-Dec	4855.0			May 15	4866.0	4861.7	4855.3	4842.2	4828.0	4828.0
				Jun 01	4870.0	4870.0	4870.0	4857.6	4844.8	4844.8
				Jun 15	4870.0	4870.0	4870.0	4863.8	4857.4	4857.4
				Jul 01	4870.0	4870.0	4870.0	4870.0	4870.0	4870.0
				Jul 15	4870.0	4870.0	4870.0	4870.0	4870.0	4870.0
				Aug 01	4861.3	4861.3	4861.3	4861.3	4861.3	4861.3
				Aug 15	4852.2	4852.2	4852.2	4852.2	4852.2	4852.2
				Sep 01	4843.1	4843.1	4843.1	4843.1	4843.1	4843.1
				Sep 15	4832.5	4832.5	4832.5	4832.5	4832.5	4832.5
				Oct 01	4821.9	4821.9	4821.9	4821.9	4821.9	4821.9
				Oct 15	4821.9	4821.9	4821.9	4821.9	4821.9	4821.9
				Nov 01	4821.9	4821.9	4821.9	4821.9	4821.9	4821.9
				Nov 15	4821.9	4821.9	4821.9	4821.9	4821.9	4821.9
				Dec 01	4821.9	4821.9	4821.9	4821.9	4821.9	4821.9
				Dec 15	4821.9	4821.9	4821.9	4821.9	4821.9	4821.9
				Dec 31	4821.9	4821.9	4821.9	4821.9	4821.9	4821.9

33	<u>Flashboards</u>	<u>Spillway with flashboards</u>
	Setting name: HRBC	<u>Elev, ft</u> <u>Flow, cfs</u>
	Desc: Gates down spillway curve calculated by MAH from Randy Jenson data	4882.5 11667.0
	Install: 01-Apr	4880.0 8348.0
	Remove: 01-Nov	4877.5 5422.0
	Average days: 1	4875.0 2952.0
	Volume date: 31-Dec	4872.5 1044.0
	Volume remain: 0 taf	<u>4870.0 0.0</u>

34	Powerhouse settings summary - Union Valley (HRBC)	Maintenance (Maintenance)	Peak/max schedule (Peak All Year)
	<u>Unit</u> <u>Headloss</u> <u>Generator</u> <u>Turbine</u>	<u>Date</u> <u>Units</u>	<u>Date</u> <u>Setting</u>
	1 Base Case U1 Base Case Base Case U1	01-Jan 0	01-Jan 1.00
		14-Oct 1	31-Dec 1.00
		24-Oct 0	
		31-Dec 0	

35	Head loss coefficients, ft/cfs ² (Base Case U1)	Generator performance, unit 1 (Base Case)
	<u>Unit</u> <u>Unit loss</u> <u>Common loss</u> <u>Max unit</u> <u>Com2?</u>	<u>Output, MWh</u> <u>Eff</u> <u>Cap</u>
	1 8.5890e-006 0.000000000 1 No	1.0 1.00 46.0
		46.0 1.00 46.0

36	Turbine performance, unit 1 (Base Case U1), Gate leakage: 0.0 cfs									
	<u>Head 170.0 ft</u>		<u>Head 235.0 ft</u>		<u>Head 300.0 ft</u>		<u>Head 365.0 ft</u>		<u>Head 430.0 ft</u>	
	<u>Flow, cfs</u>	<u>Eff</u>	<u>Flow, cfs</u>	<u>Eff</u>	<u>Flow, cfs</u>	<u>Eff</u>	<u>Flow, cfs</u>	<u>Eff</u>	<u>Flow, cfs</u>	<u>Eff</u>
	139.5	0.2640	164.0	0.2640	185.3	0.2640	204.4	0.2640	221.9	0.2640
	191.7	0.4420	225.4	0.4420	254.7	0.4420	280.9	0.4420	304.9	0.4420
	260.4	0.5810	306.2	0.5810	346.0	0.5810	381.6	0.5810	414.2	0.5810
	351.1	0.6630	412.9	0.6630	466.5	0.6630	514.5	0.6630	558.5	0.6630
	424.7	0.7270	499.3	0.7270	564.2	0.7270	622.3	0.7270	675.4	0.7270
	497.5	0.7570	585.0	0.7570	660.9	0.7570	729.0	0.7570	791.3	0.7570
	577.2	0.8000	678.7	0.8000	766.8	0.8000	845.8	0.8000	918.0	0.8000
	664.5	0.8180	781.3	0.8180	882.8	0.8180	973.7	0.8180	1056.8	0.8180
	758.7	0.8210	892.0	0.8210	1007.8	0.8210	1111.6	0.8210	1206.6	0.8210
	819.1	0.8680	963.1	0.8680	1088.1	0.8680	1200.3	0.8680	1302.7	0.8680
	863.8	0.8750	1015.6	0.8750	1147.5	0.8750	1265.7	0.8750	1373.8	0.8750
	946.3	0.8940	1112.5	0.8940	1257.0	0.8940	1386.5	0.8940	1504.9	0.8940
	1027.3	0.9010	1207.9	0.9010	1364.7	0.9010	1505.3	0.9010	1633.9	0.9010

Junction Reservoir (8)

37	Storage (HRBC)		Spillway (HRBC)		Tailwater (HRBC)	
	Elev, ft	Vol, af	Elev, ft	Flow, cfs	Flow, cfs	Elev, ft
	4550.0	20000	4475.0	114478.0	1	2915
	4540.0	12514	4470.0	64149.0		
	4525.0	10052	4466.0	41172.0		
	4510.0	8000	4465.0	36885.0		
	4495.0	6290	4462.0	25037.0		
	4480.0	4876	4458.0	11238.0		
	4465.0	3698	4454.0	2640.0		
	4460.0	3306	4450.0	0.0		
	4450.0	2610	4446.0	0.0		
	4440.0	2018				
	4430.0	1529				
	4420.0	1131				
	4410.0	819				
	4400.0	572				
	4390.0	381				
	4380.0	241				
	4370.0	144				
	4360.0	74				

38	Node options Name: Base Case Min flow: 0 cfs Capacity: 1477 cfs Op type: Strictly peaking	Flood elevations (Base Case)		Target elevations (HRBC)		Minimum elevations (Base Case)	
		Date	Elev, ft	Date	Elev, ft	Date	Elev, ft
		01-Jan	4450.0	01-Jan	4441.0	01-Jan	4397.0
		31-Dec	4450.0	31-Dec	4441.0	31-Dec	4397.0

39	Bypass flows, cfs (HRBC)						
	Date	A	B	C	D	E	Inflow
	01-Jan	5	6	8	10	0	No
	01-Feb	5	6	8	10	0	No
	01-Mar	5	6	8	10	0	No
	01-Apr	5	6	8	10	0	No
	01-May	5	10	15	20	0	No
	01-Jun	5	10	15	20	0	No
	01-Jul	5	10	15	20	0	No
	01-Aug	5	10	15	20	0	No
	01-Sep	5	10	15	20	0	No
	01-Oct	5	10	15	20	0	No
	01-Nov	5	6	8	10	0	No
	01-Dec	5	6	8	10	0	No
	31-Dec	5	6	8	10	0	No

40	Powerhouse settings summary - Jaybird (HRBC)				Maintenance (Maintenance)		Peak/max schedule (Peak All Year)	
	Unit	Headloss	Generator	Turbine	Date	Units	Date	Setting
	1	Base Case	Base Case U1 U2	HRBCU1	01-Jan	0	01-Jan	1.00
	2	Base Case	Base Case U1 U2	HRBCU2	25-Oct	1	31-Dec	1.00
					04-Nov	0		
					05-Nov	2		
					15-Nov	0		
					31-Dec	0		

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41	Head loss coefficients, ft/cfs ² (Base Case)					Generator performance, unit 1 (Base Case U1 U2)			Generator performance, unit 2 (Base Case U1 U2)		
	Unit	Unit loss	Common loss	Max unit	Com2?	Output, MWh	Eff	Cap	Output, MWh	Eff	Cap
	1	1.9500e-005	5.6500e-005	2	No	1.0	1.00	70.7	1.0	1.00	70.7
	2	3.5000e-005	5.6500e-005	2	No	70.7	1.00	70.7	70.7	1.00	70.7

42	Turbine performance, unit 1 (HRBCU1), Gate leakage: 0.0 cfs									
	Head 1350.0 ft		Head 1440.0 ft		Head 1498.0 ft		Head 1515.0 ft		Head 1530.0 ft	
	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
	256.3	0.9025	264.7	0.9025	270.0	0.9025	271.5	0.9025	272.9	0.9025
	306.6	0.9060	316.7	0.9060	323.0	0.9060	324.8	0.9060	326.4	0.9060
	362.6	0.9080	374.5	0.9080	382.0	0.9080	384.2	0.9080	386.1	0.9080
	391.1	0.9081	403.9	0.9081	412.0	0.9081	414.3	0.9081	416.4	0.9081
	418.6	0.9079	432.4	0.9079	441.0	0.9079	443.5	0.9079	445.7	0.9079
	530.7	0.9055	548.1	0.9055	559.0	0.9055	562.2	0.9055	564.9	0.9055
	597.1	0.9025	616.7	0.9025	629.0	0.9025	632.6	0.9025	635.7	0.9025

43	Turbine performance, unit 2 (HRBCU2), Gate leakage: 0.0 cfs									
	Head 1350.0 ft		Head 1440.0 ft		Head 1498.0 ft		Head 1515.0 ft		Head 1530.0 ft	
	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
	196.5	0.8390	203.0	0.8390	207.0	0.8390	208.2	0.8390	209.2	0.8390
	329.4	0.8640	340.2	0.8640	347.0	0.8640	349.0	0.8640	350.7	0.8640
	387.3	0.8700	400.0	0.8700	408.0	0.8700	410.3	0.8700	412.3	0.8700
	490.8	0.8690	506.9	0.8690	517.0	0.8690	519.9	0.8690	522.5	0.8690
	598.1	0.8640	617.7	0.8640	630.0	0.8640	633.6	0.8640	636.7	0.8640
	757.6	0.8600	782.4	0.8600	798.0	0.8600	802.5	0.8600	806.5	0.8600

Camino Reservoir (9)

44	Storage (HRBC)		Spillway (HRBC)		Tailwater (HRBC)	
	Elev, ft	Vol, af	Elev, ft	Flow, cfs	Flow, cfs	Elev, ft
	2960.0	9810	2925.0	90000.0	2800	1856.09
	2950.0	3596	2918.0	64000.0	2700	1855.93
	2940.0	1534	2915.0	62000.0	2400	1855.50
	2935.0	1100	2897.5	14500.0	1600	1854.48
	2930.0	850	2895.0	0.0	1200	1853.88
	2925.0	706			1000	1853.52
	2915.0	541			800	1853.12
	2910.0	459			600	1852.65
	2905.0	379			400	1852.11
	2900.0	311			200	1851.49
	2895.0	253			0	1850.77
	2890.0	205				
	2885.0	165				
	2880.0	130				
	2875.0	100				
	2870.0	74				
	2865.0	53				
	2860.0	35				
	2855.0	21				
	2850.0	11				

45	Node options Name: Base Case Min flow: 0 cfs Capacity: 1458 cfs Op type: Strictly peaking	Flood elevations (Base Case)		Target elevations (HRBC)		Minimum elevations (HRBC)	
		Date	Elev, ft	Date	Elev, ft	Date	Elev, ft
		01-Jan	2915.0	01-Jan	2900.0	01-Jan	2895.0
31-Dec	2915.0	31-Dec	2900.0	30-Mar	2895.0		
				31-Mar	2865.0		
				29-Nov	2865.0		
				30-Nov	2895.0		
				31-Dec	2895.0		

46	Bypass flows, cfs (HRBC)						
	Date	A	B	C	D	E	Inflow
	01-Jan	5	6	8	10	0	No
	01-Feb	5	6	8	10	0	No
	01-Mar	5	6	8	10	0	No
	01-Apr	5	6	8	10	0	No
	01-May	5	10	15	20	0	No
	01-Jun	5	10	15	20	0	No
	01-Jul	5	10	15	20	0	No
	01-Aug	5	10	15	20	0	No
	01-Sep	5	10	15	20	0	No
	01-Oct	5	10	15	20	0	No
	01-Nov	5	6	8	10	0	No
	01-Dec	5	6	8	10	0	No
	31-Dec	5	6	8	10	0	No

47	Powerhouse settings summary - Camino (HRBC)				Maintenance (Maintenance)		Peak/max schedule (Peak All Year)	
	Unit	Headloss	Generator	Turbine	Date	Units	Date	Setting
	1	Base Case	Base Case U1	Base Case U1	01-Jan	0	01-Jan	1.00
	2	Base Case	Base Case U2	HRBC U2	16-Nov	1	31-Dec	1.00
					25-Nov	0		
					26-Nov	2		
					05-Dec	0		
					31-Dec	0		

48	Head loss coefficients, ft/cfs ² (Base Case)					Generator performance, unit 1 (Base Case U1)			Generator performance, unit 2 (Base Case U2)		
	Unit	Unit loss	Common loss	Max unit	Com2?	Output, MWh	Eff	Cap	Output, MWh	Eff	Cap
	1	1.2000e-005	8.0000e-006	2	No	1.0	1.00	80.0	1.0	1.00	70.0
	2	2.6500e-005	8.0000e-006	2	No	80.0	1.00	80.0	70.0	1.00	70.0

49	Turbine performance, unit 1 (Base Case U1), Gate leakage: 0.0 cfs									
	Head 940.0 ft		Head 970.0 ft		Head 1000.0 ft		Head 1030.0 ft		Head 1065.0 ft	
	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
	213.3	0.5370	216.7	0.5370	220.0	0.5370	223.3	0.5370	227.0	0.5370
	347.1	0.6860	352.6	0.6860	358.0	0.6860	363.3	0.6860	369.5	0.6860
	553.6	0.7940	562.4	0.7940	571.0	0.7940	579.5	0.7940	589.3	0.7940
	762.1	0.8470	774.1	0.8470	786.0	0.8470	797.7	0.8470	811.1	0.8470
	879.4	0.8560	893.3	0.8560	907.0	0.8560	920.5	0.8560	936.0	0.8560
	986.0	0.8570	1001.6	0.8570	1017.0	0.8570	1032.1	0.8570	1049.5	0.8570
	1051.0	0.8560	1067.6	0.8560	1084.0	0.8560	1100.1	0.8560	1118.7	0.8560

50	Turbine performance, unit 2 (HRBC U2), Gate leakage: 0.0 cfs									
	Head 940.0 ft		Head 970.0 ft		Head 1000.0 ft		Head 1030.0 ft		Head 1065.0 ft	
	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
	105.7	0.1000	107.4	0.1000	109.0	0.1000	110.6	0.1000	112.5	0.1000
	128.9	0.2460	131.0	0.2460	133.0	0.2460	135.0	0.2460	137.3	0.2460
	152.2	0.3480	154.6	0.3480	157.0	0.3480	159.3	0.3480	162.0	0.3480
	195.8	0.5090	198.9	0.5090	202.0	0.5090	205.0	0.5090	208.5	0.5090
	425.6	0.7210	432.4	0.7210	439.0	0.7210	445.5	0.7210	453.0	0.7210
	657.3	0.8110	667.8	0.8110	678.0	0.8110	688.1	0.8110	699.7	0.8110
	772.7	0.8240	785.0	0.8240	797.0	0.8240	808.9	0.8240	822.5	0.8240
	902.6	0.8180	916.9	0.8180	931.0	0.8180	944.9	0.8180	960.8	0.8180
	992.8	0.8050	1008.5	0.8050	1024.0	0.8050	1039.2	0.8050	1056.8	0.8050
	1041.3	0.8000	1057.8	0.8000	1074.0	0.8000	1090.0	0.8000	1108.4	0.8000

Brush Creek Reservoir (10)

51	Storage (HRBC)		Spillway (HRBC)	
	Elev, ft	Vol, af	Elev, ft	Flow, cfs
	2930.0	10000	2925.0	20428.0
	2920.0	1454	2923.0	14617.0
	2915.0	1350	2922.0	11964.0
	2910.0	1250	2921.0	9494.0
	2905.0	1155	2920.0	6462.0
	2900.0	1064	2919.0	4352.0
	2895.0	976	2918.0	2827.0
	2890.0	893	2917.0	1250.0
	2885.0	813	2916.0	340.0
	2880.0	737	2915.0	0.0
	2875.0	665		
	2870.0	597		
	2865.0	531		
	2860.0	468		
	2855.0	411		
	2850.0	354		
	2845.0	302		
	2840.0	253		
	2835.0	206		
	2830.0	163		
	2825.0	124		
	2820.0	89		
	2815.0	59		
	2810.0	34		
	2805.0	16		
	2800.0	8		

52	Node options	Flood elevations (Base Case)		Target elevations (Base Case)		Minimum elevations (HRBC)	
	Name: Base Case	Date	Elev, ft	Date	Elev, ft	Date	Elev, ft
	Min flow: 0 cfs						
	Capacity: 710 cfs	01-Jan	2915.0	01-Jan	2900.0	01-Jan	2895.0
	Op type: Non-generating	31-Dec	2915.0	31-Dec	2900.0	31-Dec	2895.0

53	Bypass flows, cfs (HRBC)						
	Date	A	B	C	D	E	Inflow
	01-Jan	4	4	6	6	0	Yes
	01-Jun	2	2	3	3	0	Yes
	01-Nov	4	4	6	6	0	Yes
	31-Dec	4	4	6	6	0	Yes

Slab Creek Reservoir (11)

54	Storage (HRBC)		Spillway (HRBC)		Tailwater (Base Case)	
	Elev, ft	Vol, af	Elev, ft	Flow, cfs	Flow, cfs	Elev, ft
	1870.0	18206	1864.0	79678.0	4250	998
	1860.0	15549	1862.0	59240.0	4000	998
	1850.0	13335	1860.0	41763.0	3750	998
	1845.0	12228	1858.0	27273.0	3500	997
	1840.0	11203	1856.0	15800.0	3250	997
	1835.0	10232	1855.0	11307.0	3000	997
	1830.0	9330	1854.0	7860.0	2750	996
	1825.0	8496	1853.0	5050.0	2500	996
	1820.0	7755	1852.0	2720.0	2250	995
	1810.0	6509	1851.5	1760.0	2000	995
	1800.0	5457	1851.0	990.0	1750	995
	1790.0	4500	1850.5	395.0	1500	994
	1780.0	3644	1850.0	30.0	1250	994
	1770.0	2889	1849.9	0.0	1000	994
	1760.0	2248			750	993
	1750.0	1702			500	993
	1740.0	1245			250	993
	1730.0	865			100	992
	1720.0	589			1	992
	1710.0	390				
	1700.0	226				
	1690.0	100				
	1680.0	26				

55	Node options	Flood elevations (Base Case)		Target elevations (Base Case)		Minimum elevations (HRBC)	
	Name: Base Case	Date	Elev, ft	Date	Elev, ft	Date	Elev, ft
	Min flow: 0 cfs	01-Jan	1850.0	01-Jan	1844.0	01-Jan	1820.0
	Capacity: 3950 cfs						
	Op type: Strictly peaking	31-Dec	1850.0	31-Dec	1844.0	31-Dec	1820.0

56	Bypass flows, cfs (HRBC)							Minimum release, cfs (HRBC)		
	Date	A	B	C	D	E	Inflow	Date	Flow, cfs	Inflow
	01-Jan	10	10	36	36	0	No	01-Jan	40	No
	01-Feb	10	10	36	36	0	No	31-Dec	40	No
	01-Mar	10	10	36	36	0	No			
	01-Apr	10	10	36	36	0	No			
	01-May	10	10	36	36	0	No			
	01-Jun	36	36	36	36	0	No			
	01-Jul	36	36	36	36	0	No			
	01-Aug	36	36	36	36	0	No			
	01-Sep	36	36	36	36	0	No			
	01-Oct	36	36	36	36	0	No			
	01-Nov	36	36	36	36	0	No			
	16-Nov	10	10	36	36	0	No			
	01-Dec	10	10	36	36	0	No			
	31-Dec	10	10	36	36	0	No			

57	Powerhouse settings summary - White Rock (HRBC)				Maintenance (Maintenance)		Peak/max schedule (Peak All Year)	
	Unit	Headloss	Generator	Turbine	Date	Units	Date	Setting
	1	Base Case	Base Case U1	HRBC U1	01-Jan	0	01-Jan	1.00
	2	Base Case	Base Case U2	HRBC U2	06-Dec	1	31-Dec	1.00
					14-Dec	0		
					15-Dec	2		
					25-Dec	0		
					31-Dec	0		

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58	Head loss coefficients, ft/cfs ² (Base Case)				Generator performance, unit 1 (Base Case U1)			Generator performance, unit 2 (Base Case U2)			
	Unit	Unit loss	Common loss	Max unit	Com2?	Output, MWh	Eff	Cap	Output, MWh	Eff	Cap
	1	4.3550e-006	0.000000000	2	No	1.0	1.00	105.0	1.0	1.00	125.0
	2	4.3550e-006	0.000000000	2	No	105.0	1.00	105.0	125.0	1.00	125.0

59	Turbine performance, unit 1 (HRBC U1), Gate leakage: 0.0 cfs									
	Head 730.0 ft		Head 760.0 ft		Head 795.0 ft		Head 830.0 ft		Head 860.0 ft	
	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
	395.8	0.5340	403.8	0.5340	413.0	0.5340	422.0	0.5340	429.6	0.5340
	658.4	0.6420	671.7	0.6420	687.0	0.6420	702.0	0.6420	714.6	0.6420
	800.9	0.6880	817.2	0.6880	835.8	0.6880	854.0	0.6880	869.3	0.6880
	1030.7	0.7340	1051.6	0.7340	1075.6	0.7340	1099.0	0.7340	1118.7	0.7340
	1178.8	0.7510	1202.8	0.7510	1230.2	0.7510	1257.0	0.7510	1279.5	0.7510
	1313.0	0.7630	1339.7	0.7630	1370.2	0.7630	1400.0	0.7630	1425.1	0.7630
	1438.6	0.7660	1467.9	0.7660	1501.3	0.7660	1534.0	0.7660	1561.5	0.7660
	1554.0	0.7590	1585.6	0.7590	1621.7	0.7590	1657.0	0.7590	1686.7	0.7590

60	Turbine performance, unit 2 (HRBC U2), Gate leakage: 0.0 cfs									
	Head 730.0 ft		Head 760.0 ft		Head 795.0 ft		Head 830.0 ft		Head 860.0 ft	
	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
	417.3	0.5960	425.8	0.5960	435.5	0.5960	445.0	0.5960	453.0	0.5960
	613.3	0.6890	625.8	0.6890	640.1	0.6890	654.0	0.6890	665.7	0.6890
	795.3	0.7500	811.5	0.7500	829.9	0.7500	848.0	0.7500	863.2	0.7500
	1057.9	0.7990	1079.4	0.7990	1104.0	0.7990	1128.0	0.7990	1148.2	0.7990
	1372.0	0.8330	1399.9	0.8330	1431.8	0.8330	1463.0	0.8330	1489.2	0.8330
	1616.8	0.8530	1649.7	0.8530	1687.3	0.8530	1724.0	0.8530	1754.9	0.8530
	1869.1	0.8580	1907.1	0.8580	1950.5	0.8580	1993.0	0.8580	2028.7	0.8580
	2059.5	0.8570	2101.4	0.8570	2149.2	0.8570	2196.0	0.8570	2235.3	0.8570

Chili Bar Reservoir (Pacific Gas and Electric Co.) (12)

61	Storage (Base Case)	Spillway (Base Case)	Tailwater (Base Case)											
	Elev, ft Vol, af	Elev, ft Flow, cfs	Flow, cfs	Elev, ft										
	1020.0 5979	1017.5 60167.0	1	933										
	1014.0 5152	1017.0 57667.0												
	1008.0 4376	1016.0 52800.0												
	1002.0 3651	1015.0 48667.0												
	996.0 2976	1014.0 44667.0												
	990.0 2353	1013.0 40000.0												
	984.0 1800	1012.0 35533.0												
	978.0 1335	1011.0 31333.0												
	972.0 958	1010.0 28133.0												
	Note: Table abridged; full printout below	1009.0 23533.0												
		1008.0 20133.0												
		1007.0 16870.0												
		1006.0 14200.0												
		1005.0 11333.0												
		1004.0 9000.0												
		1003.0 7000.0												
		1002.0 5333.0												
		1001.0 3700.0												
		1000.0 2200.0												
		999.0 1100.0												
		998.0 300.0												
		997.5 0.0												
62	<u>Node options</u>	<u>UARP support</u>	Flood elevations (Base Case)	Target elevations (HRBC)	Minimum elevations (Base Case)									
	Name: Base Case Min flow: 200 cfs Capacity: unlimited Op type: Peaking w/ ramp rates	Linked: No Spill prevention: No <u>Raft flow support</u> General: No Up UARP: No	Date Elev, ft	Date Elev, ft	Date Elev, ft									
			01-Jan 997.5	01-Jan 996.0	01-Jan 984.0									
			31-Dec 997.5	31-Dec 996.0	31-Dec 984.0									
63	Bypass flows, cfs (Base Case)	Minimum release, cfs (Base Case)												
	Date A B C D E Inflow	Date	A	B	C	D	E	Inflow						
01-Jan	0	0	0	0	0	0	No	01-Jan	120	120	120	120	120	No
23-Nov	120	120	120	120	120	120	No	31-Dec	120	120	120	120	120	No
07-Dec	0	0	0	0	0	0	No							
31-Dec	0	0	0	0	0	0	No							
64	Powerhouse settings summary - Chili Bar (Base Case)	Whitewater boating release schedule (flow/duration) (cfs/hours)												
	Unit Headloss Generator Turbine	Day	Start	A	B	C	D	E						
1 Base Case Base Case Base Case	Sunday	9:00	1200 / 3	1500 / 6	1750 / 8	1750 / 8	1750 / 8							
	Monday	9:00	0 / 1	1200 / 3	1200 / 6	1500 / 6	1500 / 6							
	Tuesday	9:00	0 / 1	1200 / 3	1200 / 6	1500 / 6	1500 / 6							
	Wednesday	9:00	1200 / 3	1200 / 3	1200 / 6	1500 / 6	1500 / 6							
	Thursday	9:00	0 / 1	1200 / 3	1200 / 6	1500 / 6	1500 / 6							
	Friday	9:00	1200 / 3	1200 / 3	1200 / 6	1500 / 6	1500 / 6							
	Saturday	9:00	1200 / 3	1500 / 6	1750 / 8	1750 / 8	1750 / 8							
	Start date		26 May	26 May	26 May	1 Mar	1 Mar							
	End date		15 Sep	15 Sep	15 Sep	31 Oct	31 Oct							
65	Generator performance, unit 1 (Base Case)	Maintenance (Maintenance)	Ramping rates, cfs or ft (Base Case)											
	Output, MWh Eff Cap	Date Units	Date	Hourly up	Hourly dn	Daily up	Daily dn							
0.1 1.00 8.1	01-Jan 0	01-Jan	500	500	unl.	unl.								
8.1 1.00 8.1	23-Nov 1	31-Dec	500	500	unl.	unl.								
	07-Dec 0													
	31-Dec 0													

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66 Turbine performance, unit 1
 (Base Case), Gate leakage: 0.0 cfs

Head 56.1 ft		Head 59.2 ft		Head 61.1 ft		Head 62.9 ft		Head 64.5 ft	
Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
150.0	0.4170	150.0	0.3850	150.0	0.3530	150.0	0.3760	150.0	0.3150
250.0	0.5890	250.0	0.5500	250.0	0.5320	300.0	0.5680	250.0	0.4840
400.0	0.7040	400.0	0.6620	400.0	0.6490	400.0	0.6270	400.0	0.6090
650.0	0.7790	650.0	0.7310	700.0	0.7070	600.0	0.6740	600.0	0.6640
900.0	0.8020	900.0	0.7680	900.0	0.7310	1000.0	0.7220	950.0	0.6920
1000.0	0.8030	1000.0	0.7760	1100.0	0.7460	1350.0	0.7370	1200.0	0.7030
1100.0	0.8050	1100.0	0.7800	1300.0	0.7510	1600.0	0.7100	1500.0	0.7000
1200.0	0.8030	1200.0	0.7850	1500.0	0.7360	1800.0	0.6900	1700.0	0.6750
1300.0	0.7890	1300.0	0.7830	1700.0	0.7260	2000.0	0.6650	1950.0	0.6520
1343.0	0.7820	1407.0	0.7820	1933.0	0.6950	2200.0	0.6250	2200.0	0.6250

Base Case from Operational Data - formula created from operational data observations, grouped into 5 head bands.

Iowa Hill Development (13)

Storage (Base Case)		Peak/max schedule (Max All Year)		Head loss coefficients, ft/cfs ² (Base Case)				
Elev, ft	Vol, af	Date	Setting	Unit	Unit loss	Common loss	Max unit	Com2?
3073.0	6572	01-Jan	2.00	1	0.000000000	8.8636e-007	3	No
3070.0	6358	31-Dec	2.00	2	0.000000000	8.8636e-007	3	No
3060.0	5668			3	0.000000000	8.8636e-007	3	No
3050.0	5015							
3040.0	4398							
3030.0	3817							
3020.0	3269							
3010.0	2755							
3000.0	2272							
2990.0	1821							
2980.0	1400							
2970.0	1009							
2960.0	645							
2950.0	309							
2945.0	152							
2940.0	0							

Node options		Flood elevations (Base Case)		Minimum elevations (Base Case)	
		Date	Elev, ft	Date	Elev, ft
Name: Generating		01-Jan	3070.0	01-Jan	2950.0
Min flow: 1100 cfs		31-Dec	3070.0	31-Dec	2950.0
Capacity: 4500 cfs					
Op type: Strictly peaking					

Pump Operations	Pump Capacity (test)	Weekly cycle drawdown settings				
		Month	Days	Volume, ac-ft		
Name: Dommerl		Jan	6	2975.00		
Ancillary only: No		Feb	6	2970.00		
Ancillary dual: No		Mar	6	1730.00		
		Apr	6	2968.00		
		May	6	2227.00		
		Jun	6	1482.00		
		Jul	6	1482.00		
		Aug	6	1482.00		
		Sep	6	1482.00		
		Oct	6	2968.00		
		Nov	6	2968.00		
		Dec	6	2968.00		

70 Weekday operation schedule: number of units generating or pumping during HE01 through HE24 (Dommerl)

Month	Linked	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	No	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3
Feb	No	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3
Mar	No	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3
Apr	No	3	3	3	3	3	1	1	1	1	1	1	1	-	-	1	1	1	1	3	3	3	3	3	3
May	No	3	3	3	3	3	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3
Jun	No	3	3	3	3	3	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3
Jul	No	3	3	3	3	3	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3
Aug	No	3	3	3	3	3	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3
Sep	No	3	3	3	3	3	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3
Oct	No	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3
Nov	No	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
Dec	No	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3

71 Saturday operation schedule: number of units generating or pumping during HE01 through HE24 (Dommerl)
 Same as weekday schedule

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72 Sunday operation schedule: number of units generating or pumping during HE01 through HE24 (Dommer1)

Month	Linked	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Feb	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Mar	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Apr	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
May	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Jun	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Jul	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Aug	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Sep	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Oct	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Nov	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Dec	No	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

(Black on white: generation. White on black and underlined: pumping.)

73 Generator performance, unit 1 (Base Case) Generator performance, unit 2 (Base Case) Generator performance, unit 3 (Base Case)

Output, MWh	Eff	Cap	Output, MWh	Eff	Cap	Output, MWh	Eff	Cap
0.1	0.98	133.0	0.1	0.98	133.0	0.1	0.98	133.0
133.0	0.98	133.0	133.0	0.98	133.0	133.0	0.98	133.0

74 Turbine performance, unit 1 (Base Case), Gate leakage: 0.0 cfs

Head 1073.0 ft		Head 1112.0 ft		Head 1151.0 ft		Head 1189.0 ft		Head 1228.0 ft	
Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff	Flow, cfs	Eff
191.5	0.3360	193.5	0.3449	197.4	0.3543	201.6	0.3639	203.8	0.3666
287.3	0.4873	290.2	0.4922	296.2	0.5028	302.4	0.5136	305.6	0.5175
383.1	0.6128	386.9	0.6138	394.9	0.6181	403.2	0.6221	407.5	0.6236
478.8	0.6827	483.7	0.6837	493.6	0.6867	504.0	0.6896	509.4	0.6906
574.6	0.7387	580.4	0.7393	592.3	0.7352	604.8	0.7414	611.3	0.7414
670.3	0.7818	677.1	0.7822	691.1	0.7823	705.6	0.7815	713.1	0.7811
766.1	0.8164	773.8	0.8169	789.8	0.8169	806.4	0.8164	815.0	0.8161
861.9	0.8456	870.6	0.8462	888.5	0.8460	907.2	0.8451	916.9	0.8444
957.6	0.8707	967.3	0.8706	987.2	0.8702	1008.0	0.8690	1018.8	0.8680
1053.4	0.8894	1064.0	0.8892	1086.0	0.8887	1108.8	0.8873	1120.6	0.8864
1149.2	0.9043	1160.8	0.9041	1184.7	0.9032	1209.6	0.9009	1222.5	0.8992
1244.9	0.9144	1257.5	0.9143	1283.4	0.9133	1310.4	0.9113	1324.4	0.9102
1340.7	0.9213	1354.2	0.9212	1382.1	0.9206	1411.2	0.9187	1426.3	0.9169
1436.4	0.9260	1451.0	0.9257	1480.9	0.9249	1512.1	0.9232	1528.1	0.9213
1532.2	0.9288	1547.7	0.9283	1579.6	0.9269	1612.9	0.9257	1630.0	0.9239
1596.1	0.9302	1612.2	0.9293	1645.4	0.9274	1680.1	0.9260	1697.9	0.9246
1628.0	0.9293	1644.4	0.9290	1678.3	0.9272	1713.7	0.9258	1731.9	0.9242
1723.7	0.9265	1741.1	0.9266	1777.0	0.9257	1814.5	0.9232	1833.8	0.9219
1819.5	0.9209	1837.9	0.9209	1875.8	0.9199	1915.3	0.9176	1935.6	0.9164
1915.3	0.9116	1934.6	0.9209	1974.5	0.9111	2016.1	0.9176	2037.5	0.9079

75 Turbine performance, unit 2 (Base Case), Gate leakage: 0.0 cfs
 Same as unit 1

76 Turbine performance, unit 3 (Base Case), Gate leakage: 0.0 cfs
 Same as unit 1

Addenda

77 Buck Island Reservoir Tunnel/plant flow (HRBCnew)		Camino Reservoir Tailwater (HRBC)		Chili Bar Reservoir Storage (Base Case)	
Elev, ft	Flow, cfs	Flow, cfs	Elev, ft	Elev, ft	Vol, af
6437.6	1160.0	2800	1856	1020.0	5979
6437.5	1146.0	2700	1856	1019.0	5837
6437.4	1133.0	2600	1856	1018.0	5697
6437.3	1119.0	2500	1856	1017.0	5559
6437.2	1105.0	2400	1856	1016.0	5422
6437.1	1092.0	2300	1855	1015.0	5286
6437.0	1078.0	2200	1855	1014.0	5152
6436.9	1065.0	2100	1855	1013.0	5019
6436.8	1051.0	2000	1855	1012.0	4888
6436.7	1038.0	1900	1855	1011.0	4758
6436.6	1025.0	1800	1855	1010.0	4629
6436.5	1011.0	1700	1855	1009.0	4502
6436.4	998.0	1600	1854	1008.0	4376
6436.3	984.7	1500	1854	1007.0	4252
6436.2	971.5	1400	1854	1006.0	4129
6436.1	958.3	1300	1854	1005.0	4007
6436.0	945.1	1200	1854	1004.0	3887
6435.9	932.0	1100	1854	1003.0	3768
6435.8	919.0	1000	1854	1002.0	3651
6435.7	905.9	900	1853	1001.0	3535
6435.6	892.9	800	1853	1000.0	3420
6435.5	880.0	700	1853	999.0	3307
6435.4	867.0	600	1853	998.0	3195
6435.2	841.3	500	1852	997.0	3085
6435.1	828.5	400	1852	996.0	2976
6435.0	815.8	300	1852	995.0	2868
6434.9	803.0	200	1851	994.0	2763
6434.8	790.4	100	1851	993.0	2658
6434.7	777.7	0	1851	992.0	2555
6434.6	765.2			991.0	2453
6434.5	752.6			990.0	2353
6434.4	740.1			989.0	2255
6434.3	727.6			988.0	2159
6434.1	702.9			987.0	2065
6434.0	690.5			986.0	1974
6433.9	678.3			985.0	1886
6433.8	666.0			984.0	1800
6433.7	653.9			983.0	1716
6433.6	641.7			982.0	1635
6433.5	629.6			981.0	1556
6433.4	617.6			980.0	1480
6433.3	605.6			979.0	1406
6433.2	593.7			978.0	1335
6433.0	569.9			977.0	1266
6432.9	558.1			976.0	1200
6432.8	546.4			975.0	1136
6432.7	534.7			974.0	1074
6432.6	523.1			973.0	1015
6432.5	511.5			972.0	958
6432.4	500.0			971.0	904
6432.3	488.5			970.0	853
6432.2	477.1			922.0	0
6432.1	465.7				
6431.9	443.2				
6431.8	432.0				
6431.7	420.9				
6431.6	409.8				
6431.5	398.8				
6431.4	387.9				

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6431.3	377.0
6431.2	366.2
6431.1	355.5
6431.0	344.8
6430.9	334.2
6430.8	323.7
6430.7	313.2
6430.6	302.8
6430.5	292.5
6430.4	282.3
6430.3	272.1
6430.2	262.1
6430.1	252.0
6430.0	242.1
6429.9	232.3
6429.8	222.5
6429.7	212.9
6429.6	203.3
6429.5	193.8
6429.4	184.5
6429.3	175.2
6429.2	166.0
6429.1	156.9
6429.0	147.9
6428.9	139.0
6428.8	128.6
6428.7	118.5
6428.6	108.7
6428.5	99.2
6428.4	90.0
6428.3	80.7
6428.2	71.7
6428.1	63.1
6428.0	55.0
6427.9	46.7
6427.8	39.0
6427.7	31.4
6427.6	24.5
6427.5	18.1
6427.4	12.6
6427.3	8.1
6427.2	4.6
6427.1	2.0
6427.0	0.1
6427.0	0.0

APPENDIX B

MODEL CONFIGURATION AND SOLUTION ALGORITHM

- Data flow
- Components of a Scenario
- Physical Settings
- Unit Dispatch
- Daily Time Step Sequence
- Fifteen-Minute Time Step
- Model Logic and scheduling flow chart

APPENDIX B

MODEL CONFIGURATION AND SOLUTION ALGORITHM

The Water Balance Model takes as input hydrologic data and operating parameters. The hydrologic data consist of mean daily inflow to each UARP reservoir and to Chili Bar Reservoir. The operating parameters include details of data summarized in this document, including powerhouse characteristics and reservoir physical and operational limits. The model simulates the real-world operation of the hydraulic features of the UARP and the Chili Bar Project, constrained by these inputs. The simulation focuses on water allocation and flow; energy generation is an output and not explicitly constrained by system load.

To simulate UARP and Chili Bar Project operation, the Water Balance Model steps sequentially through each day in the period of record. It allocates water through tunnels and powerhouses each day, and then shapes the daily volume in 15-minute increments according to the operating parameters. The output consists of time series of flow, reservoir storage, and energy generated at each location in the UARP and the Chili Bar Project.

Data flow

Two types of data are input to the Water Balance Model, and one type of data is output. Input data consist of:

- Parameters. These consist of tables of data, such as water release schedules, turbine performance curves, and reservoir elevation targets. Parameters are grouped together as settings: physical settings, operation settings, generation settings, and system settings.
- Time series. These consist of day-by-day inflow volumes to project reservoirs. Each project reservoir, such as Rubicon Reservoir or Junction Reservoir, receives water each day from precipitation, snowmelt, or base flow. A time series of these volumes is provided to each reservoir in the model, for each day in the simulation, in units of sfd (second-foot-day, $\text{ft}^3/\text{s}\cdot\text{d}$).

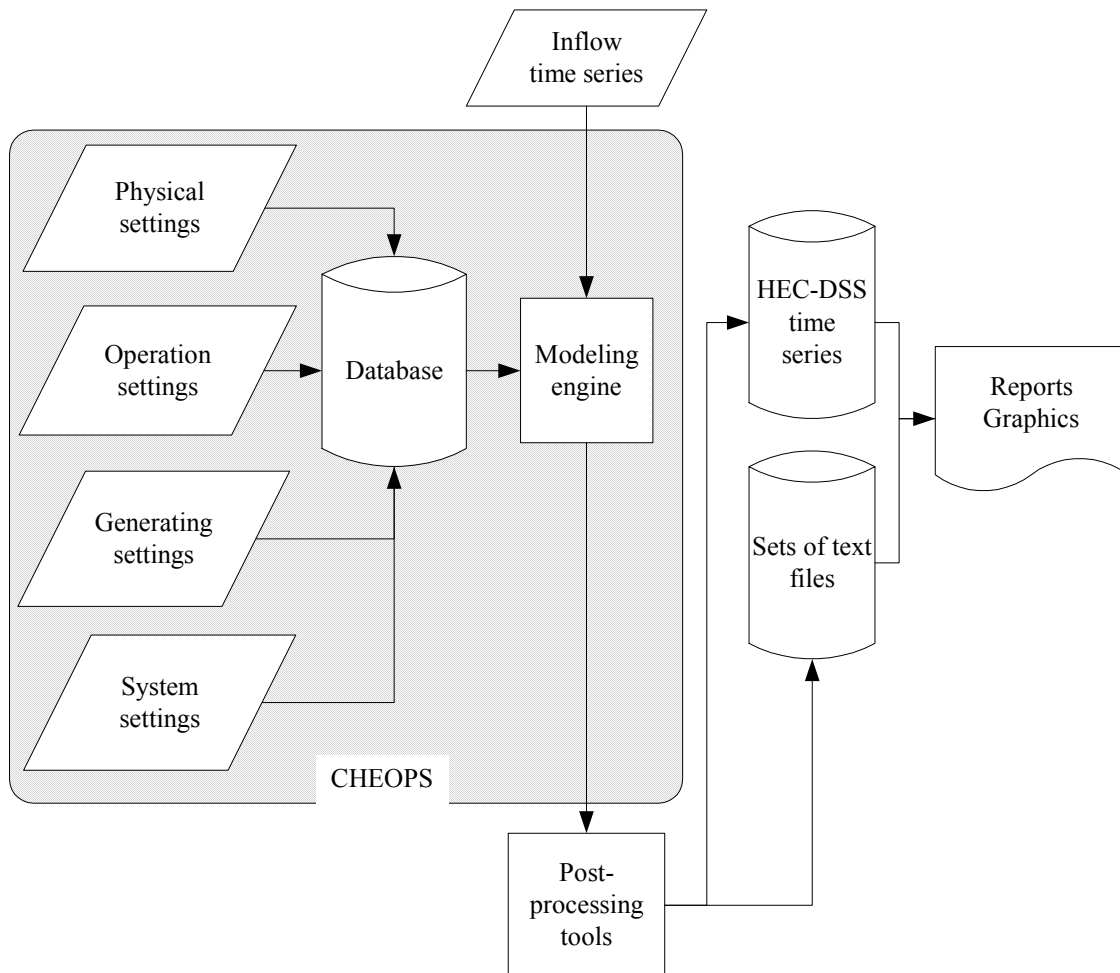
Output data consist of time series in two intervals: 15-minute and daily. The 15-minute data are transformed to hourly data. The hourly and daily data are stored in a HEC-DSS database and summarized to various text files and Excel workbooks.

The figure is a flow chart illustrating data paths in the Water Balance Model. The crosshatched area represents the CHEOPS™ software. This software executes model runs.

Within the crosshatched area is one key component, the database. The database consists of numerous files: a Microsoft Access *mdb* file, Microsoft Excel files, and text files.

A single simulation scenario is called a model run. The software evaluates model runs non-interactively, and often several model runs are batched together. A model run consists of developing a scenario, which is a selection of settings stored in the database, and then invoking

the modeling engine. A model run requires 45-90 minutes of scientific grade personal computer workstation execution time (year 2003).



After the execution is complete, post-processing software tools translate the modeling engine's raw output to two standard formats: HEC-DSS and text files. Other tools use these data to generate specific tabular reports and graphical views of the model run output.

The following are terms used in the Water Balance Model.

- | | |
|-------------------------|--|
| Accretion flow | The incremental volume of baseflow, interflow, and direct runoff that enters a reservoir. Expressed in units of second-feet-day. |
| Bypass flow destination | The location to which bypass flow is directed, either a downstream reservoir or leaving the system altogether. |
| Bypass flows | Flows released from a reservoir and are not passed through a powerhouse. |
| CHEOPS™ | Computer Hydro-Electric Operations and Planning Software, a |

	trademark of Devine Tarbell & Associates, Inc.
Condition	The main building block of a setting, containing specific data.
Discharge	Water released from a reservoir to a powerhouse, canal or tunnel.
Dispatch	A procedure that determines the most efficient way to divide flow among powerhouse units.
Diversion	An outlet to divert water, a tunnel or canal.
Fill and spill	A powerhouse that peaks with the defined load shape but will spill its forebay in order for an upstream reservoir to follow the load shape as closely as possible.
Flood elevation	The elevation of a reservoir above which it may spill. When a reservoir exceeds its flood elevation, the model will change operation of associated powerhouses to reduce the amount of spill.
Gate leakage	The amount of water that leaks through the turbine wicket gates or needle valves when closed.
Generator	A device that converts shaft power to electric power.
Gross head	A unit of pressure, describing the difference between the headwater elevation and the tailwater elevation.
Headloss	The total amount of pressure that is lost, or not available to the turbine, between the headwater and the tailwater at a powerhouse.
Inflow	The flow of water entering a node.
Level fluctuation	The change in reservoir surface elevation.
Level fluctuation limit	A constraint on the amount of level fluctuation, expressed in units of feet per day.
Level fluctuation rate	A constraint on the maximum rate of level fluctuation, expressed in units of feet per hour.
Load shape	The daily pattern of generation, categorized as primary peak, secondary peak, and off peak.
Local inflow	The incremental volume of baseflow, interflow, and direct runoff that enters a reservoir. Expressed in units of second-foot-day.
Maintenance	A period when a powerhouse does not pass water or generate power.
Minimum daily average flow	A constraint on the daily volume of water that must be released from a reservoir through its associated powerhouse.
Minimum elevation	The lowest allowable reservoir elevation, below which no release will be made through its associated powerhouse. Often is the top of a penstock tunnel inlet.
Minimum flow unit	A small unit that is installed specifically to generate power from the reservoir instream release outlet. Typically this unit is separate from the powerhouse.
Minimum instantaneous flow	A lower constraint on the release from a reservoir through its associated powerhouse.

Net head	The head or pressure difference across the turbine unit itself.
Node operation type	The manner in which water is scheduled through a powerhouse, tunnel, or canal: diversion, fill and spill, non-generating, peaking, peaking with ramp rates, run-of-river, or re-regulating.
Non-generating	A non-generating discharge, peaked to follow the load shape.
Peaking	A powerhouse that peaks its discharge and attempts to schedule water into the highest demand periods of the day. This powerhouse can instantaneously change load.
Peaking with Ramp Rates	A powerhouse where the discharge closely follows the load shape; however, the powerhouse is constrained by ramping rates.
Ramping rate	An upper constraint on the rate at which a node's discharge can change.
Ramping rate curve	The river flow-stage relationship at the location where ramping rate compliance is measured.
Re-regulating	A powerhouse designed to regulate peaked discharges from upstream plants into smooth discharges. This powerhouse releases constant outflow. Re-regulating powerhouses may be constrained by ramping rates. When constrained they are required to ramp between days.
Reservoir storage curve	A reservoir's contents (acre-ft) at various surface elevations.
Run-of-River	A powerhouse where inflows are equal to outflows on an instantaneous basis.
Scenario	A collection of settings, which constitutes a model run.
Second-foot-day	A unit of water volume (from informal "second-feet," equivalent to cfs, over one day) equal to 86400/43560 or about 1.98 acre-feet.
Setting	A collection of conditions that form a building block of a scenario. A setting is made up of conditions.
Spill	Water passed over a spillway.
Spillway capacity curve	A relationship that defines the flow rate over a spillway at a reservoir elevation.
Tailwater curve	A relationship that describes tailwater elevation versus powerhouse flow. Used when the tailwater elevation is not controlled by a reservoir elevation.
Tailwater elevation	The water surface elevation that determines the static head on the downstream side of a reaction turbine.
Turbine	A machine that converts kinetic power and pressure to shaft power.
Unit	The combined turbine-generator machine. A powerhouse may have one or more units.
Water withdrawals	Water that is withdrawn from or returned (a negative quantity) to a reservoir.

Components of a Scenario

A scenario is a collection of settings, each of which in turn is a collection of conditions.
System Settings

The system setting consists of the conditions that refer to data applicable to all nodes in the system, or unique data solely applicable to one node in the system. For example, the system setting includes the load shape condition, which contains the data for the preferred daily scheduling of powerhouse generation by hour. The load shape condition applies to each node in the system with a powerhouse. Alternatively, a system setting can also be a condition that applies to only one node. The system setting conditions are discussed below.

Load Shape Condition

The load shape condition includes typical scheduling data for the daily period-durations by month. The model uses the load shape data to schedule the release of water throughout the day, prioritizing generation during the higher demand periods.

The Water Balance Model weekday load shape allows for peak, secondary-peak (or shoulder-peak), and off-peak periods to be described. The weekday load shape is applied to every Monday through Saturday of each month, and can vary by month. The weekend load shape is described by two periods, peak and off-peak. This load shape is used every Sunday of each month and can also vary by month.

Preferred Monthly Energy Reliability Objective Condition

The preferred monthly energy reliability objective condition defines an amount of monthly generation from the system that will, at a minimum, be produced. This parameter provides guidance to the model for monthly generation when other constraints such as the preferred reservoir storage objective does not provide sufficient generation to meet the needs of the system. The model meets this condition (defined in acre-feet) from generation at Union Valley Reservoir and subsequent downstream generation facilities. If insufficient water is available at Union Valley Reservoir, the model will schedule water from Ice House and Loon Lake for release into Union Valley so that Union Valley can meet its flow requirement.

Reserve Volume Condition

The reserve volume condition establishes the minimum volume of water to remain in storage for peaking purposes. The model meets this requirement at Union Valley Reservoir, and if necessary will release water from Ice House and Loon Lake reservoirs into Union Valley Reservoir to meet the condition.

Spinning Capacity Condition

The spinning capacity condition defines the amount of spinning reserve capacity (MW) set aside for each powerhouse in the system. The model limits each powerhouse's generation to the powerhouse's maximum generation capability less the amount set aside for spinning reserve. This condition is negated when the condition would otherwise contribute to spills.

Carry Over Elevations Condition

This condition defines the establishment of beginning-of-year reservoir elevations. The model begins an analysis on January 1 of the start year with each reservoir at its preference elevation. A multi-year analysis can either start the subsequent year with the reservoirs at their preference elevations or at the ending elevations of the previous year.

Forecast Set-up Condition

The Water Balance Model can simulate the ability to forecast inflows and use the forecasted inflows to provide an estimate of the sensitivity of system performance to inflow forecast ability.

Water Year Types Condition

This condition identifies the name of an external Microsoft Excel file (e.g., WaterYearTypes.xls) that contains data pertaining to the bypass flows (minimum streamflow release schedules) and the months these schedules are to be implemented for each reservoir. This file must be identified for a scenario.

Preferred Reservoir Storage Objective Condition

This condition identifies the name of an external Microsoft Excel file (e.g., PRSO.xls) containing data for the preferred reservoir storage objective (described by reservoir level elevation) for Loon Lake, Ice House and Union Valley reservoirs. This file must be identified for a scenario if the user would like to use this option. The preferred reservoir storage objective is one of the parameters used by the model to guide reservoir operations through a year. These values, described by year type (different than the year type described for the Water Year Types Condition above) and for the end and mid-point of each month, influence the drawing or gaining of reservoir storage based on the year's water supply condition. The preferred reservoir storage objective is not an absolute objective, but instead works in concert with other objectives to guide a reservoir operation that reduces the potential of spill from the reservoirs.

Physical Settings

Each scenario contains a unique physical setting for each node. The physical setting contains the conditions that can be categorized as physical attributes of the system. The conditions included in a physical setting are described below. All elevation data must be based on a consistent datum (mean sea level, for example) as the model performs head calculations between nodes.

Reservoir Storage Curve Condition

The reservoir storage curve describes the reservoir elevation (feet) versus contents (acre-feet) relationship. The model uses this curve to calculate elevations throughout the day based on inflows and discharges. The reservoir storage curve must extend beyond the flood elevation so that the model has the ability calculate reservoir elevations during times of spill.

Reservoir Area Curve Condition

The reservoir area curve is similar to the storage curve except the relationship is elevation versus surface area (acres). The model uses these data for daily net evaporation loss calculations.

Daily Net Evaporation Condition

The daily net evaporation condition contains daily net evaporation coefficients (feet/day) for each node by month. To calculate net evaporation, the model multiplies each day's surface area by the month's coefficient to get a net evaporation volume (acre-feet) for the day. The net evaporation volume is converted into a flow for the day and is removed from the reservoir evenly throughout the day.

Tailwater Curve Condition

The tailwater curve describes the relationship between tailwater elevation (feet) and the powerhouse discharge (cfs). The model uses this relationship to calculate a tailwater elevation from the instantaneous powerhouse discharge. The tailwater elevation is subtracted from the reservoir elevation to determine the gross head available to a powerhouse unit. If the downstream reservoir elevation is greater than the calculated tailwater elevation, the model uses that downstream reservoir elevation as the tailwater elevation in the gross head calculations.

Spillway Curve Condition

The spillway curve describes the relationship between reservoir elevation (feet) and spillway maximum discharge (cfs). This relationship allows the model to determine the maximum amount of water that can be spilled at a reservoir elevation.

Ramp Rating Curve

The Ramp Rating Curve condition contains the data used to constrain a node discharge with ramping rates. The relationship is river stage (feet) versus flow (cfs) at the point of measured ramping rate compliance. The model uses this relationship to determine the allowable rate of change for the powerhouse's discharge based on river stage. Because it is expressed as a change rather than an absolute elevation, the ramp rating curve elevation data is the one elevation that does not need to be based on the common datum.

Tunnel/Canal Curve

This condition describes the tunnel or gate discharge curve for diversion or non-generating nodes. This condition applies to the Rubicon, Buck Island and Gerle Creek nodes. For the upper two diversion reservoirs, the curve is reservoir elevation (feet) versus tunnel flow (cfs), while for Gerle Creek the relationship is reservoir elevation (feet) versus canal discharge (cfs).

Node Options Condition Overview

The node options condition contains three pieces of information about the individual node. These three data values are: penstock capacity, minimum flow for powerhouse operation, and node operation type.

The penstock capacity describes the maximum amount of flow that can arrive at the powerhouse. UARP tunnel capacities are entered for these values to constrain scheduled generation within the tunnel capacity.

The minimum flow for powerhouse operation is the lowest flow that the powerhouse will use for generation. This value can constrain model discharges to occur only above a certain flow

threshold (e.g., for consideration of rough unit operation). Without this data the model will use the full performance range of the units.

The node operation type defines how the model classifies and operates the node. There are seven node operation types: non-generating, peaking, peaking with ramp rates, re-regulating, fill and spill, run-of-river and diversion. Certain nodes are restricted to diversion only due to physical characteristics of the node and model logic for these characteristics. Dan, he wanted to list the six and then have the seventh, diversion, in a separate sentence but it is not structured this way to handle it. I will let you modify.

Non-Generating Node

A non-generating node is a node that does not have a powerhouse but has the ability to control discharges.

Peaking Node

A peaking node includes a powerhouse that can instantaneously peak from no discharge to maximum discharge. It peaks discharges to generate in the peak period, then the secondary-peaks and then the off-peak periods. This powerhouse can have a single-day double peak.

Peaking with Ramp Rates Node

This type of node includes a powerhouse which prioritizes its discharge into the peak periods but is constrained by ramping rates. The powerhouse will not double peak but will ramp up to the peak period daily discharge, remain at constant discharge and then ramp back down to the off-peak period discharge. The powerhouse can be constrained by ramping rates based on stage (feet/time) or flow (flow/time). This node operation type must be selected if the user is investigating ramping rates at a particular powerhouse. Setting the node operating type to “peaking with ramp rates” and describing the ramping rate constraint must occur for the ramping rates to be used.

Re-Regulating Node

A re-regulating node includes a powerhouse that releases a constant discharge for the entire day, ramps to the next day’s discharge and releases constant flows again. This type of node is usually found downstream from a peaking powerhouse and oftentimes represents the last powerhouse in the system. This node operating type is also constrained by ramping rates. If there is no ramping rate to apply to the node, an entry of an extremely large ramping rate in the ramping rate constraint condition will negate the constraint.

Fill and Spill Node

A fill and spill node includes a powerhouse that operates like a peaking node except that it is allowed to spill. This type of facility is usually found downstream from a much larger powerhouse. The powerhouse of a fill and spill node may be undersized compared to upstream facilities; thus the fill and spill node is allowed to spill to give priority to the operation of the upstream node.

Run-of-River Node

A run-of-river node matches releases to its inflow on an instantaneous basis. If the node includes a powerhouse, releases can be made up to the maximum of its capacity or inflow, and spills any excess.

Diversions Node

A diversion node does not have a powerhouse and cannot control its discharge. These nodes do not use the load shape to control their releases. Discharge is based on reservoir elevation. Rubicon, Buck Island and Gerle Creek are examples of diversion nodes.

Operation Settings

Similar to the physical settings, operational settings are node specific. Each scenario contains one operation setting for each node. The operation settings contain conditions that define how the node is operated: reservoir elevation constraints and required flow releases. The conditions for operation settings are described below. When described, all elevations are in units of “feet,” and should be based on the same datum as the physical settings.

Flood Elevation Condition

The flood elevation is the elevation at which a reservoir begins to spill. The elevation can relate to a variety of physical situations (spillway crest, partial gate coverage, etc.), and will describe the reservoir elevation at which the model determines that a spill will occur. When the model calculates an elevation above the flood elevation, the model will calculate spill. For nodes with gates that control the spillway discharge, the flood elevation should be the elevation at which operators start spilling to prevent overtopping. For reservoirs with uncontrolled spillway crests, the flood elevation is the spillway crest elevation. The user may enter flood elevations that vary through the year. The reservoir storage curve needs to extend beyond the flood elevation so that the model has the ability to calculate reservoir elevations during times of spill. The model’s logic attempts to reduce or eliminate occurrences of spill when the reservoir elevation exceeds the flood elevation.

Target Elevations Condition

The target elevations are the reservoir elevations at which the model tries to operate the reservoir during the year. These elevations can change each day and the model attempts to end each day at the target elevation. The target elevations should be less than the flood elevations and greater than the minimum elevations. The target elevations condition and the preferred reservoir storage objective condition cannot concurrently guide operations for Loon, Ice House and Union Valley reservoirs. The preferred reservoir storage objective condition takes precedent for these three reservoirs.

Minimum Elevations Condition

The minimum elevation condition describes the minimum allowable reservoir elevation. The elevation can represent a regulation or a physical limit (e.g., lowest available outlet invert). The model will not provide an operation where the reservoir elevation drops below this elevation. This elevation should be lower than the flood elevations, target elevations, and preferred reservoir storage objective elevations.

Water Withdrawal Condition

The water withdrawal condition allows the user to model water removal and return at a node. This operation can represent diversions for irrigation and municipal water use. The model allows the user to enter a daily withdrawal rate (cfs) that is constant throughout the year and a daily discharge rate (cfs) that is constant throughout the year. The model calculates a net withdrawal and accounts for this withdrawal each day.

Fluctuation Limits Condition

Fluctuation limits describe the maximum allowable change in reservoir surface elevation, from maximum elevation to minimum elevation, within a single day. In addition to setting the maximum fluctuation for the day, the limits can be described as “hard” limits. Hard fluctuation limits reset the flood and minimum elevations based on the fluctuation limits and the target elevation. With hard limits the user enters a percentage of the fluctuation limit that is above the target and the model calculates the percentage that is below the target. This type of control allows the model to follow target elevations closer. The difference between hard level fluctuation limits and regular limits is that a hard limit will force the model to spill if the upper limit is exceeded.

Fluctuation Rates Condition

Fluctuation rates are similar to the fluctuation limits except fluctuation rates define the maximum rate of change in reservoir surface elevation. If the node has fluctuation rates (feet/hour) the reservoir operation may be constrained thus leading to a less aggressive powerhouse peaking operation.

Minimum Instantaneous Flow Condition

Minimum instantaneous flows are flows that must be released either through a low level outlet or through a powerhouse to the stream 24 hours a day. The model will meet this requirement before scheduling any excess water in the peak period.

Minimum instantaneous flow can be based on natural inflows to a node in the system. This constraint can be set to an “or inflow” option. The “or inflow” option sets the minimum instantaneous flow equal to the lesser of the user defined flow or the total natural inflow into the node.

Minimum Daily Average Flow Condition

The minimum daily average flow condition represents the minimum volume, defined as a daily average flow (cfs), that the node must release for the day. This constraint can be set to an “or inflow” option. The “or inflow” option sets the minimum daily average flow equal to the lesser of the user defined flow or the total natural inflow into the node.

Bypass Flow Condition

The bypass flow condition describes flows that are released into bypass reaches that normally go around the powerhouse. The values typically represent minimum streamflow release requirements. Bypass flows are not available for generation unless routed through a minimum flow unit. These flows have units of “cfs” and the flow is released as a constant flow for the entire day. A destination node for the flow, which could be a lower reservoir or a destination out

of the system, is also defined. The minimum bypass flow can be defined to be the lesser of the user-defined flow or the total natural inflow.

Ramping Rates Condition

The ramping rate condition constrains the rate of change allowed to a powerhouse's discharge. This constraint is only used if the node operations type is set to "peaking with ramp rates" or "re-regulating." Separate rates for increasing discharges and decreasing discharges can be defined along with separate ramping rates for hourly and daily ramping. The ramping rates can be defined as the allowable change in river stage per time (feet/hour and feet/day) or flow per time (cfs/hour and cfs/day). When ramping rates are defined as stage versus time, the relationship is defined by the ramp rating curve in the physical setting. Flow based ramping rates do not require that the entry of a ramp rating curve.

Flashboards Condition

The flashboard condition allows the user to simulate the installation and removal of flashboards. Currently the parameters that trigger the installation and removal of flashboards are: day, flow and elevation. Flashboards can be located on the spillway, as is the case with most projects or in the tunnel as is the case with Rubicon and Buck Island. Along with defining the installation and removal of the flashboards, the flashboard condition contains the discharge curve (flow versus elevation) for the outlet when the flashboards are installed.

Additional specialized logic is incorporated into the model to simulate the flashboard operation at Buck Island Reservoir. The operation is dependent on the inflows to Rubicon Reservoir and flashboard installation at Rubicon Reservoir.

Generation Settings

Generation settings are node specific and contain the data necessary to simulate power generation. The data includes turbine performance, generator performance, headloss data, gate leakage, and maintenance scheduling.

Turbine-Generator Condition

The turbine generator-condition describes each turbine-generator in the powerhouse. Performance characteristics such as the efficiency of the turbine and generator, headloss and gate leakage are included in this condition.

Headloss Component

Two common headloss coefficients for the powerhouse and an individual coefficient for each unit are available.

Turbine Component

Turbine performance is entered by node with performance data assigned to a particular powerhouse unit. Each turbine performance data set can be assigned to multiple units. If the powerhouse has three identical units, the performance data set is only entered once.

Generator Component

The generator data, like the turbine data, is defined by node and then associated with a powerhouse unit. If the powerhouse has three identical generators, the performance data need

only be entered once. The generator performance data is generator output versus generator efficiency. The generator condition also includes a maximum generator output. This value is the maximum generator output the model will allow assuming that there is turbine capacity to meet this limit. This feature allows the user to limit generator outputs if other auxiliary equipment can not handle maximum generator output. The model will limit turbine output based on the generator maximum desired output.

Gate Leakage Component

Gate leakage is the amount of water that leaks through the wicket gates when the turbine is off-line. The model leaks this amount of water when that unit is off-line. For instance if the powerhouse has three units each with gate leakage of 15 cfs, if units 1 and 2 are operating and unit 3 is off-line, then only unit 3 is leaking 15 cfs. When a unit is out for maintenance, the gate leakage for that unit is assumed to be zero.

Maintenance Schedule Condition

The maintenance schedule condition describes when specific powerhouse units are out of service. The inclusion of systematic maintenance can be simulated. The maintenance schedule allows the removal of a single unit from service at a time.

Minimum Flow Unit Condition

The minimum flow unit condition defines low-level outlet generating units. This condition contains the necessary data to calculate the energy generated by a minimum flow unit. This condition requires headloss, generator performance, turbine performance and rated net head data for the minimum flow unit.

There are two types of Minimum Flow units. The first type operates 24 hours a day and uses the bypass flows as its flow source. The second type operates during those periods when the main powerhouse is not running.

Unit Dispatch

The model uses the unit dispatch to predict generation based on the user-defined turbine-generator data. The purpose of the unit dispatch is to produce a matrix (lookup table) where powerhouse generation is plotted against gross head and total powerhouse flow. The lookup table is only created once for each turbine-generator condition.

The first step of the process is to generate a unit dispatch table to describe the best way to distribute powerhouse discharge between units. This step results in the optimal unit dispatch solution. The unit dispatch logic begins with very small flows through the powerhouse. The routines calculate the optimal unit dispatch for each small flow. The rough estimate of the individual unit distribution is fine-tuned using partial differential equations to arrive at an optimal distribution for the given flow. The fine-tuning process incrementally adds and subtracts flow from the units to hone in on the maximum possible generation for the given total powerhouse discharge. As the dispatch routine increases the total flow through the powerhouse the model uses the previous unit dispatch distributions as well as new distributions to find the

largest possible generation given the flow through the powerhouse. In this way the model is using previous solutions to “learn” about future solutions. The final result is a collection of flow distributions by unit for the entire range of powerhouse discharge flows. When provided total powerhouse discharge and gross head, the model uses the matrix to determine generation.

Daily Time Step Sequence

The final program output can be a 15-minute, detailed schedule of node operation. Prior to creating the 15-minute operation, there are several intermediate steps which must be performed by the model. First, monthly operational objectives such as target elevations and preferred monthly energy reliability objective conditions must be translated to daily operation objectives. The methodology for translating data from monthly to daily objectives will vary depending upon the parameter. For example, the model linearly interpolates between the use-defined target elevations to compute the daily target elevation objectives, and preferred monthly energy reliability objective volumes are computed for each day by equally distributing the monthly volume over each day of the month.

Once the daily objectives have been calculated, the operation at the node is evaluated on a daily time step. The first priority is to set the minimum bypass or flow constraints at the node. Next, the net evaporation is subtracted from the inflow. Based on the remaining inflow to the node, and the release, storage and other constraints at the node, the discharge is computed. The discharge is the release from a penstock, canal or tunnel. Once the daily discharge has been calculated that meets the daily constraints, the model will break down the operation into a 15-minute time step, distributing the discharge throughout the day based on the load shape and other hourly operation constraints supplied by the user. This section will detail the method used to compute the daily discharge values.

Retrieval of Constraint Data

The first step in the node loop is to retrieve the constraints for that node for that day. The model calculates the target elevation, minimum flows, bypass flow, water withdrawals, and other node constraints. All characteristics for that node, for that day, that is day specific, are calculated and loaded into the model logic.

Sum of Inflows

With the daily constraint data loaded into the model, the model retrieves the upstream node’s discharges for the day, local accretions, bypass flows and spill flows that will arrive at that node. The model sums these inflows and calculates a detailed 15-minute inflow profile for the node.

Daily Discharge Calculation

After the model determines the inflow volume for the node it calculates a daily average discharge. The daily average discharge is a function of the total daily inflow, forecasted project inflows, target elevations, release capacity (powerhouse, tunnel or canal) and minimum release requirements.

With the daily discharge calculated, the model checks the discharge against daily constraints such as minimum daily average flows, minimum instantaneous flows, downstream requirements and minimum and flood elevations. Adjustments are made to the daily average discharge as necessary to meet the node constraints.

Fifteen-Minute Time Step

Once the daily average flows have been set, the model schedules the node's 15-minute discharge. The first priority is to meet the minimum instantaneous flow for the node. This minimum instantaneous flow volume is removed from the volume available for peaking purposes. All daily constraint flows were accounted for in the derivation of the daily discharge volume. The primary guide for the 15-minute schedule is the filling of the load shape.

Discharge Priorities Based on Load Shape

The load shape contains the period-durations for both weekdays and weekends for each month. The model uses this data to create the 15-minute schedule along with the powerhouse's peak unit capacities. The model allocates the peaking volume of water into the peak periods first, the secondary peak periods and finally the off-peak periods. The model attempts to operate the units at peak efficiency in order to maximize the generation for the period.

If the powerhouse has ramp rates the model will schedule the powerhouse to not violate the ramp rate constraints. If the node is a re-regulating type the model will schedule a flat discharge, characteristic of a re-regulating facility. If the node is a run-of-river type, the model will schedule discharges to match the inflows.

Constraint Checking

After the peaking volume has been scheduled, the model calculates 15-minute reservoir elevations based on the 15-minute inflows and discharges. Reservoir elevations are checked for reservoir constraint violations. If violations are found, the model will incrementally shift water either at the current node or the upstream node to remove reservoir violations. When the violations are eliminated the model proceeds to the next downstream node.

MODEL LOGIC AND SCHEDULING FLOW CHART

The following figure is an overview of scenario development and model execution. The top section shows the basic steps followed when creating a new scenario. The bottom section describes the steps followed when making a model run. Between the two sections, the Water Balance Model database is shown. The database serves as the repository for the model input behind each scenario.

