BUREAU OF RECLAMATION

Technical Memorandum ENV-2023-013

Klamath Planning and Operations Model Documentation

Klamath Project, Oregon and California
California-Great Basin Region

U.S. Department of the Interior

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Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Disclaimer – This documentation report was developed to document the Klamath Planning and Operations Model (KPOM) using RiverWare. KPOM was developed to represent operating policy under the 2020 Interim Operations Plan, which constitutes a minor update to the previously approved 2019 Biological Opinion. While KPOM was developed with careful consideration of the policies and existing Klamath Basin Planning Model, differences in implementation and simulation results exist.

Furthermore, while documentation was drafted to best represent KPOM, the contents of this report are not exhaustive and all users are recommended to inspect the model for a fuller understanding of its functionality.

Cover Photo – Link River Dam (Reclamation Flickr).

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Klamath Project, Oregon and California
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Acronyms and Abbreviations

BiOp	Biological Opinion
CNRFC	California Nevada River Forecast Center
COPCO	California Oregon Power Company
CU	University of Colorado Boulder
CADSWES	Center for Advanced Decision Support for Water and Environmental Systems
DMI	Data Management Interface
DSS	Data Storage System
ESA	Endangered Species Act
EWA	Environmental Water Account
HDB	Hydrologic Database
HEC	Hydrologic Engineering Center
IGD	Iron Gate Dam
IOP	interim operations plan
KBAO	Klamath Basin Area Office
KBPM	Klamath Basin Planning Model
KDD	Klamath Drainage District
KPOM	Klamath Planning and Operations Model
KROM	Klamath RiverWare Operations Model
LKNWR	Lower Klamath National Wildlife Refuge
LRDC	Lost River Diversion Channel
MRM	multiple run management
NRCS	Natural Resources Conservation Service
OM	Operations Mode
PA	proposed action
PM	Planning Mode
Reclamation	Bureau of Reclamation
RBS	rulebased simulation
SCT	System Control Tables
TSC	Technical Service Center
UKL	Upper Klamath Lake
USGS	U.S. Geological Survey
WRIMS	Water Resources Integrated Modeling System
WSF	Water Supply Forecasts

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1. Introduction

1.1. Motivation

The Bureau of Reclamation's (Reclamation) Klamath Basin Area Office (KBAO) requires a water resources planning model for development of Proposed Actions (PA) within Endangered Species Act (ESA) Reconsultation efforts for the Klamath Project (Figure 1). Currently, KBAO utilizes the Klamath Basin Planning Model (KBPM) built on the California Department of Water Resources – Water Resources Integrated Modeling System (WRIMS) platform. KBAO represented proposed actions using KBPM model runs for many years. However, pending water rights adjudication, tribal water rights settlements, continued endangered species and other environmental flow requirements, and changing hydrology in the Klamath River Basin, KBAO continues to face great challenges with developing Pas that satisfy the multi-objective usage and environmental regulatory requirements of the system. KBAO identified RiverWare (Zagona et al. 2001) as a platform that may address these needs and challenges, and requested the Technical Service Center's (TSC) support for development of an Upper Klamath Basin RiverWare planning model.

Building on previous work to develop the Klamath RiverWare Operations Model (KROM), KBAO and TSC partnered with the University of Colorado Boulder (CU), Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) to combine aspects of KPBM into the existing KROM and produce the Klamath Planning and Operations Model (KPOM). In this effort, Reclamation again collaborated with CADSWES to develop a flexible model to support water management and represent changing conditions in the basin. This model was developed using the KBPM implemented to support the 2020 Interim Operations Plan (IOP) (Reclamation, 2020), which constitutes a minor update to the previously approved 2019 Biological Opinion (BiOp) (Reclamation, 2018). Primary objectives for model development included a flexible structure to account for changing hydrologic, policy, and infrastructure conditions; automated data management for data input and output; automated reporting capabilities for improved stakeholder communication; and, modular model structure to tailor model versions to specific stakeholder needs.

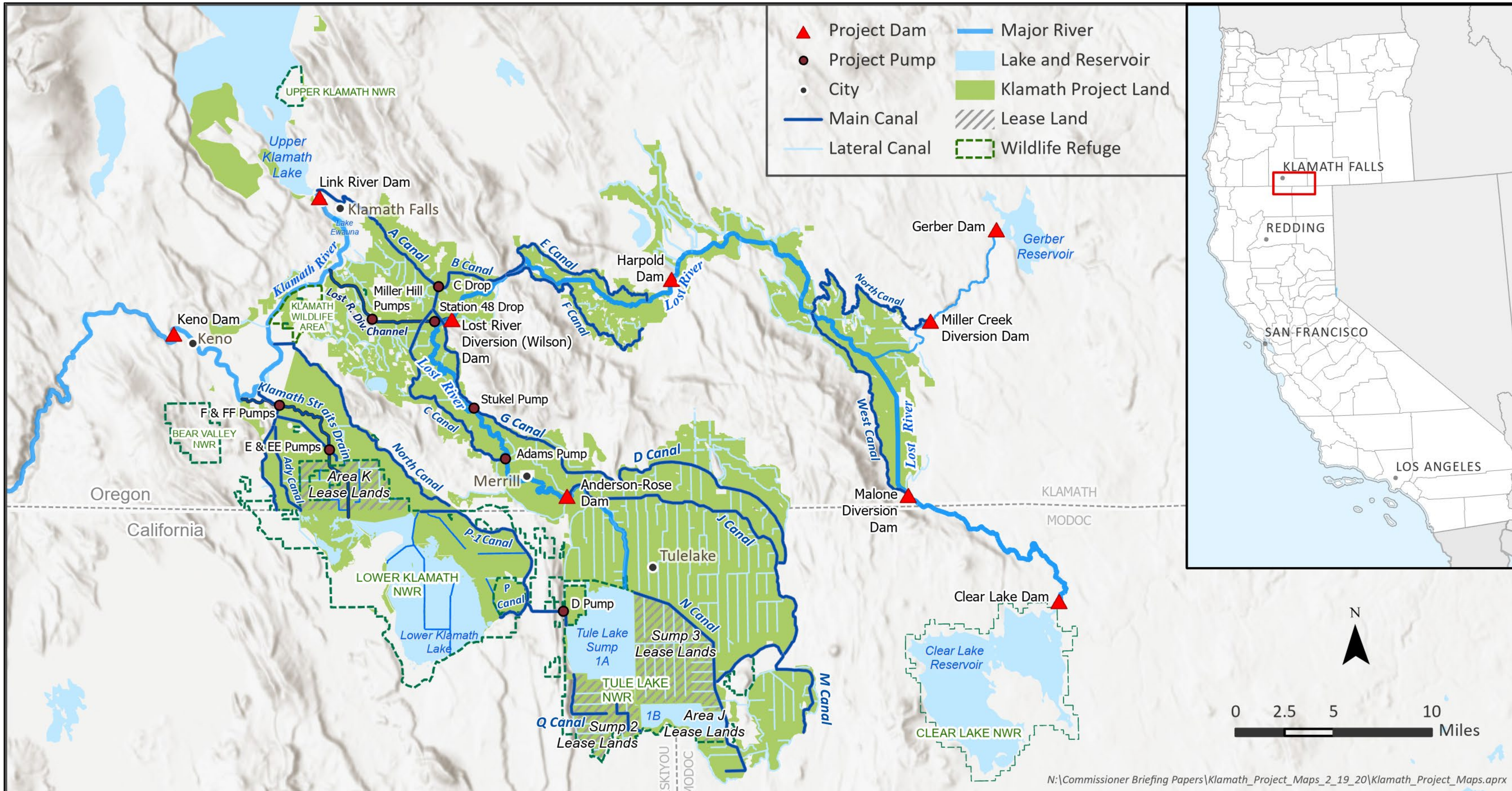


Figure 1. Overview map of Klamath Project (shaded area).

1.2. RiverWare

RiverWare (Zagona et al., 2001) was developed by the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) of Boulder, Colorado, with substantial support from Reclamation, the U.S. Army Corps of Engineers (USACE), and the Tennessee Valley Authority (TVA). The software allows reservoir operators to develop and run detailed, site-specific simulations. It includes an extensive library of modeling algorithms, several solvers, and a language for the expression of operating policy. Its graphical interface facilitates model construction, execution, and analysis of results. Federal and state agencies across the United States have developed RiverWare models to resolve a wide range of operational and planning problems.

Within RiverWare, system features (e.g., reservoirs, river reaches, diversions, etc.) are represented by “objects”, each with unique options for user-selected methods for solving during simulation (i.e., a diversion is modeled differently than a storage reservoir). Objects can be linked to represent their interactions. Within each object, there are a series of “slots”. Slots include both scalar (single value) and vector (timeseries) data, and can represent anything from measurable quantities (e.g., storage volume) to . Within RiverWare, slots are typically referenced by listing the object, then a period, then the slot name. For example, if we wanted to reference the Storage slot for Keno reservoir, that slot would be: *Keno.Storage.* Throughout this report, slots will be italicized.

More information about RiverWare can be found on the website: https://www.riverware.org/

1.3. Organization and Use

This report provides an overview of the KPOM and detailed documentation to understand RiverWare model components (Chapter 2), operating policies (Chapter 3), and workflow (Chapter 4), and to provide model run guidance (Chapter 5). The report is intended for use by individuals using KPOM for daily operations or planning studies for the Klamath Project, and who have familiarity with both RiverWare and the operating policies outlined in the 2020 IOP. KPOM is currently maintained in a GitHub repository at the following location: https://github.com/usbr/KPOM/tree/main

2. Physical Model Configuration

This section presents information on the physical KPOM configuration, including timestep, time range, observed and forecast data handling, and data objects and methods.

2.1. Timestep and Time Range

KPOM is a daily timestep model, corresponding with the frequency of operating decisions for the Klamath Project and ESA-related requirements. The KPOM has capability to run in Operations Mode to support daily operations decisions (previously the stand-alone KROM) and Planning Mode to support long-term planning decisions. The time ranges for Planning and Operations Modes are distinct. Table 1 summarizes the start and end timesteps for both planning and operations mode runs.

Table 1. Run Range for Planning Mode and Operations Mode Start Date Month

Mode	Start Timestep	End Timestep
Planning Mode (PM)	September 30, 1980	February 28, 2021
Operations Mode (OM)	October 1, Current Water Year	February 28, Next Water Year

For Planning Mode (PM), the *Start Timestep* is set to the start date used in KBPM: September 30, 1980. The *End Timestep* is set to February 28, 2021—the last date for which key simulated inputs were available. The *Start Timestep* and *End Timestep* for Planning Mode are listed in . These start and end timesteps were used for model development. The framework is agnostic to the run period, so long as input data exists.

Operations Mode (OM) uses both observed and forecasted data. The start date represents the first day of forecasted data, whereas the end date is the last day of the forecast. Observed data initializes the model to conditions as of the forecast issuance date. The model uses an *Operations Start Date*, which defines the date where the model transitions from using observational data to forecast data. Typically operators would set this date to the current day. It could also be a previous day if historical system operations must be represented due to missing data, holidays, etc. The *Operations Start Date* was devised to handle several challenges in modeling water operations, including the need to handle setting initial conditions throughout the model, and to account for routing time lags within the river system. All other dates required by the model are keyed off of the *Operations Start Date*. Operations Mode uses a *Start Timestep* of October 1 of the current water year, and *End Timestep* of February 28 of the next water year (17 months from Start Timestep).

2.2. Observed and Forecasted Data Handling

KPOM in Planning Mode uses observed or simulated historical data for inflows and initial reservoir stages. Historical Natural Resources Conservation Service (NRCS) water supply forecasts (WSF) are used throughout the simulation for the model development runs. The remaining slots are either set directly by rules or solved during simulation.

For Operations Mode in both Fall-Winter and Spring-Summer operations, the model period from the *Start Timestep* up to the *Operations Start Date* is populated with observed historical data. The model does not represent operations for the period prior to this date, although some computations may be made using the observed data. The model uses this data for plotting and analysis purposes. This period is called the observed period.

Computations from the *Operations Start Date* forward use simulated and forecast data. This is the period that the operators are actively making management decisions. Additionally, some manual adjustments to forecast data may be made to test alternative scenarios. As the *Operations Start Date* progresses through time, observational data replace forecast data.

Computations past the short-term forecast period use forecasted data. For model runs with an *Operations Start Date* from October-December, the model first uses deterministic forecasts from the California Nevada River Forecast Center (CNRFC) for the first 7 days (termed short-term forecast period) and then use an analog water year forecast for the remainder of the run period based on the NRCS seasonal forecast. These forecasts use operator-selected water years considered analogous to current basin hydrologic conditions. For model runs with an *Operations Start Date* from January-September (inclusive), CNRFC deterministic forecasts are used for the first 7 days and then NRCS WSF are used and disaggregated from seasonal volumes to daily flows for the remainder of the run period.

2.3. Objects and Methods

This section describes major features in the basin represented in KPOM. Major features include river reaches, reservoirs, diversions, gages, water users, pumps, local inflows, and power facilities. RiverWare objects and methods are required to model these features. Model features are briefly described by region within the model domain.

2.3.1. Extent

Model extents in KPOM are focused on the Upper Klamath River basin, with upstream boundaries at the Williamson River near Chiloquin (United States Geological Survey [USGS] gage number 11502500) upstream of Upper Klamath Lake (UKL) and a downstream boundary of Klamath River below Iron Gate Dam (IGD; USGS 11516530). The Lost River system below Wilson Dam is included in the model. However, the current model does not include water operations or policy in the Lost River System. The Lower Klamath River, downstream of IGD, is excluded. Select stream gage locations throughout these extents are included in the model to compare with simulated values.

The Upper Klamath basin encompasses the Klamath River watershed upstream of IGD. Reclamation's Klamath Project is in the Upper Klamath basin, where KBAO's river operations occur. The input locations for the RiverWare model in the Upper Klamath basin include *UKL Inflow* (UKL net inflow) and *Wilson Dam Inflow.* Local inflows are also represented along the Keno to IGD reach.

The RiverWare model includes the main diversion canals to the Klamath Project, but the model does not represent more fine scale water distribution within the Klamath Project (e.g.. at the irrigation district scale shown in Figure 1). Klamath Project water users are lumped according to the following groupings: *A Canal, Ady Canal, Miller Hill Pump, North Canal, and Station 48.* The Lower Klamath National Wildlife Refuge (LKNWR) is included in an object called *Refuge*.

2.3.2. Reservoirs

In the Upper Klamath basin, only UKL is represented for storage and use of water for irrigation and environmental purposes. UKL is represented in RiverWare as a storage reservoir. The RiverWare methods associated with the reservoir include a hydrologic inflow (i.e., local inflows) and a diversion directly from the reservoir, which is the A canal. The model does not include simulation of reservoir evaporation. In the case of UKL, evaporation is incorporated into the value of (observed or forecast) UKL net inflow.

Of the five reservoirs managed by PacifiCorp (i.e., Keno, JC Boyle, Copco[1] 1, Copco 2, and Iron Gate), only Keno and IGD are represented. JC Boyle, Copco 1, and Copco 2 are considered run-of-river (i.e., no change in storage) and are not represented. Keno Reservoir, which has very limited active storage, is represented as a storage reservoir. Because little information is publicly available on day-to-day operations, however, KPOM represents Keno Reservoir as a run-of-river reservoir by setting a constant pool elevation. IGD, which generates power and is used to moderate Klamath River flows downstream for salmon habitat and survival, is represented as a storage reservoir. IGD operates between 51,000 and 53,000 acre-feet, to be consistent with KBPM.

2.3.3. Local Inflows / Accretions

Accretions represent all of the gains or losses in the system, including local inflows and return flows. Accretions occur on the "Gain" reaches, for example, *Lake Ewuana Gain* and *Keno to IGD Gain*, and at the Lost River Diversion Channel and F and FF Pump where a portion of the flow is an accretion.

All accretions between Keno and IGD are included on the *Keno to IGD Gain*, directly downstream of the lag reach described Section 2.3.4 River Routing. In general, the accretions are specified on the Local Inflow slot as known values throughout the *Run Range*. Accretions are

[1] Copco is an acronym for California Oregon Power Company

computed during the observational period by differencing gaged data. Accretions for the forecast period are computed as part of the initialization rules. Forecasting computations are documented in the initialization rules.

2.3.4. River Routing

No routing methods are used. Flows released from UKL arrive at Keno, are passed through Keno and arrive at IGD in the same timestep, without loss, attenuation, or delay.

2.3.5. Diversions and Demands

Water diversions to canals are modeled with Diversion objects. Consumptive use of water is modeled within the Diversion objects, except in the case of Klamath Drainage District (KDD) and the LKNWR. Enough detail for diversions and depletions is provided to represent main canals and lumped diversion areas, but KPOM does not perform a detailed depletions analysis. KPOM represents water users on the east side in two main usage areas: Area 1 and Area 2. Area 1 receives water via the *A Canal*, *Miller Hill Pump*, and *Station 48* diversion objects. *Area 2* receives water via *North Canal* and *Ady Canal*. *Area K* (not represented by an object) and the *Refuge* receive water via *Ady Canal*. The following paragraphs describe Area 1 and Area 2 in more detail. KPOM does not explicitly represent water users on the west side of the Klamath River who are not served by Klamath Project water supply, diverting from the Klamath River. This "non-project" use is currently lumped in with accretions (i.e., generally reducing accretions by their diversion amount).

In Area 1, the Lost River Diversion Channel (LRDC) can move water in either direction. In the model, this is represented as two distinct flow paths. When water is diverted from the Klamath River to the canal, it is diverted at *LRDC Draw from Klamath* to the *Div To LRDC* object. When water is diverted from the Lost River, it is removed from the *Wilson Dam* reach to the *Lost to LRDC* object and is subsequently routed to *Station 48* and *Miller Hill Pump*. Any unused or non-diverted water can return to the Klamath River at *Lost River to Klamath River* confluence.

In Area 2, multiple objects are used to move the water from the Klamath River to the *North Canal* and *Ady Canal* objects. Water is then split into the components that go to *KDD* and the *Refuge* Water User objects. *North Canal* only diverts agricultural water, whereas *Ady Canal* diverts both agricultural and *Refuge* water. Return flows and other accretions are conveyed through the F and FF pumps at the terminus of the Klamath Straits Drain. Objects representing Area 1 and Area are shown in Figure 2 and Figure 3.

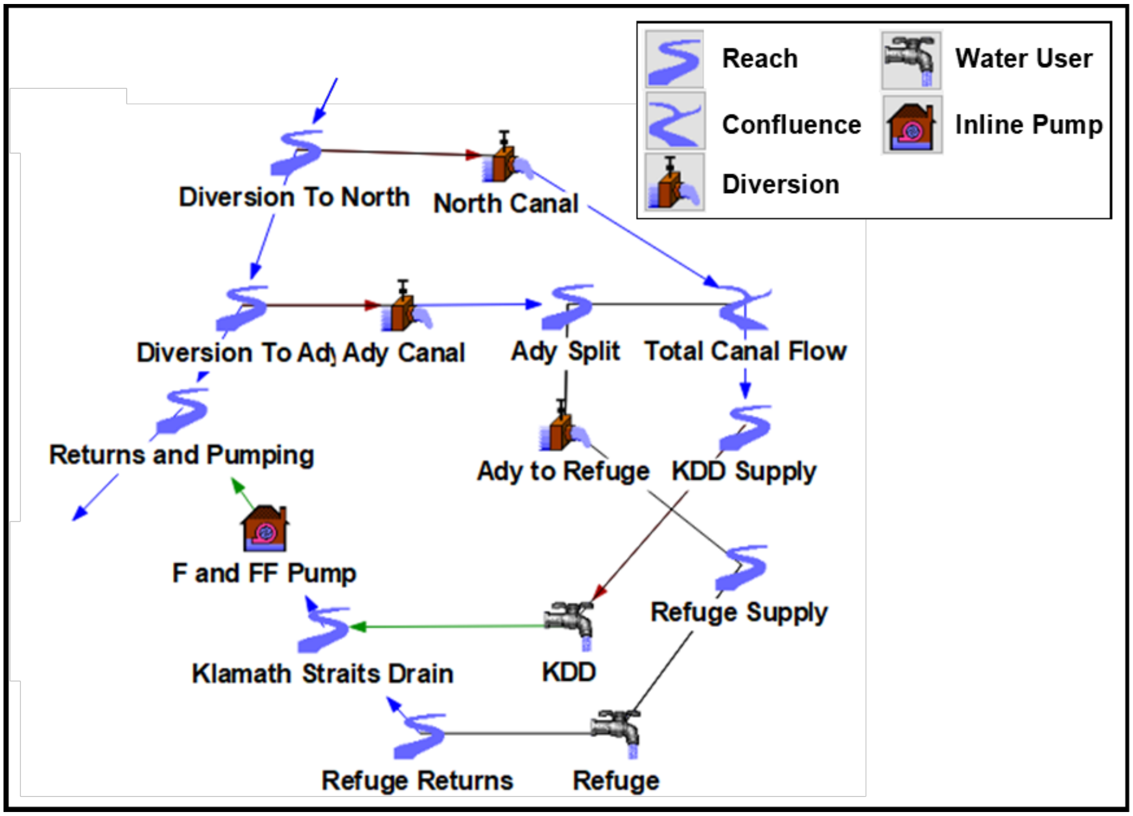


Figure 2. Area 1 KPOM representation.

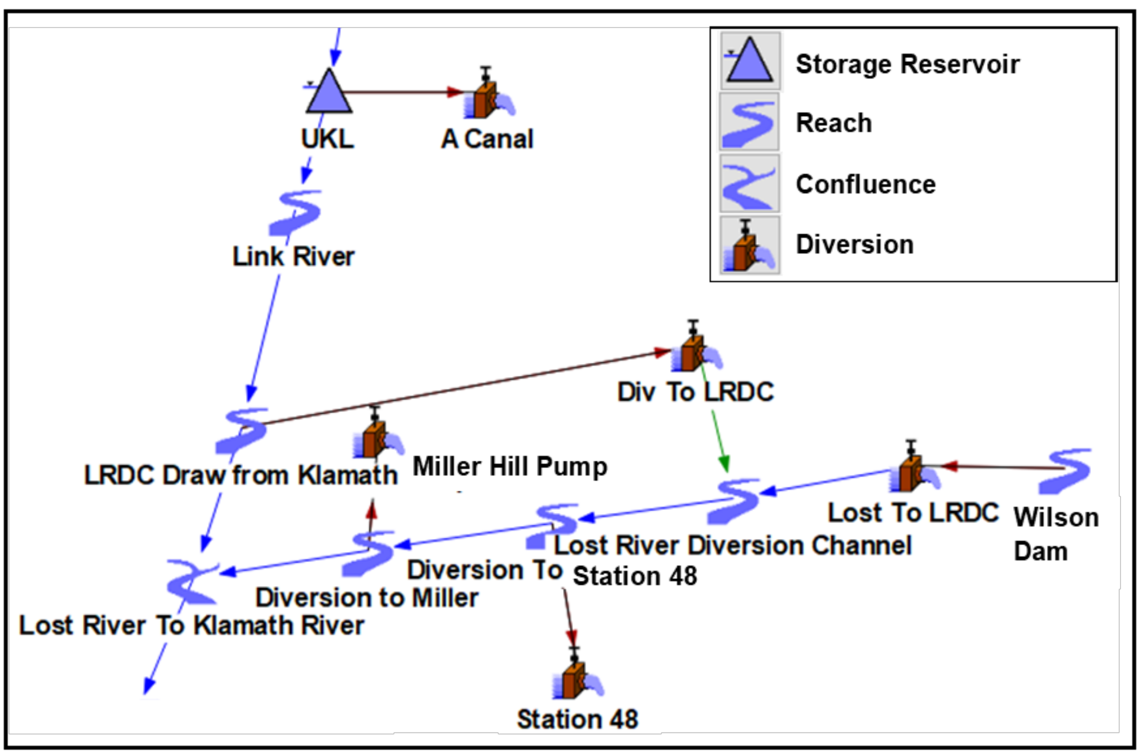


Figure 3. Area 2 KPOM representation.

3. Operating Policy

The operating policy in KPOM is contained in three policy sets: Initialization Rules, Rulebased Simulation (RBS) Rules, and Global Functions. Initialization rules execute first, at the beginning of a model run, to perform one-time configuration type tasks (e.g., clearing previous values or setting inflow values). RBS Rules execute on each model timestep and represent the operational policies and priorities. Global Functions can be called by Initialization Rules, RBS, and other Global Functions, to perform calculations (e.g., checking if the current date is the first day of a month, calculating discharge capacity for a facility, etc.). The following sections describe these three policy sets in the general order of the model's execution routine.

3.1. Initialization Rules

Initialization Rules prepare the model for a run. Initialization Rules execute once each at the beginning of a run. Rules either perform policy initialization or process observed Data. The associated rules in the model are classified into multiple policy groups as shown in Figure 4.

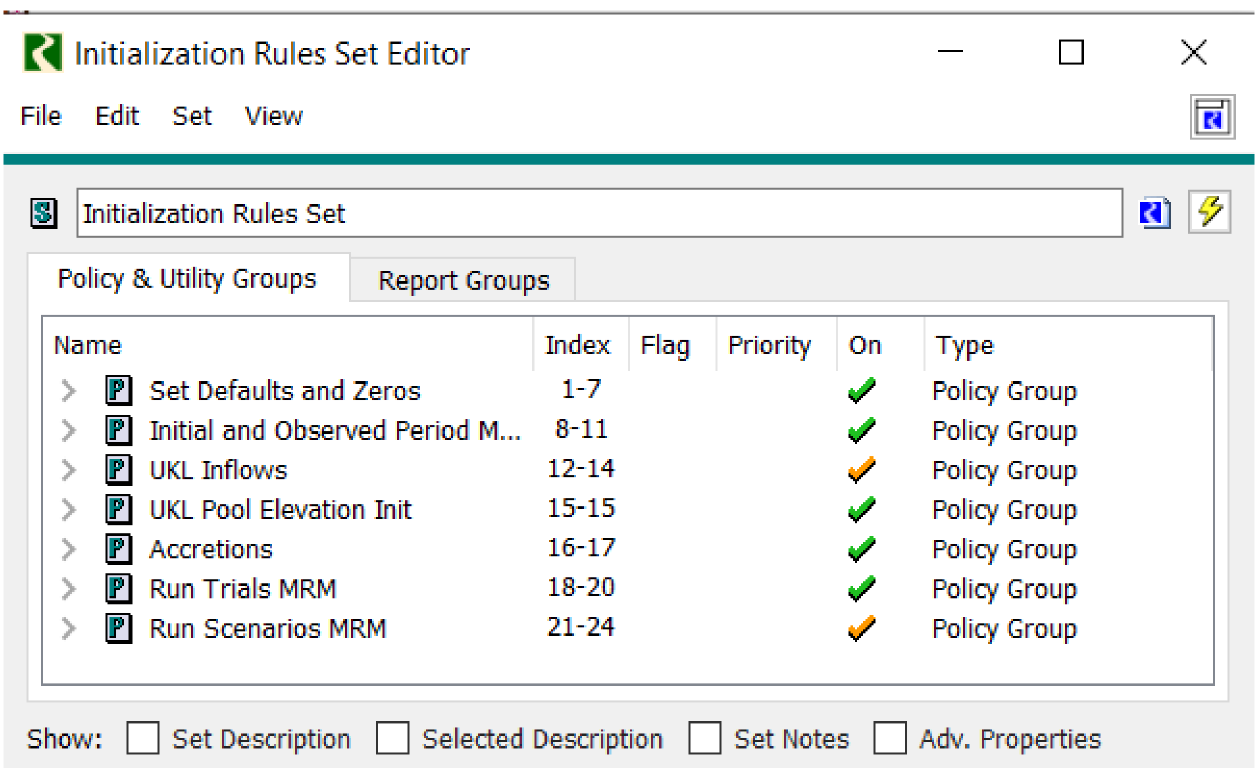


Figure 4. Policy Groups organizing logic in the KPOM Initialization ruleset.

Initialization Rules execution follows the same process as RBS Rules. It starts at the lowest priority rule (largest index) and finishes on the highest priority rule (smallest index). Unlike the RBS Rules, the Initialization Rules only execute once, on the run start timestep. Initialization Rules can set either:

- The lowest priority (R flag and IR priority). Any RBS Rule may overwrite a slot they set. The model intends for this overwrite since some Initialization Rules set a placeholder value that allows the RBS Rules to begin an iterative process to set said slot.

- The highest priority (Z flag and 0 priority). If a slot set by Initialization Rule should remain unaltered, the rule's priority is set as a Z or DMI Input. Thus, any RBS Rule, regardless of priority, cannot overwrite that slot.

Each Initialization Rule is described in more detail in Appendix A (on GitHub). The following paragraphs provide information on the groups of initialization that are performed. The Initialization Rules Policy Groups are as follows (in order of execution):

- Run Scenarios MRM: Assigns Accretions, Agricultural Adjustments, and Inflows for MRM.

- Run Trials MRM: Assign user specified inputs for Multiple Run Management (MRM).

- Accretions: Assigns inflow forecast exceedance values for reservoirs and accretion points.

- UKL Pool Elevation Init: Assigns an initial pool elevation to UKL.

- UKL Inflows: Determines UKL inflow forecast exceedance for Operations Mode and assigns UKL Inflows for 60-day prior to Start Timestep for Planning Mode.

- Initial and Observed Period Mass Balances: Sets inflow and outflow during initial and observed period for Operations Mode.

- Set Defaults and Zeros: Resets slots to default values or zeros; sets initial pool elevations for reservoirs other than UKL; and set pre-simulation data.

3.2. Rulebased Simulation Rules

The KPOM 2019 BiOp and 2020 IOP are contained in RBS Rules. The rules are grouped into the operation they perform. The ruleset and its policy groups are shown in Figure 5.

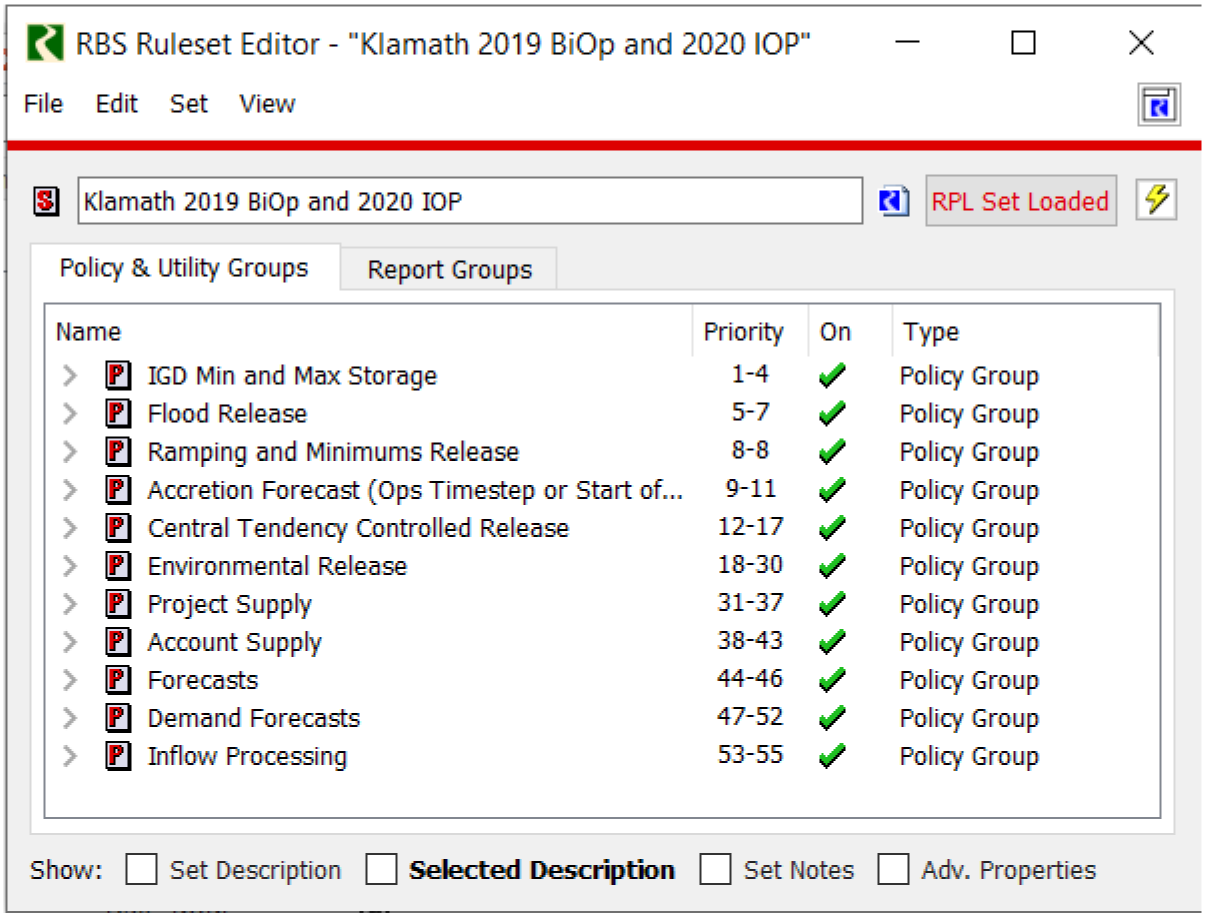


Figure 5. Policy Groups categorizing logic in the KPOM Ruleset.

Each rule executes in reverse priority order (i.e., 3, 2, 1) on every run timestep; that is, rule 55 executes first and is the lowest priority. Conversely, rule 1 executes last and is the highest priority. Higher priority rules can overwrite values set by lower priority rules, but not vice-versa. A rule can re-execute on the same timestep after the highest priority rule if one of its dependencies changes (e.g., if a lower priority rule uses a slot as input that is changed by a higher priority rule, the lower priority rule will re-execute with the modified slot value). Furthermore, some rules are used only in Operations or Planning Mode, denoted by having either "OM" or "PM" as a prefix to the rule name. These rules only execute when the applicable mode is in use (OM or PM).

The rules are documented in the model using inline comments and descriptions. Figure 6 shows a sample rule with inline comments (lines starting with red #) and description. Further, Appendix A (on GitHub) provides a model report documenting all of the *RBS Rules*. Refer to Appendix A or the model for more information on any particular group or rule. Appendix A is also ordered by execution order. The following sections provide an overview of each group.

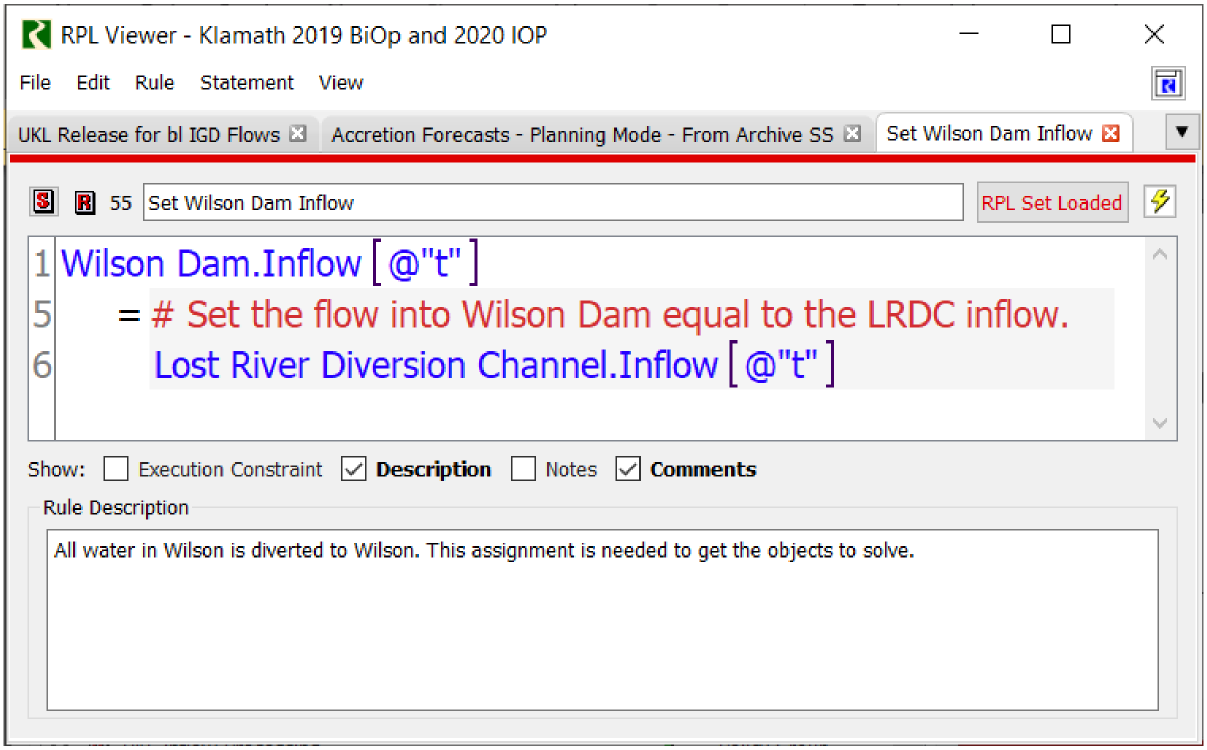


Figure 6. Sample rule showing inline comments (red # lines) and Rule Description at the bottom.

3.2.1. Inflow Processing Policy Group

Rules in the Inflow Processing Policy Group assign inflows for UKL and the Lost River basin (Wilson Dam). Methods vary depending on use of Operations and Planning Modes. These differences are described in the sections below.

3.2.1.1. Operations Mode Inflow

In Operations Mode, *Wilson Dam.Inflow* is set to the LRDC historical inflow—thus only accounting for the portion of Lost River flows actually diverted by the LRDC. *UKL.Raw Inflow* is first set to the forecasted inflow depending on how the year is characterized by exceedance curves. Next, the *UKL.Inflow* is set by multiplying the current day's *UKL.Raw Inflow* by a smoothing factor and adding to the previous day's *UKL.Inflow.* Thus, in Operations Mode, UKL inflows are a smoothed version of forecasted inflows.

3.2.1.2. Planning Mode Inflow

In Planning Mode, *Wilson Dam.Inflow* is also set to the Lost River Diversion Channel historical inflow—again only accounting for the portion of Lost River flows actually diverted by LRDC. UKL raw inflow is set to the historical inflow, while the actual UKL inflow is set to the smoothed inflows calculated as part of the 2020 IOP and KBPM development. Thus, in Planning Mode, UKL inflows are a smoothed version of historical inflows.

3.2.1.3. Rule Descriptions

The following table (Table 2) describes the prioritized rules that control the dilution and flushing. These are operations intended for disease mitigation through periods of increased flows released from UKL and IGD.

Table 2. Inflow Processing Policy Group Rule Description

Priority	Rules
55	**Set Wilson Dam Inflow:** This rule sets Wilson Dam inflow to the LRDC inflow.
54	**UKL Inflow Forecasts:** This rule sets the UKL raw inflow to forecasted values, in Operations Mode, or historical values, in Planning Mode. This init rule forecasts the inflow at Upper Klamath Lake. The inflows are set with a Z flag since they are not meant to be altered when objects dispatch or rules solve. Rather, the slots that should vary or reset are the storage and release, which the ruleset solves for.
53	**Set UKL Inflow and Smoothed Inflow:** This rule sets the UKL inflow by smoothing the UKL raw inflow, in Operations Mode, or setting directly to KBPM smoothed inflow, in Planning Mode. This rule computes the smoothed inflow at Upper Klamath Lake. Since the raw inflow is computed from a mass balance, the values tend to vary greatly across the run period. This equation smooths the inflow so it shows a more consistent curve when plotted.

3.2.2. Demand Forecasts Policy Group

Rules in Demand Forecasts Policy Group focus on initializing Agricultural demands, Refuge Demands, and setting the type of hydrology year for Planning Mode runs. The following table (Table 3) describes the prioritized rules that control the dilution and flushing.

Table 3. Demand Forecasts Policy Group Rule Description

Priority	Rules
52	**Planning - Hydrologic Year Type - WSF:** Sets the hydrologic year type based on the Water Supply Forecast: dry, normal, or wet. The hydrologic year type is used for estimating demand forecasts.
51	**Refuge Demand Forecast:** Sets the initial LKNWF Refuge demand for the current timestep.
50	**Set Agricultural Demand Forecasts:** Sets the initial diversion requests for Agricultural Users for the current timestep.
49	**Agricultural Offset Forecasts:** Sets the Agricultural Offset value, based on yesterday's project accretion and LRDC inflows, for the current timestep.
48	**Return Flow Initialization:** Sets the return flow for the current timestep, based on the KDD and Refuge demands for the current timestep.
47	**Set KDD and Refuge Div Req:** This rule sets Diversion Requested on water user objects that are necessary for them to dispatch or rules to solve. Sets multiple slots based on the forecasted values estimated in Rules 52-48.

3.2.3. Forecasts Policy Group

Rules in Forecasts Policy Group focus on initializing Forecast Timesteps, UKL Inflow Forecasts, and NRCS Forecasts (for Operations Mode runs). The following table (Table 4) describes the prioritized rules that control dilution and flushing.

Table 4. Forecasts Policy Group Rule Description

Priority	Rules
46	**Forecast Timestep Flag:** Checks if the current date has a UKL Inflow Forecast or NRCS UKL Water Supply Forecast and sets the Forecast Timestep Flag for the current timestep.
45	**UKL Inflow Forecast for Run:** This rule computes the Adjusted NRCS Inflow Forecast.
44	**Adj NRCS Forecast Input Table for Ops Mode:** This rule computes the Adjusted NRCS Inflow Forecast.

3.2.4. Account Supply Policy Group

Rules in Account Supply Policy Group focus on initializing the UKL Supply and Environmental Water Account (EWA) throughout the operations season. The following table (Table 5) describes the prioritized rules that control the dilution and flushing.

Table 5. Account Supply Policy Group Rule Description

Priority	Rules
43	**April Lock Limit and Switch:** Sets the April Lock Limit and Switch, which ensures that Project Supply is not reduced below the April allocation.
42	**Operations - Ungaged Diversions:** In Operations Mode, if ungagged diversion information is missing for the current timestep, ungagged diversions are set to a specified value.
41	**Boat Dance Supply:** In even years, add additional volume to EWA for boat dance supply.
40	**UKL Supply:** This rule computes the Upper Klamath Lake Supply, which is the cumulative volume the reservoir has to distribute to environmental and agricultural objective during the Spring/Summer season. On forecast timesteps, set UKL Supply based on the current storage in UKL, the NRCS UKL Inflow forecast, and the end of season target storage (based on Hydrologic Year Type).
39	**Environmental Water Account:** This RBS rule computes the Environmental Water Account, which is the cumulative volume Upper Klamath Lake has to distribute to environmental objectives during the Spring/Summer season. On forecast timesteps, set the EWA volume, including the boat supply and augmentation volumes, when appropriate. If July 1, add in the Augment Volumes.
38	**EWA Augment Volumes:** On March 1 and April 1, set the EWA Base Augmentation volume. On May 1, set the May June Augmentation Volume.

3.2.5. Project Supply Policy Group

Rules in Project Supply Policy Group focus on setting the Project Supply, agricultural adjustment factors, and agricultural forecast offsets throughout the operations season. The following table (Table 6) describes the prioritized rules that control the dilution and flushing.

Table 6. Project Supply Policy Group Rule Description

Priority	Rules
37	**Project Supply Reduction due to May June Augment Flows:** Reduce Project Supply by fraction of Augmentation Volume, when appropriate.
36	**Project Supply:** This rule computes the Project Supply, which is the cumulative volume Upper Klamath Lake has to distribute to agricultural objectives from March 1st to November 15. On forecast timesteps, set the Project Supply, accounting for Project Supply Reductions, ungagged diversions, EWA, and the April Lock Limit.
35	**Planning - Set Ag Adj Factor and Update Diversion Demand:** In Planning Mode, set diversion requests based on the Agricultural adjustment factor.
34	**Operations - Set Ag Adj Factor:** In Operations Mode, set Agricultural adjustment factor.
33	**Set Project Supply UKL Release:** This rule sets the Outflow from Upper Klamath Lake that satisfies agricultural objectives. Water "borrowed" from the lake for the Eastside not included in Ag Releases from UKL is added in and water "paid back" by the Eastside is removed. Set UKL Outflow to the net agricultural demand downstream of LRD.
32	**Set Klamath to LRDC:** This rule sets the diversion from the Klamath River to the LRDC that is necessary when the agricultural demands on the LRDC section exceed the supply from the Lost River System.
31	**Planning - Update Agricultural Offset Forecasts:** In Planning Mode, set the LRDC and F and FF Pump Agricultural Offsets.

3.2.6. Environmental Release Policy Group

Rules in Environmental Release Policy Group focus on setting the environmental releases for UKL and IGD, depending on the season and presence of augmentation volumes. The following table (Table 7) describes the prioritized rules that control the dilution and flushing.

Table 7. Environmental Release Policy Group Rule Description

Priority	Rules
30	**UKL Credit:** This rule computes the cumulative accrued credit water available for basin objectives.
29	**Link Release Difference:** This rule computes the difference in the Spring Release between the current and previous timestep, which also includes considerations for UKL Credit, Augment flows, PacifiCorp Payback, and Eastside Payback.
28	**EWA Used thru Yesterday:** This rule computes the cumulative Environmental Water Account volume that has been used through the previous day.
27	**EWA Remain:** This rule computes the remaining volume per month that can be allocated for environmental objectives.
26	**IGD Spawn Release:** This rule computes the release rate that meets spawning criteria, which is to send enough water from Iron Gate Dam to create spawning habitat for ESA listed fish.
25	**Fill Release:** This rule computes the release rate that meets filling criteria, which is to reach the target elevation at Upper Klamath Lake.
24	**Spring Release:** This rule computes release rate that meets the spring criteria, which is to preserve storage at Upper Klamath Lake while also satisfying basin objectives.
23	**EWA Base Augment Release:** This rule determines if Base Augmentation has been triggered and computes the release rate needed to expend the base augmentation before the end of June.
22	**EWA May June Augment Release:** This rule determines if May June Augmentation has been triggered and computes the release rate needed to expend the May June Augmentation volume in May and June.
21	**Summer Release:** This rule computes the release rate that meets the summer criteria, which is to distribute the remaining EWA volume from Upper Klamath Lake by the end of the summer.
20	**Flushing Flow:** This rule checks for triggers to initiate a surface flushing flow operation. If October 1, reset. From December 1st through the end of flushing flow (April 15 + 3 days), first check if compliance has been met. Then, if it has not, check for initiation or ongoing release. If not, repeat previous values.
19	**Set IGD Outflow for Environment:** This rule sets the release from Iron Gate Dam that satisfies environmental objectives.
18	**Set UKL Outflow for Environment:** This rule sets the release from Upper Klamath Lake that satisfies environmental objectives.

3.2.7. Central Tendency Controlled Release Policy Group

Rules in Central Tendency Controlled Release Policy Group focus on controlling UKL storage according to the Central Tendency concept. The following table (Table 8) describes the prioritized rules that control the dilution and flushing.

Table 8. Central Tendency Controlled Release Policy Group Rule Description

Priority	Rules
17	**Eastside Balance:** This rule computes the cumulative volume loaned to the Eastside of the Klamath Project from UKL, and then repaid by the Eastside to the Klamath River.
16	**PacifiCorp Balance:** This rule computes the cumulative volume that Reclamation owes to PacifiCorp. It is given a negative value since it is tracked as a debt.
15	**Storage Diff Ratio 5-day:** This rule computes the storage difference ratio that controls the Upper Klamath Lake and Iron Gate Dam releases.
14	**Set Div Req for Central Tendency Diversion Control:** This rule sets the max diversion for each canal in Area 2. It includes consideration for both agricultural and refuge demands.
13	**Set IGD Outflow for Central Tendency:** This rule sets the release from Iron Gate Dam so that it adheres to a reduction that keeps the storage from diverging too far from the central tendency.
12	**Set Div Req for Supply Control:** This rule sets the agricultural diversions in the basin based on the supply provided by the release from Upper Klamath Lake for agricultural objectives.

3.2.8. Accretion Forecast Policy Group

Rules in Accretion Forecast Policy Group focus on setting and forecasting local accretions between UKL and IGD. The following table (Table 9) describes the prioritized rules that control the dilution and flushing.

Table 9. Accretion Forecast Policy Group Rule Description

Priority	Rules
11	**Planning - Accretion Forecasts From Archive SS:** In Planning Mode, this rule sets the accretions at the Lake Ewauna Gain, Lost River Diversion Channel, F/FF Pump, or Keno to IGD Gain throughout the Operations period. The accretions are set on the day before the operations start date at a relatively high priority so that values are not overwritten by object solutions.
10	**Operations - Accretion Forecasts:** In Operations Mode, this rule sets the accretions at the Lake Ewauna Gain, Lost River Diversion Channel, F/FF Pump, or Keno to IGD Gain throughout the Operations period. The accretions are set on the day before the operations start date at a relatively high priority so that values are not overwritten by object solutions.
9	**Operations - Accretion Override:** In Operations Mode, this rule sets the accretion based on any specified overrides at the Lake Ewauna Gain, Lost River Diversion Channel, F/FF Pump, or Keno to IGD Gain throughout the Operations period. The accretions are set on the day before the operations start date at a relatively high priority so that values are not overwritten by object solutions.

3.2.9. Ramping and Minimums Release Policy Group

Rules in Ramping and Minimums Release Policy Group focus on enforcing ramping and minimum constraints on IGD. The following table (Table 10) describes the prioritized rules that control the dilution and flushing.

Table 10. Ramping and Minimums Release Policy Group Rule Description

Priority	Rules
8	**Set IGD Outflow for Ramping and Minimums:** This rule sets the Iron Gate Release at the floor release if it does not meet the minimum or ramping requirements.

3.2.10. Flood Release Policy Group

Rules in Flood Release Policy Group focus on controlling UKL storage according to the Central Tendency concept. The following table (Table 11) describes the prioritized rules that control the dilution and flushing.

Table 11. Flood Release Policy Group Rule Description

Priority	Rules
7	**Hydrologic Year Type for Flood Control:** This rule sets the type of year (dry, normal, or wet) based on the NRCS Water Supply Forecast on the first day of January, February, March, or April.
6	**Set UKL Outflow for Flood Release:** This rule sets the release from Upper Klamath Lake that satisfies flood control objectives.
5	**Set IGD Outflow for Flood Release:** This rule sets the release from Iron Gate Dam that satisfies flood control objectives.

3.2.11. IGD Min and Max Storage Policy Group

Rules in IGD Min and Max Storage Policy Group focus on maintaining the IGD storage within the constrained storage of 51,000 to 53,000 acre-feet. The following table (Table 12) describes the prioritized rules that control the dilution and flushing.

Table 12. IGD Min and Max Storage Policy Group Rule Description

Priority	Rules
4	**Set UKL Outflow for bl IGD Flows:** Releases additional water from UKL if a shortage for IGD minimum flows is projected 3 days out (due to lag from UKL to IGD).
3	**Set IGD Outflow to Maintain Min Storage:** Force IGD releases to be adjusted (lowered) in order to maintain minimum storage requirement.
2	**Set IGD Outflow to Maintain Max Storage:** Force IGD releases to be adjusted (raised) in order to maintain maximum storage requirement.
1	**Set IGD Pool Elevation to match Observed:** If it is the observed period, set IGD pool elevation to historical pool elevation.

3.3. Global Functions

Rules employ certain expressions or computations more than once. To avoid repetitive coding and to help condense a rule's structure, global functions were created to house these expressions and computations. A global function provides a named, modular, and reusable expression that is available to all policy sets that may be part of a given model. To provide further flexibility, some functions pass in arguments of objects, slots, numbers, strings, booleans, lists, or datetimes. Arguments allow the function to pass in the variable they use in their evaluation. *The Klamath 2019 BiOp and 2020 IOP Functions* policy groups are shown in Figure 7. Each line in this figure represents a policy group. There is no particular order or priority to these functions, because they are executed only when called.

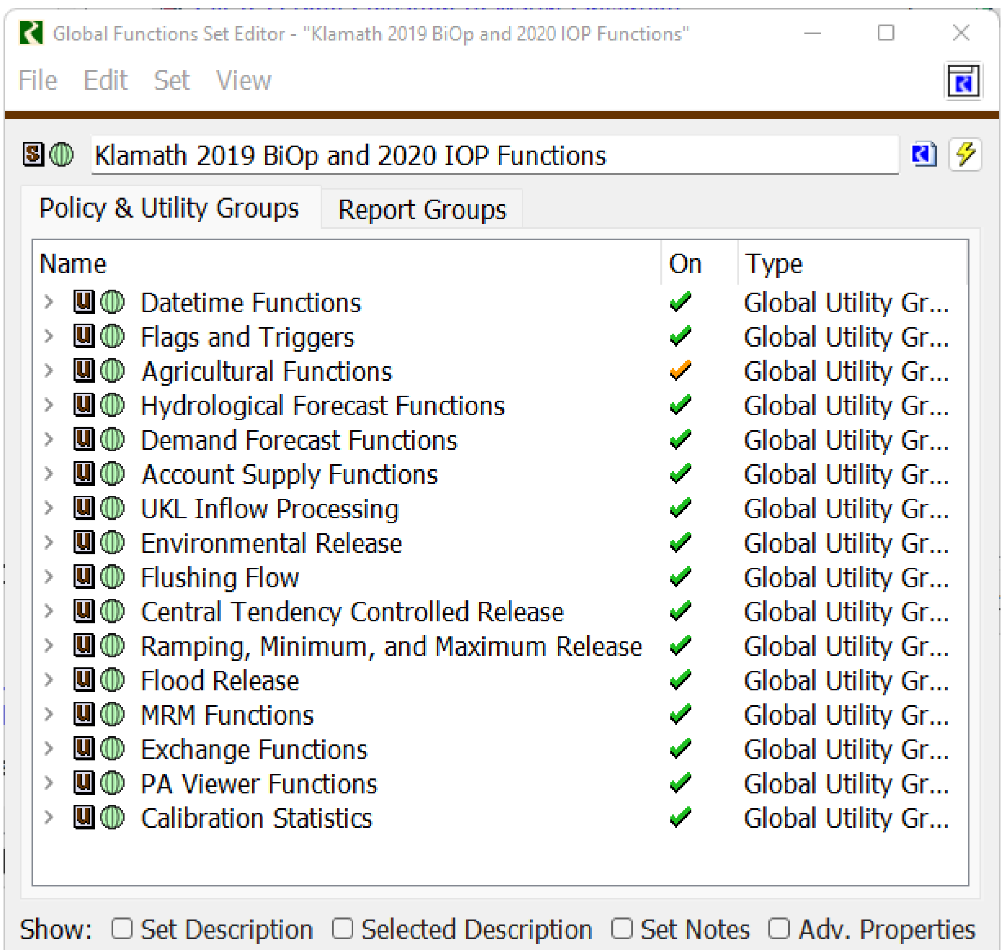


Figure 7. Policy Groups organizing logic in the Klamath 2019PA Global Functions set.

Over 180 global functions are defined in this set. These are listed and/or described in Appendix A (on GitHub).

4. Workflow Utilities

Managing input to and output from the KPOM and establishing a streamlined workflow are critical because planning studies rely on specified inputs from and for comparison to KBPM. In addition, for use of KPOM in Operations Mode, Klamath Project operators must be able to accomplish their work quickly and efficiently. The workflow needs to be reproducible to allow operators to run a variety of scenario simulations.

This section describes four commonly used RiverWare utilities and their use in KPOM:

- Data Management Interfaces (DMI): serve as data import devices from external Excel sheets and web service interfaces.
- System Control Tables (SCT): provide organized views of model inputs and outputs based on type of operation or specific flows, and other variables.
- Scripts: The KPOM Script Manager serves as the operator's main control and dashboard.
- Running the model: The single Run Control and MRM Run Control are the utilities to make runs. Making runs can also be accomplished from pre-configured scripts.
- Output Devices: Plots, Output Canvas and Model Reports provide data visualization and sharing tools

Together, these create a simple setup-and-run process for daily operations (Operations Mode) and long-term planning (Planning Mode).

The following sections summarize these utilities and provide examples of what they can do.

See Section 6 on instructions on specific instructions on how to accomplish a specific task.

4.1. Data Management Interface

The Data Management Interface (DMI) allows RiverWare to import or export data in a variety of formats, including text files, Excel files, Hydrologic Engineering Center (HEC) Data Storage System (DSS) databases, and Reclamation's Hydrologic Database (HDB). RiverWare models can contain multiple DMIs to handle both model input and output data. Interacting with a variety of data formats can be achieved by using different types of DMIs.

KPOM uses multiple types of input and output DMIs, including Excel and DSS based. Underlying Excel spreadsheets house data from KBAO, NRCS, and USGS. Table 13 lists the DMIs linking observed data to the RiverWare model as input.

Table 13. DMIs used by the Klamath Planning and Operations Model

DMI Name	Type	Data Source
Historical Accretions and Inflows	Input, Excel	$KPOM_DIR/Database/KPOM_DailyData_Import_archive.xlsx
Historical Water Supply Forecast	Input, Excel	$KPOM_DIR/Database/KPOM_DailyData_Import_archive.xlsx
Observed Hydrology	Input, Excel	$KPOM_DIR/Database/KPOM_DailyData_Import_archive.xlsx
WRIMS DSS Import	Input, DSS	$KPOM_DIR/Database/PA_2021_SV.dss
Webservice Observed Hydrology	Input, USGS	https://waterservices.usgs.gov/nwis/dv
KPOM to PA Viewer	Output, Excel	$KPOM_DIR/PAViewer/Final_Interim_Ops_Viewer_20200326.xlsm
KPOM Outputs	Output, Excel	$KPOM_DIR/Outputs/KPOM Outputs.xlsx
Mass Balance Out	Output, Control File	$KPOM_DIR /ctl/Mass Balance.ctl

Figure 8 is a screenshot of the Historical Accretions and Inflows DMI. The linked Excel database houses historical observed data collected by KBAO. Figure 8 shows the RiverWare slots to which the historical observed data and the time series range over which the data are imported. The time period can be specified as static values or using dynamic functions.

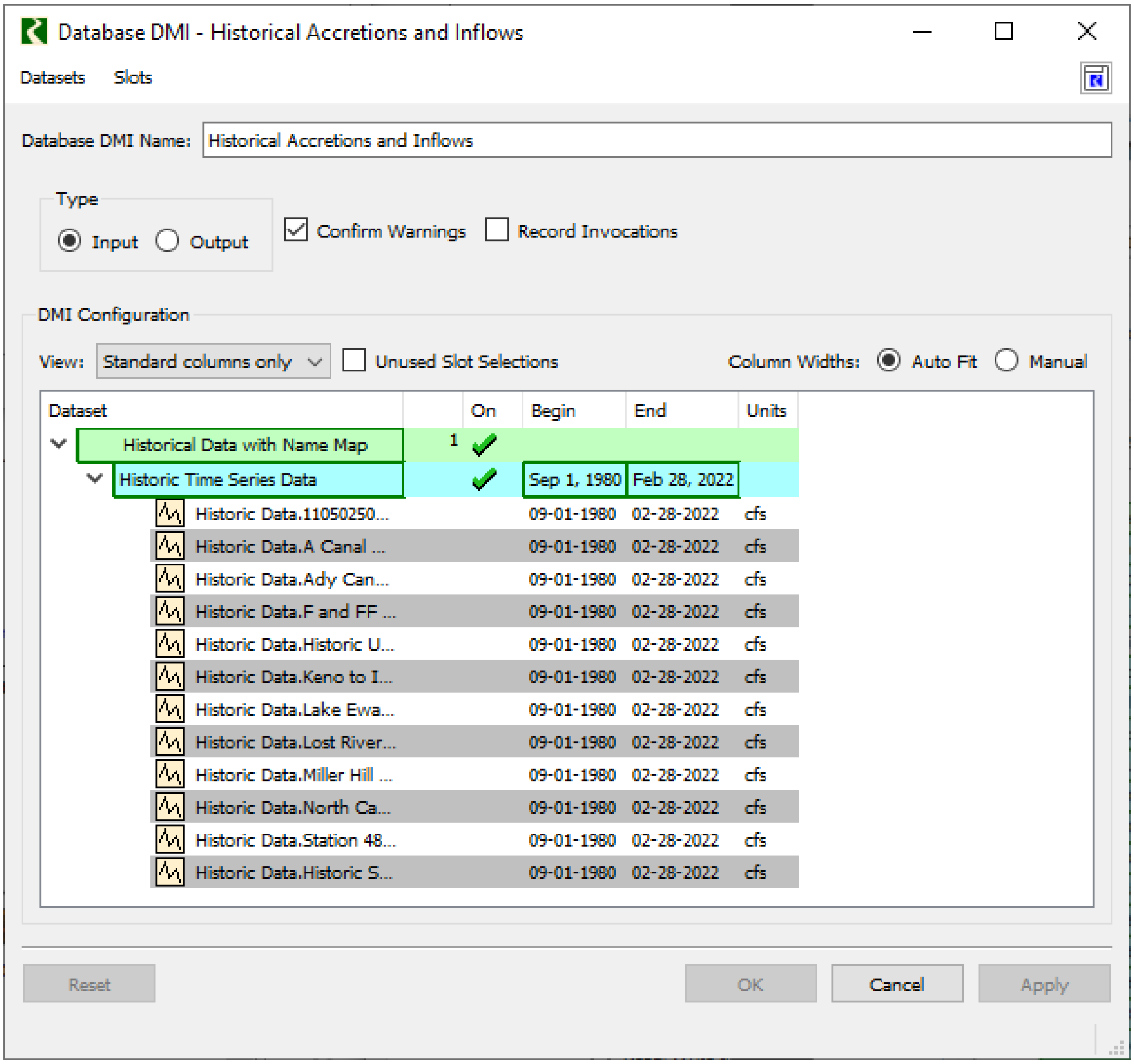


Figure 8. Historical Accretions and Inflows DMI slot categories and data time series ranges.

4.2. System Control Tables

System Control Tables (SCT) are highly customizable, editable spreadsheet-like views of the data stored in slots. The model developer or operator can create one or more SCTs tailored to individual needs. If desired, different operators can have different SCTs, allowing each operator to have their own customized view. The data in the SCT can be edited directly, and runs can be made using edited data. In addition, DMIs and scripts can be executed directly within the SCT.

Three SCTs are included with KPOM that correspond to accretions, general operations data, and MRM Config Dashboard. Figure 9 is a screenshot of the KPOM's SCT KlamathOps2019PA showing some of the slots and daily output.

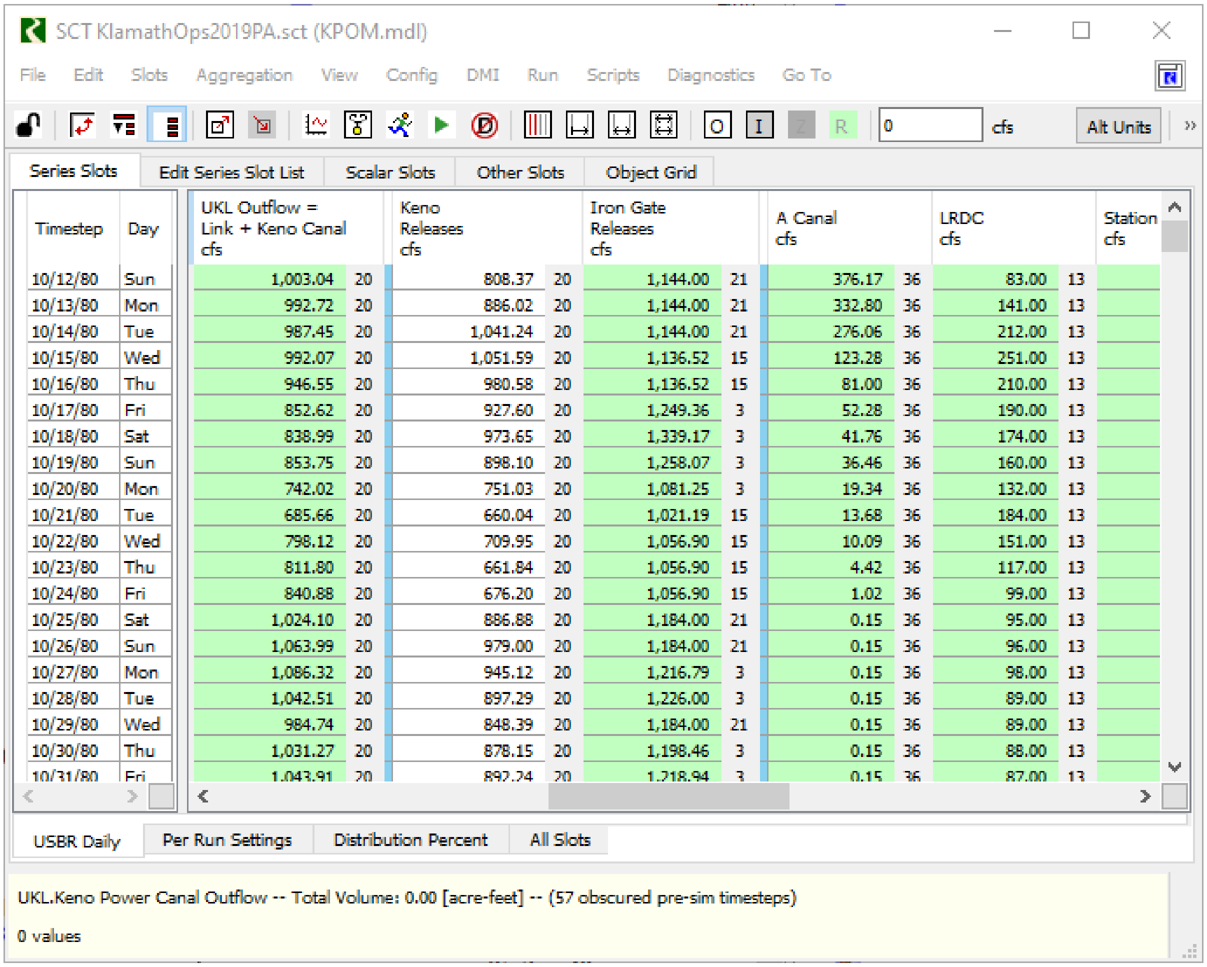


Figure 9. Screenshot of the Overview SCT showing the Winter Ops sheet.

4.3. Scripts

Scripts are used to automate commonly repeated tasks. Scripts are particularly useful for setting up modeling runs and switching between modes (Operations and Planning), because there are often a set of tasks that operators perform regularly for operations mode, that differ greatly from the needs for planning runs. For example, KPOM contains one script to prepare the model for a daily operations (OM) simulation. It performs tasks such as loading the operations ruleset, running DMIs, and setting the operation start date.

In general, the operator will use the Script Dashboard as the primary interface. Model developers use Script Editors to define, configure and test the Scripts. Use the following procedure to access the Script Dashboards:

From the main RiverWare workspace, select the Scripts and then Script Manager dialog (Figure 10). Alternatively, use the Script menu and then directly open the desired script dashboard (Figure 11).

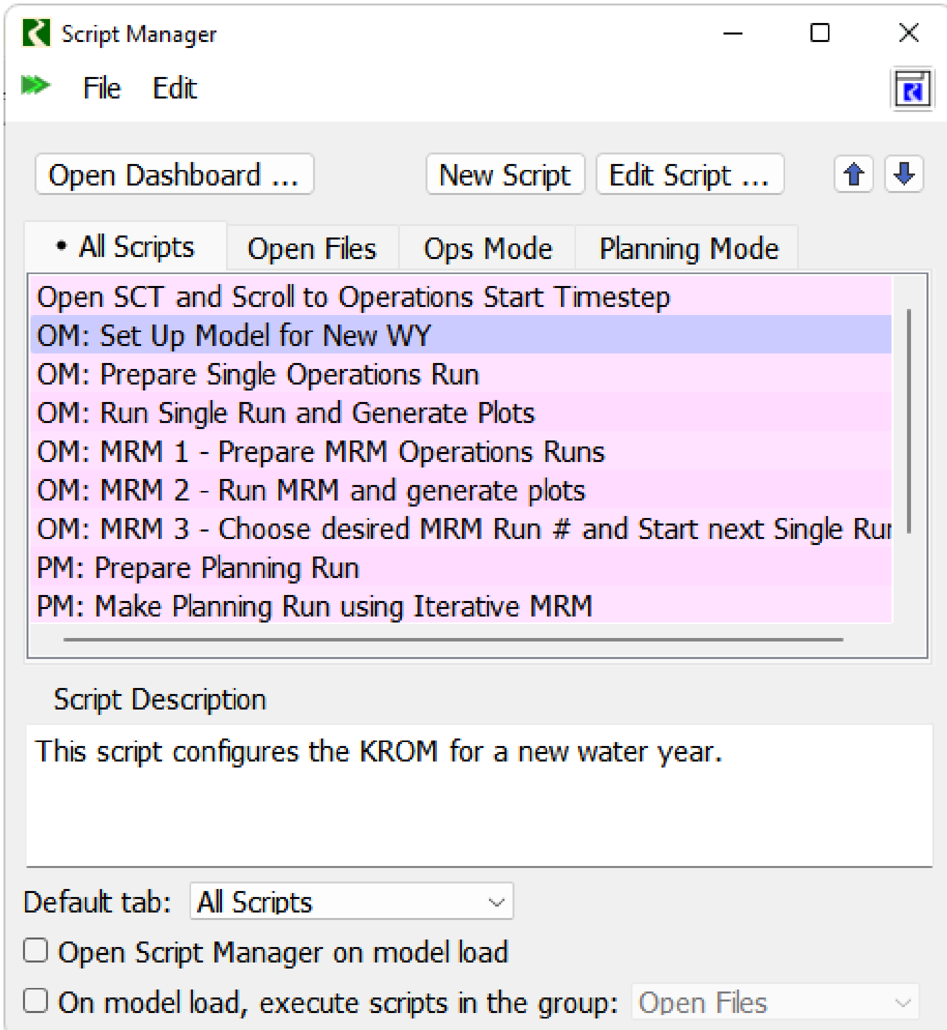


Figure 10. Script Manager Dialogue.

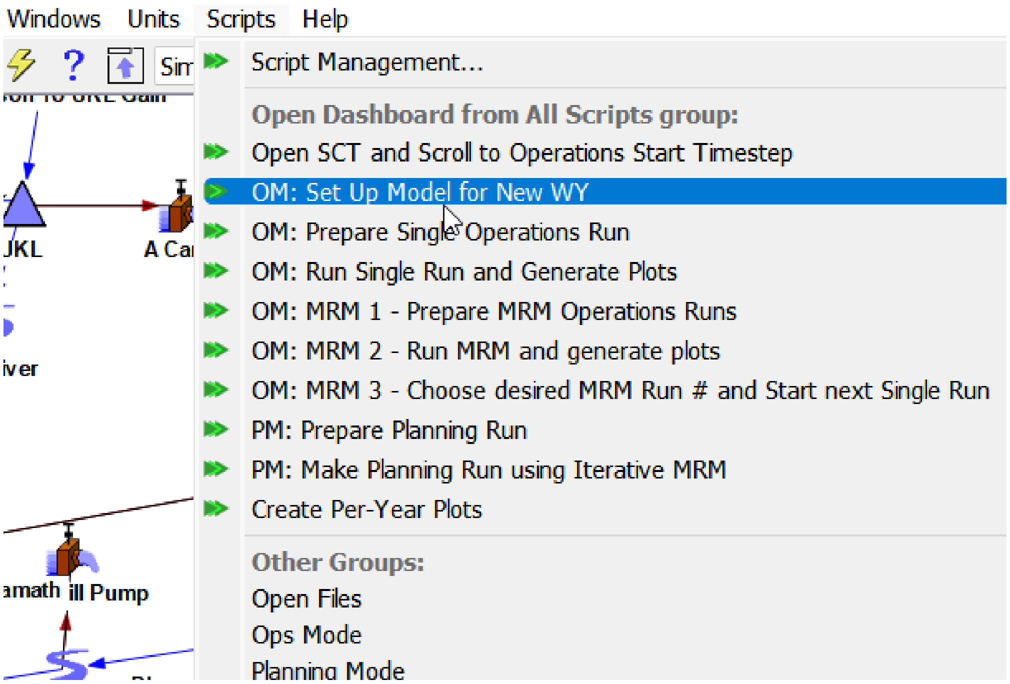


Figure 11. Script Menu.

Figure 12 provides a screenshot of KPOM's script "Prepare Single Operations Run" that shows the automated model tasks and the editable controls for the operator or developer.

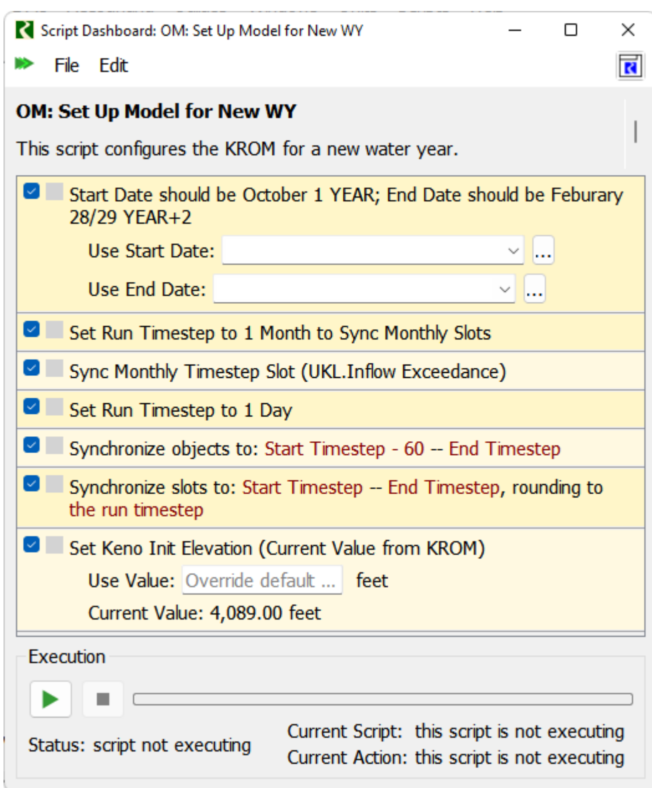


Figure 12. Task and operator input selections as part of the Prepare Single Operations Run script.

4.4. Making Runs

Making a run of KPOM means advancing through the timesteps, executing the rules and dispatching or solving objects. All runs use the single or multiple run control, depending on the task at hand. You must choose the appropriate utility based on the task although there are scripts set up to assist with making runs. This section describes the two run controls and how they work: the single run control and the multiple run control.

- **Single Run Control:** From the Control menu select Run Control Panel. This utility allows you to go through a single run, stepping through the timesteps, executing all of the rules on each timestep and solving objects as necessary. The single Run Control is used for Operations Mode for a single trace.

- **Multiple Run Control:** From the Control menu, select MRM Control Panel. This utility allows you to set up configurations that control multiple runs. There are four configurations that all use Iterative Mode. Iterative Mode of MRM makes one run and then checks logic to decide whether additional runs are needed. Additional runs are needed when user-specified performance goals are not met (e.g., not all allocated water has been used during the growing season). If so, another run is made. This process continues until no changes are necessary or the logic decides there is nothing more to do. Then the entire MRM is stopped. Following is a description of the four MRM configurations:

    - **OM Run Trials of different settings**: This configuration will cycle through the 1-year operations mode up to 5 times, where each run has a different set of input parameters. Each run is independent of the others. This allows you to try different parameters and compare the results against one another.

    - **OM Run historical hydrology scenarios**: This configuration will cycle through the 1-year operations mode using hydrology from the period of record for the operations period instead of utilizing forecasts at Upper Klamath and accretions throughout the basin. For each run, the operator selects a year in the period of record.

    - **OM Run with and without Agricultural deliveries**: This configuration will cycle through 2 runs: with and without agricultural deliveries from Upper Klamath Lake. The results from these runs are compared to determine the portion of UKL storage that remains for agricultural allocations.

    - **PM Iterate on Offset Forecasts**: This configuration is the main way to execute a planning run. This configuration will run the model and then use the computed agricultural offset results from each run as the starting conditions for the next run. The Iterative MRM rules are used to converge on a solution.

4.5. Output Devices

RiverWare has many output devices including plots, reports, charts, and the output canvas. This section provides a brief overview of each output device and how it is used in KPOM.

4.5.1. Plots

RiverWare has a feature-rich plotting package. Plots can be configured to display data from model slots and dynamically update with each model run. Figure 13 shows a sample plot of the Calibration UKL Modeled vs Historic Pool Elevation for a single year. The grey dash dot line represents the historical pool elevation, the solid blue represents the KPOM simulation, and the green dashed line represents the KBPM simulation. Flood elevation, central tendency, and water year low elevation are shown by the remaining three lines: yellow dash; red dot; and orange dash dot dot.

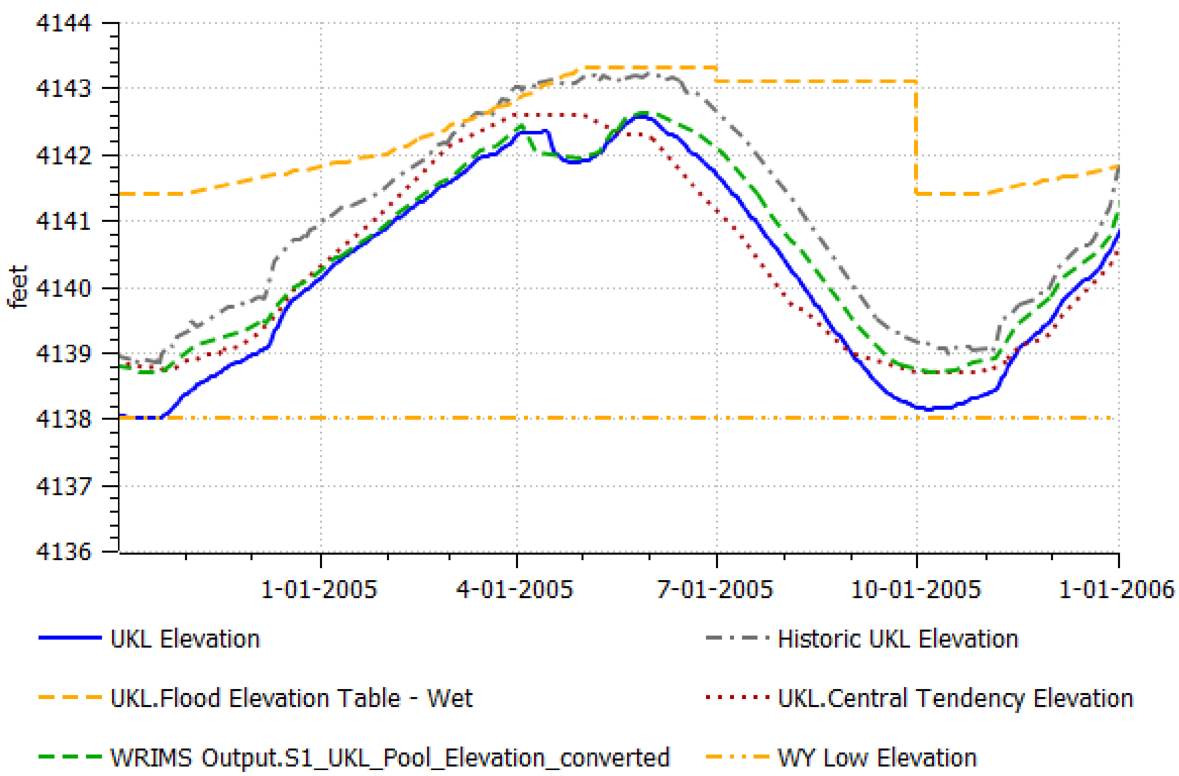


Figure 13. Screenshot of a sample plot from an operations model.

4.5.2. Model Reports

RiverWare has the ability to automatically write output information to a HTML report using the Model Report output device. The content, organization, and formatting of the Model Report is highly configurable. Model Reports are commonly used for two purposes: documenting the model and ruleset and providing output results for distribution to stakeholders, operations partners, or others. Results can be output in both tabular and graphical format, including plots, charts, and the output canvas. Text, such as comments describing individual operating rules, may also be included in a Model Report. Currently, KPOM is configured with three model reports, including a Daily Number Update, Rule and Function Documentation (Appendix A), and Sample Output Model Report (not configured).

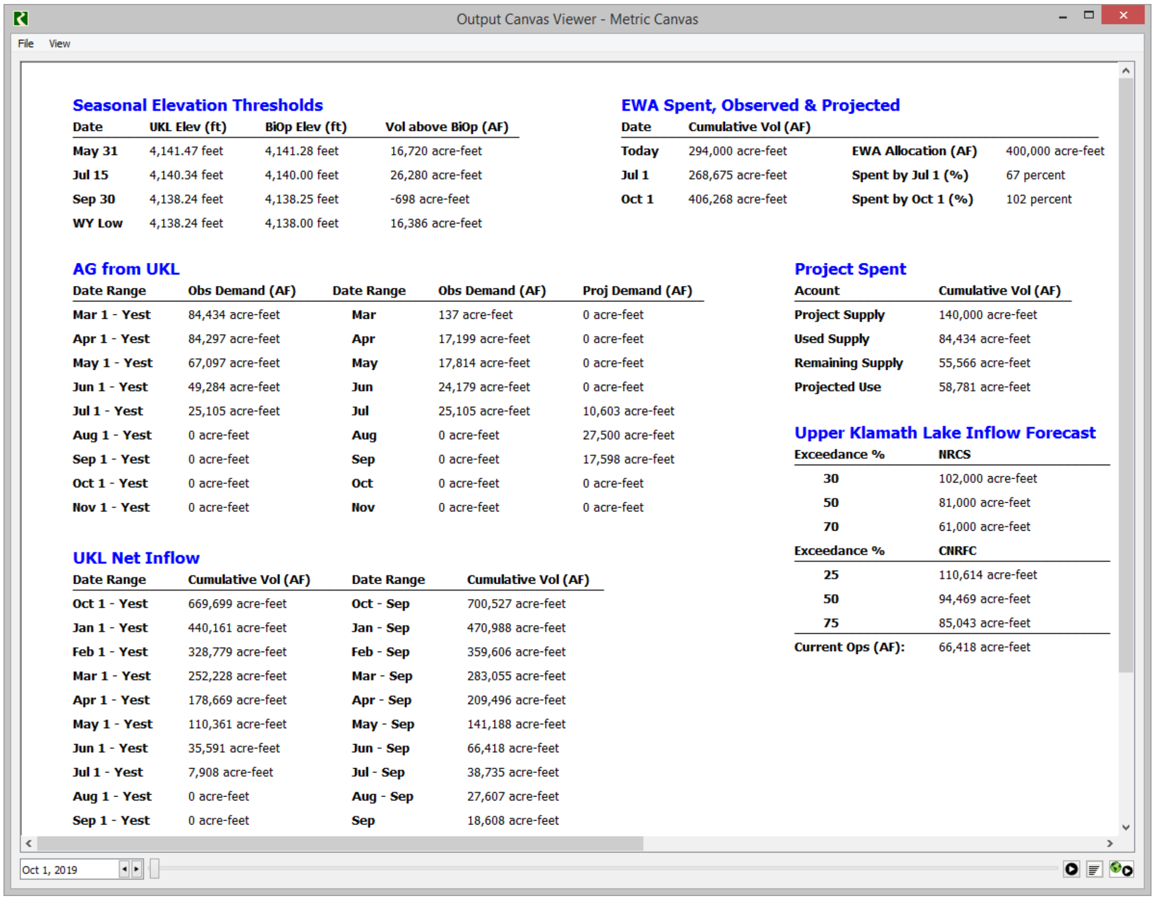
4.5.3. Output Canvas

An Output Canvas is an output device that shows various data visualization tools including Tea Cups (mini bar charts), flow lines, graphical tables, and pie charts.

After a run is completed, open the Output Manager from the Utilities menu from the workspace.

The following sections describe the common Output Canvas:

The **OM Metric Canvas Output Canvas** presents a summary of the model's observed and projected results in the form of cumulative volumes or a specific date's value. The operator views these results in tables that mimic those on the "UKL_SurfaceElevation_Chart" sheet in the PA Calculator (Figure 13).



Output Canvas Viewer - Metric Canvas

File View

Seasonal Elevation Thresholds

Date	UKL Elev (ft)	BiOp Elev (ft)	Vol above BiOp (AF)
May 31	4,141.47 feet	4,141.28 feet	16,720 acre-feet
Jul 15	4,140.34 feet	4,140.00 feet	26,280 acre-feet
Sep 30	4,138.24 feet	4,138.25 feet	-698 acre-feet
WY Low	4,138.24 feet	4,138.00 feet	16,386 acre-feet

EWA Spent, Observed & Projected

Date	Cumulative Vol (AF)		
Today	294,000 acre-feet	EWA Allocation (AF)	400,000 acre-feet
Jul 1	268,675 acre-feet	Spent by Jul 1 (%)	67 percent
Oct 1	406,268 acre-feet	Spent by Oct 1 (%)	102 percent

AG from UKL

Date Range	Obs Demand (AF)	Date Range	Obs Demand (AF)	Proj Demand (AF)
Mar 1 - Yest	84,434 acre-feet	Mar	137 acre-feet	0 acre-feet
Apr 1 - Yest	84,297 acre-feet	Apr	17,199 acre-feet	0 acre-feet
May 1 - Yest	67,097 acre-feet	May	17,814 acre-feet	0 acre-feet
Jun 1 - Yest	49,284 acre-feet	Jun	24,179 acre-feet	0 acre-feet
Jul 1 - Yest	25,105 acre-feet	Jul	25,105 acre-feet	10,603 acre-feet
Aug 1 - Yest	0 acre-feet	Aug	0 acre-feet	27,500 acre-feet
Sep 1 - Yest	0 acre-feet	Sep	0 acre-feet	17,598 acre-feet
Oct 1 - Yest	0 acre-feet	Oct	0 acre-feet	0 acre-feet
Nov 1 - Yest	0 acre-feet	Nov	0 acre-feet	0 acre-feet

Project Spent

Acount	Cumulative Vol (AF)
Project Supply	140,000 acre-feet
Used Supply	84,434 acre-feet
Remaining Supply	55,566 acre-feet
Projected Use	58,781 acre-feet

Upper Klamath Lake Inflow Forecast

Exceedance %	NRCS
30	102,000 acre-feet
50	81,000 acre-feet
70	61,000 acre-feet
Exceedance %	**CNRFC**
25	110,614 acre-feet
50	94,469 acre-feet
75	85,043 acre-feet
Current Ops (AF):	66,418 acre-feet

UKL Net Inflow

Date Range	Cumulative Vol (AF)	Date Range	Cumulative Vol (AF)
Oct 1 - Yest	669,699 acre-feet	Oct - Sep	700,527 acre-feet
Jan 1 - Yest	440,161 acre-feet	Jan - Sep	470,988 acre-feet
Feb 1 - Yest	328,779 acre-feet	Feb - Sep	359,606 acre-feet
Mar 1 - Yest	252,228 acre-feet	Mar - Sep	283,055 acre-feet
Apr 1 - Yest	178,669 acre-feet	Apr - Sep	209,496 acre-feet
May 1 - Yest	110,361 acre-feet	May - Sep	141,188 acre-feet
Jun 1 - Yest	35,591 acre-feet	Jun - Sep	66,418 acre-feet
Jul 1 - Yest	7,908 acre-feet	Jul - Sep	38,735 acre-feet
Aug 1 - Yest	0 acre-feet	Aug - Sep	27,607 acre-feet
Sep 1 - Yest	0 acre-feet	Sep	18,608 acre-feet

Oct 1, 2019

Figure 14. Output Canvas for Operations Mode.

From the listed outputs, select the Metric Canvas and click Generate to create the Output Canvas. The OM Metric Canvas has not been configured for Planning Mode.

Here is a brief summary for each here.

- Seasonal Elevation Thresholds: Confirm the UKL pool elevation for each date exceeds the BiOp specified pool elevation. Also evaluate if the volume above the BiOp is sufficient enough.

- EWA Spent, Observed and Projected: Validate the EWA spent by July exceeds 61% and EWA by October 1 exceeds 95%. The corresponding volume for the percentage spent by that date is shown and evaluated as well.

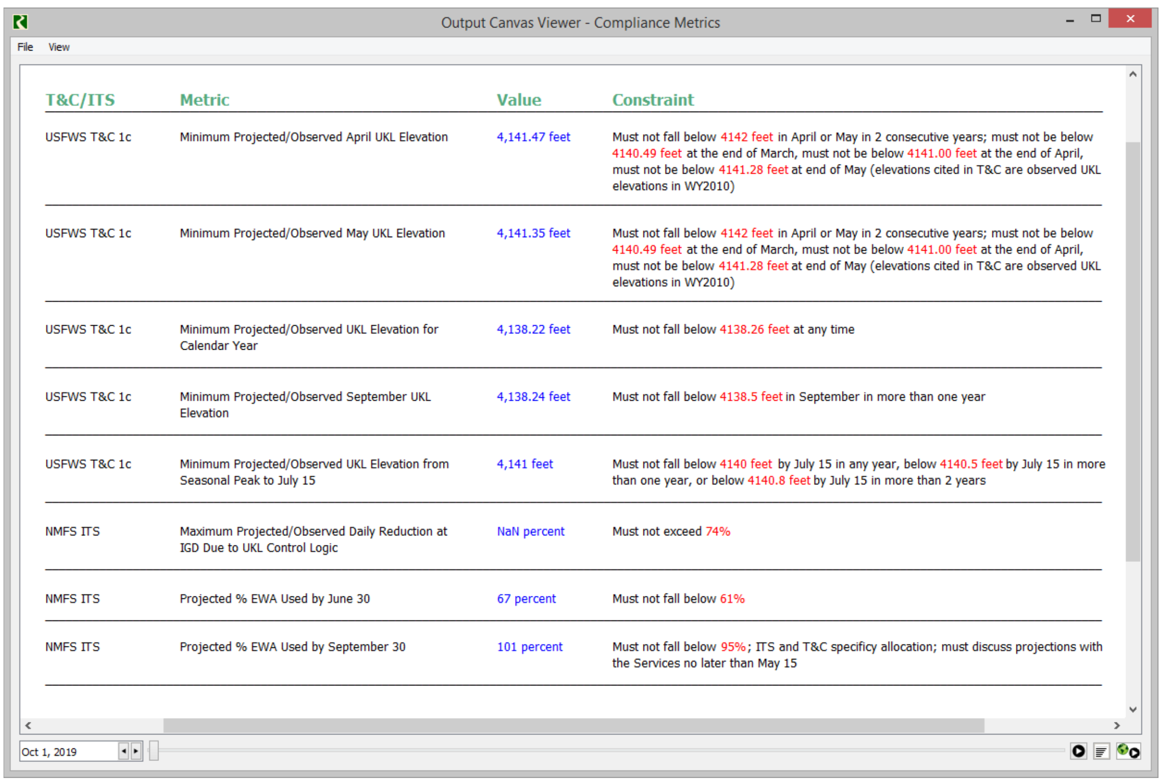
- AG from UKL: Perform a strictly judgement-based assessment of the values in this table. Check if the timing of distribution matches expectations or follows recent observations.

- Project Spent: Track the used and remaining Project Supply in this table. Use it to validate that distribution does not exceed the seasonal allocation for agriculture.

- Upper Klamath Lake Inflow Forecast: This table shows the most recent NRCS and CNRFC Inflow Forecast the operator input to the model. Compare the Current Ops inflow volume to determine what inflow scenario their settings produced.

- UKL Net Inflow: The operator analyzes the timing of observed and projected inflows in this table. Based on external forecasts and recent observations, check if too much or too little supply enters UKL for a given period.

Additional metrics are stored in the **Compliance Metrics Canvas** (Figure 14). This shows the key compliance metrics, values, and constraints.


Output Canvas Viewer - Compliance Metrics
File View

T&C/ITS	Metric	Value	Constraint
USFWS T&C 1c	Minimum Projected/Observed April UKL Elevation	4,141.47 feet	Must not fall below 4142 feet in April or May in 2 consecutive years; must not be below 4140.49 feet at the end of March, must not be below 4141.00 feet at the end of April, must not be below 4141.28 feet at end of May (elevations cited in T&C are observed UKL elevations in WY2010)
USFWS T&C 1c	Minimum Projected/Observed May UKL Elevation	4,141.35 feet	Must not fall below 4142 feet in April or May in 2 consecutive years; must not be below 4140.49 feet at the end of March, must not be below 4141.00 feet at the end of April, must not be below 4141.28 feet at end of May (elevations cited in T&C are observed UKL elevations in WY2010)
USFWS T&C 1c	Minimum Projected/Observed UKL Elevation for Calendar Year	4,138.22 feet	Must not fall below 4138.26 feet at any time
USFWS T&C 1c	Minimum Projected/Observed September UKL Elevation	4,138.24 feet	Must not fall below 4138.5 feet in September in more than one year
USFWS T&C 1c	Minimum Projected/Observed UKL Elevation from Seasonal Peak to July 15	4,141 feet	Must not fall below 4140 feet by July 15 in any year, below 4140.5 feet by July 15 in more than one year, or below 4140.8 feet by July 15 in more than 2 years
NMFS ITS	Maximum Projected/Observed Daily Reduction at IGD Due to UKL Control Logic	NaN percent	Must not exceed 74%
NMFS ITS	Projected % EWA Used by June 30	67 percent	Must not fall below 61%
NMFS ITS	Projected % EWA Used by September 30	101 percent	Must not fall below 95%; ITS and T&C specificy allocation; must discuss projections with the Services no later than May 15

Oct 1, 2019

Figure 15. Example of Compliance Metrics Output Canvas Viewer.

4.5.4. Proposed Action Viewer

In addition to standard HTML *Model Report* capabilities and RiverWare's plotting capabilities, the DMI *KPOM to PA Viewer* enables the user to export model run results directly to the Proposed Action Viewer (previously the IGD Calculator) Excel Spreadsheet.

5. User Guide

This section provides a user guide for common tasks within KPOM, for example, setting up the model, updating the model for a new operations start timestep, converting the model from one operations mode to planning mode, and running alternative scenarios. The model uses many of the utilities described in Section 5. The base mode for KPOM is Operations Mode.

5.1. How to Setup KPOM on Your System

The model files are held in a working directory, *KPOM,* which contains subfolders for Models, Database, SCTs, and Documentation. The model relies on Environment Variables to locate rulesets, global function sets, and DMI files. Before opening RiverWare, set the KPOM_DIR environment variable to this working directory, for example, C:\Temp\KPOM. Instructions on setting environment variables for your operating system exist on the internet or the Script_To_Set_KPOM_DIR_variable.bat can be used.

5.2. How to Update Operations Mode for a New Water Year or How to Convert from Planning Mode to Operations Mode

Use the following procedure to update the model when in Operations Mode from one water year to a new water year or from Planning Mode to Operations Mode.

1. Open the *OM: Set Up Model for New WY* script dashboard.

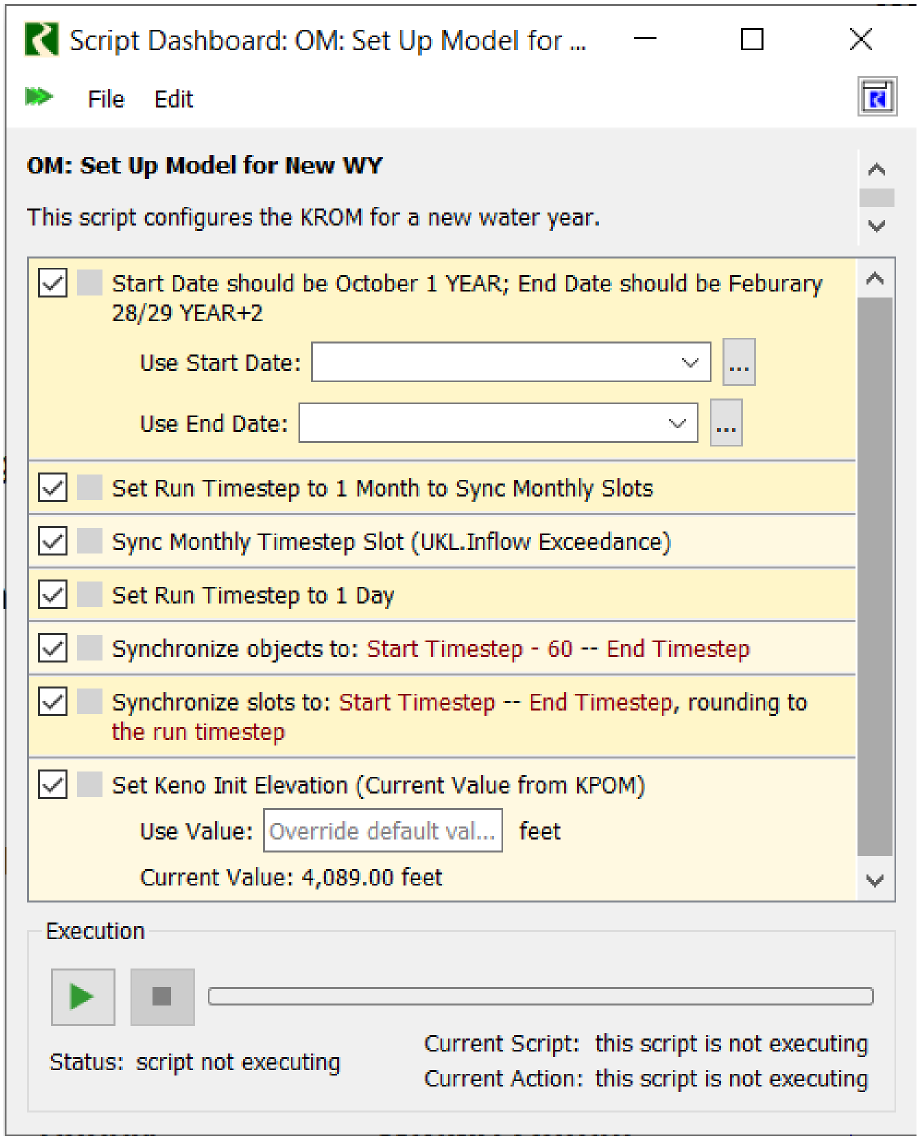


Figure 16. Screenshot of script to setup for a new water year.

2. In the script dashboard, set the range of the new water year. It should start on Oct 1 and finish on Feb 28/29 of the following year (~18 months later). For example, the start timestep could be Oct 1, 2019 and end timestep would then be Feb 28, 2021.

3. Set Keno's initial elevation if desired.

4. Run the script to update to the new water year.

5. Complete the steps in How to run the model in Operations Mode.

5.3. How to Update to a New Operations Start Timestep and Run the Model in Operations Mode

This section describes the steps to update the model that is in Operations Mode to a new Operations Start Timestep and perform a run. Note, if the model is in Planning Mode or configured for another water year, you should use the steps in Section 5.2

Use the following steps to update the Operations Start Timestep and run the model:

1. **Update Excel Sheets**. Confirm each sheet has timeseries data spanning the beginning of the initial water year until the *Operations Start Timestep*. This can also be done in the model after running the script.

2. **Open the Script:** *OM Prepare for Single Operations* script.

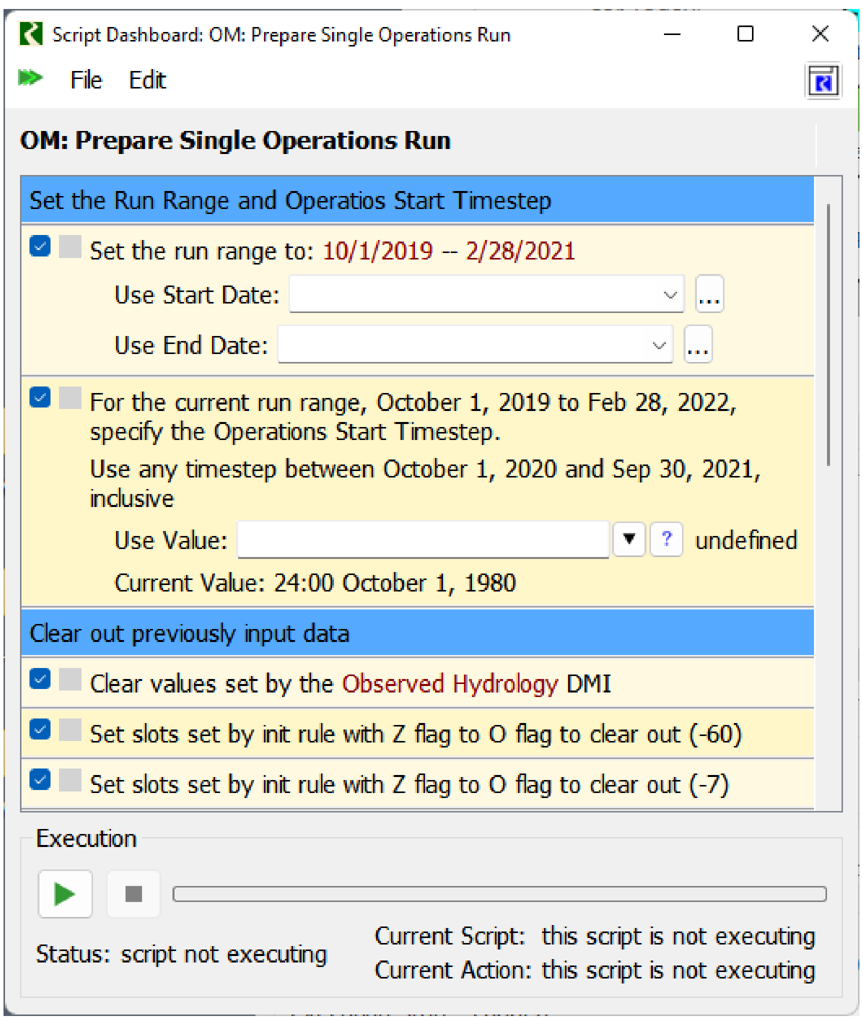


Figure 17. Screenshot of the script to prepare a single operations run.

3. **Set the *Operations Start Timestep* and *Flood Scenario* and run the script.** The script automatically clears slots set by the previous run's DMIs and initialization rules. In addition, the script automates the execution of the DMIs to bring in the updated date.

4. **Check Parameters and input slot values**. Confirm that the model run period, adjustment factors, and triggers are set as intended. Since adjustment factors and triggers change less frequently, they are not set in the script. Rather, adjust these values in the corresponding *object.slot* (i.e., UKL Inflow Season Adj Factor and *UKL.Season Adj Factor*). Use the SCT to possibly set the following slots:

   Series Data:
   a. Keno to IGD Accretions (from PacifiCorp)
   b. Distribution Percentages
   c. Exchange Data
   d. Flushing Flows (Flex Release)
   e. Augment Flows
   f. UKL Inflow Exceedance Monthly values
   g. Overrides

   Table and Scalar Data:
   a. Previous Year Project Supply
   b. UKL Inflow Adjust Tables
   c. Diversion – Seasonal Supply and Adj
   d. Accretion – Exceedance and Adjust Input
   e. NRCS and CNRFC Forecasts

5. **Run the Model**. Run the model from the single *Run Control* dialog.

6. **Investigate Outputs**. Open the SCT window. This contains important slots organized by specific operation or object. The following tabs are available: *Winter Ops*, *Summer Ops*, *Agricultural Ops*, *Dilution & Flushing*, and *UKL Overview*. View graphical representations of flows by selecting the plot icon. The following plots are available: *Upper Klamath Flows*, *Iron Gate Release*, *Gerber & Clear Inflows/Outflows*, *UKL Elevation and Threshold*, and *UKL Flows*. Observe other slots by selecting directly from the object viewer.

5.4. How to Run KPOM in Operation Mode with MRM

Running KPOM in Operations Mode using MRM allows you to automate the process of testing different scenarios and operations for the specified water year. This section describes how to run in Operations Mode using MRM.

First, make sure the model is already running in Operations Mode. If not, follow the procedure in Section 5.3. Also, make sure the model runs for the desired Operations Start Timestep, using the procedure in Section 5.3.

1. Open the script dashboard "OM: MRM 1- Prepare MRM Operations Runs."

    a. Specify the number of runs to make. This is a required input.

    b. Make selections as desired for Forecast or Input Keno to Iron Gate Accretions.

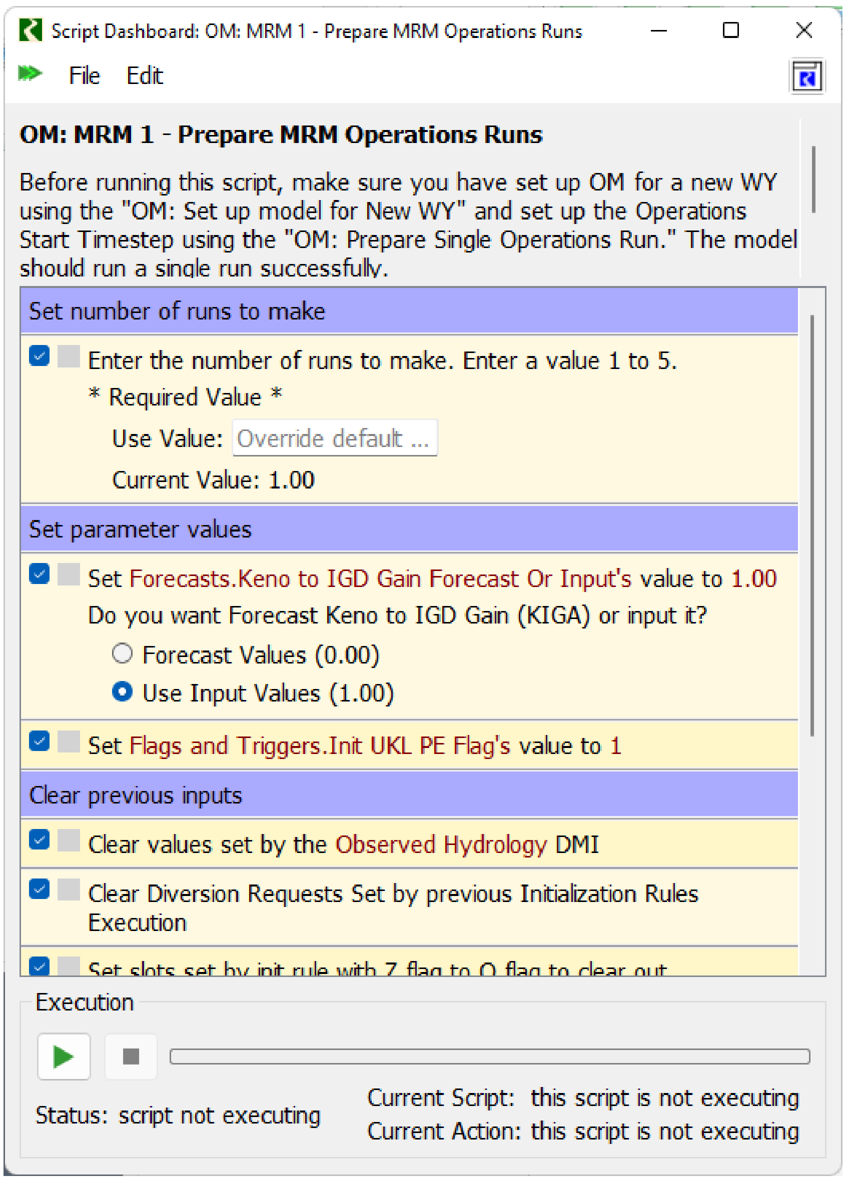


Figure 18. Script dashboard to prepare MRM operation runs.

    c. Run the Script

2. Specify run input parameters in the Operations SCT that opens.

3. Open the script dashboard for "OM: MRM 2 – Run MRM and generate plots."

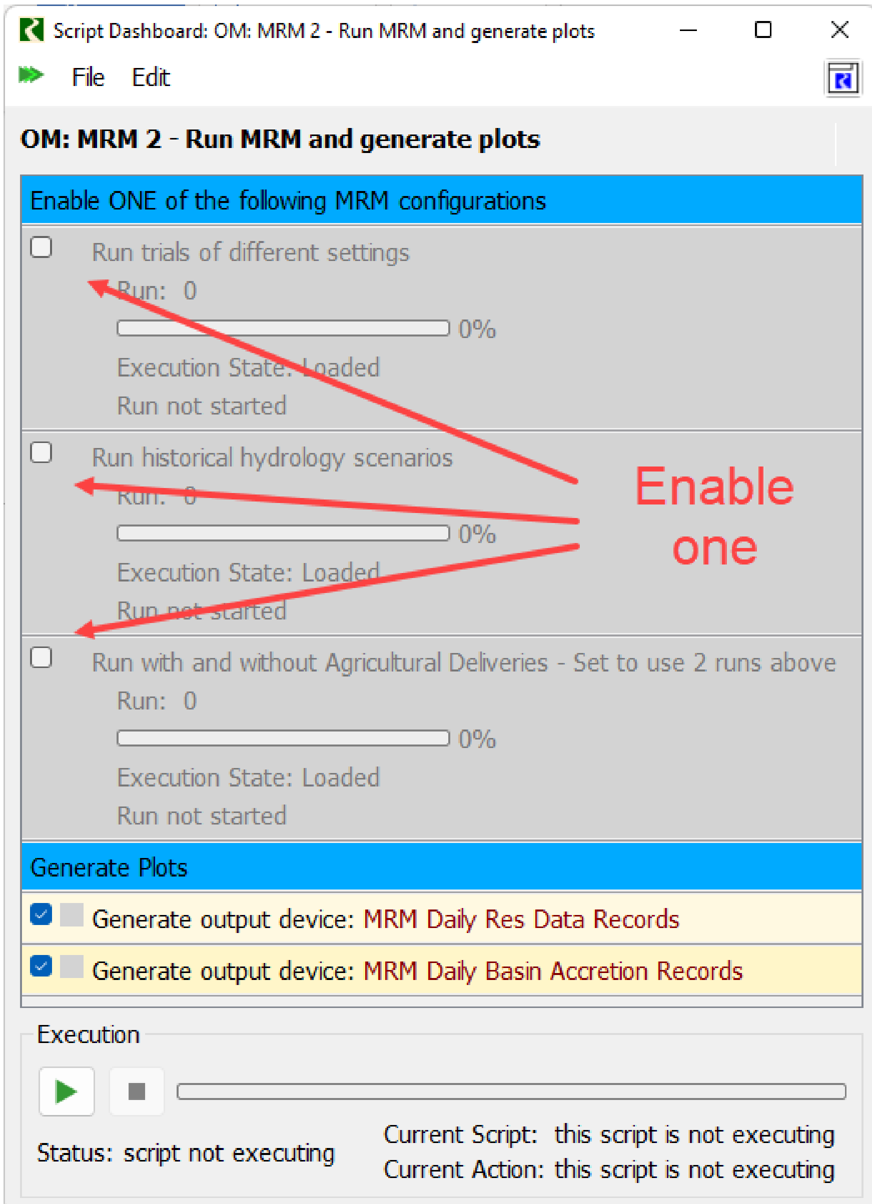


Figure 19. Script Dashboard to run MRM and generate plots.

a. Select the desired run to make by enabling one of the MRM configurations. Each of the configurations and additional data requirements is described below.

b. When satisfied, run the script.

5.4.1. Operations Mode to Test Trials of Different Inputs

Since the operations process is often iterative with many trials of different inputs, KPOM can use MRM to automate this process. The "OM Run trials of different settings" configuration uses Iterative mode and is designed to automate the process of iterating through multiple runs, each with different settings, until suitable results are found.

- UKL Inflow Adjustments produce forecasted seasonal inflows that match with the NRCS Inflow Forecast

- UKL Agricultural Adjustments produce the forecasted diversions supplied by UKL that match with the Project Supply.

- Accretion Exceedance Percentages and Adjustment Factors produce forecasted accretions that match with expected hydrology.

For the configuration of multiple runs with different adjustments/settings, specify the sets of values to try. Specify in slots, accessible from an SCT, the following:

- The number of runs to make in the MRM Dashboard.Number of Runs to Make.

- Values for each adjustment factor on integer indexes slots. Figure 19 shows a. Each row represents a discrete run. In this example, there are 5 rows so 5 sets of setting values.

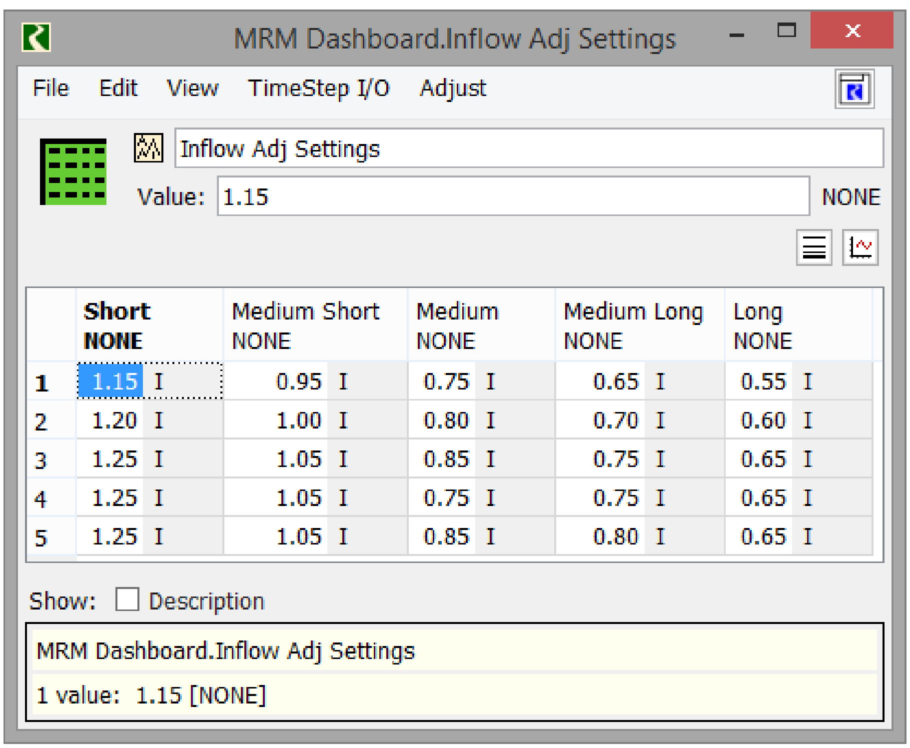


Figure 20. Sample integer indexed slot where MRM settings are specified, one row per run.

Once the runs are finished, the operator will want to view certain outputs. As above, the results will be presented in a table where each row represents the values of one run (Figure 13). These results can be shown on the same SCT or a different SCT (Figure 20).

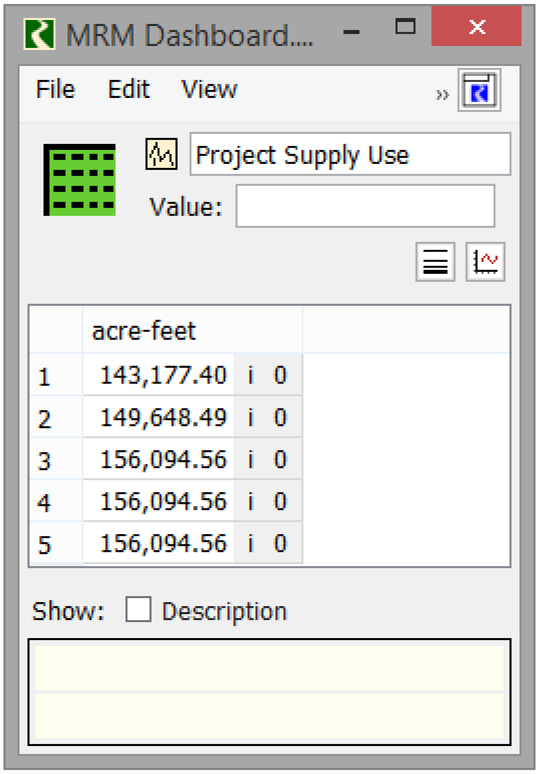


Figure 21. Sample Integer Index Slot showing a metric for 5 MRM runs.

The key metrics are the following:

- Cumulative UKL Inflow: For each iteration, how does the cumulative volume progress over the season? Check that the cumulative March through September volume is similar to the NRCS Inflow Volume for the same period.

- Project Supply: For each iteration, see how the Project Supply is distributed over the seasons and check that the cumulative distribution is similar to the total Project Supply allocation.

- Compliance Metrics: For each iteration, check if all the compliance metric minimum conditions are met. Metrics include UKL pool elevation and EWA use requirements at various points through the water year.

After analyzing the iterative run outputs and choosing the desired adjustments/settings configuration. The operator will run that setup in a single run to compute the official release at Iron Gate Dam and the hydrological forecasts they will report. To do this, open the script named “Choose desired MRM Run # and Start next Single Run” and choose the desired run to use. Then execute the script. It transfers the values to the single run slots and starts a run (Figure 21).

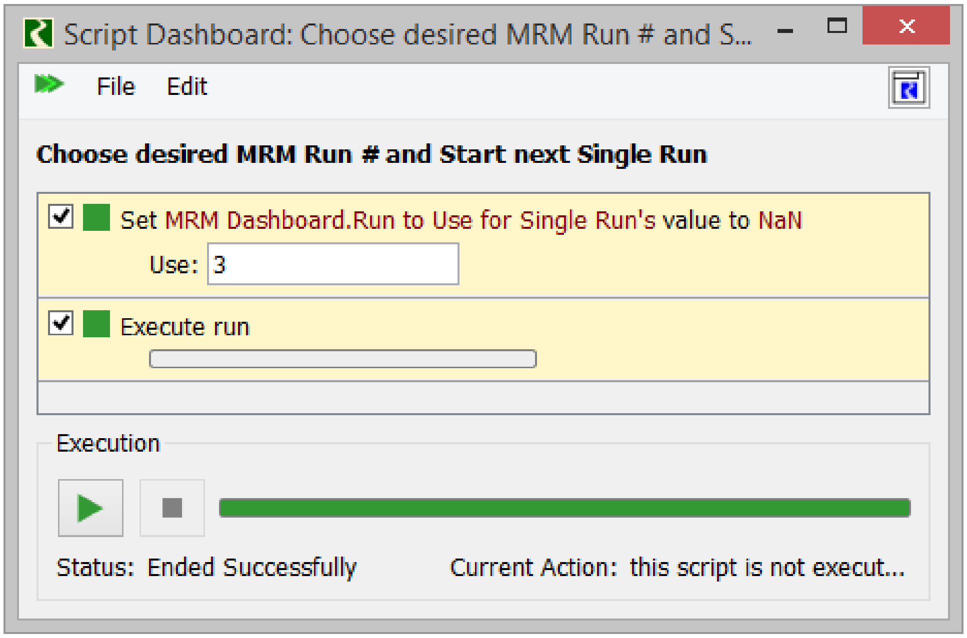


Figure 22. Script dashboard for choosing the desired MRM.

5.4.2. Operations Mode for multiple historical years

With the specified input data (forecasted inflows, demands, etc.), the operator may want to run scenarios using previous year's hydrology to see what would occur under different conditions. Use the "*OM Run historical hydrology scenarios*" MRM configuration uses Iterative mode. It is designed to run scenarios with various alternative physical inputs. The two types of alternative input configurations used are as follows:

- Historical UKL Inflows instead of UKL Inflow Forecast logic: Commonly, the historical years the operator selects are similar to the current year's conditions. It may be any year from 1981 through the present.

- Historical accretions instead of Accretion Forecast logic: In the PA Calculator, the operator only has the capability to import hydrology from 2014 through the present.

5.4.3. Operations Mode with and without Agricultural Deliveries

The MRM configuration, "*OM Run with and without Agricultural Deliveries*" is used to make two runs: one using the standard operating procedure and one run where agricultural diversions are set to zero. In the second run, the Project Supply remains as UKL storage. The operator uses this to estimate the portion of storage UKL holds for agricultural demands throughout the rest of the year.

5.5. How to Convert from Operations Mode to Planning Mode

Use the following procedure to update the model from Operations Mode to Planning Mode for 1 to 46 water years. Also use this procedure to reduce a longer planning model run (i.e., 46 years) and want to reduce it to a shorter period for testing.

1. Open the *PM: Prepare Planning Run* script dashboard (Figure 22).

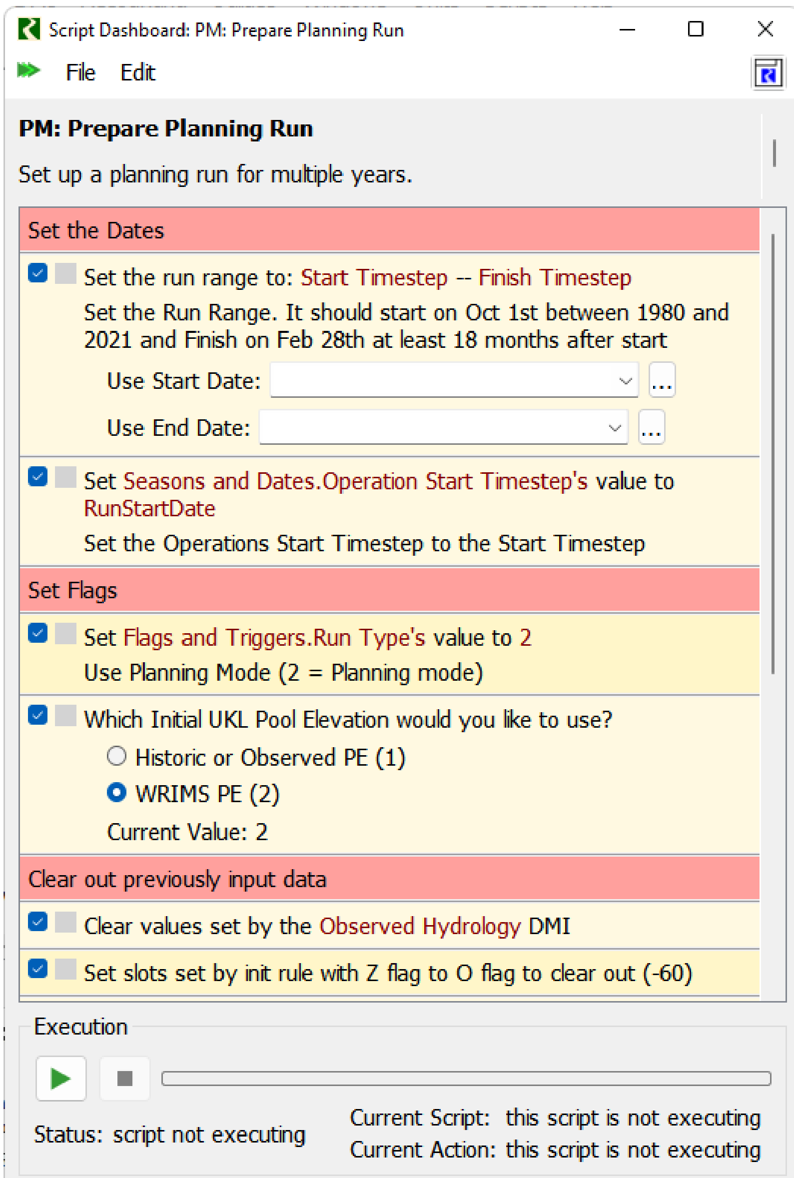


Figure 23. Script dashboard for preparing a planning run.

2. In the script dashboard, set the range of the new water year.

   a. Start dates must be on October 1, any year between 1980 and 2019.
   b. End dates must be on Feb 28/29 at least 18 months after the start timestep. Thus, use any year between 1982 and 2021 depending on the specified start timestep.

3. Specify which initial UKL Pool Elevation you'd like to use: Historic/Observed or WRIMS PE.

4. Specify the Project Supply for the WY prior to the start year in the slot that opens: Supply.Project Supply Prior WY. This value represents the Project Supply for the previous WY and is used to compute various quantities for the first few months of the planning run.
5. To make a run, follow the steps in the next section.

5.6. How to Make a Run in Planning Mode

Use the following procedure to make a run in Planning Mode. This mode uses Iterative MRM as described in Making Runs. There are two ways to run the model in planning mode:

1. Run from a script:
   a. Open the *PM: Make Planning Run using Iterative MRM* script dashboard (Figure 23).
   b. Start the script.

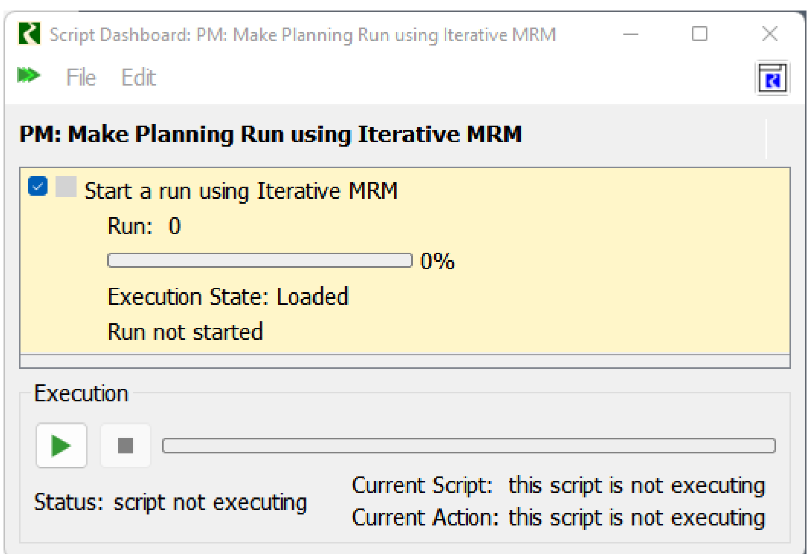


Figure 24. Script dashboard for making an Iterative MRM run.

6. Alternatively, run the model directly from the MRM Run Control:
    a. From the main RiverWare workspace, select Control and then MRM Control Panel.
    b. Select the "PM Iterate on Offset Forecasts" configuration (Figure 24).

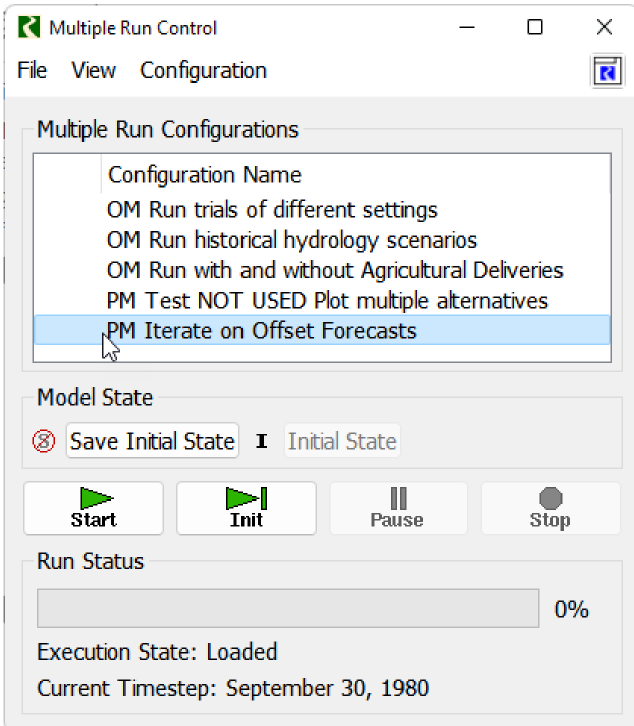


Figure 25. MRM Run Control with PM Iterate on Offset Forecasts selected.

    c. Select the Start Button.
    d. The run will iterate through up to four runs of the defined run range. Between each run, logic is executed to check if the convergence criteria are met. When satisfied, the run will stop and a message will be posted that: "Iteration is complete. The computed Ag Offset difference is less than the convergence criteria."
    e. If you want to stop the iterative run before it is complete:
        i. Locate the MRM Run Control and select Stop.
        ii. Then find the (Single) Run Control and select Stop there as well.

5.7. How to View Planning Mode Results – In RiverWare

This section provides guidance and advice on viewing Planning Mode Results in RiverWare, focusing on comparing the planning mode results to WRIMS results. RiverWare provide many other utilities and interfaces to view results that are not covered here.

5.7.1. Pre-configured plots

There are many preconfigured plots accessed from the Utilities and then Output Management menu. Select any device and select Generate. The following are some that may be useful for planning purposes; some screenshots are shown for informational purposes.

- Allocation vs Supply – Shows four plots comparing Supply on the X axis and Allocation on the Y axis. Figure 25 shows a zoomed-in sample:
-

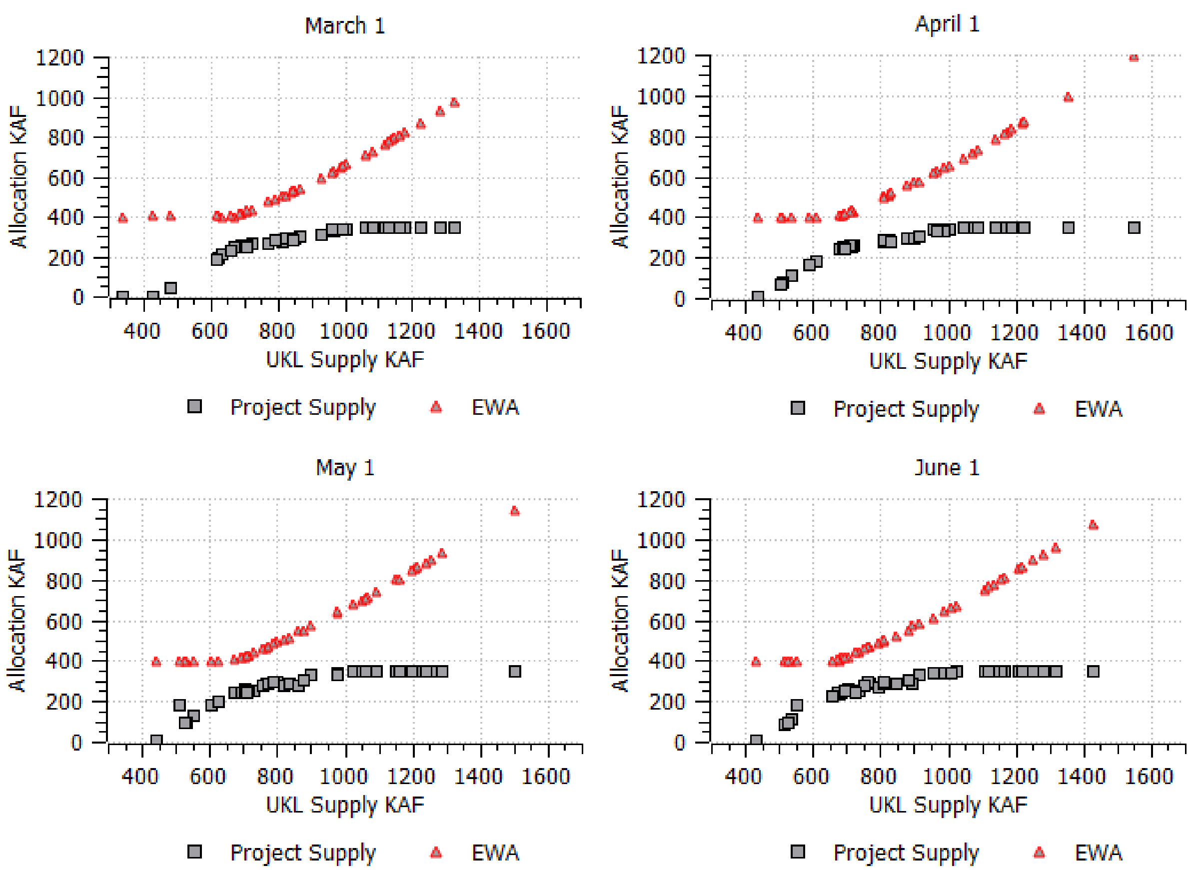


Figure 26. Sample Supply vs Allocation by Month Plot.

- Flow Gains Link to Iron Gat: Shows Flows at Link Release, Below Keno and at IGD.

- IGD Flow: shows flows at IGD including minimums.

- Project Ag Deliveries by Account. Shows the deliveries to the major canals. Figure 26 shows a zoomed in sample:

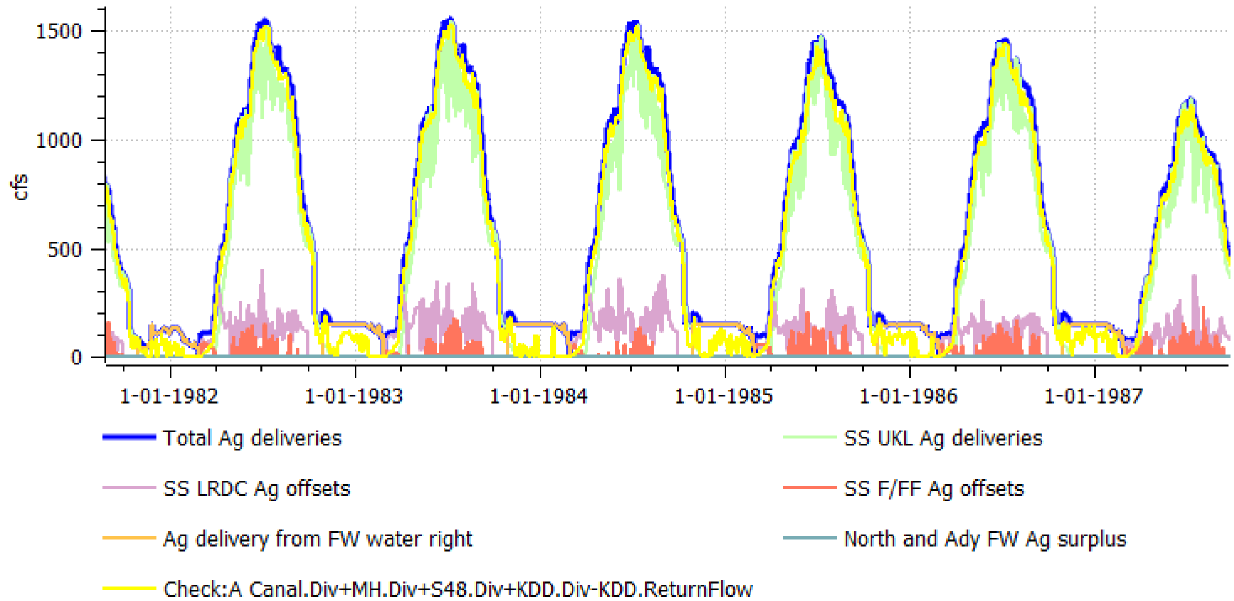


Figure 27. Agriculture Supply Plot.

- Project and Refuge Deliveries. Shows major deliveries and the flows to Refuge.

- UKL Surface Elevation: Shows the UKL Pool elevation including bounds and guidelines. Figure 27 shows a zoomed-in sample:

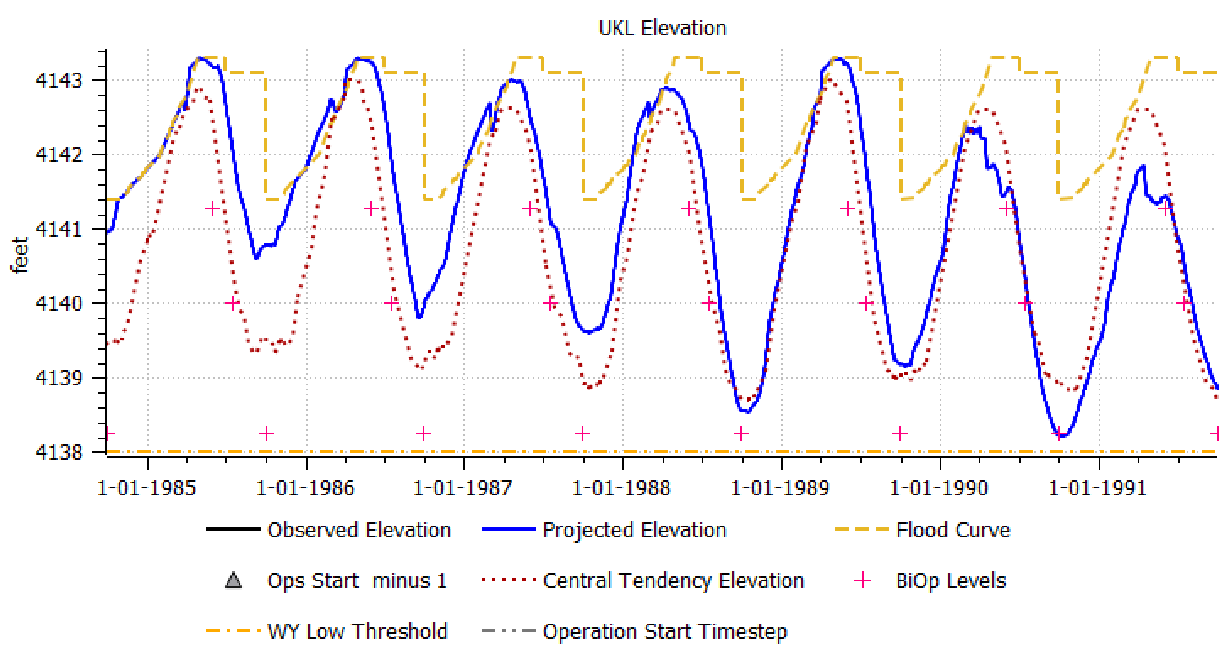


Figure 28. Sample UKL Pool Elevation Plot.

5.7.2. Viewing one year at a time

All of the plots described in Section 5.7.1also have a variation with a "_ 1 Year" suffix that can be used to view one year at a time in the run period. Use a script to adjust the desired plots as follows:

1. Open the dashboard for the script "Create Per-Year Plots" (Figure 28).

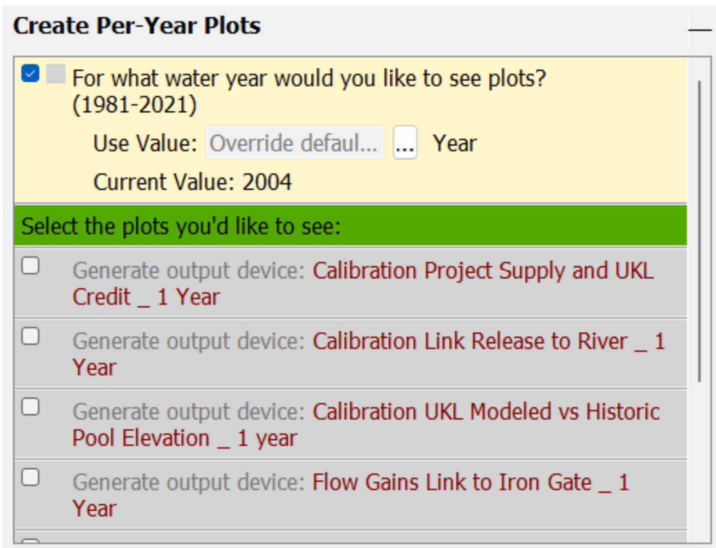


Figure 29. Script Dashboard to create per-year plots.

2. Select the "…" button and enter the desired water year between 1981 and 2021, assuming the planning run was completed for all those years. For example (Figure 29):

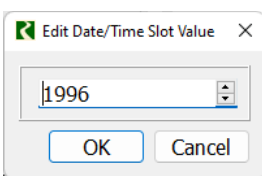


Figure 30. Edit Date/Time Slot Value window.

3. Select OK.

4. Enable one or more rows of the script dashboard for the desired plots.

5. Run the script. It will set the plots to the specified year and generate the plots. For example, for 1996 (Figure 30):

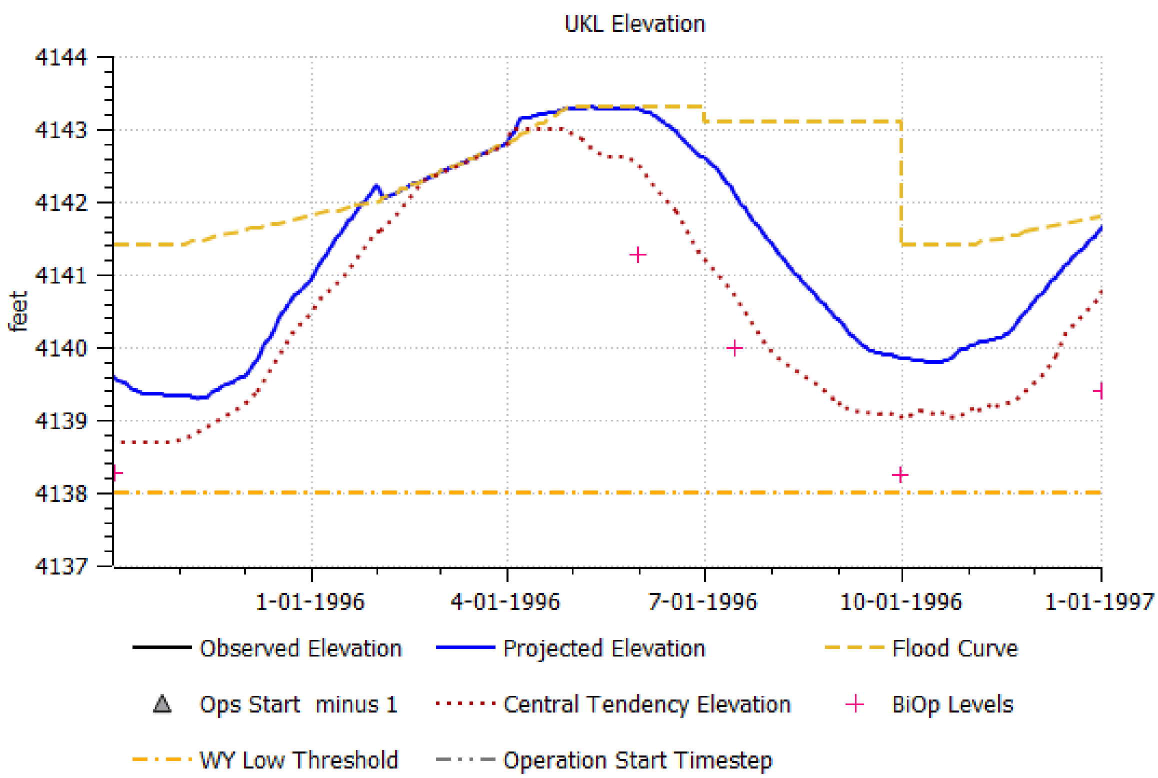


Figure 31. Sample UKL Elevation per-year plot showing 1996

5.8. How to Compare Planning Run Results to KBPM Results

KBPM (WRIMS) results can be imported into KPOM using a DMI and then compared, including in plots. This section describes the components and procedure to make comparisons.

First, the KBPM data must be imported to KPOM. Step by step instructions are beyond the scope of this document, but the general steps are:

1. The DMI is configured to import data to the WRIMS Output data object's slots. If desired, export/import that object or take a sanpshot of those slots to preserve any previous results.

2. Configure the "WRIMS DSS Import" DMI to point to the correct WRIMS DSS file.

3. Run the WRIMS DSS Import DMI to import the data.
   Now the KBPM/WRIMS data is in the WRIMS Output data object.

The slots on the object are named such that the KBPM variable name is concatenated with the corresponding RiverWare slot name. For example, S1_UKL_Storage is clearly S1 in KBPM and UKL.Storage in KPOM (Figure 31).

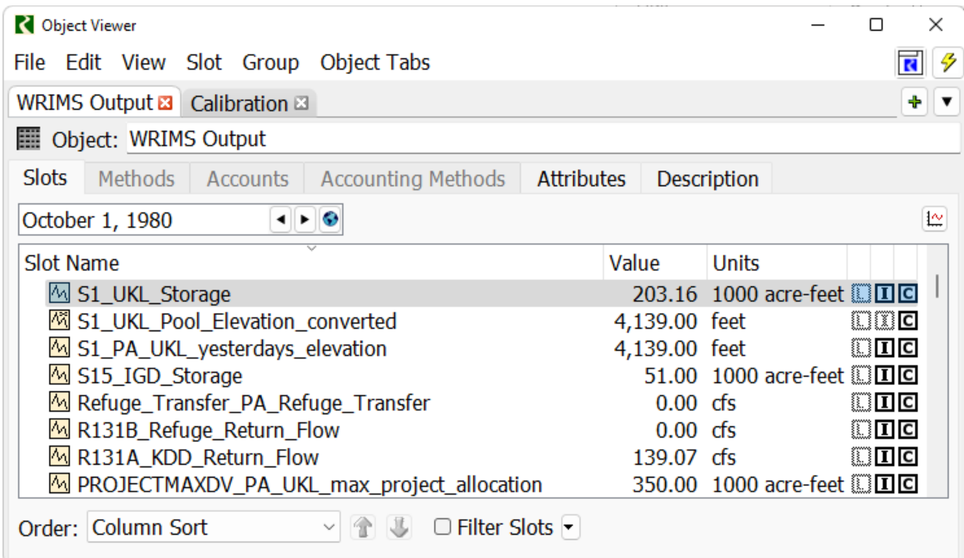


Figure 32. Screenshot of WRIMS Output object.

Second, use the pre-configured "Calibration" plots to show the RiverWare run results and the KBPM results together. For example, the "Calibration UKL Elevation" plot shows UKL elevation for both runs, KPOM in blue and WRIMS in dashed green (Figure 32):

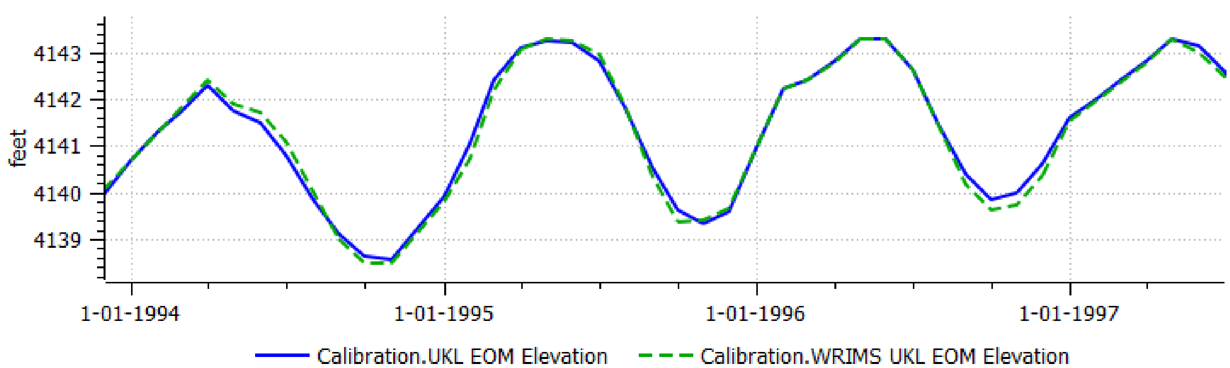


Figure 33. Sample Plot of UKL Elevation from KPOM and KBPM/WRIMS.

The Calibration object also is used to aggregate, compare, and compute statistics on KBPM and KPOM results.

5.9. How to Export Planning Mode Results for Viewing and analysis in the PA Viewer Tool

As described above, you can compare KPOM results with KBPM/WRIMS results within RiverWare. This section describes the process to export data from KPOM to a format that can be accessed by the PA Viewer Excel tool for comparison and analysis.

As described in Section 4.1, all imports and exports of data from RiverWare use the DMI.

1. On the main workspace, use the DMI and then DMI Manager menu (Figure 33).

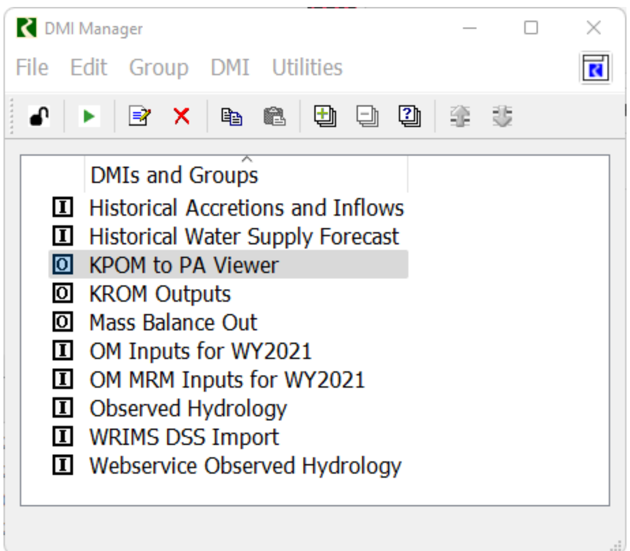


Figure 34. Screenshot of DMI Manager with KPOM to PA Viewer DMI highlighted.

2. Invoke the KPOM to PA Viewer DMI highlighted above. This will update the values in the ALT_OUTPUT_RW worksheet in the workbook (Figure 34) :$KPOM/Outputs/Final_Interim_Ops_Viewer_RIVERWARE_ALT_Output.xlsx
   The sheet is formatted to accept the RiverWare data.

3. Assuming no columns have been added or deleted, you should be able to copy the data and paste it in the ALT_OUTPUT tab of the Final Interim Ops Viewer (PA Viewer).

4. Analyze, plot and compare the Base vs ALT (now KPOM data) in the PA Viewer as desired.

	A	B	C	D	E
2			C1	C13	C131
3			FLOW-CHANNEL	FLOW-CHANNEL	FLOW-CHANNEL
4					
5					
6			KBPM	KBPM	KBPM
7				1-Oct-80	
8				2400	
9				30-Nov-19	
10				2400	
11		9/30/80 23:59	CFS	CFS	CFS
12	# calculated from B #	# imported from RW #	PER-AVER	PER-AVER	PER-AVER
13	Excel Date Format (12:00am)	RiverWare Date Format (11:59 PM)	UKL.Outflow (cfs)	Keno.Outflow (cfs)	F and FF Pump.Inflow (cfs)
14	9/30/80 12:00 AM	9/30/80 23:59			
15	10/1/80 12:00 AM	10/1/80 23:59	672.1502192	700.5758902	27.14674879
16	10/2/80 12:00 AM	10/2/80 23:59	643.5206551	699.8820773	57.49876723
17	10/3/80 12:00 AM	10/3/80 23:59	583.4664964	658.5987415	77.1612667
18	10/4/80 12:00 AM	10/4/80 23:59	624.7364312	726.0445766	132.115433
19	10/5/80 12:00 AM	10/5/80 23:59	812.7193499	823.2666506	132.115433
20	10/6/80 12:00 AM	10/6/80 23:59	804.0197845	662.674985	43.88626782
21	10/7/80 12:00 AM	10/7/80 23:59	799.4665955	647.0833201	0
22	10/8/80 12:00 AM	10/8/80 23:59	832.0384528	716.5137229	0
23	10/9/80 12:00 AM	10/9/80 23:59	960.9817917	836.1678895	11.09166661

Figure 35. Screenshot of RiverWare Output Spreadsheet Ready for copy to PA Viewer.

5.10. How to Run Alternative Scenarios in Planning Mode

This procedure describes how to make alternative scenario runs in Planning Mode. This procedure is a prototype that allows you to preserve the results from one run as the “Base” and then make changes in the system, rerun and then preserve the results as Alt 1. Note, only a few output slots are configured in the original prototype. Also, only Base and Alt 1 are currently supported. In the future additional output slots and more alternatives can be added.
Use the following steps:

1. If necessary, use the procedure in Section 5.5 to convert from Operations to Planning.

2. Make any desired changes to the planning setup for this Base alternative.

3. Run the model as described in Section 5.6, “How to Make a Run in Planning Mode.” Now, you will preserve the results of that run in snapshots.

4. Open and run the Script Dashboard “PM Preserve Previous Run Results as Base.” In the confirmation, select Close, you do want to overwrite the snapshot (Figure 35).

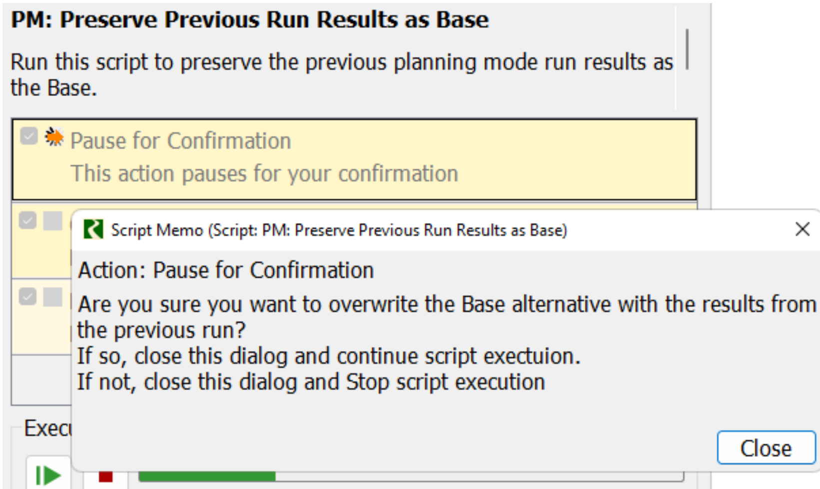


Figure 36. Script dashboard and Memo confirmation for preserving Run Results as Base.

5. On the script dashboard, select the green Start button to resume the script. The results are preserved on the snapshot object called "Base" (Figure 36).

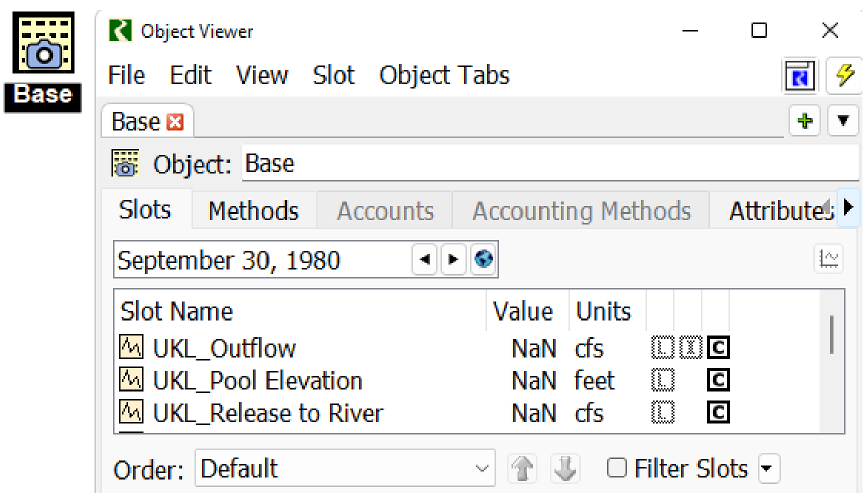


Figure 37. Base Data Object Icon and Object Viewer.

Now, set up the Alternative 1 run:

6. Make any desired changes to the setup for Alternative 1. This could involve changing data, modifying rules, or infrastructure.

7. Run the model as described in Section 5.6, "How to Make a Run in Planning Mode". Now, you will preserve the results of that run as slots in a snapshot object.

8. Open and run the Script Dashboard “PM Preserve Previous Run Results as Alt 1”. In the confirmation, select Close, you do want to overwrite the snapshot.

9. On the script dashboard, select the green Start button to resume the script.

   The results are preserved on the snapshot object called “Alt 1”.

   Now, let’s create plots that compare Base and Alt 1.

10. Open the script dashboard “PM: Create Plots of Base and Alt 1” (Figure 37).

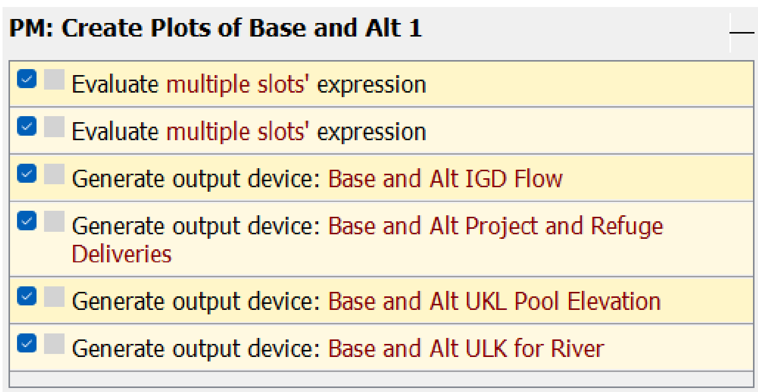


Figure 38. Script dashboard for creating plots of Base and Alt 1.

11. In the last four actions, uncheck any plots you don’t want to generate.

12. Run the script. The specified plots will open. For example (Figure 38):

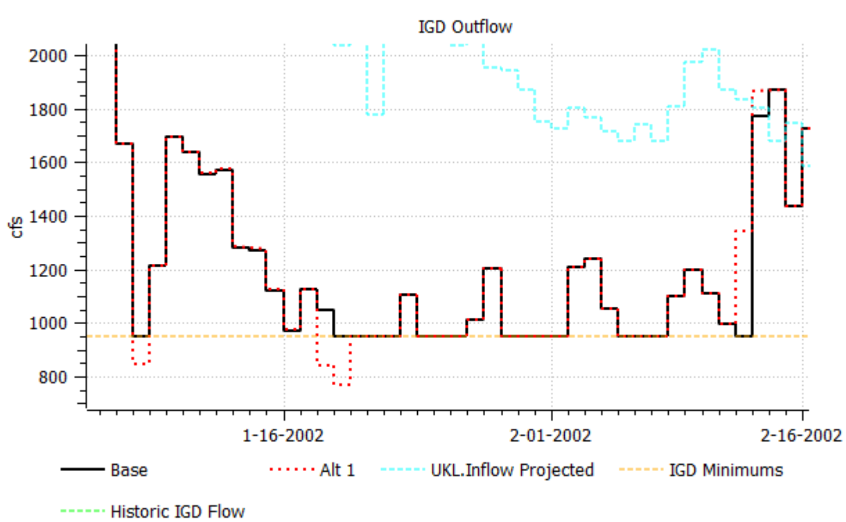


Figure 39. Sample plot (zoomed in) of Base and Alt 1 results.

6. Disclaimer and Future Work

KPOM was developed to mimic the KBPM implemented to support the 2020 IOP, which constitutes a minor update to the previously approved 2019 BiOp. While KPOM was developed with careful consideration of the policies and existing model, differences in implementation and simulation results exist. Furthermore, as new PAs are developed for the basin, the policies represented in the model will no longer reflect the actual policies active in the basin. Additional updates will be necessary to ensure KPOM remains current with basin policy.

Furthermore, future updates may consider some of the following recommendations:

- **Water Accounting**: RiverWare includes a "water accounting" functionality. Simply, water accounting is a layer added to a simulation model to track the ownership and type of the simulated water. In an accounting model, accounts, slots, and data are added to track why water is released, stored, or diverted. These additional components include water ownership, type, and purpose as water moves through the basin. This network is separate from the simulation network, but there are methods that allocate physical water to the accounting network. This functionality could be useful in refining modeling of the water operations throughout the Klamath River Basin.

- **Existing Observations and Forecasts**: Some aspects of the KBPM rely on tailored regressions using multiple hydrometeorological datasets. As new policies and models are developed, use of existing observations and forecasts (e.g., NRCS forecasts) may increase the ease of understanding, transparency, and operability of new policies.

- **RiverSmart**: A RiverSMART model was developed using KPOM, however, additional work is needed to fully implement the multiple run management and scenario exploration features of this model. Furthermore, during development, a program error in RiverWare was discovered. CADSWES is actively working to resolve this error.

7. References

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Reclamation, 2020. Transmittal of Proposed Interim Operations Plan for operation of Klamath Project for Water Years 2020-2022. U.S. Department of the Interior, Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, OR: Mar 27, 2020. 11 pp.

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