**Historic Data Development and Management**

**Klamath Basin Study**

**Bureau of Reclamation**

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**Introduction**

The Klamath River Basin Study (Basin Study) takes a comprehensive approach to evaluate water supply and demand over the entire watershed and develop adaptation strategies to work toward future water security. The Bureau of Reclamation (Reclamation) developed the Basin Studies Program as a means of fulfilling obligations outlined in the SECUREWater Act of 2009 (Public Law [P.L.] 111-11) and Department of Interior’s (Interior) Sustain and Manage America’s Resources for Tomorrow (WaterSMART) Program, which was developed as a result.

Hydrologic and management studies are analyzed in a basin study. In particular, impacts of projected changes in climate are evaluated. To support these analyzes, historic data are used to understand current conditions, to establish a baseline and to bias-correct climate change scenarios. These pages document development of historic data to support the KBS.

Available historic Reclamation, meteorological, USGS and PacifiCorp data were obtained for water years 1961 through 2013, extended to fill in missing periods, and used to compute hydrologic inflows to the basin. The primary developed data for the study are the historic gains, also known as accretions or local inflows. Historic data are used with the historic period for model development. Historic data from water years 1961 through 2013 were used to support development of twenty hydrid delta climate change hydrologies for use by the KBS. This includes bias corrections of the twenty climate change hydrologies and the reference hydrology, also known as the Maurer observed trace. See various KBS Technical Memoranda for additional information on climate change hydrologies.

**Data Inventory**

Historic monthly data from 1961 upstream of Iron Gate Reservoir were developed by the Klamath Basin Area Office (KBAO) to support other modeling efforts. Additional monthly data and daily data were developed downstream of Keno Dam to support the Klamath Data Removal (KDR) study. More recently, KBAO developed daily data from Upper Klamath Lake (UKL) to Iron Gate Reservoir. These data include revised canal diversions but do not include Lost River nor data on scale of KDR or KBS in Keno Dam to Iron Gate Reservoir reach.

The KBS started with KDR data and most recent KBAO data. KBAO data include data collected during daily operations and data developed for the Klamath Basin Planning Model (KBPM). These data were supplemented with USGS, CDEC, ODNR, PacifiCorp, and KBAO data. In addition, the KBS extended the spatial extent of the KDR data upstream of UKL and to include Trinity River to Trinity Reservoir and South Fork of Trinity River.

Previous data sets did not include reservoir evaporation. The KBS estimated historic evaporation in computation of historic hydrology.

Table 1 is a summary of available historic data downstream of Keno Reservoir.

Table 1. Downstream Klamath River Hydrologic Data Inventory.

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| --- | --- | --- |
| Data Item | Source | Available Data |
| Klamath Near Keno Flow | USGS | 1961 – 2014 |
| JC Boyle Pool Elevation | PacifiCorp | 1961 – 2014 with a few missing days. |
| JC Boyle Reservoir Spill | PacifiCorp | 1979 - 2009 with some missing periods. |
| JC Boyle PP Turbine Release | PacifiCorp | 1979 - 1982 and 1988 – 2014 |
| Klamath Below JC Boyle PP Flow | USGS | 1961 – 2014 |
| Copco 1 Monthly Pool Elevation | USGS | 1968 – 2002 |
| Copco 1 Daily Pool Elevation | PacifiCorp | 1979 - 2009 with some missing periods. |
| Copco 1 Outflow | PacifiCorp | 1979 - 2009 with some missing periods. |
| Iron Gate Monthly Pool Elevation | USGS | 1968 – 2002 |
| Iron Gate Daily Pool Elevation | PacifiCorp | 1979 – 2014 with some missing periods. |
| Klamath Below Iron Gate Flow | USGS | 1961 – 2014 |
| Shasta Near Yreka Flow | USGS | 1961 – 2014 |
| Scott Near Ft Jones Flow | USGS | 1961 – 2014 |
| Klamath Near Seiad Valley Flow | USGS | 1961 – 2014 |
| Indian Creek Near Happy Camp Flow | USGS | 1961 – 2014 |
| Salmon River At Somes Bar Flow | USGS | 1961 – 2014 |
| Seiad to Orleans Gain Reach | USGS | 1961 – 2014 |
| Klamath At Orleans Flow | USGS | 1961 – 2014 |
| Trinity At Hoopa Flow | USGS | 1961 – 2014 |
| Klamath Near Klamath Flow | USGS | 1961-1994 and 1998 – 2014 |

**KBSM Hydrology Nodes**

The Klamath Basin Study Model (KBSM) model was created for this study. The KBSM is a RiverWare model that includes hydrology nodes, routing nodes, confluences, power plants and reservoirs. Additional nodes exist between nodes downstream of Iron Gate to support water temperature modeling. These nodes correspond to additional tributary inflows. Primary gains developed from historic data are spatially disaggregated to the tributary nodes. Table 2 is an inventory of primary nodes downstream of Keno Dam.

The bias correction process produces monthly flows that are temporally disaggregated to daily flows. The disaggregation process is described in a later section.

Table 2. Downstream of Keno Dam Hydrology Nodes.

|  |
| --- |
| Klamath River Near Keno |
| Keno to Boyle Reservoir Gain |
| JC Boyle Reservoir |
| Boyle Reservoir To Boyle Gage Gain |
| Boyle Gage To Copco Gain |
| Copco 1 Reservoir |
| Copco 2 Reservoir |
| Copco To Iron Gate Gain |
| Iron Gate Reservoir |
| Iron Gate to Seiad Gain |
| Seiad to Orleans Gain |
| Scott Near Ft Jones |
| Salmon At Somes Bar |
| Indian Creek Near Happy Camp |
| Shasta Near Yreka |
| Lewiston to Hoopa Gain |
| Trinity At Hoopa |
| Trinity River |
| South Fork Trinity |

**Data Development**

Because of file sizes involved, individual workbooks were created for subareas of basin. These areas are UKL, Lost River, Lake Ewauna, Keno Dam to Iron Gate Dam, Trinity Lake, and remainder of basin. UKL data include Williamson and Sprague River flows upstream of UKL. Reservoir reaches workbook consists of USGS and PacifiCorp data and is supported by several other workbooks. Power reservoir reach workbooks includes USGS streamflow data, Boyle spills, Boyle power plant flows, and change in storage for Boyle, Copco 1, and Iron Gate reservoirs expressed as flow. Computation of change in storage and conversion to flow is done in a separate workbook that has all end-of-period data obtained for the study. These data include a mix of USGS and PacifiCorp daily and monthly data. Table 3 is a listing of primary[[1]](#footnote-1) subarea workbooks and basin wide workbook “KBS\_HistoricHydrology”.

A Reclamation developed Excel Add-In called the Data Utilities Toolkit (DUT) was used to move data between workbooks, between workbooks and HEC Data Storage System (DSS) files, and other data stores. The DUT also includes temporal aggregation utilities. A DUT data management interface (DMI) specification exist in all most historic data workbooks to pull USGS streamflow data.

All primary workbooks include a DMI to push data into workbook “KBS\_HistoricHydrology”. Except for two missing days for Klamath Below JC Boyle PP and three missing years for Klamath Near Klamath, these data are complete. The two missing days for Klamath Below JC Boyle PP were linearly interpolated. Missing data for Klamath Near Klamath were filled using regressions of monthly data. For instance, if a January value was missing, the January regression was used to fill that value.

Table 3. Primary Historic Hydrology Workbooks

|  |  |
| --- | --- |
| Workbook | Description |
| A2PseudoNaturalFlow.xlsx | Area 2 pseudo natural flow |
| KBS\_DSofDamsHydroData.xlsx | Pseudo natural flows downstream of Iron Gate |
| KBS\_HistoricHydrology.xlsx | Pseudo natural flow for all hydrology nodes |
| KBS\_LakeEwaunaAccretions.xlsx | Lake Ewauna pseudo natural flow |
| KBS\_LostRiverData.xlsx | Lost River pseudo natural flow data |
| KBS\_MI\_RD\_Demands.xlsx | Municipal, industrial and rural domestic depletion |
| KBS\_PowerDamHydroData.xlsx | Power reservoirs hydrology |
| KBS\_RefugeHistoricDepletion.xlsx | Refuge depletions |
| KBS\_TrinityLakeData.xlsx | Trinity Lake pseudo natural flow data |
| KBS\_UKLData.xlsx | UKL hydrology with evaporation |
| KBS\_UKLData\_NoEvap.xlsx | UKL hydrology without evaporation |
| KBS\_US\_USGSData.xlsx | Upstream of UKL hydrology |

Because of temporal and data quality issues, gains computed using historic streamflow data often have unnatural spikes including negative values. While negative gains can exist, they would typically not include large spikes. A smoothing method was applied to all gains downstream of Iron Gate reservoir that consisted of applying the flow pattern of the next downstream gage to the monthly gain. This approach maintains continuity on a monthly basis while computing a more natural hydrograph on a daily basis.

As seen in Table 1, data availability was problematic in the reservoir reaches. The record for the total hydrologic gain from Keno to Iron Gate is complete, so the missing data only affects the estimation of the total natural gain and the distribution of those gains between Keno and Iron Gate.

Insufficient historic data exists to naturalize all flows. Computed flows are a mixture of hydrologic (historic), unregulated, and natural. The composite of these was called ‘pseudo’ natural. Although final data set include a mixture of natural flow, unregulated flow and hydrologic flow, this is acceptable for bias correction process as long as model use of data is consistent. For instance, model use an unregulated flow as natural or a hydrologic flow as natural.

Boyle pool elevation data were obtained but not storage values. An area-capacity table for Boyle reservoir was developed from an area-capacity curve provided by PacifiCorp. Historic Copco 1 and Iron Gate data include USGS end-of-month pool elevations and contents from 1968 through 2002. These data were used with PacifiCorp area-capacity curves to develop area-capacity tables for Copco 1 and Iron Gate reservoirs.

Missing reservoir data were handled in a number of ways. Small periods of 1 to 4 days were linearly interpolated. Periods where monthly elevations existed but daily values did not, a straight line interpolation of the monthly storage values was used. Missing change in storage for longer periods for Copco 1 and Iron Gate were computed using monthly regressions to Boyle’s change in storage. Although these regressions are poor, they only affect data before 1968. Since these estimates only affect pseudo natural gain computations before 1968 and those data are only used for the deconstruction scenarios and model development, it was decided that these estimates are sufficient for this study.

Four additional adjustments of the daily data were made. First, PacifiCorp has periodically measured the gain from spring inflows between Boyle Reservoir and the gage below the power plant. The average flow of 220 cfs was incorporated as the minimum gain in this reach, also known as the bypass reach. Second, the years that Copco reservoir releases are available were used to compute the average monthly spatial distribution of gains between the Klamath River Below JC Boyle Power Plant gage and Iron Gate reservoir upstream and downstream of Copco reservoir. These distributions were applied to total gain when the measured distribution was unavailable.

The third adjustment was to compute a provisional change in storage for the regressed and interpolated periods, then adjust the change in storage if it produced negative reservoir inflows. When negative inflows are computed, they were set to zero. Then the change in storage was recomputed using the adjusted inflow. This adjustment mostly affects computations before 1979. However, it can affect the distribution of gains between reservoirs on any day if bad recorded data exists. The fourth adjustment was to make pseudo natural gain consistent with hydrologic gain between Keno gage and below JC Boyle Powerplant gage. This compensated for some of the error in the 220 cfs spring flow estimate.

Because the KBS modelers did not wish to model upstream of Trinity Reservoir, a regression of Trinity River inflows to CDEC operations was developed. This regression is applied to Trinity River inflows for each hydrology scenario.

Historic developed gains are consolidated from subbasin workooks into workbook “KBS\_HistoricHydrology”. This workbook is source of monthly data used for bias corrections and daily data used for temporal disaggregations. Historic data were used for bias corrections of Maurer observed (S0) trace and climate change ensemble traces for 1961 through 1999. Historic data were also used to develop the KBSM using 1961 through 2013 data. This provided a longer period for comparison to recent historic operations and to the KBPM.

**Temporal Disaggregations**

The KBSM requires daily data. Disaggregations of monthly to daily data are based on historic daily to monthly relations. The disaggregation fractions are computed using the filled historic daily data and equivalent monthly data. The disaggregations are computed during scenario data management.

Gains between Keno and Iron Gate use pattern of disaggregated Keno flow. This was done to enable the KBSM to better meet Iron Gate IFR’s. In actual operations, additional water is released from UKL to meet Iron Gate IFR’s.

**Spatial Disaggregations**

The temporally disaggregated data downstream of Iron Gate Dam are spatially disaggregated to a number of tributaries. The spatial distribution factors were estimated as a function of the drainage area at the tributary and the drainage area of the next downstream gage. This approach produces similarly shaped hydrographs for all the tributaries between gages but maintains mass balance with respect to the total daily gain of the reach. This is done using an initialization rule in the KBSM.

**Streamflow Routing**

Travel times from upstream of UKL and from UKL to Keno Dam and through power reservoirs were obtained from KBAO. Hourly data from gages downstream of Keno were used to estimate travel times between gages as a function of flow. These were used in the KBSM to route (lag) flows down river. More sophisticated routing methods require more data than were available for this study.

**Data Management**

Data development and the numerous steps to generate model input and process model output require considerable data management. Most of the hydrologic workbooks used for the study include DMI’s managed by the DUT. Each DMI requires a header worksheet which is basically a mapping of the workbook’s data for one time-series worksheet to another data store. These DMI’s are usually ran interactively using the DUT.

Automated management of climate change scenarios and respective data including hydrology, depletions and reservoir evaporation rate was facilitated by creating Excel macro based workbook KBSRiverWareManager. KBSRiverWareManager is supported by workbooks in folder “simulated” and climatechange (or historic if running an historic data).

1. Some of the sub area workbooks require additional data are also in workbooks. Historic data assembled and developed for the KBS exist in folder “\data\historic”. Data obtained from PacifiCorp and other sources are in subfolders of “historic”. [↑](#footnote-ref-1)