Application of RiverWare to Climate Change Studies

Authors: By Carly Jerla & Paul Miller (*Bureau of Reclamation, Lower Colorado Region*)

Abstract: Streamflow projections by Bureau of Reclamation (Reclamation) have traditionally been based upon historical streamflow records and have assumed that future mean streamflow and variability is adequately represented through past observations. As climate change research continues to advance, the assumption that past flows are indicative of future flows may no longer be valid; to this end, Reclamation is currently investigating how to best incorporate projections of future climate into operational and policy models. The World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset has recently been made available through a joint effort between Reclamation, Santa Clara University, and the Lawrence Livermore National Laboratory and provides statistically downscaled climate projection data from a myriad of climate models over the continental United States. Through cooperation with AMEC and the Colorado Basin River Forecasting Center (CBRFC), Reclamation is working to develop projections of streamflow throughout the Colorado River Basin using the Variable Infiltration Capacity (VIC) and CBRFC River Forecasting System (RFS), respectively, forced with data from the WCRP CMIP3. These streamflow projections are then used to drive Reclamation RiverWare based models to assess potential impacts to reservoir impacts under changing climate conditions.

CoE-SWD Model for Alternative Reservoir and System Operations for Dam Safety

Author: John Daylor, P.E. (*Tulsa District, Corps of Engineers*)

Abstract: Keystone Dam and Reservoir is one of numerous impoundments on the Arkansas River system that is operated to meet multipurpose operational objectives. Current operation, in part, includes delaying the lower 30% of flood storage evacuation for some reservoirs to provide post-flood scour and dredging in the navigation system. Recent evaluation of Keystone Dam by the Corps of Engineers dam safety team resulted in safety concerns. As a result, a request was made for early screening and evaluation of alternative operation that involves evacuating Keystone Reservoir flood storage without delaying the lower 30%. A target flow guide curve for the lower Arkansas River is used for operation that is based on system percent flood storage and "fullness" of the reservoirs. Using the Corps of Engineers SWD flood control methods in RiverWare a period of record rule simulation analysis is performed to evaluate proposed changes of Keystone Reservoir operation. Results are compared to existing conditions run for evaluation. Analysis includes system effects as well as Keystone Reservoir. RiverWare statistical applications are also included.

Daily River Operation Models (DROM) for LCRA

Authors: Steve Setzer, John Carron and Kevin Wheeler (*AMEC Earth and Environmental*)

Abstract: AMEC developed three RiverWare models for the Lower Colorado River Authority, Texas, as part of the Daily River Operation Model (DROM) project. These include an hourly routing model, a daily reservoir release model, and a daily accounting model. The hourly model is used to route release from Tom Miller Dam to diversion points downstream. It is intended to identify short term gaps at diversion points and instream flow targets as a result of hourly release schedules. The daily reservoir release model uses the RiverWare water rights solver to determine the minimum daily release volume from the Highland Lakes required to meet downstream demands and instream flow targets. The daily accounting model also uses the RiverWare water rights solver. It uses the actual reservoir releases that occurred earlier in the month and determines the breakdown of run-of-river and stored water release. It also determines the breakdown of run-of-river water and stored water diverted by each water user.

Hourly operations on the Lake Fork River, Utah

Author: Brad Vickers (*Wave Engineering*)

Abstract: Real-time operations of Moon Lake, Big Sand Wash and Twin Pots Reservoirs and water rights allocations on an hourly basis. The model will be used by the Moon Lake Water Users Association and the Lake Fork River Commissioner. The model development is sponsored by the Duchesne County Water Conservancy District. This is the first RiverWare model with hourly water rights allocation.

Operating the St. Mary Canal Using an Annual Balancing Period

Authors: Steve Setzer & John Carron (*AMEC Earth and Environmental*)

Abstract: AMEC enhanced the RiverWare model of the Milk - St. Mary River System, previously developed by the Montana Department of Natural Resources and Conservation, to incorporate the use of an annual balancing period to determine the operation of the St. Mary Canal. This allows the United States to build a credit, based on over delivery to Canada early in the runoff season, that can be drawn upon later in the year during irrigation season.

Operational Model Development in the Colorado River Basin

Authors: Dan Bunk (*Bureau of Reclamation, Lower Colorado Region*) & Katrina Grantz (*Bureau of Reclamation, Upper Colorado Region*)

Abstract: Several new operations models have been implemented or are in development in the Colorado River Basin. The Lower Colorado Region replaced an outdated spreadsheet application used for scheduling hourly releases out of Davis Dam and Parker Dam with an hourly RiverWare model which utilizes the new Unit Power method. The new model allows for easy storage and access of data in the Hydrologic Database (HDB) and better security of the short term operations system. Also, Reclamation's mid-term operational model, the 24-Month Study, has been expanded so that all water use in the Lower Colorado basin is explicitly modeled in RiverWare. Previously, all data and functions that calculate the Parker Dam releases were in an external spreadsheet model. The RiverWare model expansion allows for easier access to water use data and more efficient accounting for water deliveries in the Lower Basin. Development of a probabilistic version of the 24-Month Study model is also currently underway. The model is based on the expanded 24-Month Study model but will utilize multiple inflow forecasts generated by the River Forecasting Center's (RFC) Ensemble Streamflow Prediction model to produce probabilistic output of variables such as reservoir releases and diversions. Current work includes the development of rules for the Upper Basin reservoirs and a conversion for the model to use natural inflow forecasts rather than unregulated inflow forecast. The model will be a key tool for Reclamation and stakeholders to assess risk and uncertainty in the Colorado River Basin.

Optimizing TVA's Hydropower Systems using RiverWare

Authors: Susan Jacks, Lana Bean and Robin Kirsch (*Tennessee Valley Authority*)

Abstract: The Tennessee Valley Authority (TVA) is a multipurpose federal corporation which owns and operates 29 conventional hydropower plants and one pumped storage hydropower plant in the Tennessee Valley. In addition to hydropower generation, the reservoir system provides other beneficial services throughout the Tennessee Valley, including minimum depth for navigation, flood risk reduction, minimum flows for water supply and aquatic habitat, and recreation. TVA uses two different RiverWare models to schedule turbine discharges, spillway releases, power generation, and resulting pool elevations at each of its reservoirs. The first model uses a six-hour timestep and covers a two week planning horizon. Daily scheduled releases from each reservoir provide input to the second RiverWare model, which uses an hourly timestep. This model covers a planning horizon of up to two days and is

used to schedule hourly power generation from each hydropower plant. TVA's optimization model contains a comprehensive list of policy constraints that guide decisions about water releases and pool elevations at each reservoir. Policy constraints are prioritized and must be satisfied to the extent possible before an economic objective function can be maximized. Policy constraints include water supply, navigation, flood regulation, flows for aquatic habitat, recreational flow releases, and special operations.
A second RiverWare solution methodology, rulebased simulation, is used following each optimization model run. Rulebased simulation allows modelers to make manual changes to optimization results. Hourly hydropower schedules for the following day and daily average discharges and pool elevations for the upcoming two week period are then distributed to plant operators, recreationists, barge operators, and others throughout the Tennessee Valley.

RiverWare Model of Dallas Water Supply System

Authors: Denis Qualls, Senior Engineer; Varghese Abraham, Engineer Assistant; Larry Brown, Engineer (*Dallas Water Utilities*); and Ken Choffel, Senior Project Manager; Cory Shockley, Senior Hydrologist; Sumant Mallavaram; Ted Shannon, Water Resources Engineer (*HDR Engineering*)

Abstract: Dallas Water Utilities (DWU) supplies drinking water for a service population of 2.3 million people for the City of Dallas and 27 municipalities. DWU currently obtains water from five major water supply reservoirs, which deliver water to three water treatment plants. An additional reservoir, Lake Fork Reservoir, was connected to the DWU system in 2009, with the new pipeline and pump station currently under testing. DWU is partnering with the Tarrant Regional Water District (TRWD - the major water supplier to the City of Fort Worth) on a study to evaluate options for obtaining water from an additional major reservoir, Lake Palestine, by 2015. To evaluate the reliability of this water source and associated operating agreements with TRWD, DWU selected RiverWare as the platform to revise its current simulation model of its water supply system. Future applications of this model include: annual forecasting; optimization of reservoir operating rules; evaluation of impacts from potential climate change including potential changes in reservoir firm yields; and other water planning needs.

Truckee River Planning Model

Authors: Shane Coors (*Precision Water Resources Engineering*)

Abstract: The Bureau of Reclamation, in collaboration with several of the Truckee River Basin's significant stakeholders, has started development a RiverWare Planning Model for the Truckee River Basin. The model is an adaptation of the RiverWare Operations model that has been in use in the Truckee Basin since 2003. The development process will be discussed and some sample output will be shown. Finally, the variety of uses intended for the model will be presented.

Using Improved Climate Forecasting and the Flexibility of Riverware to Develop Operational Policies to Increase Efficiency for the Tarrant Regional Water District

Authors: Kevin Wheeler and John Carron (*AMEC Earth and Environmental*); Laura Blaylock (*Tarrent Regional Water District*); and Kirk Kennedy (*Kennedy Resource Company*)

Abstract: AMEC and the Kennedy Resource Company applied the RiverWare model developed for the Tarrant Regional Water District to study the effects of a number of proposed operational policy improvements. These policy improvements allowed projected climate conditions to be considered in the operational guidelines along with system state conditions. Methods of estimating climate conditions were developed, tested and applied to the RiverWare model based on transition probabilities and downscaled atmospheric climate parameters. Benefits including reduced pumping costs, decreased

reservoir spills, fewer shortages to water users and minimizing evaporation losses were evaluated to select a combination of policies to maximize system efficiency.