CHALLENGES ON DEVELOPMENT OF RESSIM MODEL FOR COLUMBIA RIVER SYSTEM

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Abstract: Columbia Basin Water Management Division (WM), Northwestern Division (NWD) operates the complex system of multiple-purpose projects in the Columbia River system. To support seasonal and real-time operations, WM conducts planning studies addressing hydrologic variability, power system analysis, flood control impacts, and fish and wildlife recovery issues.

The Hydrologic Engineering Center (HEC) has developed a new reservoir model, the Reservoir Evaluation and System Simulation (ResSim) model, as part of the Corps of Engineers Water Management System (CWMS). The model departs from traditional simulation models where operations are part of the model input. One feature of the ResSim model is the incorporation of a rules-based approach which allows the model to prescribe an operation instead of only direct input from the user. The incorporation of a rules-based approach has presented major technical challenges in the development of such a large complex multiple purpose system reservoir regulation models that would meet real-time and planning study needs.

The computer demonstration and posters will highlight the challenges of the ResSim model development and present the current model to date.

INTRODUCTION

Columbia Basin Overview: The Columbia River Basin is the fourth largest river basin in North America and drains 259,000 square miles of which 40,000 square miles resides in Canada. The basin spans 4 states (Washington, Idaho, Montana and Oregon) and 1 Canadian province (see Figure 1). The Corps and Bureau of Reclamation are responsible for the operation of 14 major dams. In all there are over 200 dams and projects throughout the basin that are operated by numerous federal, non-federal and Canadian entities.

The Columbia Basin has an average annual runoff of 200 million acre-feet (MAF) as measured at The Dalles Dam. The storage available upstream of The Dalles Dam is 42 MAF. Since 1928, annual runoff volume has varied between 80 and 196 MAF. Flood control requirements for the upstream storage projects vary depending on the volume of water forecasted in the official Water Supply Forecast. The regulation objective is to control stages at Portland, Oregon and Vancouver, Washington which are located downstream of all projects at the confluence of the Columbia and Willamette Rivers.

Water supply forecasts are produced by the National Weather Service's Northwest River Forecast Center (NWRFC) three times every month between January and July. The forecasts provide predicted runoff volumes for several time periods at various reference points within the basin. The NWRFC also tracks accumulated observed runoff volumes. For both streamflow and water supply forecasts, the Corps and NWRFC work collaboratively to develop forecasts throughout the basin based on stream gage readings, climate forecasts, and planned reservoir operations.

Figure 1: Major Federal and non-Federal projects in the Columbia River basin.

<u>Modeling Needs</u>: Since its creation in the 1950s, WM has relied on the Streamflow Synthesis and Reservoir Regulation (SSARR) model. Over the years, loss of programming expertise and lack of technical support for the model have led WM to abandon the SSARR model and convert to newer technology. WM utilized the SSARR model for both planning studies and for real-time operation modeling. Over the past several years, the models to accomplish these objectives have changed and different models are being used.

Planning Studies: The Hydrologic Engineering Branch (HEB) within WM conducts hydrologic, hydraulic, and system reservoir regulation studies to investigate flood control and other operational criteria in the Columbia River basins. There are currently two models in use, SSARR and AutoReg.

The SSARR model is capable of routing the flows as a function of multivariable relationships involving backwater effects and natural lake channel restriction. The current SSARR model computes unregulated flows throughout the Columbia and Snake Rivers by using reservoir storage changes, project outflows, flow gage data and irrigation diversions. The unregulated flow data is being used for studies, the calculation of annual prevented flood damages, and for inclusion in various reports.

AutoReg, a user interface to SSARR, was designed in 1992 to dramatically reduce the time required to conduct studies of the Columbia Basin system of dams and reservoirs. AutoReg automated the SSARR data input requirements and output processing and incorporated the SSARR river model algorithms. AutoReg is being used for Columbia Basin flood control studies and planning studies to evaluate multi-purpose reservoir operations. The AutoReg model has fewer reservoirs and flood control points than are currently needed.

Real-Time Modeling: The Reservoir Control Center (RCC) within WM works with the NWRFC to prepare short term (10-day) and longer-term streamflow forecasts. The NWRFC provides WM the forecasted streamflows, and RCC inputs the project regulation. In the late 1990s the NWRFC switched from the SSARR model to the National Weather Service River Forecasting System (NWSRFS) model. The NWSRFS is a suite of models that includes a hydrologic forecasting model and a reservoir routing component. The short-term forecasts utilize current antecedent conditions throughout the basin combined with 10-day deterministic precipitation and temperature forecasts. One component of NWSRFS is the Ensemble Streamflow Predictor (ESP), which is used for longer-term modeling. With ESP, the current antecedent conditions are combined with historic meteorological data (temperature and precipitation from 1948 to 1993) to generate a suite of 44 hydrographs. Statistics can then be applied to the hydrographs to look at potential water scenarios. RCC wanted a model that could analyze the ESP hydrographs and decided to turn to the newly developed ResSim model. The model's rule-based approach made possible to analyze all 44 hydrographs without requiring the user to hand regulates each and every trace.

RESSIM MODEL DEVELOPMENT

ResSim Modeling Basics: For real-time operation planning, RCC planned to use the NWRFC ESP inflows and local flows. To incorporate the flows, the Columbia Basin ResSim model needed many of the same forecast points and routings as the NWSRFS Columbia model. For planning studies, HEB planned to utilize the historical flow database, so the new model would also need to match up well with the old SSARR model while incorporating more reservoirs and new flood control points. The basic configuration for the ResSim model included 32 projects and incorporated the same routings from the previous models (Figure 2).

Work to Date: Once all the forecast points, projects and routing reaches were entered to form the basic configuration in the Columbia Basin ResSim model, WM still faced many challenges, including:

- Converting 44 daily hydrographs for each inflow component (48 in all) into the appropriate format for ResSim
- Combining ESP time series with observed data for model input
- Computing appropriate flood control evacuation requirements at storage projects for each of the 44 ESP hydrographs (and corresponding runoff volumes)

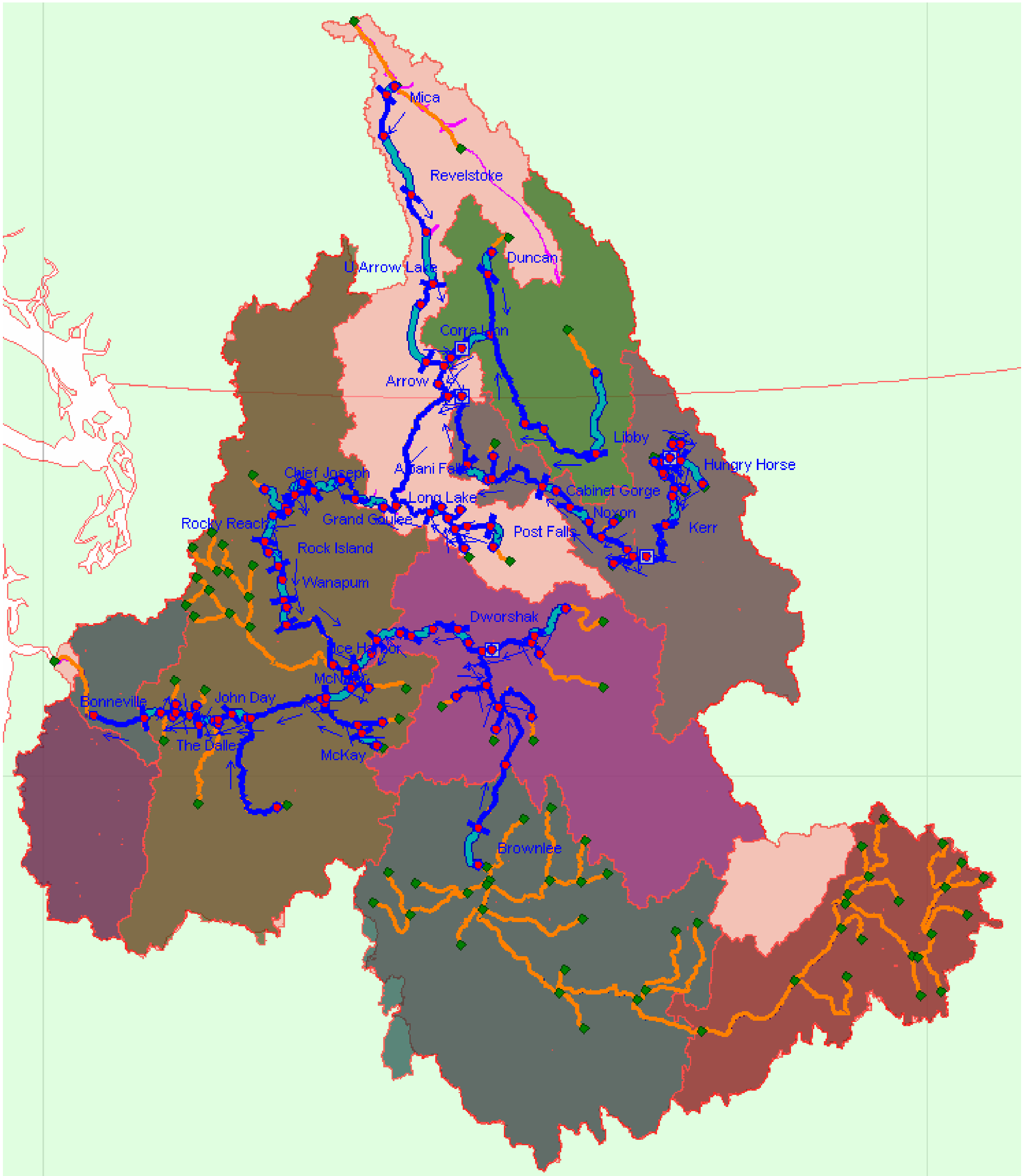
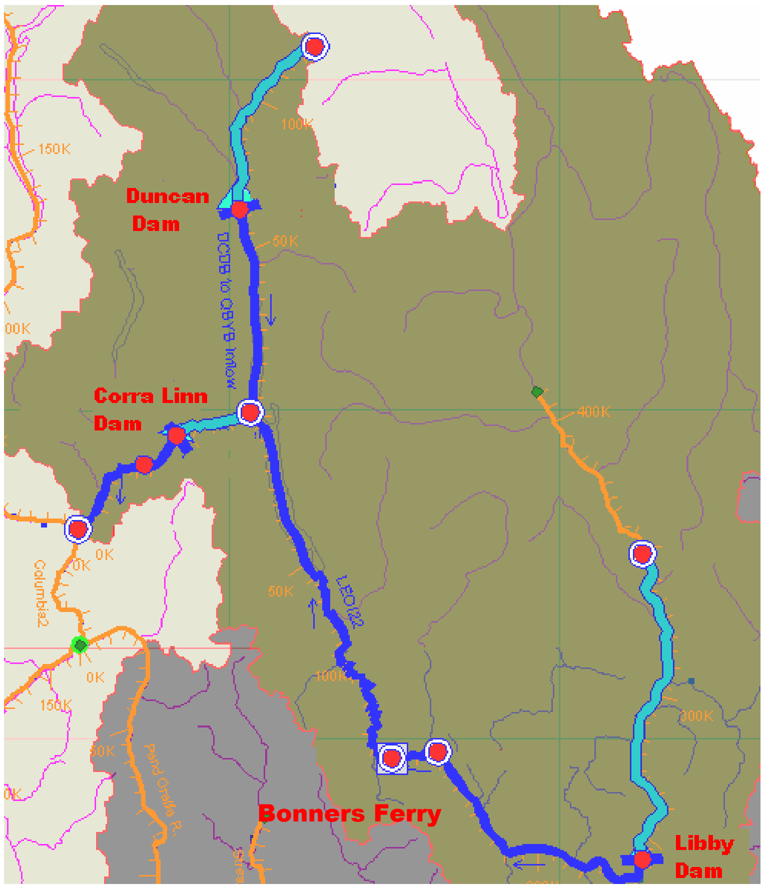


Figure 2. ResSim Model Configuration

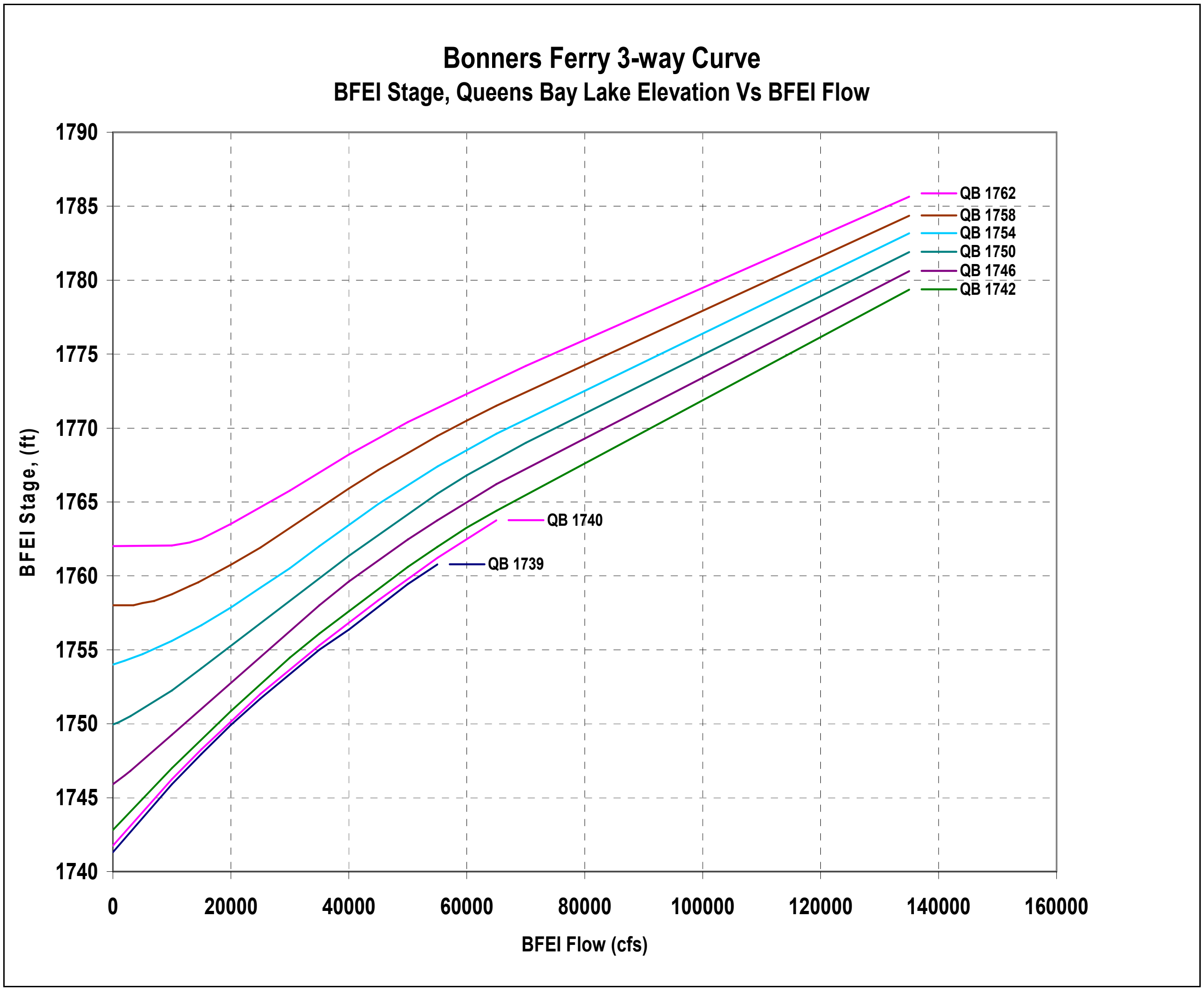
<u>Kootenai Sub-Basin Example:</u> One particularly difficult sub-basin to model is the Kootenai Basin that resides in Montana, Idaho and British Columbia. Kootenay Lake is a natural lake with two major rivers feeding it, the Kootenai River from the south and the Duncan River from the north (see Figure 3). Libby Dam, a Corps of Engineers storage project, sits on the Kootenai River and provides system flood control for Portland, OR and Vancouver, WA and also local flood control for the town of Bonners Ferry, Idaho. Duncan Dam, owned and operated by B.C. Hydro on the Duncan River regulates inflow into Kootenay Lake and also provides system flood control for Portland, OR and Vancouver, WA. Corra Linn is a small project operated by Fortis BC that sits downstream of the channel restriction on the lower end of Kootenay Lake.

Figure 3. Kootenai Basin configuration



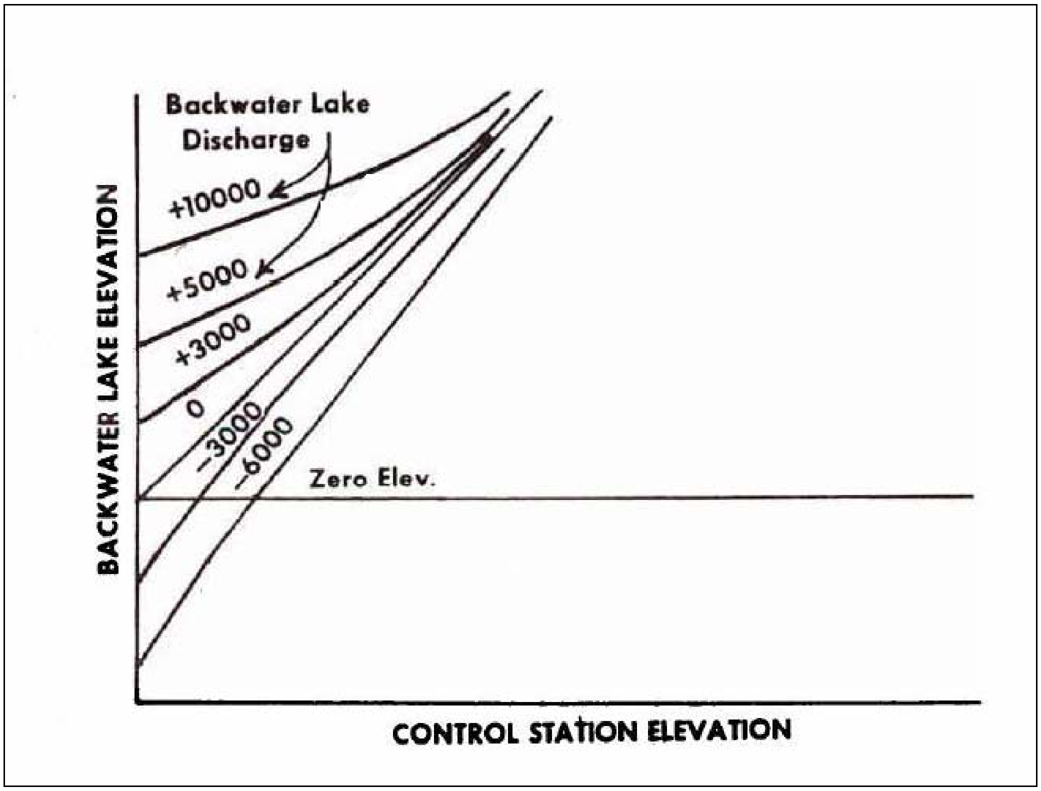
Bonners Ferry Forecast Point: The US Geologic Survey (USGS) gage at Bonners Ferry only measures stage due to the backwater effect from Kootenay Lake. Libby is operated to maintain Bonners Ferry below flood stage (1764.0 ft). The ResSim model can forecast the flow at Bonners Ferry, but in order to properly operate Libby for Bonners Ferry flood control, the stage also needs to be computed. The stage needs to be computed from a three-variable curve (Bonners Ferry (BFEI) flow vs. Kootenai Lake elevation at Queens Bay (QB) vs. Bonners Ferry stage), a feature that the current version of ResSim does not have (see Figure 4).

Figure 4. Bonners Ferry Stage Three-Variable Curve



Lake Routing with Channel Restriction and Backwater effect: This tool in the SSARR model is used where independent downstream channel restrictions affect the hydraulic characteristics at a given upstream location. This tool was applied at the natural channel restriction at Grohman Narrows. Here the lake elevation of Corra Linn Dam affects the discharge and pool elevation of Kootenay Lake. This three-variable relationship shown in Figure 5 (from SSARR User Manual), is also not in the current version of ResSim model.

Figure 5. 3-way Backwater Relationship



Developing Rules for International Joint Commission (IJC) operation: Upstream of Corra Linn Dam (see Figure 3), a natural canyon (Grohman Narrows) restricted the flow from the Kootenay lake. In order to reduce the head loss between Corra Linn Dam and the main portion of Kootenay Lake, Grohman Narrows was excavated in 1940. Increasing the hydraulic capacity of the narrows decreased the maximum lake level that would be reached during the spring freshet. The IJC Order, which governs the regulation of Kootenay Lake, sets forth a table which requires the lake to be held below its natural level before the narrows were excavated. In the spring months, the IJC order's requirements are followed to set the upper elevation limit. If the elevation is going to be exceeded, the projects which affect the level of Kootenay Lake need to respond. The standard protocol is:

- Corra Linn increases outflow to allow the lake to go to free flow.
- Duncan outflow is reduced to pass inflow.
- Libby outflow is reduced to pass inflow.

The upper elevation limit is calculated using actual Kootenay Lake inflows. In order to correctly model the operation in ResSim, an internal computation needs to be done using the regulated inflow into Kootenay Lake for each day. Then all 3 projects will follow different operation plans. This level of computation will likely require the use of computer programming scripts.

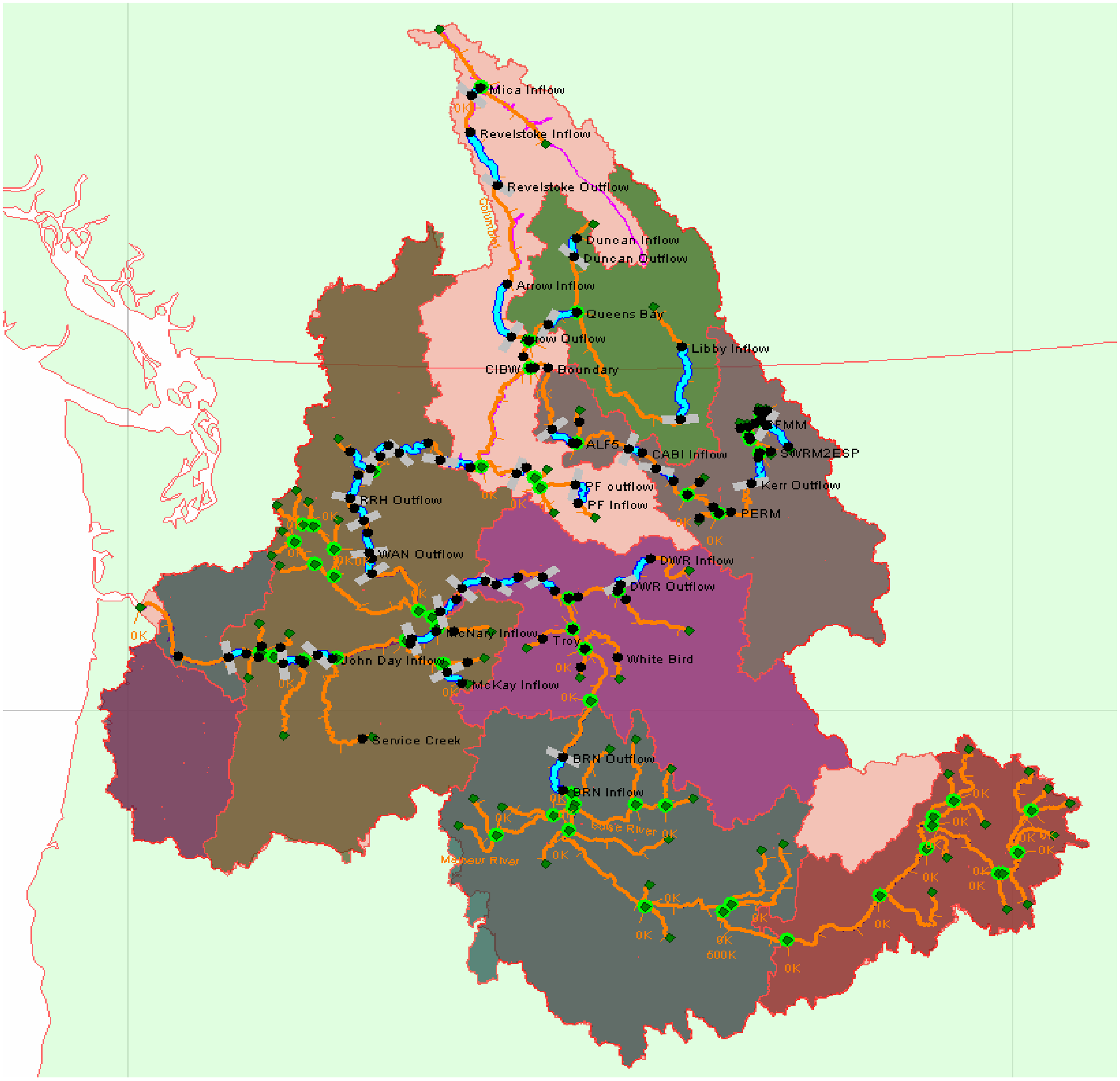
CONCLUSION

Attempting to model the Columbia Basin has proven to be quite a challenge. This basin covers a very large area and is filled with complex hydraulic relationships. Developing rules within ResSim can be difficult because of the large variability in annual runoff volume and the number of projects operating for the single point at Portland, OR and Vancouver, WA. Although WM has made significant progress in developing the basic model, additional work still needs to be done. HEC is looking at adding new tools to the ResSim model to handle the three variable curves. WM is exploring the capabilities of programming scripts within ResSim to handle the IJC requirements. HEC and WM will continue to work collaboratively on new tools to add to the ResSim model to address all the unique needs. The computer demonstration and posters will highlight the up to date ResSim model and the difference between the ResSim model outputs and the old model outputs.

REFERENCES

Northwestern Division, U.S. Army Corps of Engineers (1966). Streamflow Synthesis and Reservoir Regulation (SSARR) User Manual.

Hydraulic Engineering Center (HEC), U.S. Army Corps of Engineers (2003). Reservoir System Simulation (ResSim) User Manual.



Mica Inflow
Revelstoke Inflow
Revelstoke Outflow
Duncan Inflow
Duncan Outflow
Arrow Inflow
Queens Bay
Libby Inflow
CIBW
Boundary
ALF5
CABI Inflow
SWRM2ESP
Kerr Outflow
PERM
PF outflow
PF Inflow
RRH Outflow
WAN Outflow
DWR Inflow
DWR Outflow
McNary Inflow
Troy
White Bird
John Day Inflow
McKay Inflow
Service Creek
BRN Outflow
BRN Inflow