INTEGRATION OF RIVERWARE INTO THE CORPS WATER MANAGEMENT SYSTEM

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Abstract: The Corps Water Management System (CWMS) provides a single, integrated package of data management and near-term modeling tools. The built-in modeling tools of CWMS include a hydrologic model (HEC-HMS), a reservoir simulation model (HEC-ResSim), a river hydraulics model (HEC-RAS) and an economic impacts model (HEC-FIA). Recently, the modeling tool RiverWare has been also integrated into the suite of modeling tools. RiverWare™ is a general purpose river and reservoir modeling application. Researched and developed by the University of Colorado Center for Advanced Decision Support for Water and Environmental Systems (CU-CADSWES) in collaboration with the Tennessee Valley Authority (TVA), the U.S. Bureau of Reclamation (USBR), and the U.S. Army Corp of Engineers (USACE), RiverWare can be run either as a stand-alone application, or in concert with other models and databases. CWMS and RiverWare have been enhanced to allow CWMS to incorporate RiverWare as the reservoir simulation model. This paper briefly presents the CWMS, describes RiverWare, and explains the enhancements made to integrate RiverWare into the CWMS.

INTRODUCTION

The US Army Corps of Engineers is responsible for regulating water storage and releases at about 700 water projects in the US. These projects are managed for multiple purposes to satisfy a variety of needs (flood control, navigation, water supply, hydroelectric power, water quality control, recreation, etc) and affect the lives of millions of people and the value of billions (if not trillions) of dollars of property. It is critical that water control managers have access to timely, accurate, and reliable information upon which to base their release and storage decisions.

The Corps Water Management System (CWMS) has been developed for the purpose of providing a single, integrated package of data management and near-term modeling tools to meet the needs of water control managers within the Corps of Engineers. CWMS retrieves precipitation, river stage, gate settings and other data from field sensors, and validates, transforms and stores those measurements in a database. The measurements are used for calibration and adjustment of hydrologic and hydraulic models to reflect current conditions. Once the models have been adjusted to reflect current hydro-meteorological conditions within a watershed, they can be executed to produce forecasts of hydrologic conditions that will assist water managers to evaluate the effects of their operating decisions in the near future.

One such model is RiverWare, a general purpose river and reservoir modeling platform researched and developed by the University of Colorado Center for Advanced Decision Support for Water and Environmental Systems (CU-CADSWES) in collaboration with the Tennessee Valley Authority (TVA), the U.S. Bureau of Reclamation (USBR), and the U.S. Army Corp of Engineers (USACE). RiverWare simulates the hydrologic response of the river system, given unregulated inflows and management decisions such as reservoir releases and diversions. The USACE Southwestern Division recently began implementing RiverWare as a planning and operations model. As part of this implementation, it was decided that it would be useful to integrate RiverWare into CWMS. This will allow the Southwestern Division to better move data between models and the data base repository. This paper describes the CWMS, RiverWare and the integration of the two.

CORPS WATER MANAGEMENT SYSTEM

In its basic configuration, the built-in modeling components of CWMS include a hydrologic model (HEC-HMS), a reservoir simulation model (HEC-ResSim), a river hydraulics model (HEC-RAS), and an economic impacts model (HEC-FIA). Gauged precipitation, combined with Quantitative Precipitation Forecasts (QPF) or other future precipitation scenarios, are used by the HEC-HMS hydrology model to forecast possible future river flows into and downstream of reservoirs. The existing reservoir operations model, HEC-ResSim, uses these flow scenarios to provide operational decision information for the engineer. The river hydraulics program, HEC-RAS, computes river stages and water surface profiles for these scenarios. The economic impacts of the different flows are computed by HEC-FIA. This sequence of modeling software allows engineers to evaluate operational decisions for reservoirs and other control structures, and view and compare hydraulic and economic scenarios for various "what if?" analyses.

It is fundamental to the purpose and structure of CWMS that each of these models can be run with different parameters. CWMS refers to a parameter set for a particular model as a "model alternative" and to the combination of model alternatives in sequence as a "forecast alternative." Model alternatives for a hydrologic model might include "wet basin" and "dry basin" parameter sets, for example. A forecast alternative might combine the "dry basin" hydrologic model alternative with the "drought conditions" reservoir model alternative, a "low flow" channel hydraulics model alternative, and a "spring planting season" economic model alternative. By mixing and matching alternatives for individual models, the user has great flexibility in configuring scenarios for "what if" analyses that represent the response of the watershed in its current condition to a variety of possible forecasted meteorologic and hydrologic conditions.

Because all CWMS's built-in models have been developed by the Corps's Hydrologic Engineering Center and share a common data storage and exchange system, HEC-DSS, the integration of the models into CWMS was relatively straightforward, and was accomplished with only minor changes to the models themselves. No water resources model, however, meets all the needs of all users, and the CWMS development project always included plans to integrate models from other developers, such as RiverWare, within the forecasting component of CWMS. With the addition of other models to the CWMS package, the user will be able to select the best modeling tool for the application.

RIVERWARE

RiverWare is a fully supported and documented general river and reservoir computer modeling application supported on Sun Solaris Unix and Windows operating systems (Zagona et al., 2001; Zagona et al., 2005). RiverWare can be run either as a stand-alone application, or in concert with other models and databases. RiverWare simulates the hydrologic response of the river system, given unregulated inflows and management decisions such as reservoir releases and diversions. The basic approach to modeling is as follows: objects represent features like reservoir, reaches, and diversions. For each object, the user selects methods that best represent physical processes such as evaporation, seepage, spill, or stage depending on the object type. The objects are then linked together to form a network representing the basin. Data is entered through the user interface or the model can be connected to a database or data files through the Data Management Interface (DMI). Figure 1 shows the workspace, palette and open object window.

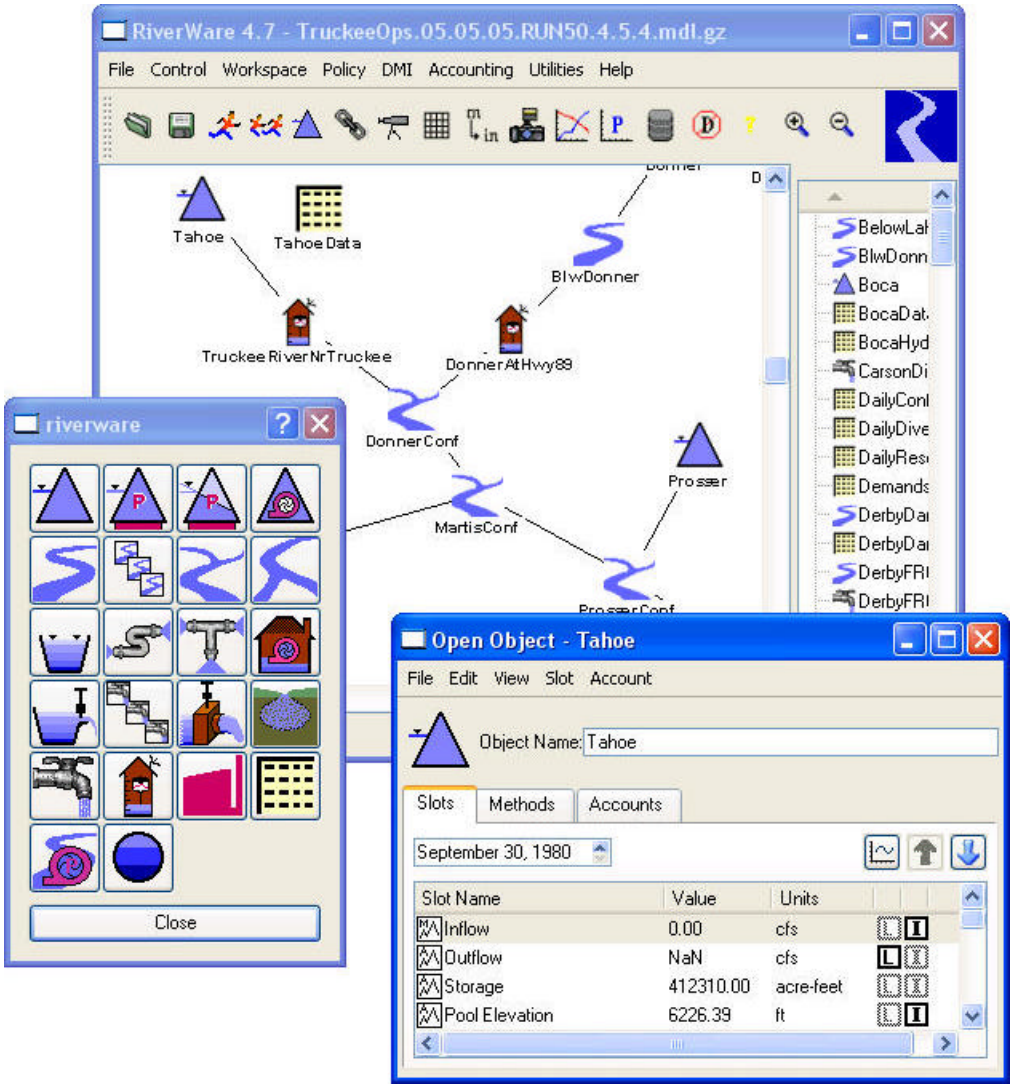

Figure 1 RiverWare Workspace, Palette, and Open Object view

In many basins, it is necessary to track water type and water ownership, not just the physical volume of water. In RiverWare, this is accomplished by creating a water accounting network. In RiverWare "physical" water is modeled in the simulation object network and "paper" water (water type and ownership) is modeled in the accounting network. For example, a reservoir's storage indicates the quantity of physical water in the reservoir at each timestep.

CWMS AND RIVERWARE INTEGRATION

In order to work with CWMS, a RiverWare model needs to be able to read and write hydrologic time series into HEC-DSS records, and to have execution controls that can be manipulated by the CWMS model controller for the following purposes:

1. Setting the time window for the model run. CWMS models are configured for a specific hydrologic region, but not for a specific time. Each new set of model runs must be adjusted to a new start and end time, set at run time to meet the user's forecasting needs.

2. Selecting input time series data from outputs of models that precede it in a sequence. For example, within a CWMS forecast alternative, a reservoir model may take forecast inflows from one among several hydrologic model alternatives. To run "what if?" analyses, the user must be able to generate multiple rainfall/runoff scenarios and select the outputs of those scenarios as inputs to the reservoir model.

3. Labeling its time series output records appropriately to allow later models in a sequence to identify which scenario has produced them. For example, outputs from a reservoir model can become inputs to an economic impacts model. Just as the user must be able select from multiple hydrologic inputs to the reservoir model to produce a scenario, the user must also be able to select from multiple reservoir modeling results to carry out the next step in the analysis of a scenario.

RiverWare has been enhanced to meet the requirements outlined above. In particular, the Data Management Interface and Batch Mode features of RiverWare have been enhanced as described in the following sections.

Data Management Interface (DMI) RiverWare provides a Data Management Interface to connect a RiverWare model to any external database or data files. Input DMIs read data into a model from a database, while output DMIs write data from a model run to a database. The original DMI is "data neutral" – it doesn't have knowledge of any database technology. It achieves its neutrality by using text files as intermediaries – the modeler provides a program (invoked by RiverWare) which has knowledge of the database, and which writes and reads the text files. The DMI has been enhanced to allow RiverWare to read and write hydrologic time series into HEC-DSS records (satisfying requirements 2 and 3). Highlights include:

- An open, extensible architecture to support multiple database technologies (of which HEC-DSS is the first.)

- A graphical user interface to configure DMIs. (Previously text files were used to configure DMIs.)

Batch Mode RiverWare provides a batch mode to run models without opening the user interface; batch mode provides the execution controls that the CWMS model controller will manipulate. In batch mode RiverWare reads a RiverWare Command Language (Rcl) script file which contains the commands RiverWare is to execute. Rcl supports basic model-run commands, for example loading a model and ruleset, setting the run parameters (satisfying requirement 1), invoking DMIs, starting the simulation run, and saving the model. Batch mode has been enhanced to allow the CWMS model controller to verify the RiverWare model timestep and to configure the RiverWare model diagnostics.

By making these enhancements to RiverWare, the integration of RiverWare into the CWMS package is seamless. Figure 2 shows a screen shot of the CWMS workspace and the RiverWare workspace (as accessed from the CWMS workspace). Users are now able to prepare forecasts using HEC-HMS, run the hydrology through the RiverWare decision support system, calculate river stages using HEC-RAS, and calculate economic impacts using HEC-FIA all within the framework of the CWMS.

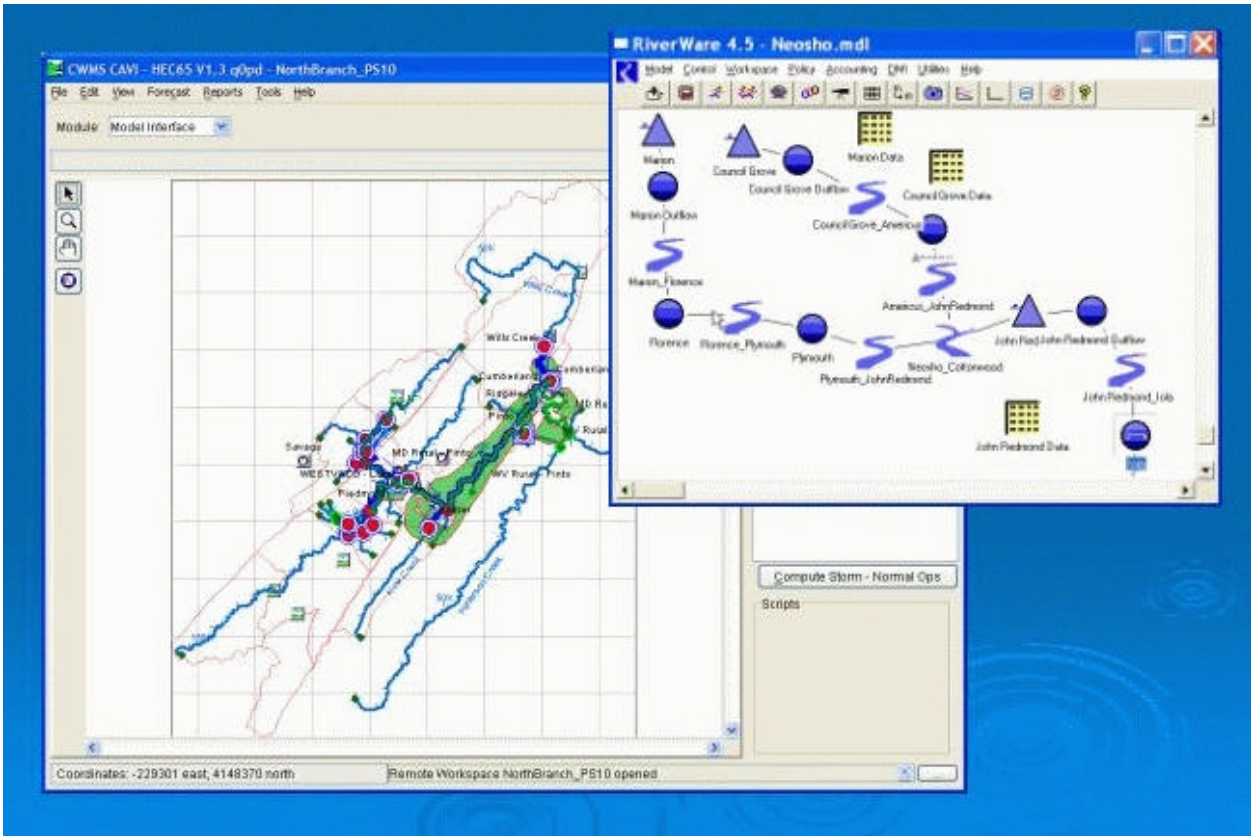

Figure 2 - CWMS and RiverWare Workspaces

SUMMARY

The Corp Water Management System provides a comprehensive, integrated system for real-time water control decisions. Integrating RiverWare into this system enables users to select the reservoir simulation model which best suits their needs. Furthermore, the enhancements to the RiverWare Data Management Interface allow all RiverWare users to easily read data from and write data to a HEC-DSS file.

REFERENCES

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