Model Details

Tar River Hydrologic Model

OVERVIEW

A hydrologic model is "a conceptual or physically-based procedure for numerically simulating a process or processes which occur in a watershed." The model used for this analysis, the Tar River Basin Hydrologic Model, uses Operational Analysis and Simulation of Integrated Systems, or OASIS, with Operations Control Language, or OCL,™ developed by HydroLogics, Inc. OASIS is a generalized simulation program designed to characterize water resource systems. OCL is a proprietary program that facilitates the customization of OASIS for specific applications. The Tar River Basin Hydrologic Model is a computer-based mathematical model that simulates surface water flows in the Tar River. It has the capability to take into account a great deal of hydrologic information and water use data and can be used to evaluate the impacts to water quantity of projected future demands and operational scenarios. The model produces a hypothetical picture of surface water conditions in the basin based on the data and assumptions used to create a modeling scenario.

The Tar River Basin Hydrologic Model was developed in consultation with the major water withdrawers in the basin and representatives of state and federal resource management agencies. It is intended as a planning and decision support tool. The model development process started in July 2010 with a kickoff meeting to outline the needs and scope of the model and the basin plan, followed by two more stakeholder meetings to present the model schematic, collect data and review the data used in the current conditions scenario. Three meetings were held in three different locations across the central part of the basin at Pitt County Community College, Rocky Mount City Hall and Edgecombe Community College to facilitate participation and engagement of interested parties. These meetings were held to provide face to face discussions with citizens, water users and water suppliers to gather information on water supply or management issues and to address concerns about the model development process as well as the development of the basin plan. More information on the model and its development is available at the following link on the state Division of Water Resources' website: http://www.ncwater.org/Data_and_Modeling/Tar/.

The current methodology for developing model data requires a large amount of input data, including understanding how flows have been and are currently affected by reservoir operations, water supply withdrawals, wastewater returns and agricultural withdrawals and the adjustments necessary for inflows to ensure that the model preserves the known volume of flow at downstream gages. Streamflow records are adjusted for human induced alterations to natural flows and are statistically augmented to fill in missing stream flow data. These processes are the most time-intensive parts of model development to create a computer simulation program specifically designed to characterize water resources of a specific area. The resulting model balances water coming into and out of the river system, subject to the assumptions, goals and constraints built into the model. The model includes a node at each location where inflows or outflows must be evaluated. At each node inflows are added and outflows are allocated to demands based on a set of priorities that reflect operating guidelines and protocols. These priorities may be consistent in all modeling scenarios or they may vary between scenarios to

reflect plan changes or to evaluate management options. At the reservoir nodes, water is stored and released subject to user-defined operating rules constructed to simulate real operations. The model operates on a daily time step making one set of calculations for each day using daily average values for each calculation.

In this exercise, the 2010 conditions are used to characterize current conditions, the base-case scenario, against which the alternative scenarios of demands and return flows are compared. Using the model to compare future demand conditions with the base case conditions, provides information to identify the possible impacts on reservoir water levels and stream flows at points of interest around the basin due to future surface water withdrawals.

Scope of the Model

The geographic scope of the model extends from the headwaters of the Upper Tar and Fishing Creek subbasins, in eastern Person and Vance Counties respectively, down to Greenville in Lower Tar, where the river becomes tidally influenced. Even though the Tar Pamlico plan covers the five watersheds, Tar model is limited to surface water withdrawals [the Upper Tar, Fishing Creek and Lower Tar] subbasins. The following schematic map of the basin shows the geographic coverage of the model and the relative location of the various model nodes.

Figure 1: Tar Hydrologic Model Schematic

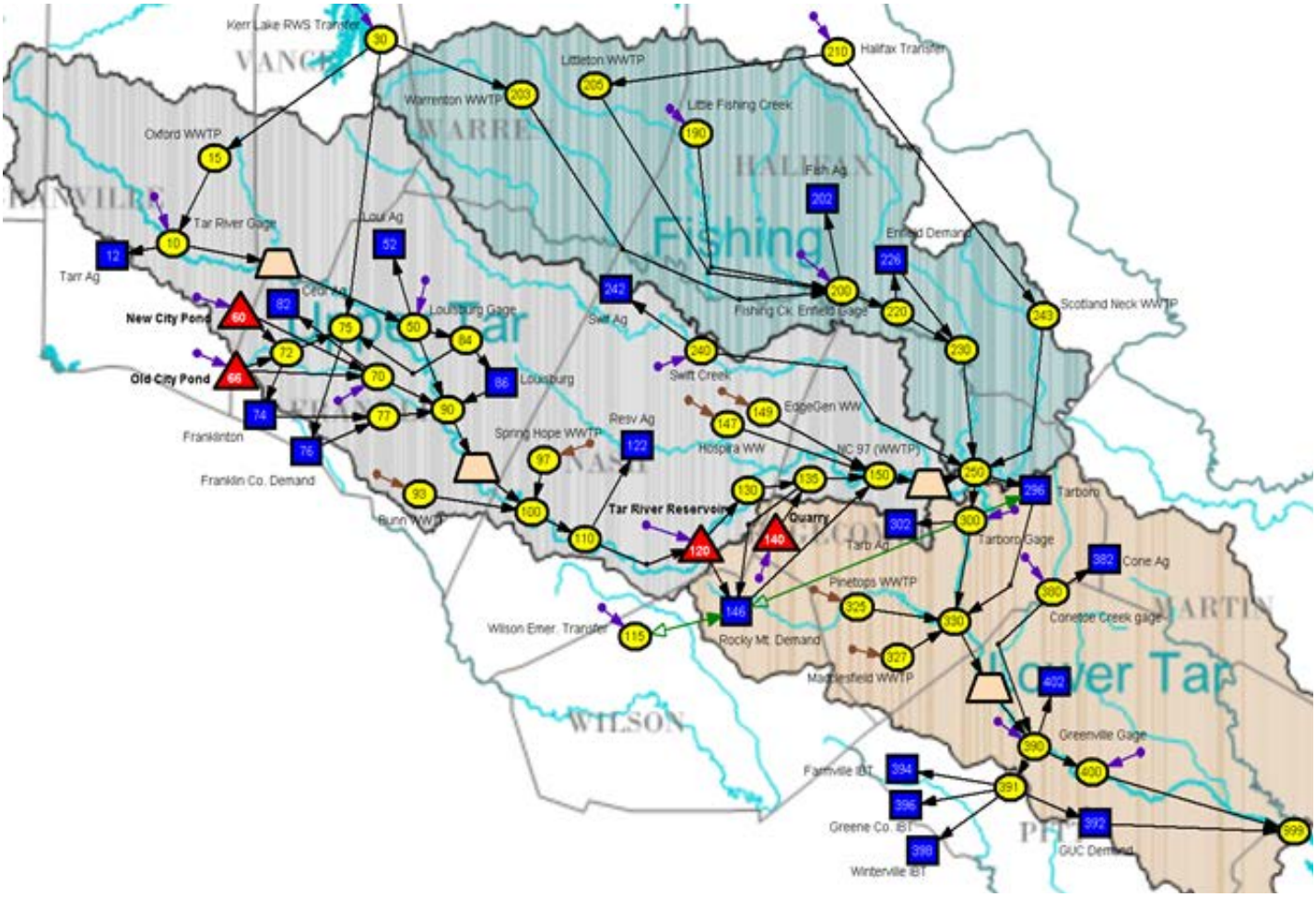

Figure 1 also shows the complexity of the model. Each of the polygons in the schematic represents a node where the model performs a calculation to sum up the effects of inflows and

outflows of water. The squares represent the withdrawal points and the triangles represent the reservoirs.

Model Components

The Tar River Basin Hydrologic Model balances water coming in with water going out of the river system, subject to goals and constraints established for each node. Priorities established during model development determine how water is allocated between competing uses at each withdrawal node. At the reservoir nodes, water is stored and released subject to operating rules defined during model development. The model operates on a daily time step, making one set of calculations for each day in the 79-year flow record, using daily average values for each input. Annual daily average demands for each withdrawer are adjusted within the model to compensate for seasonal variation of water. Annual average withdrawal amounts are adjusted for each month by a set of user specific coefficients to produce lower withdrawals in months when use is typically below average and to increase withdrawals in the months when the system use is typically above average.

Inputs

The model uses a set of estimated daily natural inflows to characterize the water entering the river system. The inflow dataset was developed using 80 years of flow records adjusted for known withdrawals, discharges, and reservoir operations. The portion of the Tar River basin covered by the model was subdivided into smaller drainage areas. An average daily inflow was estimated for each drainage area and for each of the more than 29,000 days in the 80 years of flow data. Inflows to the system enter the model at discrete points shown in the schematic in Figure 1 as purple arrows.

Water is removed from the system at discrete withdrawal nodes shown as blue boxes on the model schematic. Withdrawals can be for water supply systems, industrial water users, or agricultural and other off-stream water uses. Public water supply withdrawals are based on local water supply plan data submitted to the division by local water utilities that includes projections of future water demands. Self-supplied industrial water withdrawals were derived from data submitted under the division's water withdrawal registration program that do not include future demand projections. For self-supplied industries, it was assumed that future withdrawals will be the same in the 2030 and 2060 scenarios, as in the 2010 base case scenario, unless additional information was available to justify changes in projections.

Based on the aerial photos and communication with local agricultural resources professionals, agricultural water use from surface water sources was eliminated and assigned to specific drainage areas. Agricultural uses for livestock and irrigation were estimated with the help of county agricultural extension agents and an agricultural extension irrigation specialist. Water use estimates were developed for irrigated crops, taking into consideration variations in planting times in the Tar basin. Livestock water needs are based on animal head counts in each county and the water use factors used by the U.S. Geological Survey in the 1995 estimated water use in North Carolina. Acreage of irrigated crops and number of livestock units were developed for each county in consultation with county agricultural extension agents. The resulting values from each county were proportioned to specific withdrawal nodes at the locations of the calibrated gages used in the model.

Discharges from wastewater treatment plants and water reclamation facilities constitute inflows into the river system. They enter the model similarly to natural inflows, as water inputs at

discrete nodes. They are represented in the schematic as brown arrows. Wastewater return flows, associated with water withdrawn at some other location in the basin, are typically estimated as a percentage of the volume of water withdrawn. The appropriate percentages were determined by evaluating historical data submitted to the department by water purveyors.

At most nodes, the model balances inflows and outflows at each node. Outflows and withdrawals equal inflows on all days for all nodes except reservoir nodes, represented by red triangles in the schematic. In the case of a reservoir node, change in daily storage is considered in the balance equation. Each reservoir in the model has a set of operating guidelines that define such things as the available storage at specific water levels, minimum release requirements and drought management protocols. Only Tar River reservoir has minimum release requirements. Further in this document, some specific results will be shown for the reservoirs. Nodes in the model are connected by arcs which define how the model moves water through the system. Arcs are represented in the model schematic by black arrows that define the direction of water movement from one node to the next downstream node.

Outputs

The Tar River Basin Hydrologic Model can provide a variety of outputs in a variety of configurations. The primary outputs used for this analysis include the following:

1. Daily flows: The model provides estimates of daily water flows into a node, out of a node or through an arc.
2. Daily reservoir levels.
3. Daily reservoir releases.
4. Drought Stages – Drought stages, number of days in different drought stages can be determined for municipalities with adopted water shortage response plans (WSRP), and thus the demand for the municipalities and reservoir releases can be reduced based on the protocol of the WRSP during droughts.

More information on the Tar River basin model components, flow charts and procedure are available on this online report "Modeling the Tar River Basin Operations with OASIS" .

[2] http://www.ncwater.org/Data_and_Modeling/Tar/final_updates/01_TRBM_Agri_Data_Report_M&N_01-31-2011.pdf

[3] http://www.ncwater.org/Data_and_Modeling/Tar/final_updates/02_TRBM_Modeling_the_Tar_River_Basin_Operations_with_OASIS.pdf