U.S. Department of the Interior
U.S. Geological Survey

Managing Drought Risk with a Computer Model of the Raritan River Basin Water-Supply System in Central New Jersey

The reservoirs and pumping stations that comprise the Raritan River Basin water-supply system and its interconnections to the Delaware-Raritan Canal water-supply system, operated by the New Jersey Water Supply Authority (NJWSA), provide potable water to central New Jersey communities. The water reserve of this combined system can easily be depleted by an extended period of below-normal precipitation. Efficient operation of the combined system is vital to meeting the water-supply needs of central New Jersey. In an effort to improve the efficiency of the system operation, the U.S. Geological Survey (USGS), in cooperation with the NJWSA, has developed a computer model that provides a technical basis for evaluating the effects of alternative patterns of operation of the Raritan River Basin water-supply system. This fact sheet describes the model, its technical basis, and its operation.

DESCRIPTION OF THE STUDY AREA

The Raritan River Basin water-supply system is located in central New Jersey and encompasses Hunterdon, Mercer, Middlesex, Monmouth, Morris, and Somerset Counties (fig. 1). Features of the water-supply system include Round Valley Reservoir, Spruce Run Reservoir, Hamden Pumping Station, the Delaware-Raritan Canal, and several streamflow-gaging stations. These features are used for storage and release of surface water to supply the demands of public and private water utilities and to meet statutory passing-flow requirements, which are required to protect both aquatic habitat and downstream users.

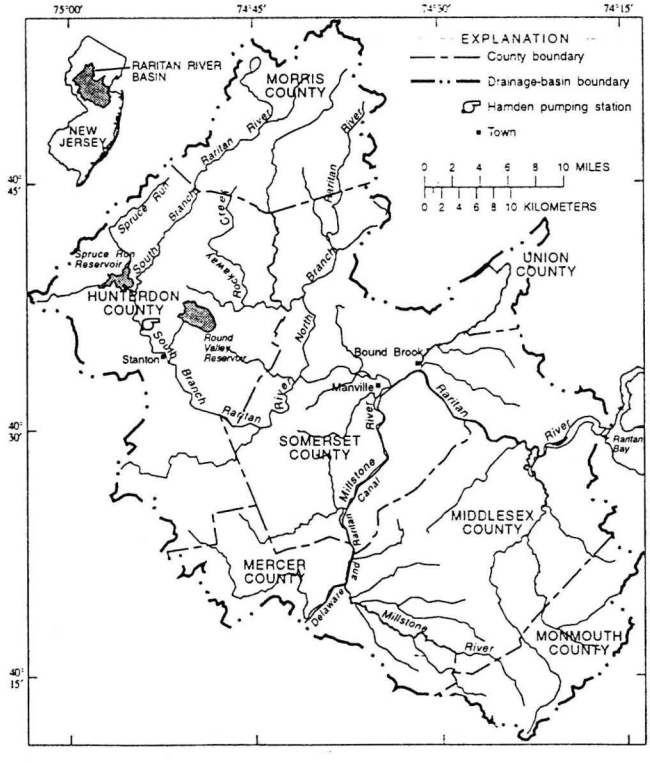

Figure 1. Raritan River Basin water-supply system, central New Jersey.

Spruce Run Reservoir, located in Hunterdon County, has a usable capacity of 11 Ggal (billion gallons) of water and a drainage area of 41.3 mi^2 (square miles). Round Valley Reservoir, also in Hunterdon County, is a pump-storage reservoir that has a capacity at the spillway level of 55 Ggal of water and a drainage area of 5.7 mi^2. To augment water storage, water is pumped into Round Valley Reservoir from the South Branch Raritan River at Hamden Pumping Station.

The Delaware-Raritan Canal is an integral part of the Raritan River Basin water-supply system. The canal begins on the Delaware River in Hunterdon County and flows south to Trenton and then northeast to New Brunswick, where it empties into the Raritan River. The canal is connected to the reservoir system through the Millstone River near Bound Brook (fig. 1).

The Raritan River Basin water-supply system must meet statutory passing-flow requirements at three locations. A passing-flow requirement is the minimum volume of water required to be maintained at a selected point to ensure adequate water-quality conditions after consideration of the needs of downstream users. These requirements include 40 Mgal/d (million gallons per day) on the South Branch of the Raritan River at Stanton, 70 Mgal/d on the Raritan River at Manville, and 90 Mgal/d on the Raritan River at Bound Brook below Calco Dam (fig. 1).

THE RARITAN RIVER BASIN WATER-SUPPLY MODEL

The Raritan River Basin water-supply model is a computer program containing a series of equations that simulate key elements of Raritan River Basin streamflow hydrology and reservoir operations. The model computes and records reservoir contents on the basis of an accounting of flow of water into and out of system reservoirs. The model accounts for water flowing into the reservoirs in the form of streamflow from feeder streams and rivers, runoff from adjacent land, and pumpage of water diverted from other reservoirs or streams. Outflows consist of water-supply withdrawals, transfers of water to other reservoirs, and flows that are released downstream from the reservoir. All calculations are done monthly.

The model mimics actual reservoir-system operations by numerically transferring, inputting, or withdrawing water on the basis of an established set of reservoir operating rules that govern actual reservoir releases, pumpages, and water-supply withdrawals. Superimposed on these rules are the statutory passing-flow requirements. The power and usefulness of the model are derived from the fact that it contains options that allow the user to alter the operating rules and test reservoir operations under a variety of conditions in order to evaluate the effects on the Raritan River Basin water-supply system.

The reservoir system can be in one of three operating conditions --normal, drought warning, or drought emergency--depending on current storage available in Spruce Run and Round Valley Reservoirs. The model includes options that enable the user to alter permitted withdrawal rates and passing-flow requirements to simulate the changes in the reservoir levels that might result.

MODEL INPUT

Model reliance is greatly enhanced by using long records of observed streamflow to simulate flows and to develop outcome statistics, including values for streamflows, storages, releases, and diversions. USGS streamflow records are incorporated into the model for this purpose. The longest record available for the Raritan River Basin spanned 75 years, October 1918 to September 1993. Shorter flow records were reconstructed and extended to 75 years by using the MOVE.1 regression technique (Hirsch, 1982). From these reconstructed flow records, time series of monthly runoff values were developed for the 75-year period for three regions in the Raritan River Basin and two regions in the Delaware River Basin.

RUNNING THE MODEL

The model can be run in one of two modes-- as a General Risk Analysis Model (GRAM) or a Position Analysis Model (PAM). GRAM (Hirsch, 1978) is based on the reconstructed historical flow records for the base period of 75 years. GRAM can provide estimates of probabilities of certain events--such as reservoir storage falling below a specified level-- given an assumed set of operating rules and withdrawal rates. GRAM can help water managers assess the performance of the water system in past years under alternative sets of operating rules. PAM (Hirsch, 1978) forecasts the likelihood of specified outcomes, such as the likelihood that a reservoir level will fall below a specified level or that streamflows will fall below passing-flow requirements, associated with a specific operating plan for the basin over a period of a few months. PAM can aid the water manager in selecting a plan of operation by providing a means to evaluate and rank each proposed plan in terms of future drought risks. PAM allows the user to specify operating rules, current streamflows, and current reservoir levels.

MODEL OUTPUT

The primary purpose of the model is to relate reservoir operating rules and legal and resource constraints that are imposed on the system to the probability of various reservoir storage levels during the simulated period. Given initial streamflow and reservoir conditions that represent current conditions, the model also can be used to forecast the probability of future reservoir levels under various operating rules on the basis of likely future hydrologic and climatologic conditions. For instance, in the example model output shown in figure 2, the 50-percent, or median, line indicates values of storage that will occur under normal conditions. The example model output also indicates that the probability of the reservoir storage falling below the drought-warning level is less than 1 percent for the first 10 months of the simulated period. Thereafter, the probability rises to more than 1 percent, but never approaches 12.5 percent. Using these probabilities, a reservoir manager could assess the risk of water shortage in June and July and evaluate the desirability of altering the reservoir operations, perhaps to store more water early in the year, to decrease that risk.

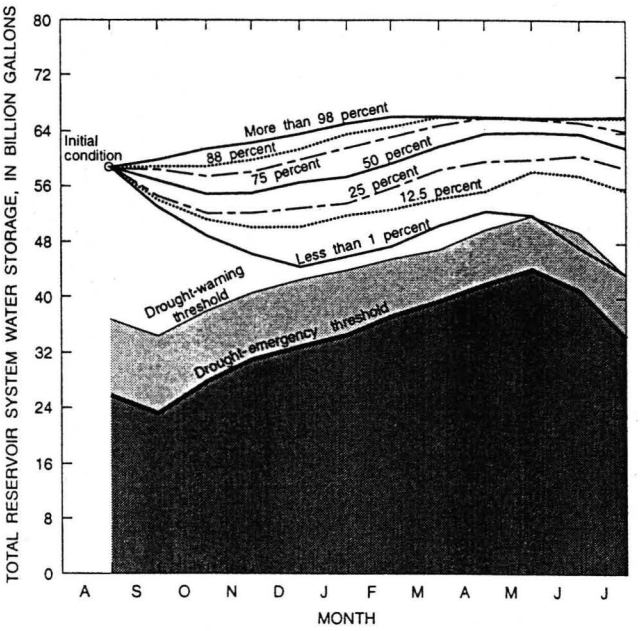

Figure 2. Model output showing probability of selected reservoir-system water-shortage levels at end of each month of projected year based on current or hypothetical start-up conditions, selected reservoir operations, withdrawal rates, and reconstructed inflow records, Raritan River Basin water-supply system, central New Jersey.

SELECTED REFERENCES

Dunne, Paul, and Tasker, Gary, 1996, Computer Model of Raritan River Basin water-supply system, in central New Jersey: U.S. Geological Survey Open-File Report 96-360, 62 p.

Hirsch, R.M., 1978, Risk analysis for a water-supply system--Occoquan Reservoir, Fairfax and Prince William Counties, Virginia: Hydrological Sciences Bulletin v. 23, no. 4, p. 476-505.

Hirsch, R.M., 1981, Stochastic hydrologic model for drought management: Journal of Water Resources Planning and Management Division, ASCE, v. 107, no. WR2, p. 303-313.

Hirsch, R.M., 1982, A comparison of four streamflow record extension techniques: Water Resources Research, v. 18, no. 4, p. 1081-1088.

-- Paul Dunne and Gary Tasker

For additional information contact:
District Chief
U.S. Geological Survey
810 Bear Tavern Road
West Trenton, New Jersey 08628