DON'T COUNT ON FANCY COMPUTER MODELS TO PROTECT THE GROUNDWATER OF THE NORTHERN NECK

By Frank W. Fletcher – April 2006

What Is the Issue?

Recent public reports of declining artesian water levels across the Northern Neck and debate over the future of the water supply of this region have brought attention to the extensive use of groundwater flow models by the Virginia Department of Environmental Quality and the Maryland Department of the Environment. These regulatory agencies employ these models in order to assess the impact of water pumping on the groundwater system and to provide guidance for managing water use. Staff members of the Virginia DEQ utilize the current Virginia Coastal Plain model to evaluate requests by large water users, such as power plants, public water systems, and manufacturing facilities, for permits to pump groundwater from the aquifers of the State's Groundwater Management Areas on the Eastern Shore and the Virginia Tidewater. It is important to understand that such groundwater flow models, while useful as one tool of a balanced program of water management, are not magical solutions to the problems of regional groundwater depletion.

What Is a Groundwater Flow Model?

A groundwater flow model is simply a mathematical representation of an aquifer system created on a computer. It is used to calculate the rate and direction of movement of groundwater through aquifers and confining units. These calculations are called simulations. Employing equations that represent the basic laws of physics that govern groundwater flow and input information that describes various hydrogeologic characteristics of the area being modeled, the computer simulates the behavior of the aquifer system over time. These results are commonly expressed as groundwater levels (and groundwater flow rates) at designated locations within a particular geographic region, such as the Coastal Plain of southern Maryland or the lower Virginia Peninsula.

The modeler runs many computer simulations using different input parameters until the resulting groundwater levels closely match the trend time of measured, historical levels over time. In the jargon of the modelers, this technique of running the model backward in time is called "post-diction." Running the model forward in time results in the prediction of groundwater levels for a time period in the future. If a model includes groundwater withdrawals by pumping at designated localities, then the modeler can produce a simulation of future groundwater levels resulting from specified rates of pumpage. These results are routinely used to predict likely regions of groundwater overdraft and provide guidance for managing future withdrawals.

So What is the Problem?

A thorough discussion of the pros and cons of groundwater flow models is beyond the scope of this brief survey, but several points are salient.

First, an accurate groundwater model requires an enormous amount of information about the aquifer system to be simulated, including detailed information on geology, water levels, hydraulic properties, and pumping. In the case of the two eastern counties of the Northern Neck, Northumberland County and Lancaster County, this information is remarkably skimpy. According to the most recently-published source of the hydrogeologic framework of the region, U.S. Geological Survey Professional Paper 1404-C (1988), only two wells provide the geologic basis for

interpreting the aquifer system of Northumberland County (and neither of these penetrate to the deepest artesian aquifers), and only two wells provide the basis for the hydrogeology of Lancaster County. As a result any picture of the depth, thickness, and geometry of the aquifers beneath the eastern Northern Neck is purely hypothetical. Similarly, the DEQ regularly monitors the artesian water level in only two wells in Lancaster County; no water-level monitoring wells are present at all in Northumberland County. Data concerning the hydraulic properties of the aquifers is likewise scarce and tentative. Finally, because so much drinking water of the Northern Neck (perhaps as high a one-half) originates from unmetered sources, any determination of annual pumping rates is strictly a rough estimate.

Second, an accurate groundwater model depends upon the design of its architecture. The model architecture refers to its internal, three-dimensional structure: the size of the geographic region covered; the number and size of the subareas (i.e., "cells") which the model region is divided into, the number and dimensions of vertical layers (which define the various aquifers and confining units) employed, etc. Currently, there is no single groundwater flow model that accurately simulates the effect of pumping in both southern Maryland and Tidewater Virginia on the artesian water levels of the Northern Neck. The model employed by the Maryland Department of the Environment extends only a short distance into Virginia and does not incorporate large groundwater withdrawals in the vicinity West Point, Va. The Virginia DEQ model does not take into account groundwater withdrawals in southern Maryland. There's a prominent crack in the groundwater models of the Coastal Plain. and the Northern Neck has fallen through it.

Third, an accurate groundwater flow model depends on proper calibration and verification of the equations used to define the model and of the input data representing field measurements. Calibration and verification involve demonstrating that the model is capable of producing water levels that match those measured in the past. An effective calibration and verification provides the confidence that the model can produce reasonable predictions of water levels in the future. One chief problem inherent in this aspect of modeling groundwater flow is that the simulation resulting from a model run is "non-unique." That is to say, the same water level results of a simulation may be produced from different sets of input data and equation parameters. This mathematical truth should warn us not to hold a false impression of model capability.

What Good Are Groundwater Models?

The problems with groundwater flow models that are described above demonstrate that we should avoid building false confidence in the predictive power of models and instead place emphasis in utilizing models to help us understand complex hydrogeologic systems. Carrying this thought further, extreme caution should be exercised by regulatory agencies that apply the results of groundwater flow models to water management actions such as permitting. A model is not the world: it is only one incomplete and imperfect picture of the world. Like art, as Picasso once said, it is "lie that helps us understand the truth." It is possible to construct a model that more accurately describes a picture of the groundwater system beneath the Northern Neck and enhances our understanding of the impact of water withdrawals on this system, but it does not yet exist. And there is a long way still to go.