Automated well permitting in a coastal region using SEAWAT and ArcGIS

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ABSTRACT

In this paper we describe a GIS-based system for automated well permitting in Eastern Virginia. The system involves the integration of a calibrated MODFLOW and SEAWAT models into an ArcGIS geodatabase. The model is then used as a baseline for the analysis of candidate wells. Each candidate well is added to the models and the models are run to determine the impact of the well in terms of drawdown and potential for saltwater intrusion. The entire process is implemented using a series of connected, low-level geoprocessing tools resulting in a simple automated process. The automation serves to reduce error and increase efficiency. The outputs include tables and GIS maps. The process, evaluation criteria, and products can be customized on an agency-by-agency basis.

INTRODUCTION

As fresh water becomes increasingly scarce, most government agencies tasked with managing water resources have employed a formal legal and administrative process for granting new groundwater withdrawal permits. The steps involved in reviewing each application may be complex and include non-technical factors such as a demonstration of need and a detailed plan of how the water will be utilized. In addition, the impact of the new withdrawal on the aquifer system is typically analyzed to determine how much drawdown will occur as a result of the new well and what affect the well will have on other groundwater users, neighboring streams, rivers, and on salt-water intrusion. This impact is often estimated with the aid of a groundwater simulation model. The problem with using a groundwater model for well permitting is that the process of updating and modifying a model must be done carefully and requires the expertise of a trained modeler. It can also be a time consuming process, leading to a significant backlog of permit applications. In this paper we present an automated system for analyzing proposed withdrawals using regional MODFLOW and SEAWAT models. The system is being used to analyze groundwater withdrawal permits in the coastal plain and eastern shore regions of Virginia.

ARC HYDRO GROUNDWATER

The well-permitting system is based on Arc Hydro Groundwater (AHGW). AHGW is a data model and a suite of tools for managing groundwater data in ArcGIS (Strassberg, et al., 2007). It is a companion to the Arc Hydro surface water data model (Maidment, 2002) and it includes features for surface water objects (stream networks, lakes, and reservoirs), aquifer boundaries, wells, time series data, and multi-dimensional representations of hydrogeology (borehole logs, cross sections, 3D volumetric models). The Arc Hydro Groundwater data model includes a

Simulation feature dataset that facilitates the storage of simulation models (grids, meshes, and associated data) in a geodatabase. The MODFLOW data model (Jones and Strassberg, 2008) is an extension to the simulation feature dataset and it supports the storage and management of an entire MODFLOW simulation within a geodatabase. The MODFLOW data is stored in a set of tables corresponding to the MODFLOW input traditionally stored in text files. The full design can be viewed at http://www.archydrogw.com.

The MODFLOW Analyst is a set of tools for creating and managing data in the MODFLOW data model. The tools allow the data tracked in the resource management program to be directly linked to groundwater simulation activities. There are several classes of tools, including tools for importing and exporting MODFLOW files, building map layers from MODFLOW data, editing MODFLOW data, building package input from GIS features, and building/editing time series data for transient simulations.

The MODFLOW Analyst tools are all implemented as geoprocessing tools. A geoprocessing tool is a stand-alone utility within ArcGIS that can be launched interactively from the Arc Toolbox, from a command line, within Python scripts, or as functions within any program language (C++, C#, VB, FORTRAN, etc.) using a COM interface. Furthermore, geoprocessing tools can be pulled into a special utility in ArcGIS called Model Builder. In the Model Builder each geoprocessing tool is shown in graphical form with a symbol for the tool and ovals illustrating the inputs and the outputs. A set of geoprocessing tools can then be connected into a sequence where the outputs from one tool become the inputs to the next tool in the sequence. This makes it possible to use low-level tools as building blocks for more sophisticated custom workflows.

VA-DEQ WELL PERMITTING APPLICATION

The Virginia Department of Environmental Quality (VA-DEQ) utilizes a pair of models to evaluate groundwater withdrawals as part of a permitting process that is regulated by state law (VA-DEQ, 2006). The Virginia Coastal Plain Model is a ten-layer MODFLOW model that covers the Eastern counties in Virginia (McFarland and Bruce, 2006). A SEAWAT model called the Eastern Shore Model is used to analyze candidate wells on the Eastern Shore region (Sanford, *et al.*, 2009). Aquaveo LLC of Provo, Utah was recently awarded a contract along with Wittman Hydro Planning Associates of Bloomington, Indiana to perform the technical analysis associated with groundwater permit applications, including running the MODFLOW and SEAWAT models to analyze the impact of candidate wells.

Virginia Coastal Plain MODFLOW Model

We have implemented and deployed an automated system using Arc Hydro Groundwater and the process described above to analyze candidate wells using the Virginia Coastal Plain Model. The associated ArcGIS workflow developed using the Model Builder utility is shown in Figure 1.

Most of the wells in the Virginia's Coastal Plain draw from deep, confined aquifers. By state law, the piezometric head is not allowed to drop below a "critical surface" defined by 80% drawdown from the original pre-pumping conditions and the top of each confined aquifer. Furthermore, the area of impact for a well is defined as the region surrounding the well where the drawdown is equal to or greater than one foot. Permittees are required to mitigate any adverse effects to existing lawful withdrawals within the area of impact.
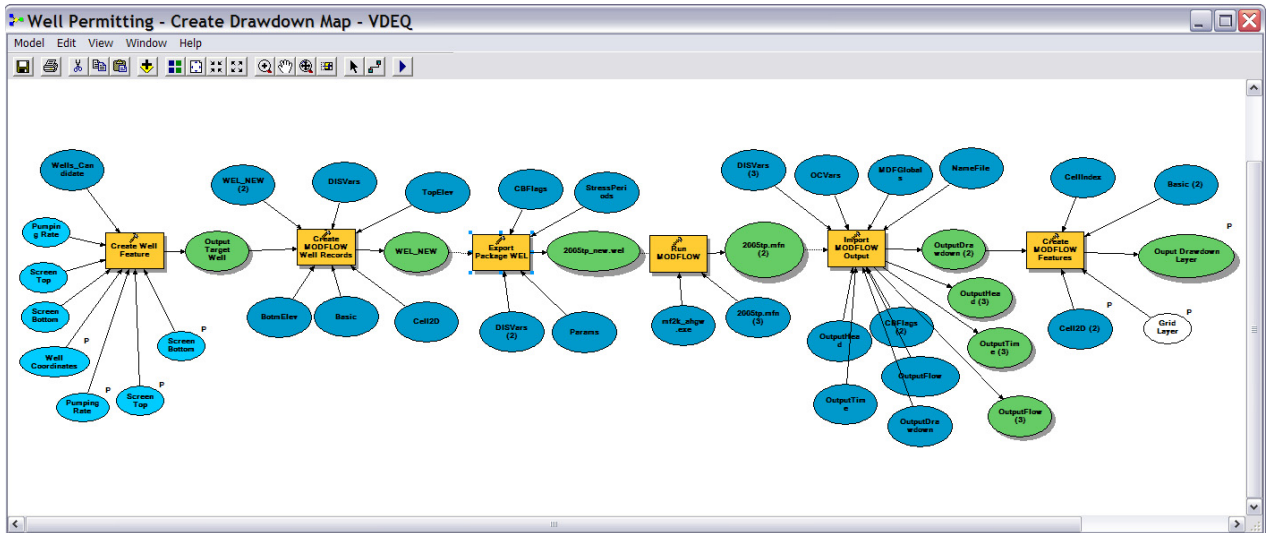
Figure 1. Automated GIS workflow for analyzing a candidate well for the VA-DEQ model.

The results of a sample run using a hypothetical well (does not correspond to an actual candidate well) are shown in Figure 2. The cells within the area of impact are highlighted in Figure 2(a) and the area of impact contour is illustrated in Figure 2(b).
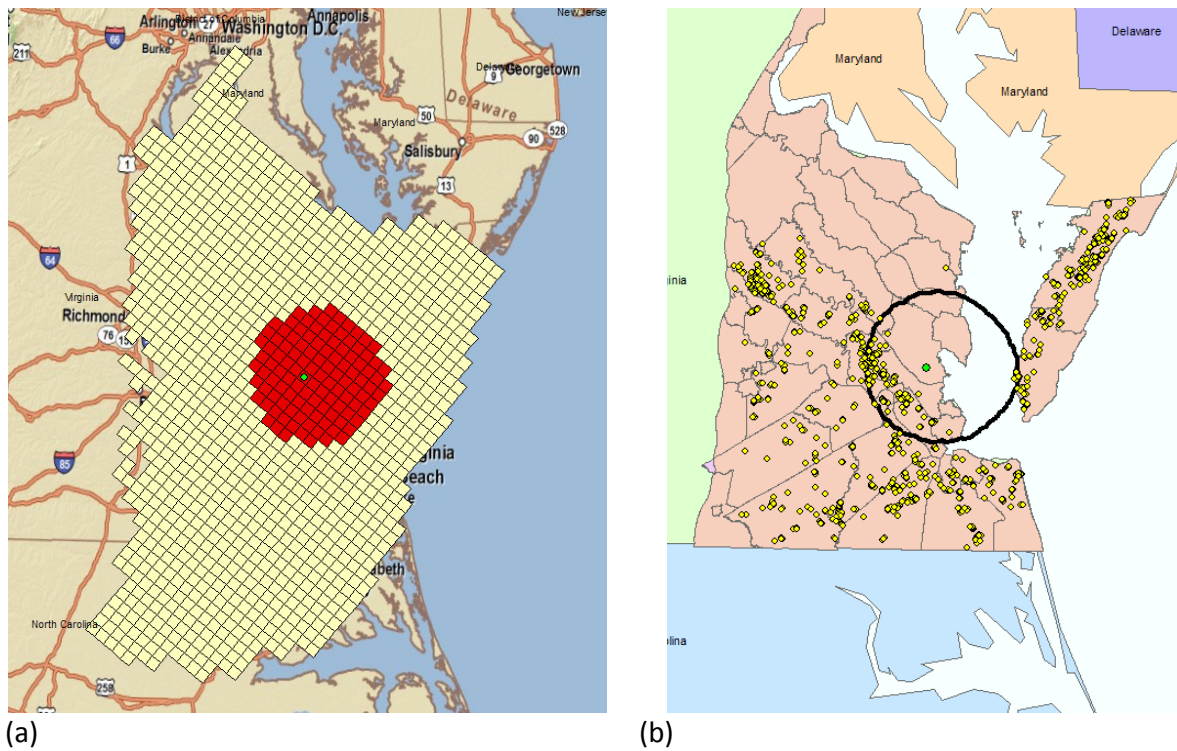

(a)   (b)

Figure 2. The Virginia Coastal Plain Model. (a) MODFLOW cells indicating candidate well and area of impact. Permitted wells and area of impact (one foot drawdown) contour.

Eastern Shore SEAWAT Model

The Eastern Shore SEAWAT model consists of 370 rows, 102 columns, and 46 layers. The model simulation begins in 1901 and runs to 2050. When candidate wells are analyzed on the Eastern Shore both the drawdown and the change in salinity are analyzed.   A set of automated workflows similar to the one illustrated in Figure 1 were developed for the Eastern Shore model. The drawdown for a particular well is analyzed by converting the SEAWAT model to a steady-

state flow model. The model is run without the candidate wells and the heads are computed. Then the model is run a second time with the candidate wells included in the model at the appropriate pumping rate and the heads are computed again. The drawdown for the candidate wells is calculated by comparing the two head solutions. If the drawdown is too great the candidate wells may be rejected. The change in salinity caused by candidate wells is analyzed by performing a steady-state SEAWAT simulation. First, the starting concentrations for chloride were updated to be the calculated concentrations at the end of 2009 from the original Eastern Shore Model. Then a ten-year run is conducted without the candidate wells to establish the baseline concentrations. The model is run a second time with the candidate wells included. The concentrations at the end of the ten-year run for both models are then compared to determine if the candidate wells should be rejected.

CONCLUSIONS

The automated system described in this paper is in production mode for technical evaluation of groundwater impacts resulting from proposed withdrawal permits under consideration by the VA-DEQ. The system has greatly streamlined the permitting evaluation by automating repetitive modeling processes. These automated processes also insure consistent application of the regulatory process and reduces data manipulation error. We anticipate expanding the tools to include automated linkage to the master well database and a web interface to a server-based system for quick screening of new well permits.

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