

APPENDIX A

DESCRIPTION OF NFSEG MODEL INPUT FILES

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NFSEG MODEL INPUT FILES

INTRODUCTION

The NFSEG groundwater flow model is an application of the MODFLOW-NWT formulation of MODFLOW 2005. MODFLOW-NWT (<http://water.usgs.gov/ogw/modflow-nwt/>) is intended specifically for solving problems involving drying and rewetting nonlinearities of the unconfined groundwater flow equation, a critical concern in the development of the NFSEG groundwater flow model. The purpose of the present report is to list the various NFSEG-utilized MODFLOW-NWT packages or input-file types, the groundwater-system or model features represented by them, and the file extensions used to denote them.

MODEL OVERVIEW

The North Florida Southeast Georgia (NFSEG) groundwater flow model is a three-dimensional, steady-state MODFLOW model covering approximately 60,000 square miles (see Figure A-1).

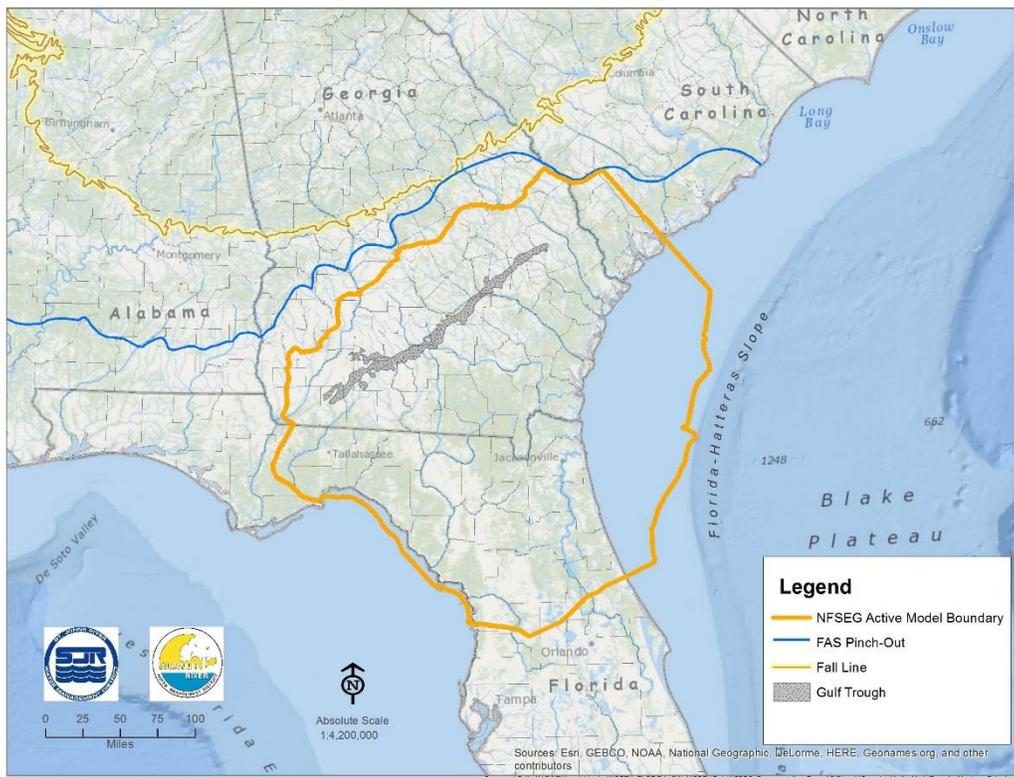


Figure A-1. NFSEG Model Domain

The model has seven layers, and employs a horizontally uniform grid of cells measuring 2500 feet by 2500 feet. The model calibration consists of two steady-state simulations of calendar years 2001 and 2009. Figure A-2 shows the model layering scheme.

Downdip of Gulf Trough			Updip of Gulf Trough				
Series	Hydrogeologic Unit	Model Layer	Series	Hydrogeologic Unit	Model Layer		
Post-Miocene	Surficial Aquifer System	Layer 1 ¹	Post-Miocene	Surficial Aquifer System ¹	Layer 1 ¹		
Miocene	Intermediate Aquifer System/Intermediate Confining Unit	Layer 2 ¹	Miocene	Intermediate Aquifer System/Intermediate Confining Unit ¹	Layer 2 ¹		
Oligocene	Floridan Aquifer System	Layer 3 ¹	Oligocene	Upper Floridan Aquifer	Layer 3 ¹		
Upper Eocene			Upper Eocene	Pearl River Aquifer Confining Unit	Layer 4 ¹		
Middle Eocene		Middle Semiconfining Unit, where present, otherwise Upper Floridan	Layer 4 ¹	Middle Eocene	Pearl River Aquifer	Layer 5	
		Lower Floridan Aquifer (Upper Zone), where present, otherwise Upper Floridan	Layer 5 ¹				
Lower Eocene		Lower Semiconfining Unit	Layer 6 ¹	Lower Eocene			
Paleocene		Lower Floridan Aquifer (Fernandina Permeable Zone)	Layer 7 ¹	Paleocene	Chattahoochee River Aquifer Confining Unit		Layer 6 ²
		Upper Cretaceous	Inactive	Upper Cretaceous	Chattahoochee River Aquifer		Layer 7 ²
					Inactive		
				Southeastern Coastal Plain Aquifer System			

Figure A-2. NFSEG Model Layering Approach

A general plan for the NFSEG model configuration and development process is contained in the “NFSEG Model Conceptualization Report,” located at (http://northfloridawater.com/pdfs/NFSEG/NFSEG_modelconceptualization.pdf). This report contains detailed information on various NFSEG model-configuration and development-process concepts, including the model-layering scheme, proposed model-domain extent, selection of the model steady-state calibration periods, and the estimation process for recharge, maximum saturated evapotranspiration (MSET), and base flow. The reader is advised to review this report for additional information concerning the NFSEG model configuration and development process.

DESCRIPTIONS OF NFSEG MODFLOW-NWT INPUT FILES

Applications of MODFLOW-NWT must utilize, at minimum, the “basic,” “upstream-weighting,” and “discretization,” packages and a solver routine as specified in the “NWT” input file. Other packages, used to represent model boundary conditions, are utilized as needed. A number of different MODFLOW-NWT packages were utilized to represent the boundary conditions of the NFSEG groundwater flow model. In some cases, the same package was used

to represent more than one boundary-condition type. File types used to represent NFSEG boundary conditions are denoted by “BC” in the list of NFSEG input files that follows.

Data for each package or input-file type are represented in a separate input file denoted by a particular file extension. For example, the input files for the basic and upstream-weighting packages have extensions “.bas” and “.upw, ” respectively. Likewise, the NWT input file has the extension “.nwt”.

The MODFLOW-NWT input files used in the NFSEG groundwater model are as follows.

1. Name [.nam];
2. Upstream-Weighting [.upw];
3. NWT [.nwt];
4. Basic [.bas];
5. Discretization [.dis];
6. Recharge [.rch; BC];
7. Evapotranspiration [.evt; BC];
8. General-head boundary [.ghb; BC];
9. Drain [.drn; BC];
10. River [.riv; BC];
11. Multi-node well, version 2 [.mnw2; BC];
12. Well [.wel; BC]; and
13. Time-variant specified head [.chd; BC]
14. Output control (.oc)

The descriptions of these files as provided in the present report are intended to emphasize NFSEG-specific applications. Full, detailed descriptions of these file types for general application can be found in the MODFLOW-2005 and MODFLOW-NWT manuals located, respectively, at

<http://pubs.usgs.gov/tm/2005/tm6A16/PDF/TM6A16.pdf>

<http://pubs.usgs.gov/tm/tm6a37/pdf/tm6a37.pdf>

Name Input File

The .nam input file is a list of file types, FORTRAN file-unit numbers, and file names of model input and output files.

Upstream-Weighting Package and Input File

The Upstream-Weighting Package calculates the intercellular conductance between model grid cells based on the head and hydraulic characteristics of each model grid cell. Accordingly, the .upw input file includes information about the layer type (i.e., whether a layer is confined, has

the potential to convert from unconfined to confined), and the values of hydraulic conductivity (and possibly vertical or horizontal anisotropy) and storage properties (for transient simulations) of each grid cell.

NWT Package and Input File

The .nwt input file provides input for the MODFLOW-NWT matrix solver. A choice of two different solver routines exists. A solver routine uses model inputs to solve groundwater equations to compute the inflows, outflows and water level at each model cell in the active portion of the model domain.

Basic Package and Input File

The Basic Package processes starting-head and IBOUND arrays, as well as other information. Starting heads are the modeler's initial aquifer water-level estimates (i.e., "heads"). These values are required by the solver routine, and serve as a starting point in the iterative processes used to determine model-generated heads. The IBOUND array contains coded designations that categorize each grid cell as either variable-head (IBOUND value > 0); constant (i.e., constant-head; IBOUND value < 0); or no-flow (i.e., inactive; IBOUND value = 0). Separate starting-head and IBOUND arrays are specified for each model layer. Data input to the basic package is contained in the .bas input file.

Discretization Package and Input File

The Discretization Package processes information about the model grid, including the number of rows, columns, and layers, and cell sizes. The thickness of individual cells is determined from arrays of top and bottom elevations of the model layers that are contained or referenced in the Discretization Package input file. Aquifer top and bottom elevations were obtained from Jeff Davis of the St. Johns River Water Management District (digital communication), Lester Williams of the U.S. Geological Survey (digital communication), from Miller (1986), and from Miller (personal communication). The data input to the discretization package is contained in the .dis input file.

Recharge Package and Input File

The Recharge Package processes arrays of specified recharge rates. In the NFSEG groundwater model, separate arrays are specified for representation of recharge rates in years 2001 and 2009. Data input to the recharge package is contained in the .rch input file.

During model simulations, a specified recharge rate is applied to the uppermost active grid cell of each vertical column of grid cells. In the usual situation, the grid cells of layers 1 through 3 of a vertical column are all active. However, in some cases, the layer-1 grid cell or layer-1 and layer-2 grid cells are dry. Such grid cells are treated as inactive by the model in the application of recharge. Dry cells occur in areas of the model domain in which the water table is simulated

as lying beneath the bottom of layer 1 or bottoms of layers 1 and 2. Areas in which layer 1 or layers 1 and 2 are dry correspond generally to those in which the surficial aquifer system and/or intermediate aquifer system are thin to nonexistent. In cases in which a layer-1 grid cell is active, recharge is applied to the layer-1 grid cell. For cases in which a layer-1 grid cell is dry but the underlying layer-2 grid cell is not, recharge is applied to the layer-2 grid cell. For cases in which the layer-1 and layer-2 grid cells are both dry, recharge is applied to the underlying layer-3 grid cell.

The recharge arrays used in the NFSEG groundwater model are weighted averages of the sums of the “AGWI” (i.e., active groundwater inflow) and “IGWI” (i.e., inactive groundwater inflow) parameters obtained from all or portions of 48 different HSPF (Hydrological Simulation Program—FORTRAN, Bicknell and others, 1997) models. HSPF is a model code used primarily to represent surface-water hydrological processes, including the processes of interaction between the surface-water and the unsaturated and saturated groundwater hydrological systems.

The HSPF models of the present project were developed as part of the overall NFSEG groundwater-model development process for the specific purposes of estimating recharge rates, maximum saturated evapotranspiration (MSET) rates, and base-flow rates within the NFSEG model domain. Each HSPF model corresponds to a separate U.S. Geological Survey HUC-8 basin area. The HSPF models simulate both naturally occurring and human-induced recharge. Examples of human-induced recharge simulated by the HSPF models include that due to spray fields, septic tanks, rapid infiltration basins and agricultural and domestic lawn irrigation. Runoff to closed basins, such as sinkholes and drainage wells and rapid infiltration basin flows are represented using the well package rather than the recharge package.

Evapotranspiration Package and Input File

The Evapotranspiration (ET) Package determines rates of ET from the saturated groundwater flow system. To do this, arrays of maximum saturated evapotranspiration (MSET), elevation at which maximum saturation occurs, and estimated ET extinction depth must be read from the .evt input file. The NFSEG .evt input file contains separate arrays of MSET for the years 2001 and 2009. These MSET rates were estimated as the difference between estimated potential ET (PET) and the sum of unsaturated ET components simulated by HSPF (i.e., “interception storage—CEPS,” “upper zone storage—UZS,” and “lower zone storage—LZS”). The PET rates used in this calculation were obtained from the NLDAS and U.S. Geological Survey Florida ET databases. The estimated ET extinction depths were based on an adaptation of an approach utilized in Shah et al. (2007). This adaptation was developed by Freese (written communication) and implemented by Stokes (digital communication).

General-Head Boundary Package and Input File

The General-Head Boundary (GHB) package is an implementation of Darcy's Law, as expressed by the following formula:

$$Q = C(H_{srce} - H_{ijk}), \text{ where}$$

Q is the GHB-condition flow rate, in units of length³/time;

H_{srce} is a specified "source head" representing a known or estimated constant water level located outside the model domain, in units of length;

H_{ijk} is the model-calculated head at grid cell i,j,k (i.e., row i, column j, layer k), to which the GHB condition is assigned, in units of length; and

C is the GHB "conductance" and is equal to the product of hydraulic conductivity and flow area divided by the length of flow path. C is expressed in units of length²/time.

C and H_{srce} are specified by the modeler based on system knowledge. Q and H_{ijk} are calculated by the model. Data input for the general-head boundary package is contained in the NFSEG .ghb input file. The NFSEG .ghb input file contains data necessary for determination of GHB conditions for years 2001 and 2009.

The purpose of the GHB condition is to simulate rates of flow (flux rates) into or out of the model domain at the grid cell to which the GHB condition is assigned. As noted above, GHB flux rates are proportional to the difference in a source head at a point outside of the model domain and the simulated head at the grid cell to which the GHB is assigned. In steady-state applications, such as the present NFSEG groundwater model, the source head is held constant throughout the simulation. The GHB condition is one of three types of "head-dependent flux" boundary conditions utilized in the NFSEG groundwater model, the other two being the Drain and River Package boundary-condition types.

In the NFSEG groundwater model, the GHB package is used to represent two kinds of boundary conditions—lateral boundary flows and spring discharges. Lateral flows into or out of the NFSEG model domain in areas corresponding to the Gulf coastal region were represented in model layer 3 using the GHB package. These flows represent the remaining flow in the Upper Floridan aquifer near the pinch-out of the fresh-water flow system of the Upper Floridan aquifer. GHB conditions were used also to represent lateral flows into and out of the model domain along the model northern boundary. The northern boundary corresponds to the estimated line of pinch-out of the Upper Floridan aquifer. The lines of pinch-out of the middle semiconfining unit and Lower Floridan aquifer are farther to the north, however. Use of GHB conditions enables fluxes in the middle semiconfining unit and Lower Floridan aquifer to and from areas to the north to be simulated without extending the active domains of layers 4 and 5, respectively, into those areas. GHB conditions were used also to represent lateral flows into and out of the model domain along

a portion the model southern boundary that intersects with the northern extent of the Green Swamp potentiometric high. GHB conditions were applied to model layers 3, 4, and 5 along this boundary.

In addition to representing lateral fluxes, GHB conditions were used also to represent spring discharges. In this application, the value of H_{srce} represents the elevation of the surface of the receiving body of water into which a given spring discharges (i.e., the “spring-pool elevation”). Use of the GHB Package as opposed to the Drain Package to represent springs enables the simulation of reverse spring flow. This phenomenon, which is typically the result of seasonally high surface water, occurs whenever a spring-pool elevation exceeds the aquifer head at the spring. Most springs within the NFSEG model domain emanate from the Upper Floridan aquifer. A smaller number emanate from the Intermediate Aquifer system. Accordingly, most GHB conditions used to represent springs are assigned to model layer 3, which corresponds to the Upper Floridan aquifer in the NFSEG groundwater model. Some are assigned to aquifer layer 2 instead, which represents the Intermediate Aquifer system at the locations of such springs. The .ghb input file includes a spring “reach ID” for each spring. This ID can be cross-referenced with other data provided to determine the spring name, location coordinates, etc.

The use of GHB conditions to represent springs is an example of internal-boundary specification. By contrast, the use of GHB conditions to represent flux across lateral boundaries is lateral-boundary specification. The same boundary-condition type can thus be used to represent two different groundwater flow processes.

Drain Package and Input File

The Drain Package is another implementation of Darcy’s Law. Drains are classified as a type of “head-dependent flux” boundary condition, along with the GHB and river boundary condition types. Drain boundary conditions are identical to GHB conditions in all respects except that simulated flow between drains and aquifers is allowed to occur in only one direction (as groundwater outflow from the aquifer to the drain). Reverse (drain-to-aquifer) flow is not allowed. Whenever the simulated head in the grid cell becomes less than the elevation of the drain, the drain flow rate is set to zero. Drain-package input data are contained in the NFSEG .drn input file for years 2001 and 2009.

The Drain Package is used in the NFSEG groundwater model to represent artesian discharge from the Floridan aquifer in low-lying areas of the Gulf Coast region, particularly in the SRWMD. In this application, portions of wetlands in areas of the model domain that are unconfined and in which the elevation of the May-June 2010 potentiometric surface of the Upper Floridan aquifer (Kinnaman and Dixon 2011) exceeded land-surface elevation were assumed to be areas of artesian discharge from the Upper Floridan aquifer to land surface. These drain boundaries were assigned to model layer 1, as model layers 1 and 2, in addition to model layer 3, represent the Upper Floridan aquifer in unconfined areas.

The Drain Package was also used to represent ephemeral portions of streams. These are portions of streams that typically flow only during periods of relatively high water table. In the NFSEG implementation, the portions of streams represented using the drain boundary condition type flow only when the elevation of the simulated water table of a given grid cell exceeds the specified source head of the drain boundary, which represents the bottom elevation of the stream segment. Ephemeral portions of streams were identified in this process as the portions of NHDPlus flow paths with an assigned Strahler order of 1. The portions of streams with assigned Strahler orders in excess of 1 are represented using the NFSEG River-Package implementation. Drain Package boundary conditions are used in this application to represent only the base-flow portion of the stream flow (i.e., only the groundwater-derived portion of the total stream flow as opposed to the overland-flow portion).

River Package and Input File

The River Package is used to represent the interaction between surface-water bodies and groundwater system in the NFSEG groundwater model. As with the GHB- and Drain-Package boundary-condition types, the River Package boundary-condition type is a head-dependent flux boundary condition type. As with Drain Package boundary conditions, River Package boundary conditions are similar but not identical to GHB conditions, which is the most *general* of the head-dependent flux boundary-condition types. River Package boundary conditions require the specification of a (river or stream) stage and conductance in the input file for the River Package, just as with the input file for the GHB Package. In addition, River Package boundary conditions require the specification of the stream bottom elevation. Whenever the simulated head of the grid cell to which a River Package boundary condition is assigned is above the specified stream bottom, then the flux rate into or out of the River Package boundary condition is proportional to the difference in the River Package stage and the simulated head. If the simulated head drops below the bottom of the stream, however, then the flux rate becomes a constant value that is proportional to the difference in the specified River Package stage and river bottom elevation. River Package input data are contained in the NFSEG .riv input file for years 2001 and 2009.

Two different types of surface-water bodies are represented in the NFSEG groundwater model using the river package: streams and lakes. As stated previously, the portions of streams with assigned Strahler orders greater than 1 are represented with river boundary conditions.

Multi-Node Well Package and Input File

The Multi-Node Well Package was used to represent withdrawal wells that are open to both the Upper and Lower Floridan aquifers (i.e., “dual-zone” wells). As applied in the NFSEG groundwater model, the Multi-Node Well Package distributes flow in the well bore between the Upper and Lower Floridan aquifers based on hydraulic conductivity, aquifer hydraulic head, and open-hole length. The input data for the Multi-Node Well Package are contained the NFSEG .mnw2 input file for years 2001 and 2009.

Well Package and Input File

The Well Package was used to represent withdrawal wells that are open to only one aquifer layer. It was also used to represent drainage wells, rapid infiltration basin flows, and closed-basin point inflows, such as flow into the Upper Floridan aquifer via sink holes. Drainage-well and closed-basin point inflow rates were estimated in the HSPF modeling process. The input data for the Well Package are contained in the NFSEG .wel input file for years 2001 and 2009.

Time-Variant Specified Head Package and Input File

The Time-Variant Specified Head Package was used to represent constant-head boundary assignments for years 2001 and 2009. Constant-head boundaries were used in the model primarily to represent sea level. Input data for the time-variant specified head package are contained in the NFSEG .chd input file for years 2001 and 2009.

References:

Bicknell, B.R., Imhoff, J.C., Kittle, J.L., Jr., Donigian, A.S., Jr., and Johanson, R.C., 1997, Hydrological Simulation Program--Fortran, User's manual for version 11: U.S. Environmental Protection Agency, National Exposure Research Laboratory, Athens, Ga., EPA/600/R-97/080, 755 p.

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