readme_SFR.pdf

Modifications to the Streamflow Routing Package originally documented by Prudic and others (2004) and Niswonger and Prudic (2005):

Update to the SFR7 Package for MODFLOW-2005 version 1.7 (August 2009):

A bug was fixed that caused the model to fail to converge or to produce erroneous results. The bug only affected simulations with transient streamflow routing and when the ICALC=3 option was used to define relations between streamflow, stream depth, and cross-sectional area.

Another bug was found in the calculations of mid-point flow, which is printed to the gage output. This erroneous streamflow calculation is not used for internal routing calculations and thus it did not affect any other simulation results other than the streamflow at the mid-point of a stream reach that is printed to the gage file.

Input instructions for the SFR Package were revised to clarify some of the input variables and to define new variables that have been added to the package since its initial release. The latest version of the input instructions are provided in version 1.20 of the SFR2 documentation report, which is available in PDF form at the persistent URL http://pubs.usgs.gov/tm/2006/tm6A13/. Also, a simplified set of input instructions for the SFR Package that is applicable to simulations that do not use the parameters options of the package is available in the 'doc' subdirectory of the MODFLOW-2005 release, in the file 'SFR2_simplified_instructions.pdf'.

Update to the SFR7 Package for MODFLOW-2005 version 1.6.01 (March 2009):

Following the modification of SFR2 to simulate transient streamflow routing based on the kinematic-wave equation, three new input variables were added if the option for transient routing is used. The option for simulating transient streamflow routing is documented by Markstrom and others (2008). The following three input variables are now required when transient routing is simulated (IRTFLG>0). NUMTIM, WEIGHT, and FLWTOL follow directly after IRTFLG in item 1.

NUMTIM-- is the number of sub time steps used to route streamflow. The time step that will be used to route streamflow will be equal to the MODFLOW time step divided by NUMTIM.

WEIGHT-- is the time weighting factor used to calculate the change in channel storage. WEIGHT has a value between 0.5 and 1. Please refer to equation 83 of Markstrom and others (2008) for further details.

FLWTOL-- is the streamflow tolerance for convergence of the kinematic wave equation used for transient streamflow routing. A value of 0.00003 cubic meters per second has been used successfully in test simulations (and would need to be converted to whatever units are being used in the particular simulation).

Update to the SFR7 Package for MODFLOW-2005 version 1.6 (January 2009):

Following the modification of SFR2 to simulate transient streamflow routing based on the kinematic-wave equation, two new input variables were added if the

option for transient routing is used. The option for simulating transient streamflow routing is documented by Markstrom and others (2008). The following two input variables are now required when transient routing is simulated (IRTFLG>0). NUMTIM and WEIGHT follow directly after and on the same line as the variable IRTFLG.

NUMTIM-- is the number of sub-time steps used to route streamflow. The time step that will be used to route streamflow will be equal to the MODFLOW time step divided by NUMTIM.

WEIGHT-- is the time weighting factor used to calculate the change in channel storage. WEIGHT has values between 0.5 and 1. Refer to equation 83 of Markstrom and others (2008)for further details.

Changes to the SFR7 package for MODFLOW-2005 version 1.5 (April 2008):

A few small changes were made to the Streamflow Routing Package (Niswonger and Prudic, 2005) since its last release. A change was made in the calculation of stream seepage during steady-state simulations. In the previous version, single precision variables were used during intermediate calculations of streambed seepage. As a result, the model could fail to converge for some steady-state simulations. The code was modified such that only double precision arithmetic is used during the calculations of streambed seepage during steady-state simulations.

Another larger modification was made to SFR7 to include the capability of distributed streamflow routing using the kinematic-wave approximation to the Saint-Venant Equations (Lighthill and Whitham, 1955). This new capability is described in Markstrom and others (2008) on pages 68-69. This capability requires the addition of one new input variable that needs to be appended to the end of the first record of input variables in the SFR7. This new input variable is a flag that specifies whether or not the kinematic-wave equation will be used to route water in channels. The updated input instructions for SFR7 are documented in Markstrom and others (2008), pp 202-210.

Update (June 2006):

Several minor coding changes were made since the initial release to fix bugs in relation to the different input options for SFR2 (Niswonger and Prudic, 2005). These fixes to SFR2 resulted from inconsistencies in the original data input by stream segments in the SFR1 documentation (Prudic and others, 2004) and the new data input option by stream reaches in the instructions published by Niswonger and Prudic (2005). The SFR2 documentation report has been revised to better explain the different options available in SFR2. The latest version of the SFR2 documentation report is version 1.10 and is available in PDF form at the persistent URL http://pubs.water.usgs.gov/tm6A13/. Corrections to the original printed document are listed in file tma6a13_SFR2revision_history.pdf included in the document (doc) directory distributed with MODFLOW.

An important change was made to SFR2 in the Formulate and Budget modules that pertain to the computation of outflow from lakes when streams are connected to lakes in the LAKE(LAK3) Package (Merritt and Konikow, 2000). These changes were necessary to remain compatible with the most recent version of the Lake Package. The initial version of SFR1 and SFR2 made the computation of lake outflow on the basis of either the lake stage from the previous time step or the

previous MODFLOW iteration or a combination of both. This formulation of lake outflow can produce an oscillation in the lake outflow that affects streamflow leakage downstream of the lake and could prevent MODFLOW from reaching convergence during a time step.

A new subroutine named GWF1SFR2LAKOUTFLW was added to SFR2. The new subroutine computes the relation of stream stage with streamflow at the beginning of a stream segment that receives outflow from a lake. The relation between stream stage and streamflow are saved in tables that are passed to the revised Lake (LAK3) Package where the tables are used in computing lake stage and lake outflow to the stream segment using the Newton iteration method.

The changes to the Formulate and Budget modules in SFR2 do not affect previous model results unless outflow from a lake is simulated as inflow to a stream. Model results when lake outflow is simulated as inflow to a stream could differ from eariler models that used the previous method of computing lake outflow. The greatest differences will occur for steady-state simulations with computed lake outflows to streams or for transient simulations when a time weighting factor (THETA) of 0.0 was used for computing lake stage and lake outflow when time steps were long and lake outflow was sensitive to small changes in lake stage.

References:

Lighthill, M.J., and Whitham, G.B., 1955, On kinematic floods—flood movements in long rivers: Proceedings, R. Soc. London, v. A220, p. 281-316.

Markstrom, S.L., Niswonger, R.G., Regan, R.S., Prudic, D.E., and Barlow, P.M., 2008, GSFLOW—Coupled ground-water and surface-water flow model based on the integration of the Precipitation-Runoff Modeling System (PRMS) and the Modular Ground-Water Flow Model (MODFLOW-2005): U.S. Geological Survey Techniques and Methods 6-D1, 240 p.

Merritt, M.L., and Konikow, L.F., 2000, Documentation of a computer program to simulate lake-aquifer interaction using the MODFLOW ground-water model and the MOC3D solute-transport model: U.S. Geological Survey Water Resources-Investigations Report 00-4167, 146 p.

Niswonger, R.G., and Prudic, D.E.,2005, Documentation of the Streamflow-Routing (SFR2) Package to include unsaturated flow beneath streams--A Modification to SFR1: U.S. Geological Survey Techniques and Methods 6-A13, 48 p.

Prudic, D.E., Konikow, L.F., and Banta, E.R.,2004, A new streamflow-routing (SFR1) Package to simulate stream-aquifer interaction with MODFLOW-2000: U.S. Geological Survey Open-File Report 2004-1042, 95 p.