Updated input instructions for the Streamflow-Routing (SFR2) Package released with GSFLOW version 1.1.5, January 2012

These input instructions have been updated for the version 1.1.5 release of GSFLOW to accommodate the MODFLOW-NWT functionality. Additional small changes, shown in highlighted text, have also been made. Input to the Streamflow-Routing (SFR2) Package is read from the file that has file type *SFR* in the Name File. The user can optionally specify that stream gages and monitoring stations are to be represented at one or more locations along a stream channel by including a record in the MODFLOW name file using the file type *GAGE* that specifies the relevant input data file giving locations of gages (see "Gage Package" section).

The modification of SFR2 to simulate unsaturated flow relies on the specific yield values as specified in the UPW Package when using the NWT Solver Package, and as specified in the Block-Centered Flow (BCF) Package, the Layer-Property Flow (LPF) Package, or the Hydrogeologic-Unit Flow (HUF) Package when using standard MODFLOW-2005 functionality. If MODFLOW-NWT is run with the option to use vertical hydraulic conductivity specified in the UPW Package, the layer(s) that contain cells where unsaturated flow will be simulated must be specified as convertible. Similarly, if MODFLOW-2005 functionality is used and the option to use vertical hydraulic conductivity in the LPF or HUF Package is specified, the layer(s) that contain cells where unsaturated flow will be simulated must be specified as convertible. That is, the variable LAYTYP specified in UPW or LPF (or variable LTHUF in HUF) must not be equal to zero, otherwise the model will print an error message and stop execution.

Additional variables that must be specified to define hydraulic properties of the unsaturated zone are all included within the SFR2 input file. All values are entered in free format.

The Streamflow-Routing Package is documented in Prudic and others (2004) and Niswonger and Prudic (2005) and users of GSFLOW are encouraged to review those documents when using the SFR Package. However, unlike previous versions of SFR, input data for SFR2 cannot be specified using parameters in GSFLOW.

For Each Simulation:

0. Data: [#Text]

Text   A character variable (up to 199 characters) that is printed when the file is read. The "#" character must be in column 1, and, accordingly, the variable starts in column 2. Lines beginning with # are restricted to the first lines of the file. Any characters can be included in Text.

Note 1: Item 0 is optional and can be repeated multiple times.

1a. Data: [***REACHINPUT***   ***TRANSROUTE***]

REACHINPUT An optional character variable. When ***REACHINPUT*** is specified, variable ISFROPT must be specified in item 1c. ISFROPT can be used to change the default format for entering reach and segment data or to specify that unsaturated flow beneath streams will be simulated.

TRANSROUTE An optional character variable that is a flag to indicate that transient streamflow routing is active. When ***TRANSROUTE*** is specified, optional variables IRTFLG, NUMTIM, WEIGHT, and FLWTOL also must be specified in Item 1c.

1b. Data: [***TABFILES***   NUMTAB   MAXVAL]

TABFILES   An optional character variable that is a flag to indicate that inflows to one or more stream segments will be specified with tabular inflow files.

NUMTAB   An integer value equal to the number of tabular inflow files that will be read if ***TABFILES*** is specified. A separate input file is required for each segment that receives specified inflow. Thus, the maximum value of NUMTAB that can be specified is equal to the total number of segments specified in Item 1c with variables NSS. The name (Fname) and unit number (Nunit) of each tabular file must be specified in the MODFLOW-2005 or MODFLOW-NWT Name Files using tile type (Ftype) ***DATA***.

MAXVAL   An integer value equal to the largest number of rows of specified inflows for any of the tabular inflow files if ***TABFILES*** is specified. MAXVAL is used for memory allocation. For example, if there are two tabular inflow files and the files contain 100 and 200 inflow values, respectively, then MAXVAL would be specified as 200.

Note 2: Items 1a and 1b are optional.

1c. Data: NSTRM NSS NSFRPAR NPARSEG CONST DLEAK ISTCB1 ISTCB2 {ISFROPT}
          {NSTRAIL} {ISUZN} {NSFRSETS} {IRTFLG} {NUMTIM} {WEIGHT} {FLWTOL}

NSTRM   An integer value equal to the number of stream reaches (finite-difference cells) that are active during the simulation. The value of NSTRM also represents the number of lines of data to be included in Item 2, described below.

NSS   An integer value equal to the number of stream segments (consisting of one or more reaches) that are used to define the complete stream network.

NSFRPAR   {This variable must be zero because parameters are not supported in GSFLOW.}

NPARSEG   {This variable must be zero because parameters are not supported in GSFLOW.}

CONST   A real value (or conversion factor) used in calculating stream depth for a stream reach. If stream depth is not calculated using Manning's equation for any stream segment (that is, ICALC does not equal 1 or 2), then a value of zero can be entered. If Manning's equation is used, a constant of 1.486 is used for flow units of cubic feet per second, and a constant of 1.0 is used for units of cubic meters per second. The constant must be multiplied by 86,400 when using time units of days in the simulation. An explanation of time units used in MODFLOW is given by Harbaugh and others (2000, p. 10.)

DLEAK   A real value equal to the tolerance level of stream depth used in computing leakage between each stream reach and active model cell. Value is in units of length. SFR2 differs from the Stream (STR1) Package (Prudic, 1989) in that it solves for stream depth at the midpoint of each reach instead of at the beginning of the reach. SFR2 does this by use of Newton's iterative method. As a consequence, the user must specify variable DLEAK, which is a closure tolerance used for stopping the iterative process. Values of 1.0×10^{-5} and 1.0×10^{-6} meters has been used successfully in test simulations (and would need to be converted to whatever units are being used in the particular simulation).

ISTCB1   An integer value used as a flag for writing stream-aquifer leakage values. If ISTCB1 > 0, it is the unit number to which unformatted leakage between each stream reach and corresponding model cell will be saved to a file whenever the cell-by-cell budget has been specified in Output Control (see Harbaugh and others, 2000, pages 52-55). If ISTCB1 = 0, leakage values will not be printed or saved. If ISTCB1 < 0, all information on inflows and outflows from each reach; on stream depth, width, and streambed conductance; and on head difference and gradient across

the streambed will be printed in the main listing file whenever a cell-by-cell budget has been specified in Output Control.

ISTCB2   An integer value used as a flag for writing to a separate formatted file all information on inflows and outflows from each reach; on stream depth, width, and streambed conductance; and on head difference and gradient across the streambed. If ISTCB2 > 0, then ISTCB2 also represents the unit number to which all information for each stream reach will be saved to a separate file when a cell-by-cell budget has been specified in Output Control. If ISTCB2 < 0, it is the unit number to which unformatted streamflow out of each reach will be saved to a file whenever the cell-by-cell budget has been specified in Output Control. If ISTCB2 = 0, then results will not be printed or saved.

Note 3: Variables NSTRM and NSS are used for dimensioning arrays. NSTRM must equal the actual number of stream reaches defined in Item 2; NSS must equal the number of stream segments that define the complete stream network.

If keyword _REACHINPUT_ has been specified:

ISFROPT   An integer value that defines the format of the input data and whether or not unsaturated flow is simulated beneath streams. Unsaturated flow is simulated for ISFROPT $\geq$ 2; unsaturated flow is not simulated for ISFROPT = 0 or 1. Optional variables NSTRAIL, ISUZN, and NSFRSETS also must be specified if ISFROPT>1. Values of ISFROPT are defined as follows:

ISFROPT=0   No vertical unsaturated flow beneath streams. Streambed elevation, stream slope, streambed thickness, and streambed hydraulic conductivity are read for each reach stress period using variables defined in Items 4b and 4c; the optional variables in Item 2 are not used.

ISFROPT=1   No vertical unsaturated flow beneath streams. Streambed elevation, stream slope, streambed thickness, and streambed hydraulic conductivity are read for each reach only once at the beginning of the simulation using optional variables defined in Item 2; Items 4b and 4c are used to define stream width and depth for ICALC = 0 and stream width for ICALC = 1.

ISFROPT=2   Streambed and unsaturated-zone properties are read for each reach only once at the beginning of the simulation using optional variables defined in Item 2; Items 4b and 4c are used to define stream width and depth for ICALC = 0 and stream width for ICALC = 1. When using the UPW Package (LPF or HUF Packages for MODFLOW-2005 functionality), saturated vertical hydraulic conductivity for the unsaturated zone is the same as the vertical hydraulic conductivity of the corresponding layer in UPW (LPF or HUF), and input variable UHC is not read.

ISFROPT=3   Same as 2 except saturated vertical hydraulic conductivity for the unsaturated zone (input variable UHC) is read for each reach.

ISFROPT=4   Streambed and unsaturated-zone properties are read for the beginning and end of each stream segment using variables defined in Items 4b and 4c; the optional variables in Item 2 are not used. Streambed properties can vary each stress period. When using the UPW Package (LPF or HUF Packages for MODFLOW-2005 functionality), saturated vertical hydraulic conductivity for the unsaturated zone is the same as the vertical hydraulic conductivity of the corresponding layer in UPW (LPF or HUF) and input variable UHC1 is not read.

ISFROPT=5 Same as 4 except saturated vertical hydraulic conductivity for the unsaturated zone (input variable UHC1) is read for each segment at the beginning of the first stress period only.

Note 4: If BCF or HUF are used and unsaturated flow is active, then ISFROPT must equal 3 or 5. If ISFROPT>1, the specific yield must be specified in the flow package for each SFR reach for which ICALC=1 or 2. This will require that at least one transient stress period be included in the simulation and that any cells connected to such SFR reaches be unconfined or convertible.

If ISFROPT is greater than 1 (that is, unsaturated flow beneath streams is being simulated), read the following variables (otherwise, skip these variables):

NSTRAIL   An integer value that is the number of trailing-wave increments used to represent a trailing wave. Trailing waves are used to represent a decrease in the surface infiltration rate. The value can be increased to improve mass balance in the unsaturated zone. Values between 10 and 15 work well, although for large problems we recommend fewer trailing waves (7) due to memory and computational requirements. See Smith (1983) for further details.
ISUZN   An integer value that is the maximum number of vertical cells used to define the unsaturated zone beneath a stream reach. If ICALC is 1 for all segments, then ISUZN should be set to 1.
NSFRSETS   An integer value that is the maximum number of different sets of trailing waves used to allocate arrays. Arrays are allocated by multiplying NSTRAIL by NSFRSETS. A value of 30 is sufficient for problems where the stream depth varies often. However, in some cases a value of 50 may be required. If this value is set too small then the simulation will terminate prematurely and an error will be printed to the List file. NSFRSETS does not affect model run time.

If keyword *TRANSROUTE* has been specified:
IRTFLG   An integer value that indicates the method of transient streamflow routing. IRTFLG must be specified if *TRANSROUTE* has been specified. Currently, the only routing method available is the kinematic-wave equation approach (see USGS Techniques and Methods 6-D1, p. 68-69). Enter IRTFLG=1, if streamflow will be routed using the kinematic-wave equation; otherwise, IRTFLG should be specified as 0 (steady flow).

If IRTFLG = 1:

NUMTIM   An integer value equal to 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   A real number equal to the time weighting factor used to calculate the change in channel storage. WEIGHT has a value between 0.5 and 1. Refer to equation 83 in USGS Techniques and Methods 6-D1 for further details.
FLWTOL   A real number equal to 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).

One record for each stream reach:

2. Data: KRCH IRCH JRCH ISEG IREACH RCHLEN {STRTOP} {SLOPE} {STRTHICK} {STRHC1} {THTS} {THTI} {EPS} {UHC}

KRCH   An integer value equal to the layer number of the cell containing the stream reach.

IRCH   An integer value equal to the row number of the cell containing the stream reach.

JRCH   An integer value equal to the column number of the cell containing the stream reach.

ISEG   An integer value equal to the stream-segment number in which this reach is located. Stream segments contain one or more reaches and are assumed to have uniform or linearly varying characteristics unless keyword **_REACHINPUT_** has been specified and ISFROPT is 1, 2, or 3 (in which case streambed information is specified individually for each reach).

IREACH   An integer value equal to the sequential number in a stream segment of this reach (where a reach corresponds to a single cell in the model). Numbering of reaches in a segment begins with 1 for the farthest upstream reach and continues in downstream order to the last reach of the segment.

RCHLEN   A real number equal to the length of channel of the stream reach within this model cell. The length of a stream reach can exceed the model cell dimensions because of the meandering nature of many streams. The length is used to calculate the streambed conductance for this reach. Also, the sum of the lengths of all stream reaches within a segment is used to calculate the average slope of the channel for the segment and subsequently other values, such as the elevation of the streambed and stream stage.

STRTOP   A real number equal to the top elevation of the streambed. This variable is read when ISFROPT is 1, 2, or 3.

SLOPE   A real number equal to the stream slope across the reach. This variable is read when ISFROPT is 1, 2, or 3. SLOPE must be greater than zero.

STRTHICK   A real number equal to the thickness of the streambed. This variable is read when ISFROPT is 1, 2, or 3.

STRHC1   A real number equal to the hydraulic conductivity of the streambed. This variable is read when ISFROPT is 1, 2, or 3.

THTS   A real number equal to the saturated volumetric water content in the unsaturated zone. This variable is read when ISFROPT is 2 or 3.

THTI   A real number equal to the initial volumetric water content. THTI must be less than or equal to THTS and greater than or equal to THTS minus the specific yield defined in UPW, BCF, LPF, or HUF. This variable is read when ISFROPT is 2 or 3.

EPS   A real number equal to the Brooks-Corey exponent used in the relation between water content and hydraulic conductivity within the unsaturated zone (Brooks and Corey, 1966). This variable is read when ISFROPT is 2 or 3.

UHC   A real number equal to the vertical saturated hydraulic conductivity of the unsaturated zone. This variable is optional when using UPW, and for MODFLOW-2005 functionality it is optional when using LPF or HUF, whereas it is necessary when using BCF. This variable is read when ISFROPT is 3.

Note 5: Reach information is read in sequential order from upstream to downstream, first by segments, and then sequentially by reaches. If segments are not numbered sequentially in downstream order, then the inflow to a segment during the current MODFLOW (or MODFLOW-NWT) iteration will be the outflow from an upstream segment calculated during the previous iteration. Lagging the inflow by one iteration does not change the

solution for flows into and out of a segment after MODFLOW (or MODFLOW-NWT) converges; however, this approach may require an additional iteration for the model to converge. Reaches must be listed and read sequentially because the order determines the connections of inflows and outflows within a stream segment.

Note 6: The stream network is assumed to remain fixed geometrically over the duration of a simulation. However, the active part of the stream network can be made to vary over time by making selected stream segments inactive for selected stress periods. This would be implemented by setting the streambed hydraulic conductivity, segment inflow, overland runoff, and direct precipitation to zero for the inactive segments in Item 4 for the specific stress periods when they are known to be inactive or dry.

Note 7: If the model cell corresponding to a stream reach is inactive, the program will search for the uppermost active cell in the vertical column to apply the leakage. If there are no active cells or if the cell is a constant head, no interaction is allowed and flow in the reach is passed to the next reach.

Note 8: When STRTOP, SLOPE, STRTHICK, and STRHC1 are specified for each reach, then HCOND1, THICKM1, ELEVUP, HCOND2, THICKM2, and ELEVDN are not read using Items 4b or 4c.

Note 9: The residual water content for each cell is not specified by the user because it is calculated based on the specified saturated water content minus the specific yield of the active model cell corresponding to the stream reach. The calculation is made internally to assure continuity between unsaturated and saturated zone storage.

Note 10: Although unsaturated flow variables THTS, THTI, EPS, and UHC will not be used for reaches that are designated as ICALC = 0, 3, or 4, values for these variables must be included for all reaches when ISFROPT = 2 or 3. Dummy values for these variables may be used for reaches that are designated as ICALC = 0, 3, and 4.

For Each Stress Period:

3. Data: ITMP IRDFLG IPTFLG

ITMP   An integer value for reading or reusing stream-segment data that can change each stress period. ITMP must be equal to the number of stream segments (NSEG) for the first stress period of a simulation. For subsequent stress periods, if 0 <ITMP <NSEG, then ITMP segments will be defined for the stress period and the remaining segments will be defined based on data from the previous stress period. If ITMP ≤ 0, then stream-segment data from the previous stress period will be reused.

IRDFLG   An integer value for printing input data specified for this stress period. If IRDFLG = 0, input data for this stress period will be printed. If IRDFLG > 0, then input data for this stress period will not be printed.

IPTFLG   An integer value for printing streamflow-routing results during this stress period. If IPTFLG = 0, or whenever the variable ICBCFL is specified in Output Control, the results for specified time steps during this stress period will be printed. If IPTFLG > 0, then the results during this stress period will not be printed.

If ITMP > 0, repeat Item 4 ITMP times (the data need not be defined in sequential order by stream-segment number):

4a. Data: NSEG ICALC OUTSEG IUPSEG {IPRIOR} {NSTRPTS} FLOW RUNOFF ETSW
            PPTSW {ROUGHCH} {ROUGHBK} {CDPTH} {FDPTH} {AWDTH} {BWDTH}

NSEG	An integer value equal to the stream segment for which information is given to identify inflow, outflow, and computation of stream depth.
ICALC	An integer value used to indicate the method used to calculate stream depth in this segment.

• If ICALC ≤ 0, stream depth in each reach is specified at the beginning of a stress period and remains unchanged unless flow at the midpoint of a reach is zero, then depth is set to zero in that reach. No unsaturated flow is allowed.

• If ICALC > 0, stream depth is calculated and updated each iteration of the MODFLOW (or MODFLOW-NWT) solver within a time step.

• If ICALC = 1, stream depth is calculated using Manning's equation and assuming a wide rectangular channel. Unsaturated flow is simulated when ISFROPT > 1 and the value of ICALC must remain 1 for the specified segment during the simulation.

• If ICALC = 2, stream depth is calculated using Manning's equation and assuming an eight-point channel cross section for each segment (which allows for the computation of a wetted perimeter and for changing hydraulic conductance of the streambed in relation to changes in flow). Unsaturated flow is simulated when ISFROPT > 1 and the value of ICALC must remain 2 for the specified segment during the simulation.

• If ICALC = 3, stream depth and width are calculated using a power function relating each to streamflow (Q) using equations 8 and 9 in Prudic and others (2004): DEPTH(y) = CDPTH × Q^{FDPTH} and WIDTH(w) = AWDTH × Q^{BWDTH}. Unsaturated flow is not allowed.

• If ICALC = 4, stream depth and width are calculated using a table relating streamflow to depth and width (the table is defined in Item 4e). Unsaturated flow is not allowed.

OUTSEG   An integer value of the downstream stream segment that receives tributary inflow from the last downstream reach of this segment. If this segment (identified by NSEG) does not feed (or discharge into) another downstream (tributary) segment, then enter a value of "0" for this variable. If the segment ends within the modeled grid and OUTSEG = 0, outflow from the segment is not routed anywhere and is no longer part of the stream network. One may wish to use this if all flow in the stream gets diverted into a lined canal or into a pipe. If the flow out of this segment discharges into a lake, set OUTSEG equal to the negative value of the lake identification number (where the minus sign is used as a flag to tell the model that flow enters a lake rather than a tributary stream segment).

IUPSEG   An integer value of the upstream segment from which water is diverted (or withdrawn) to supply inflow to this stream segment if this segment originates as a diversion from an upstream segment. If the source of a stream segment is discharge from a lake, set IUPSEG equal to the negative value of the lake identification number (where the minus sign is used as a flag to tell the model that streamflow into this segment is derived from lake outflow rather than a stream segment). If this stream segment (identified by NSEG) does not receive inflow as a diversion from an upstream segment, then set IUPSEG = 0.

IPRIOR   An integer value that only is specified if IUPSEG > 0 (do not specify a value in this field if IUPSEG = 0 or IUPSEG < 0). IPRIOR defines the prioritization system for diversion, such as when insufficient water is available to meet all diversion stipulations, and is used in conjunction with the value of FLOW (specified below).

• When IPRIOR = 0, then if the specified diversion flow (FLOW) is greater than the flow available in the stream segment from which the diversion is made, the diversion is reduced to the amount available, which will leave no flow available for tributary flow into a downstream tributary of segment IUPSEG.

• When IPRIOR = -1, then if the specified diversion flow (FLOW) is greater than the flow available in the stream segment from which the diversion is made, no water is diverted from the stream. This approach assumes that once flow in the stream is sufficiently low, diversions from

the stream cease, and is the "priority" algorithm that originally was programmed into the STR1 Package (Prudic, 1989).

• When `IPRIOR` = -2, then the amount of the diversion is computed as a fraction of the available flow in segment `IUPSEG`; in this case, $0.0 \leq$ `FLOW` ≤ 1.0.

• When `IPRIOR` = -3, then a diversion is made only if the streamflow leaving segment `IUPSEG` exceeds the value of `FLOW`. If this occurs, then the quantity of water diverted is the excess flow and the quantity that flows from the last reach of segment `IUPSEG` into its downstream tributary (`OUTSEG`) is equal to `FLOW`. This represents a flood-control type of diversion, as described by Danskin and Hanson (2002).

NSTRPTS	An integer value specified only when `ICALC` = 4. It is used to dimension a table relating streamflow with stream depth and width as specified in Item 4e. `NSTRPTS` must be at least 2 but not more than 50. If the table exceeds 3 × 50 (for streamflow, stream depth, and width) values, then `MAXPTS` in the allocation subroutine GWF1SFR1ALP will need to be increased from 3 × 50 to 3 × (the desired maximum value).
FLOW	A real number that is the streamflow (in units of volume per time) entering or leaving the upstream end of a stream segment (that is, into the first reach). • If the stream is a headwater stream, `FLOW` defines the total inflow to the first reach of the segment. The value can be any number ≥ 0. • If the stream is a tributary stream, `FLOW` defines additional specified inflow to or withdrawal from the first reach of the segment (that is, in addition to the discharge from the upstream segment of which this is a tributary). This additional flow does not interact with the groundwater system. For example, a positive number might be used to represent direct outflow into a stream from a sewage treatment plant, whereas a negative number might be used to represent pumpage directly from a stream into an intake pipe for a municipal water treatment plant. • If the stream is a diversionary stream, and the diversion is from another stream segment, `FLOW` defines the streamflow diverted from the last reach of stream segment `IUPSEG` into the first reach of this segment. The diversion is computed or adjusted according to the value of `IPRIOR`. • If the stream is a diversionary stream, and the diversion is from a lake, `FLOW` defines a fixed rate of discharge diverted from the lake into the first reach of this stream segment (unless the lake goes dry) and flow from the lake is not dependent on the value of `ICALC`. However, if `FLOW` = 0, then the lake outflow into the first reach of this segment will be calculated on the basis of lake stage relative to the top of the streambed for the first reach using one of the methods defined by `ICALC`. • If a tabular inflow file is used to define inflows for a segment, then any values of `FLOW` specified in Item 4a will be ignored.
RUNOFF	A real number that is the volumetric rate of the diffuse overland runoff that enters the stream segment (in units of volume per time). The specified rate is apportioned to each reach of the segment in direct relation to the fraction of the total length of the stream channel in the segment that is present in each reach.
ETSW	A real number that is the volumetric rate per unit area of water removed by evapotranspiration directly from the stream channel (in units of length per time). `ETSW` is defined as a positive value.
PPTSW	A real number that is the volumetric rate per unit area of water added by precipitation directly on the stream channel (in units of length per time).
ROUGHCH	A real number that is Manning's roughness coefficient for the channel in all reaches in this segment. This variable is only specified if `ICALC` = 1 or 2.

ROUGHBK   A real number that is Manning's roughness coefficient for the overbank areas in all reaches in
               this segment. This variable is only specified if ICALC = 2.

CDPTH   A real number that is the coefficient used in the equation:
               ($DEPTH = CDPTH \times Q^{FDPTH}$) that relates stream depth in all reaches in this segment to
               streamflow. This variable is only specified if ICALC = 3.

FDPTH   A real number that is the coefficient used in the equation:
               ($DEPTH = CDPTH \times Q^{FDPTH}$) that relates stream depth in all reaches in this segment to
               streamflow. This variable is only specified if ICALC = 3.

AWDTH   A real number that is the coefficient used in the equation:
               ($WIDTH = AWDTH \times Q^{BWDTH}$) that relates stream width in all reaches in this segment to
               streamflow. This variable is only specified if ICALC = 3.

BWDTH   A real number that is the coefficient used in the equation:
               ($WIDTH = AWDTH \times Q^{BWDTH}$) that relates stream width in all reaches in this segment to
               streamflow. This variable is only specified if ICALC = 3.

Note 11: A stream segment that receives inflow from upstream segments is allowed to have as many as 10
upstream segments feeding it, as defined by the respective values of OUTSEG.

Note 12: If the Lake Package (Merritt and Konikow, 2000) is also implemented, then flow out of the lake into a
stream segment is dependent on the option used to compute stream depth (ICALC = 1, 2, 3, or 4). Constant
discharge from a lake can be simulated no matter what value of ICALC is assigned to the stream segment
emanating from the lake by assigning a positive value to FLOW.

Note 13: If a diversionary flow is large enough to warrant representation in the model, but is discharged into a
pipeline, lined canal, or other structure or system that does not interact with the aquifer and the flow might
exceed the available streamflow, then there is an alternative means to represent it. Instead of specifying a
negative value of FLOW, we suggest representing the withdrawal by a single-reach diversionary stream segment,
which would be located in the same model cell as the reach from the upstream segment (IUPSEG) from which
the diversion is made; specifying the segment's streambed hydraulic conductivity equal to 0 will preclude
interaction with the aquifer and setting OUTSEG = 0 will remove the flow from the system. The diversion will
then be subject to the constraints associated with the value of IPRIOR.

**Items 4b and 4c: Items 4b and 4c may include no input when all are defined by stream reaches in Item 2
or they may include as many as nine variables, depending on the values of *REACHINPUT*, ISFROPT, and
ICALC specified in Items 1 and 4a.**

4b. Data: {HCOND1} {THICKM1} {ELEVUP} {WIDTH1} {DEPTH1} {THTS1} {THTI1}
             {EPS1} {UHC1}

HCOND1   Hydraulic conductivity of the streambed at the upstream end of this segment (units of length per
               time). This variable is read for each stress period when NSTRM is positive or when
               REACHINPUT has been specified and ISFROPT is 0, 4, or 5.

THICKM1   Thickness of streambed material at the upstream end of this segment (in units of length). This
               variable is read each stress period for all segments when NSTRM is positive or when
               REACHINPUT has been specified and ISFROPT is 0. When ISFROPT is 4 or 5, the variable is
               read each stress period for a segment when ICALC is 0, 3, or 4, and is read only the first stress
               period when ICALC is 1 or 2.

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ELEVUP	Elevation of the top of the streambed at the upstream end of this segment (in units of length). This variable is read each stress period for all segments when NSTRM is positive or when **REACHINPUT** has been specified and ISFROPT is 0. When ISFROPT is 4 or 5, the variable is read each stress period for a segment when ICALC is 0, 3, or 4, and is read only the first stress period when ICALC is 1 or 2.
WIDTH1	Average width of the stream channel at the upstream end of this segment (in units of length). This variable is read each stress period for all segments identified with an ICALC of 0 and is not dependent on ISFROPT. When ICALC is 1, the variable is read each stress period when NSTRM is positive or when **REACHINPUT** has been specified and ISFROPT is 0 or 1, and is read only for the first stress period when ISFROPT is 2, 3, 4, or 5.
DEPTH1	Average depth of water in the channel at the upstream end of this segment (units of length). This variable is only specified if ICALC is 0 and is not dependent on the value of NSTRM or ISFROPT. The stream stage in a reach is assumed to equal the elevation of the top of the streambed plus the depth of water.
THTS1	Saturated volumetric water content in the unsaturated zone beneath the upstream end of this segment. This variable is read for the first stress period when ICALC is 1 or 2 and ISFROPT is 4 or 5.
THTI1	Initial volumetric water content beneath the upstream end of this segment. THTI1 must be less than or equal to THTS and greater than or equal to THTS minus the specific yield defined in UPW, BCF, LPF, or HUF. This variable is read for the first stress period when ICALC is 1 or 2 and ISFROPT is 4 or 5.
EPS1	Brooks-Corey exponent used in the relation between water content and hydraulic conductivity within the unsaturated zone beneath the upstream end of this segment. This variable is read for the first stress period when ICALC is 1 or 2 and ISFROPT is 4 or 5.
UHC1	Vertical saturated hydraulic conductivity of the unsaturated zone beneath the upstream end of this segment. This variable is optional when using UPW, and for MODFLOW-2005 functionality it is optional when using LPF or HUF, whereas it is necessary when using BCF. This variable is read only for the first stress period when ICALC is 1 or 2 and ISFROPT is 5.

4c. Data: {HCOND2} {THICKM2} {ELEVDN} {WIDTH2} {DEPTH2} {THTS2} {THTI2} {EPS2} {UHC2}

HCOND2	Hydraulic conductivity of the streambed at the downstream end of this segment (units of length per time). This variable is read for each stress period when NSTRM is positive or when **REACHINPUT** has been specified and ISFROPT is 0, 4, or 5.
THICKM2	Thickness of streambed material at the downstream end of this segment (in units of length). This variable is read each stress period for all segments when NSTRM is positive or when **REACHINPUT** has been specified and ISFROPT is 0. When ISFROPT is 4 or 5, the variable is read each stress period for a segment when ICALC is 0, 3, or 4, and is read only the first stress period when ICALC is 1 or 2.
ELEVDN	Elevation of the top of the streambed at the downstream end of this segment (in units of length). This variable is read each stress period for all segments when NSTRM is positive or when **REACHINPUT** has been specified and ISFROPT is 0. When ISFROPT is 4 or 5, the variable is read each stress period for a segment when ICALC is 0, 3, or 4, and is read only the first stress period when ICALC is 1 or 2.

WIDTH2	Average width of the stream channel at the downstream end of this segment (in units of length). This variable is read each stress period for all segments identified with an ICALC of 0 and is not dependent on ISFROPT. When ICALC is 1, the variable is read each stress period when NSTRM is positive or when **REACHINPUT** has been specified and ISFROPT is 0 or 1, and is read only for the first stress period when ISFROPT is 2, 3, 4, or 5.
DEPTH2	Average depth of water in the channel at the downstream end of this segment (units of length). This variable is only specified if ICALC is 0 and is not dependent on the value of NSTRM or ISFROPT. The stream stage in a reach is assumed to equal the elevation of the top of the streambed plus the depth of water.
THTS2	Saturated volumetric water content in the unsaturated zone beneath the downstream end of this segment. This variable is read for the first stress period when ICALC is 1 or 2 and ISFROPT is 4 or 5.
THTI2	Initial volumetric water content beneath the downstream end of this segment. THTI2 must be less than or equal to THTS and greater than or equal to THTS minus the specific yield defined in UPW, BCF, LPF, or HUF. This variable is read for the first stress period when ICALC is 1 or 2 and ISFROPT is 4 or 5.
EPS2	Brooks-Corey exponent used in the relation between water content and hydraulic conductivity within the unsaturated zone beneath the downstream end of this segment. This variable is read for the first stress period when ICALC is 1 or 2 and ISFROPT is 4 or 5.
UHC2	Vertical saturated hydraulic conductivity of the unsaturated zone beneath the downstream end of this segment. This variable is optional when using UPW, and for MODFLOW-2005 functionality, it is optional for LPF or HUF, whereas it is necessary when using BCF. This variable is read only for the first stress period when ICALC is 1 or 2 and ISFROPT is 5.

Note 14: Stream properties and stresses are assumed to be constant and uniform within a single stream segment. Additionally, hydraulic conductivity, streambed thickness, elevation of the top of streambed, stream width, and stream depth may vary smoothly and linearly within a single stream segment. For these variables, data values at the upstream end of the segment are described in Item 4b and data values at the downstream end of the segment are described in Item 4c. Values of these variables for individual reaches of a segment are estimated using linear interpolation. To make any variable the same throughout the segment, simply specify equal values in Items 4b and 4c. The two elevations in Items 4b and 4c are used in conjunction with the total length of the stream segment (calculated from RCHLEN given for each reach in Item 2) to compute the slope of the stream and the elevations for any intermediate reaches. The streambed thickness is subtracted from the top of the streambed elevations to calculate the elevations of the bottom of the streambed (used in calculations of leakeage).

If ICALC = 2:

4d. Data: XCPT1 XCPT2 **...** XCPT8
  Data: ZCPT1 ZCPT2 **...** ZCPT8

XCPT*i*	A real number that is the distance relative to the left bank of the stream channel (when looking downstream) for the eight points (XCPT1 through XCPT8) used to describe the geometry of this segment of the stream channel. By definition, location XCPT1 represents the left edge of the channel cross section, and its value should be set equal to 0.0; values XCPT2 through XCPT8 should equal to or be greater than the previous distance.

ZCPT*i*   A real number that is the height relative to the top of the lowest elevation of the streambed (thalweg). One value (ZCPT1 through ZCPT8) is needed for each of the eight horizontal distances defined by XCPT*i*. The location of the thalweg (set equal to 0.0) can be any location from XCPT2 through XCPT7.

Note 15: These variables are read only for the first stress period when ISFROPT is 2, 3, 4, or 5 (that is, unsaturated flow is active) because the channel geometry cannot change during the simulation when unsaturated flow is active.

Note 16: It is assumed that the cross-sectional geometry defined by these data is the same over the entire length of the segment.

If ICALC = 4:

4e. Data: FLOWTAB(1) FLOWTAB(2) ... FLOWTAB(NSTRPTS)
     Data: DPTHTAB(1) DPTHTAB(2) ... DPTHTAB(NSTRPTS)
     Data: WDTHTAB(1) WDTHTAB(2) ... WDTHTAB(NSTRPTS)

FLOWTAB   A real number that is the streamflow (units of volume per time) related to a given depth and width. One value is needed for each streamflow that has a corresponding value of depth and width up to the total number of values used to define the table—FLOWTAB(1) through FLOWTAB(NSTRPTS). NSTRPTS is defined in Item 4a.

DPTHTAB   A real number that is the average depth (units of length) corresponding to a given flow. The number and order of values, DPTHTAB(1) through DPTHTAB(NSTRPTS) must coincide with streamflow values FLOWTAB(1) through FLOWTAB(NSTRPTS).

WDTHTAB   A real number that is the stream width (units of length) corresponding to a given flow. The number and order of values, WDTHTAB(1) through WDTHTAB(NSTRPTS), must coincide with streamflow values FLOWTAB(1) through FLOWTAB(NSTRPTS).

Note 17: It is assumed that the tabulated relation between streamflow and stream depth and width is the same over the entire length of the segment.

If keyword _TABFILES_ has been specified, repeat Item 4f NUMTAB **times for the first stress period only:**

4f. Data: SEGNUM NUMVAL IUNIT

SEGNUM   An integer value equal to the segment number to which the specified inflows will be applied.

NUMVAL   An integer value equal to the number of rows in the tabular inflow file. Each inflow file may contain a different number of rows, but the number of rows in any file cannot exceed MAXVAL specified in Item 1b.

IUNIT   An integer value equal to the unit number of the tabular inflow file. IUNIT must match the unit number for the file specified in the Name File.

Note 18: The external files that contain the specified inflows are referred to as tabular flow files. Each tabular file consists of two columns of input that are read using free format: TIME and INFLOW. Time is the point in the simulation when the inflow is specified for the segment; INFLOW is the specified flow, in units of length cubed per time. The units for TIME and INFLOW should be consistent with those specified for variables ITMUNI and LENUNI in the MODFLOW Discretization File. Times listed in the tabular flow file do not need to correspond to the beginning of MODFLOW time steps. If the beginning of the MODFLOW time steps fall between times listed in the tabular flow file, then the specified inflow is calculated using a time-weighted

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average of specified flows within the MODFLOW time step. Times can be listed in the tabular flow file either more frequently or less frequently than the MODFLOW time steps.