
MODFLOW 6 Program Documentation

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Contents:

MODFLOW 6 Input Guide

The latest version of the complete MODFLOW 6 input output guide can be found [here](#).

1.1 Simulation

1.1.1 SIM-NAM

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [CONTINUE]
  [NOCHECK]
  [MEMORY_PRINT_OPTION <memory_print_option>]
  [MAXERRORS <maxerrors>]
END OPTIONS
```

```
BEGIN TIMING
  TDIS6 <tdis6>
END TIMING
```

```
BEGIN MODELS
  <mtype> <mfname> <mname>
  <mtype> <mfname> <mname>
  ...
END MODELS
```

```
BEGIN EXCHANGES
  <exgtype> <exgfile> <exgmnamea> <exgmnameb>
  <exgtype> <exgfile> <exgmnamea> <exgmnameb>
```

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```
...  
END EXCHANGES
```

```
BEGIN SOLUTIONGROUP <group_num>  
  [MXITER <mxiter>]  
  <slntype> <slnfname> <slnmnames(:)>  
  <slntype> <slnfname> <slnmnames(:)>  
  ...  
END SOLUTIONGROUP
```

Explanation of Variables

Block: OPTIONS

- `CONTINUE` keyword flag to indicate that the simulation should continue even if one or more solutions do not converge.
- `NOCHECK` keyword flag to indicate that the model input check routines should not be called prior to each time step. Checks are performed by default.
- `memory_print_option` is a flag that controls printing of detailed memory manager usage to the end of the simulation list file. `NONE` means do not print detailed information. `SUMMARY` means print only the total memory for each simulation component. `ALL` means print information for each variable stored in the memory manager. `NONE` is default if `MEMORY_PRINT_OPTION` is not specified.
- `maxerrors` maximum number of errors that will be stored and printed.

Block: TIMING

- `tdis6` is the name of the Temporal Discretization (TDIS) Input File.

Block: MODELS

- `mtype` is the type of model to add to simulation.
- `mfname` is the file name of the model name file.
- `mname` is the user-assigned name of the model. The model name cannot exceed 16 characters and must not have blanks within the name. The model name is case insensitive; any lowercase letters are converted and stored as upper case letters.

Block: EXCHANGES

- `exgtype` is the exchange type.
- `exgfile` is the input file for the exchange.
- `exgmnamea` is the name of the first model that is part of this exchange.
- `exgmnameb` is the name of the second model that is part of this exchange.

Block: SOLUTIONGROUP

- `group_num` is the group number of the solution group. Solution groups must be numbered sequentially, starting with group number one.
- `mxiter` is the maximum number of outer iterations for this solution group. The default value is 1. If there is only one solution in the solution group, then `MXITER` must be 1.
- `slntype` is the type of solution. The Integrated Model Solution (IMS6) is the only supported option in this version.
- `slnfname` name of file containing solution input.
- `slnmnames` is the array of model names to add to this solution. The number of model names is determined by the number of model names the user provides on this line.

Example Input File

```

# This block is optional
BEGIN OPTIONS
END OPTIONS

# Simulation timing information
BEGIN TIMING
    TDIS6 simulation.tdis
END TIMING

# List of models in the simulation
BEGIN MODELS
    #modeltype      namefile      modelname
        GWF6      model1.nam      GWF_Model_1
        GWF6      model2.nam      GWF_Model_2
END MODELS

# List of exchanges in the simulation
BEGIN EXCHANGES
    GWF6-GWF6 simulation.exg GWF_Model_1 GWF_Model_2
END EXCHANGES

# Models are part of the same numerical solution
BEGIN SOLUTIONGROUP 1
    IMS6 simulation.ims GWF_Model_1 GWF_Model_2
END SOLUTIONGROUP

```

1.1.2 SIM-TDIS**Structure of Blocks***FOR EACH SIMULATION*

```

BEGIN OPTIONS
    [TIME_UNITS <time_units>]
    [START_DATE_TIME <start_date_time>]
    [ATS6 FILEIN <ats6_filename>]
END OPTIONS

```

```
BEGIN DIMENSIONS
  NPER <nper>
END DIMENSIONS
```

FOR ANY STRESS PERIOD

```
BEGIN PERIODDATA
  <perlen> <nstp> <tsmult>
  <perlen> <nstp> <tsmult>
  ...
END PERIODDATA
```

Explanation of Variables

Block: OPTIONS

- `time_units` is the time units of the simulation. This is a text string that is used as a label within model output files. Values for `time_units` may be “unknown”, “seconds”, “minutes”, “hours”, “days”, or “years”. The default time unit is “unknown”.
- `start_date_time` is the starting date and time of the simulation. This is a text string that is used as a label within the simulation list file. The value has no effect on the simulation. The recommended format for the starting date and time is described at <https://www.w3.org/TR/NOTE-datetime>.
- `ATS6` keyword to specify that record corresponds to an adaptive time step (ATS) input file. The behavior of ATS and a description of the input file is provided separately.
- `FILEIN` keyword to specify that an input filename is expected next.
- `ats6_filename` defines an adaptive time step (ATS) input file defining ATS controls. Records in the ATS file can be used to override the time step behavior for selected stress periods.

Block: DIMENSIONS

- `nper` is the number of stress periods for the simulation.

Block: PERIODDATA

- `perlen` is the length of a stress period.
- `nstp` is the number of time steps in a stress period.
- `tsmult` is the multiplier for the length of successive time steps. The length of a time step is calculated by multiplying the length of the previous time step by TSMULT. The length of the first time step, Δt_1 , is related to PERLEN, NSTP, and TSMULT by the relation $\Delta t_1 = \text{perlen} \cdot \frac{\text{tsmult} - 1}{\text{tsmult}^{\text{nstp}} - 1}$.

Example Input File

```
# Comment for this TDIS input file

BEGIN OPTIONS
  TIME_UNITS DAYS
```

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```

END OPTIONS

BEGIN DIMENSIONS
  NPER 2
END DIMENSIONS

BEGIN PERIODDATA
  365.00 1 1.0   Items: PERLEN NSTP TSMULT
  365.00 10 1.2  Items: PERLEN NSTP TSMULT
END PERIODDATA

```

1.2 Iterative Model Solution

1.2.1 SLN-IMS

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN OPTIONS
  [PRINT_OPTION <print_option>]
  [COMPLEXITY <complexity>]
  [CSV_OUTER_OUTPUT FILEOUT <outer_csvfile>]
  [CSV_INNER_OUTPUT FILEOUT <inner_csvfile>]
  [NO_PTC [<no_ptc_option>]]
  [ATS_OUTER_MAXIMUM_FRACTION <ats_outer_maximum_fraction>]
END OPTIONS

```

```

BEGIN NONLINEAR
  OUTER_DVCLOSE <outer_dvclose>
  OUTER_MAXIMUM <outer_maximum>
  [UNDER_RELAXATION <under_relaxation>]
  [UNDER_RELAXATION_GAMMA <under_relaxation_gamma>]
  [UNDER_RELAXATION_THETA <under_relaxation_theta>]
  [UNDER_RELAXATION_KAPPA <under_relaxation_kappa>]
  [UNDER_RELAXATION_MOMENTUM <under_relaxation_momentum>]
  [BACKTRACKING_NUMBER <backtracking_number>]
  [BACKTRACKING_TOLERANCE <backtracking_tolerance>]
  [BACKTRACKING_REDUCTION_FACTOR <backtracking_reduction_factor>]
  [BACKTRACKING_RESIDUAL_LIMIT <backtracking_residual_limit>]
END NONLINEAR

```

```

BEGIN LINEAR
  INNER_MAXIMUM <inner_maximum>
  INNER_DVCLOSE <inner_dvclose>
  INNER_RCLOSE <inner_rclose> [<rclose_option>]
  LINEAR_ACCELERATION <linear_acceleration>
  [RELAXATION_FACTOR <relaxation_factor>]
  [PRECONDITIONER_LEVELS <preconditioner_levels>]
  [PRECONDITIONER_DROP_TOLERANCE <preconditioner_drop_tolerance>]
  [NUMBER_ORTHOGONALIZATIONS <number_orthogonalizations>]
  [SCALING_METHOD <scaling_method>]

```

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```
[REORDERING_METHOD <reordering_method>]
END LINEAR
```

Explanation of Variables

Block: OPTIONS

- `print_option` is a flag that controls printing of convergence information from the solver. NONE means print nothing. SUMMARY means print only the total number of iterations and nonlinear residual reduction summaries. ALL means print linear matrix solver convergence information to the solution listing file and model specific linear matrix solver convergence information to each model listing file in addition to SUMMARY information. NONE is default if PRINT_OPTION is not specified.
- `complexity` is an optional keyword that defines default non-linear and linear solver parameters. SIMPLE - indicates that default solver input values will be defined that work well for nearly linear models. This would be used for models that do not include nonlinear stress packages and models that are either confined or consist of a single unconfined layer that is thick enough to contain the water table within a single layer. MODERATE - indicates that default solver input values will be defined that work well for moderately nonlinear models. This would be used for models that include nonlinear stress packages and models that consist of one or more unconfined layers. The MODERATE option should be used when the SIMPLE option does not result in successful convergence. COMPLEX - indicates that default solver input values will be defined that work well for highly nonlinear models. This would be used for models that include nonlinear stress packages and models that consist of one or more unconfined layers representing complex geology and surface-water/groundwater interaction. The COMPLEX option should be used when the MODERATE option does not result in successful convergence. Non-linear and linear solver parameters assigned using a specified complexity can be modified in the NONLINEAR and LINEAR blocks. If the COMPLEXITY option is not specified, NONLINEAR and LINEAR variables will be assigned the simple complexity values.
- CSV_OUTER_OUTPUT keyword to specify that the record corresponds to the comma separated values outer iteration convergence output.
- FILEOUT keyword to specify that an output filename is expected next.
- `outer_csvfile` name of the ascii comma separated values output file to write maximum dependent-variable (for example, head) change convergence information at the end of each outer iteration for each time step.
- CSV_INNER_OUTPUT keyword to specify that the record corresponds to the comma separated values solver convergence output.
- `inner_csvfile` name of the ascii comma separated values output file to write solver convergence information. Comma separated values output includes maximum dependent-variable (for example, head) change and maximum residual convergence information for the solution and each model (if the solution includes more than one model) and linear acceleration information for each inner iteration.
- NO_PTC is a flag that is used to disable pseudo-transient continuation (PTC). Option only applies to steady-state stress periods for models using the Newton-Raphson formulation. For many problems, PTC can significantly improve convergence behavior for steady-state simulations, and for this reason it is active by default. In some cases, however, PTC can worsen the convergence behavior, especially when the initial conditions are similar to the solution. When the initial conditions are similar to, or exactly the same as, the solution and convergence is slow, then the NO_PTC FIRST option should be used to deactivate PTC for the first stress period. The NO_PTC ALL option should also be used in order to compare convergence behavior with other MODFLOW versions, as PTC is only available in MODFLOW 6.
- `no_ptc_option` is an optional keyword that is used to define options for disabling pseudo-transient continuation (PTC). FIRST is an optional keyword to disable PTC for the first stress period, if steady-state and

one or more model is using the Newton-Raphson formulation. ALL is an optional keyword to disable PTC for all steady-state stress periods for models using the Newton-Raphson formulation. If NO_PTC_OPTION is not specified, the NO_PTC ALL option is used.

- `ats_outer_maximum_fraction` real value defining the fraction of the maximum allowable outer iterations used with the Adaptive Time Step (ATS) capability if it is active. If this value is set to zero by the user, then this solution will have no effect on ATS behavior. This value must be greater than or equal to zero and less than or equal to 0.5 or the program will terminate with an error. If it not specified by the user, then it is assigned a default value of one third. When the number of outer iterations for this solution is less than the product of this value and the maximum allowable outer iterations, then ATS will increase the time step length by a factor of DTADJ in the ATS input file. When the number of outer iterations for this solution is greater than the maximum allowable outer iterations minus the product of this value and the maximum allowable outer iterations, then the ATS (if active) will decrease the time step length by a factor of $1 / \text{DTADJ}$.

Block: NONLINEAR

- `outer_dvclose` real value defining the dependent-variable (for example, head) change criterion for convergence of the outer (nonlinear) iterations, in units of the dependent-variable (for example, length for head). When the maximum absolute value of the dependent-variable change at all nodes during an iteration is less than or equal to OUTER_DVCLOSE, iteration stops. Commonly, OUTER_DVCLOSE equals 0.01. The keyword, OUTER_HCLOSE can be still be specified instead of OUTER_DVCLOSE for backward compatibility with previous versions of MODFLOW 6 but eventually OUTER_HCLOSE will be deprecated and specification of OUTER_HCLOSE will cause MODFLOW 6 to terminate with an error.
- `outer_maximum` integer value defining the maximum number of outer (nonlinear) iterations – that is, calls to the solution routine. For a linear problem OUTER_MAXIMUM should be 1.
- `under_relaxation` is an optional keyword that defines the nonlinear under-relaxation schemes used. Under-relaxation is also known as dampening, and is used to reduce the size of the calculated dependent variable before proceeding to the next outer iteration. Under-relaxation can be an effective tool for highly nonlinear models when there are large and often counteracting changes in the calculated dependent variable between successive outer iterations. By default under-relaxation is not used. NONE - under-relaxation is not used (default). SIMPLE - Simple under-relaxation scheme with a fixed relaxation factor (UNDER_RELAXATION_GAMMA) is used. COOLEY - Cooley under-relaxation scheme is used. DBD - delta-bar-delta under-relaxation is used. Note that the under-relaxation schemes are often used in conjunction with problems that use the Newton-Raphson formulation, however, experience has indicated that they also work well for non-Newton problems, such as those with the wet/dry options of MODFLOW 6.
- `under_relaxation_gamma` real value defining either the relaxation factor for the SIMPLE scheme or the history or memory term factor of the Cooley and delta-bar-delta algorithms. For the SIMPLE scheme, a value of one indicates that there is no under-relaxation and the full head change is applied. This value can be gradually reduced from one as a way to improve convergence; for well behaved problems, using a value less than one can increase the number of outer iterations required for convergence and needlessly increase run times. UNDER_RELAXATION_GAMMA must be greater than zero for the SIMPLE scheme or the program will terminate with an error. For the Cooley and delta-bar-delta schemes, UNDER_RELAXATION_GAMMA is a memory term that can range between zero and one. When UNDER_RELAXATION_GAMMA is zero, only the most recent history (previous iteration value) is maintained. As UNDER_RELAXATION_GAMMA is increased, past history of iteration changes has greater influence on the memory term. The memory term is maintained as an exponential average of past changes. Retaining some past history can overcome granular behavior in the calculated function surface and therefore helps to overcome cyclic patterns of non-convergence. The value usually ranges from 0.1 to 0.3; a value of 0.2 works well for most problems. UNDER_RELAXATION_GAMMA only needs to be specified if UNDER_RELAXATION is not NONE.
- `under_relaxation_theta` real value defining the reduction factor for the learning rate (under-relaxation term) of the delta-bar-delta algorithm. The value of UNDER_RELAXATION_THETA is between zero and one.

If the change in the dependent-variable (for example, head) is of opposite sign to that of the previous iteration, the under-relaxation term is reduced by a factor of `UNDER_RELAXATION_THETA`. The value usually ranges from 0.3 to 0.9; a value of 0.7 works well for most problems. `UNDER_RELAXATION_THETA` only needs to be specified if `UNDER_RELAXATION` is DBD.

- `under_relaxation_kappa` real value defining the increment for the learning rate (under-relaxation term) of the delta-bar-delta algorithm. The value of `UNDER_RELAXATION_KAPPA` is between zero and one. If the change in the dependent-variable (for example, head) is of the same sign to that of the previous iteration, the under-relaxation term is increased by an increment of `UNDER_RELAXATION_KAPPA`. The value usually ranges from 0.03 to 0.3; a value of 0.1 works well for most problems. `UNDER_RELAXATION_KAPPA` only needs to be specified if `UNDER_RELAXATION` is DBD.
- `under_relaxation_momentum` real value defining the fraction of past history changes that is added as a momentum term to the step change for a nonlinear iteration. The value of `UNDER_RELAXATION_MOMENTUM` is between zero and one. A large momentum term should only be used when small learning rates are expected. Small amounts of the momentum term help convergence. The value usually ranges from 0.0001 to 0.1; a value of 0.001 works well for most problems. `UNDER_RELAXATION_MOMENTUM` only needs to be specified if `UNDER_RELAXATION` is DBD.
- `backtracking_number` integer value defining the maximum number of backtracking iterations allowed for residual reduction computations. If `BACKTRACKING_NUMBER` = 0 then the backtracking iterations are omitted. The value usually ranges from 2 to 20; a value of 10 works well for most problems.
- `backtracking_tolerance` real value defining the tolerance for residual change that is allowed for residual reduction computations. `BACKTRACKING_TOLERANCE` should not be less than one to avoid getting stuck in local minima. A large value serves to check for extreme residual increases, while a low value serves to control step size more severely. The value usually ranges from 1.0 to 106; a value of 104 works well for most problems but lower values like 1.1 may be required for harder problems. `BACKTRACKING_TOLERANCE` only needs to be specified if `BACKTRACKING_NUMBER` is greater than zero.
- `backtracking_reduction_factor` real value defining the reduction in step size used for residual reduction computations. The value of `BACKTRACKING_REDUCTION_FACTOR` is between zero and one. The value usually ranges from 0.1 to 0.3; a value of 0.2 works well for most problems. `BACKTRACKING_REDUCTION_FACTOR` only needs to be specified if `BACKTRACKING_NUMBER` is greater than zero.
- `backtracking_residual_limit` real value defining the limit to which the residual is reduced with backtracking. If the residual is smaller than `BACKTRACKING_RESIDUAL_LIMIT`, then further backtracking is not performed. A value of 100 is suitable for large problems and residual reduction to smaller values may only slow down computations. `BACKTRACKING_RESIDUAL_LIMIT` only needs to be specified if `BACKTRACKING_NUMBER` is greater than zero.

Block: LINEAR

- `inner_maximum` integer value defining the maximum number of inner (linear) iterations. The number typically depends on the characteristics of the matrix solution scheme being used. For nonlinear problems, `INNER_MAXIMUM` usually ranges from 60 to 600; a value of 100 will be sufficient for most linear problems.
- `inner_dvclose` real value defining the dependent-variable (for example, head) change criterion for convergence of the inner (linear) iterations, in units of the dependent-variable (for example, length for head). When the maximum absolute value of the dependent-variable change at all nodes during an iteration is less than or equal to `INNER_DVCLOSE`, the matrix solver assumes convergence. Commonly, `INNER_DVCLOSE` is set equal to or an order of magnitude less than the `OUTER_DVCLOSE` value specified for the `NONLINEAR` block. The keyword, `INNER_HCLOSE` can be still be specified instead of `INNER_DVCLOSE` for backward compatibility with previous versions of MODFLOW 6 but eventually `INNER_HCLOSE` will be deprecated and specification of `INNER_HCLOSE` will cause MODFLOW 6 to terminate with an error.

- `inner_rclose` real value that defines the flow residual tolerance for convergence of the IMS linear solver and specific flow residual criteria used. This value represents the maximum allowable residual at any single node. Value is in units of length cubed per time, and must be consistent with MODFLOW 6 length and time units. Usually a value of 1.0×10^{-1} is sufficient for the flow-residual criteria when meters and seconds are the defined MODFLOW 6 length and time.
- `rclose_option` an optional keyword that defines the specific flow residual criterion used. `STRICT`—an optional keyword that is used to specify that `INNER_RCLOSE` represents a infinity-Norm (absolute convergence criteria) and that the dependent-variable (for example, head) and flow convergence criteria must be met on the first inner iteration (this criteria is equivalent to the criteria used by the MODFLOW-2005 PCG package). `L2NORM_RCLOSE`—an optional keyword that is used to specify that `INNER_RCLOSE` represents a L-2 Norm closure criteria instead of a infinity-Norm (absolute convergence criteria). When `L2NORM_RCLOSE` is specified, a reasonable initial `INNER_RCLOSE` value is 0.1 times the number of active cells when meters and seconds are the defined MODFLOW 6 length and time. `RELATIVE_RCLOSE`—an optional keyword that is used to specify that `INNER_RCLOSE` represents a relative L-2 Norm reduction closure criteria instead of a infinity-Norm (absolute convergence criteria). When `RELATIVE_RCLOSE` is specified, a reasonable initial `INNER_RCLOSE` value is 1.0×10^{-4} and convergence is achieved for a given inner (linear) iteration when $\Delta h / \text{INNER_DVCLOSE}$ and the current L-2 Norm is the product of the `RELATIVE_RCLOSE` and the initial L-2 Norm for the current inner (linear) iteration. If `RCLOSE_OPTION` is not specified, an absolute residual (infinity-norm) criterion is used.
- `linear_acceleration` a keyword that defines the linear acceleration method used by the default IMS linear solvers. `CG` - preconditioned conjugate gradient method. `BICGSTAB` - preconditioned bi-conjugate gradient stabilized method.
- `relaxation_factor` optional real value that defines the relaxation factor used by the incomplete LU factorization preconditioners (`MILU(0)` and `MILUT`). `RELAXATION_FACTOR` is unitless and should be greater than or equal to 0.0 and less than or equal to 1.0. `RELAXATION_FACTOR` values of about 1.0 are commonly used, and experience suggests that convergence can be optimized in some cases with relax values of 0.97. A `RELAXATION_FACTOR` value of 0.0 will result in either `ILU(0)` or `ILUT` preconditioning (depending on the value specified for `PRECONDITIONER_LEVELS` and/or `PRECONDITIONER_DROP_TOLERANCE`). By default, `RELAXATION_FACTOR` is zero.
- `preconditioner_levels` optional integer value defining the level of fill for `ILU` decomposition used in the `ILUT` and `MILUT` preconditioners. Higher levels of fill provide more robustness but also require more memory. For optimal performance, it is suggested that a large level of fill be applied (7 or 8) with use of a drop tolerance. Specification of a `PRECONDITIONER_LEVELS` value greater than zero results in use of the `ILUT` preconditioner. By default, `PRECONDITIONER_LEVELS` is zero and the zero-fill incomplete `LU` factorization preconditioners (`ILU(0)` and `MILU(0)`) are used.
- `preconditioner_drop_tolerance` optional real value that defines the drop tolerance used to drop preconditioner terms based on the magnitude of matrix entries in the `ILUT` and `MILUT` preconditioners. A value of 10^{-4} works well for most problems. By default, `PRECONDITIONER_DROP_TOLERANCE` is zero and the zero-fill incomplete `LU` factorization preconditioners (`ILU(0)` and `MILU(0)`) are used.
- `number_orthogonalizations` optional integer value defining the interval used to explicitly recalculate the residual of the flow equation using the solver coefficient matrix, the latest dependent-variable (for example, head) estimates, and the right hand side. For problems that benefit from explicit recalculation of the residual, a number between 4 and 10 is appropriate. By default, `NUMBER_ORTHOGONALIZATIONS` is zero.
- `scaling_method` an optional keyword that defines the matrix scaling approach used. By default, matrix scaling is not applied. `NONE` - no matrix scaling applied. `DIAGONAL` - symmetric matrix scaling using the `POLCG` preconditioner scaling method in Hill (1992). `L2NORM` - symmetric matrix scaling using the L2 norm.
- `reordering_method` an optional keyword that defines the matrix reordering approach used. By default, matrix reordering is not applied. `NONE` - original ordering. `RCM` - reverse Cuthill McKee ordering. `MD` - minimum degree ordering.

Example Input File

```
BEGIN OPTIONS
  PRINT_OPTION ALL
  COMPLEXITY MODERATE
END OPTIONS

BEGIN NONLINEAR
  OUTER_DVCLOSE 1.E-4
  OUTER_MAXIMUM 2000
  UNDER_RELAXATION DBD
  UNDER_RELAXATION_THETA 0.70
  UNDER_RELAXATION_KAPPA 0.100000E-03
  UNDER_RELAXATION_GAMMA 0.
  UNDER_RELAXATION_MOMENTUM 0.
  BACKTRACKING_NUMBER 20
  BACKTRACKING_TOLERANCE 2.
  BACKTRACKING_REDUCTION_FACTOR 0.6
  BACKTRACKING_RESIDUAL_LIMIT 5.000000E-04
END NONLINEAR

BEGIN LINEAR
  INNER_MAXIMUM 100
  INNER_DVCLOSE 1.0E-4
  INNER_RCLOSE 0.001
  LINEAR_ACCELERATION BICGSTAB
  RELAXATION_FACTOR 0.97
  SCALING_METHOD NONE
  REORDERING_METHOD NONE
END LINEAR
```

1.3 Groundwater Flow

1.3.1 GWF-API

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [BOUNDNAMES]
  [PRINT_INPUT]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [OBS6 FILEIN <obs6_filename>]
  [MOVER]
END OPTIONS
```

```
BEGIN DIMENSIONS
  MAXBOUND <maxbound>
END DIMENSIONS
```


Explanation of Variables

Block: OPTIONS

- BOUNDNAMES keyword to indicate that boundary names may be provided with the list of api boundary cells.
- PRINT_INPUT keyword to indicate that the list of api boundary information will be written to the listing file immediately after it is read.
- PRINT_FLOWS keyword to indicate that the list of api boundary flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- SAVE_FLOWS keyword to indicate that api boundary flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- OBS6 keyword to specify that record corresponds to an observations file.
- FILEIN keyword to specify that an input filename is expected next.
- obs6_filename name of input file to define observations for the api boundary package. See the “Observation utility” section for instructions for preparing observation input files. Tables [ref{table:gwf-obstypetable}](#) and [ref{table:gwt-obstypetable}](#) lists observation type(s) supported by the api boundary package.
- MOVER keyword to indicate that this instance of the api boundary Package can be used with the Water Mover (MVR) Package. When the MOVER option is specified, additional memory is allocated within the package to store the available, provided, and received water.

Block: DIMENSIONS

- maxbound integer value specifying the maximum number of api boundary cells that will be specified for use during any stress period.

1.3.2 GWF-BUY

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [HHFORMULATION_RHS]
  [DENSEREF <denseref>]
  [DENSITY FILEOUT <densityfile>]
END OPTIONS
```

```
BEGIN DIMENSIONS
  NRHOSPECIES <nrhospecies>
END DIMENSIONS
```

```
BEGIN PACKAGEDATA
  <irhospec> <drhodc> <crhoref> <modelname> <auxspeciesname>
  <irhospec> <drhodc> <crhoref> <modelname> <auxspeciesname>
  ...
END PACKAGEDATA
```

Explanation of Variables

Block: OPTIONS

- `HHFORMULATION_RHS` use the variable-density hydraulic head formulation and add off-diagonal terms to the right-hand. This option will prevent the BUY Package from adding asymmetric terms to the flow matrix.
- `denseref` fluid reference density used in the equation of state. This value is set to 1000. if not specified as an option.
- `DENSITY` keyword to specify that record corresponds to density.
- `FILEOUT` keyword to specify that an output filename is expected next.
- `densityfile` name of the binary output file to write density information. The density file has the same format as the head file. Density values will be written to the density file whenever heads are written to the binary head file. The settings for controlling head output are contained in the Output Control option.

Block: DIMENSIONS

- `nrhospecies` number of species used in density equation of state. This value must be one or greater. The value must be one if concentrations are specified using the `CONCENTRATION` keyword in the `PERIOD` block below.

Block: PACKAGEDATA

- `irhospec` integer value that defines the species number associated with the specified `PACKAGEDATA` data on the line. `IRHOSPECIES` must be greater than zero and less than or equal to `NRHOSPECIES`. Information must be specified for each of the `NRHOSPECIES` species or the program will terminate with an error. The program will also terminate with an error if information for a species is specified more than once.
- `drhodic` real value that defines the slope of the density-concentration line for this species used in the density equation of state.
- `crhoref` real value that defines the reference concentration value used for this species in the density equation of state.
- `modelname` name of GWT model used to simulate a species that will be used in the density equation of state. This name will have no effect if the simulation does not include a GWT model that corresponds to this GWF model.
- `auxspeciesname` name of an auxiliary variable in a GWF stress package that will be used for this species to calculate a density value. If a density value is needed by the Buoyancy Package then it will use the concentration values in this `AUXSPECIESNAME` column in the density equation of state. For advanced stress packages (`LAK`, `SFR`, `MAW`, and `UZF`) that have an associated advanced transport package (`LKT`, `SFT`, `MWT`, and `UZF`), the `FLOW_PACKAGE_AUXILIARY_NAME` option in the advanced transport package can be used to transfer simulated concentrations into the flow package auxiliary variable. In this manner, the Buoyancy Package can calculate density values for lakes, streams, multi-aquifer wells, and unsaturated zone flow cells using simulated concentrations.

Example Input File

```

BEGIN OPTIONS
    DENSEREF 1000.
END OPTIONS

BEGIN DIMENSIONS
    NRHOSPECIES 2
END DIMENSIONS

BEGIN PACKAGEDATA
    #ISPEC DRHODC    CRHOREF MODELNAME    AUXSPECIESNAME
        1      0.7      0.      GWT-1      SALINITY
        2    -0.375    25.      GWT-2      TEMPERATURE
END PACKAGEDATA

```

1.3.3 GWF-CHD

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN OPTIONS
    [AUXILIARY <auxiliary(naux)>]
    [AUXMULTNAME <auxmultname>]
    [BOUNDNAMES]
    [PRINT_INPUT]
    [PRINT_FLOWS]
    [SAVE_FLOWS]
    [TS6 FILEIN <ts6_filename>]
    [OBS6 FILEIN <obs6_filename>]
END OPTIONS

```

```

BEGIN DIMENSIONS
    MAXBOUND <maxbound>
END DIMENSIONS

```

FOR ANY STRESS PERIOD

```

BEGIN PERIOD <iper>
    <cellid(ncelldim)> <head> [<aux(naux)>] [<boundname>]
    <cellid(ncelldim)> <head> [<aux(naux)>] [<boundname>]
    ...
END PERIOD

```

Explanation of Variables

Block: OPTIONS

- **auxiliary** defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for `naux`. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they

will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.

- `auxmultname` name of auxiliary variable to be used as multiplier of CHD head value.
- `BOUNDNAMES` keyword to indicate that boundary names may be provided with the list of constant-head cells.
- `PRINT_INPUT` keyword to indicate that the list of constant-head information will be written to the listing file immediately after it is read.
- `PRINT_FLOWS` keyword to indicate that the list of constant-head flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- `SAVE_FLOWS` keyword to indicate that constant-head flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- `TS6` keyword to specify that record corresponds to a time-series file.
- `FILEIN` keyword to specify that an input filename is expected next.
- `ts6_filename` defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- `OBS6` keyword to specify that record corresponds to an observations file.
- `obs6_filename` name of input file to define observations for the constant-head package. See the “Observation utility” section for instructions for preparing observation input files. Tables `ref{table:gwf-obstypetable}` and `ref{table:gwt-obstypetable}` lists observation type(s) supported by the constant-head package.

Block: DIMENSIONS

- `maxbound` integer value specifying the maximum number of constant-head cells that will be specified for use during any stress period.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. IPER must be less than or equal to NPER in the TDIS Package and greater than zero. The IPER value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- `cellid` is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell.
- `head` is the head at the boundary. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `aux` represents the values of the auxiliary variables for each constant head. The values of auxiliary variables must be present for each constant head. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- **boundname** name of the constant head boundary cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

Example Input File

```
#The OPTIONS block is optional
BEGIN OPTIONS
  AUXILIARY temperature
  BOUNDNAMES
  PRINT_INPUT
  PRINT_FLOWS
  SAVE_FLOWS
END OPTIONS

#The DIMENSIONS block is required
BEGIN DIMENSIONS
  MAXBOUND 2
END DIMENSIONS

#The following block of constant-head cells will be activated
#for stress period 1. This block will remain active throughout
#the simulation.

BEGIN PERIOD 1
#l r c head temperature boundname
  1 1 2 100. 20.5 chd_1_2
  1 1 3 100. 20.4 chd_1_3
END PERIOD 1
```

Available Observation Types

Example Observation Input File

```
BEGIN OPTIONS
  DIGITS 8
  PRINT_INPUT
END OPTIONS

BEGIN CONTINUOUS FILEOUT my_model.chd01.csv
# obsname obstype ID
  chd_2_1 CHD 1 1 2
  chd_2_2 CHD 1 2 2
  chd_2_3 CHD 1 3 2
  chd_2_4 CHD 1 4 2
END CONTINUOUS

BEGIN CONTINUOUS FILEOUT my_model.chd02.csv
# obsname obstype ID
  chd_3_flow CHD CHD_1_3
END CONTINUOUS
```

1.3.4 GWF-CSUB

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN OPTIONS
  [BOUNDNAMES]
  [PRINT_INPUT]
  [SAVE_FLOWS]
  [GAMMAW <gammaw>]
  [BETA <beta>]
  [HEAD_BASED]
  [INITIAL_PRECONSOLIDATION_HEAD]
  [NDELAYCELLS <ndelaycells>]
  [COMPRESSION_INDICES]
  [UPDATE_MATERIAL_PROPERTIES]
  [CELL_FRACTION]
  [SPECIFIED_INITIAL_INTERBED_STATE]
  [SPECIFIED_INITIAL_PRECONSOLIDATION_STRESS]
  [SPECIFIED_INITIAL_DELAY_HEAD]
  [EFFECTIVE_STRESS_LAG]
  [STRAIN_CSV_INTERBED FILEOUT <interbedstrain_filename>]
  [STRAIN_CSV_COARSE FILEOUT <coarsestrain_filename>]
  [COMPACTION FILEOUT <compaction_filename>]
  [COMPACTION_ELASTIC FILEOUT <elastic_compaction_filename>]
  [COMPACTION_INELASTIC FILEOUT <inelastic_compaction_filename>]
  [COMPACTION_INTERBED FILEOUT <interbed_compaction_filename>]
  [COMPACTION_COARSE FILEOUT <coarse_compaction_filename>]
  [ZDISPLACEMENT FILEOUT <zdisplacement_filename>]
  [PACKAGE_CONVERGENCE FILEOUT <package_convergence_filename>]
  [TS6 FILEIN <ts6_filename>]
  [OBS6 FILEIN <obs6_filename>]
END OPTIONS

```

```

BEGIN DIMENSIONS
  NINTERBEDS <ninterbeds>
  [MAXSIG0 <maxsig0>]
END DIMENSIONS

```

```

BEGIN GRIDDATA
  CG_SKE_CR
    <cg_ske_cr(nodes)> -- READARRAY
  CG_THETA
    <cg_theta(nodes)> -- READARRAY
  [SGM
    <sgm(nodes)> -- READARRAY]
  [SGS
    <sgs(nodes)> -- READARRAY]
END GRIDDATA

```

```

BEGIN PACKAGEDATA
  <icsubno> <cellid(ncelldim)> <cdelay> <pcs0> <thick_frac> <rnb> <ssv_cc> <sse_
→cr> <theta> <kv> <h0> [<boundname>]
  <icsubno> <cellid(ncelldim)> <cdelay> <pcs0> <thick_frac> <rnb> <ssv_cc> <sse_
→cr> <theta> <kv> <h0> [<boundname>]
  ...
END PACKAGEDATA

```

FOR ANY STRESS PERIOD

```

BEGIN PERIOD <iper>
  <cellid(ncellldim)> <sig0>
  <cellid(ncellldim)> <sig0>
  ...
END PERIOD

```

Explanation of Variables**Block: OPTIONS**

- **BOUNDNAMES** keyword to indicate that boundary names may be provided with the list of CSUB cells.
- **PRINT_INPUT** keyword to indicate that the list of CSUB information will be written to the listing file immediately after it is read.
- **SAVE_FLOWS** keyword to indicate that cell-by-cell flow terms will be written to the file specified with “BUDGET SAVE FILE” in Output Control.
- **gammaw** unit weight of water. For freshwater, GAMMAW is 9806.65 Newtons/cubic meters or 62.48 lb/cubic foot in SI and English units, respectively. By default, GAMMAW is 9806.65 Newtons/cubic meters.
- **beta** compressibility of water. Typical values of BETA are 4.6512e-10 1/Pa or 2.2270e-8 lb/square foot in SI and English units, respectively. By default, BETA is 4.6512e-10 1/Pa.
- **HEAD_BASED** keyword to indicate the head-based formulation will be used to simulate coarse-grained aquifer materials and no-delay and delay interbeds. Specifying HEAD_BASED also specifies the INITIAL_PRECONSOLIDATION_HEAD option.
- **INITIAL_PRECONSOLIDATION_HEAD** keyword to indicate that preconsolidation heads will be specified for no-delay and delay interbeds in the PACKAGEDATA block. If the SPECIFIED_INITIAL_INTERBED_STATE option is specified in the OPTIONS block, user-specified preconsolidation heads in the PACKAGEDATA block are absolute values. Otherwise, user-specified preconsolidation heads in the PACKAGEDATA block are relative to steady-state or initial heads.
- **ndelaycells** number of nodes used to discretize delay interbeds. If not specified, then a default value of 19 is assigned.
- **COMPRESSION_INDICES** keyword to indicate that the recompression (CR) and compression (CC) indices are specified instead of the elastic specific storage (SSE) and inelastic specific storage (SSV) coefficients. If not specified, then elastic specific storage (SSE) and inelastic specific storage (SSV) coefficients must be specified.
- **UPDATE_MATERIAL_PROPERTIES** keyword to indicate that the thickness and void ratio of coarse-grained and interbed sediments (delay and no-delay) will vary during the simulation. If not specified, the thickness and void ratio of coarse-grained and interbed sediments will not vary during the simulation.
- **CELL_FRACTION** keyword to indicate that the thickness of interbeds will be specified in terms of the fraction of cell thickness. If not specified, interbed thickness must be specified.
- **SPECIFIED_INITIAL_INTERBED_STATE** keyword to indicate that absolute preconsolidation stresses (heads) and delay bed heads will be specified for interbeds defined in the PACKAGEDATA block. The SPECIFIED_INITIAL_INTERBED_STATE option is equivalent to specifying the SPECIFIED_INITIAL_PRECONSOLIDATION_STRESS and SPECIFIED_INITIAL_DELAY_HEAD. If SPECIFIED_INITIAL_INTERBED_STATE is not specified then preconsolidation stress (head) and delay bed head values specified in the PACKAGEDATA block are relative to simulated values of the first stress period if steady-state or initial stresses and GWF heads if the first stress period is transient.

- `SPECIFIED_INITIAL_PRECONSOLIDATION_STRESS` keyword to indicate that absolute preconsolidation stresses (heads) will be specified for interbeds defined in the `PACKAGEDATA` block. If `SPECIFIED_INITIAL_PRECONSOLIDATION_STRESS` and `SPECIFIED_INITIAL_INTERBED_STATE` are not specified then preconsolidation stress (head) values specified in the `PACKAGEDATA` block are relative to simulated values if the first stress period is steady-state or initial stresses (heads) if the first stress period is transient.
- `SPECIFIED_INITIAL_DELAY_HEAD` keyword to indicate that absolute initial delay bed head will be specified for interbeds defined in the `PACKAGEDATA` block. If `SPECIFIED_INITIAL_DELAY_HEAD` and `SPECIFIED_INITIAL_INTERBED_STATE` are not specified then delay bed head values specified in the `PACKAGEDATA` block are relative to simulated values if the first stress period is steady-state or initial GWF heads if the first stress period is transient.
- `EFFECTIVE_STRESS_LAG` keyword to indicate the effective stress from the previous time step will be used to calculate specific storage values. This option can 1) help with convergence in models with thin cells and water table elevations close to land surface; 2) is identical to the approach used in the SUBWT package for MODFLOW-2005; and 3) is only used if the effective-stress formulation is being used. By default, current effective stress values are used to calculate specific storage values.
- `STRAIN_CSV_INTERBED` keyword to specify the record that corresponds to final interbed strain output.
- `FILEOUT` keyword to specify that an output filename is expected next.
- `interbedstrain_filename` name of the comma-separated-values output file to write final interbed strain information.
- `STRAIN_CSV_COARSE` keyword to specify the record that corresponds to final coarse-grained material strain output.
- `coarsestrain_filename` name of the comma-separated-values output file to write final coarse-grained material strain information.
- `COMPACTION` keyword to specify that record corresponds to the compaction.
- `compaction_filename` name of the binary output file to write compaction information.
- `COMPACTION_ELASTIC` keyword to specify that record corresponds to the elastic interbed compaction binary file.
- `elastic_compaction_filename` name of the binary output file to write elastic interbed compaction information.
- `COMPACTION_INELASTIC` keyword to specify that record corresponds to the inelastic interbed compaction binary file.
- `inelastic_compaction_filename` name of the binary output file to write inelastic interbed compaction information.
- `COMPACTION_INTERBED` keyword to specify that record corresponds to the interbed compaction binary file.
- `interbed_compaction_filename` name of the binary output file to write interbed compaction information.
- `COMPACTION_COARSE` keyword to specify that record corresponds to the elastic coarse-grained material compaction binary file.
- `coarse_compaction_filename` name of the binary output file to write elastic coarse-grained material compaction information.
- `ZDISPLACEMENT` keyword to specify that record corresponds to the z-displacement binary file.
- `zdisplacement_filename` name of the binary output file to write z-displacement information.
- `PACKAGE_CONVERGENCE` keyword to specify that record corresponds to the package convergence comma spaced values file.

- `package_convergence_filename` name of the comma spaced values output file to write package convergence information.
- `TS6` keyword to specify that record corresponds to a time-series file.
- `FILEIN` keyword to specify that an input filename is expected next.
- `ts6_filename` defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- `OBS6` keyword to specify that record corresponds to an observations file.
- `obs6_filename` name of input file to define observations for the CSUB package. See the “Observation utility” section for instructions for preparing observation input files. Tables `ref{table:gwf-obstypetable}` and `ref{table:gwt-obstypetable}` lists observation type(s) supported by the CSUB package.

Block: DIMENSIONS

- `ninterbeds` is the number of CSUB interbed systems. More than 1 CSUB interbed systems can be assigned to a GWF cell; however, only 1 GWF cell can be assigned to a single CSUB interbed system.
- `maxsig0` is the maximum number of cells that can have a specified stress offset. More than 1 stress offset can be assigned to a GWF cell. By default, `MAXSIG0` is 0.

Block: GRIDDATA

- `cg_ske_cr` is the initial elastic coarse-grained material specific storage or recompression index. The recompression index is specified if `COMPRESSION_INDICES` is specified in the `OPTIONS` block. Specified or calculated elastic coarse-grained material specific storage values are not adjusted from initial values if `HEAD_BASED` is specified in the `OPTIONS` block.
- `cg_theta` is the initial porosity of coarse-grained materials.
- `sgm` is the specific gravity of moist or unsaturated sediments. If not specified, then a default value of 1.7 is assigned.
- `sgs` is the specific gravity of saturated sediments. If not specified, then a default value of 2.0 is assigned.

Block: PACKAGEDATA

- `icsubno` integer value that defines the CSUB interbed number associated with the specified `PACKAGEDATA` data on the line. `CSUBNO` must be greater than zero and less than or equal to `NINTERBEDS`. CSUB information must be specified for every CSUB cell or the program will terminate with an error. The program will also terminate with an error if information for a CSUB interbed number is specified more than once.
- `cellid` is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the `DIS` input file, `CELLID` is the layer, row, and column. For a grid that uses the `DISV` input file, `CELLID` is the layer and `CELL2D` number. If the model uses the unstructured discretization (`DISU`) input file, `CELLID` is the node number for the cell.
- `cdelay` character string that defines the subsidence delay type for the interbed. Possible subsidence package `CDELAY` strings include: `NODELAY`—character keyword to indicate that delay will not be simulated in the interbed. `DELAY`—character keyword to indicate that delay will be simulated in the interbed.

- `pcs0` is the initial offset from the calculated initial effective stress or initial preconsolidation stress in the interbed, in units of height of a column of water. `PCS0` is the initial preconsolidation stress if `SPECIFIED_INITIAL_INTERBED_STATE` or `SPECIFIED_INITIAL_PRECONSOLIDATION_STRESS` are specified in the `OPTIONS` block. If `HEAD_BASED` is specified in the `OPTIONS` block, `PCS0` is the initial offset from the calculated initial head or initial preconsolidation head in the `CSUB` interbed and the initial preconsolidation stress is calculated from the calculated initial effective stress or calculated initial geostatic stress, respectively.
- `thick_frac` is the interbed thickness or cell fraction of the interbed. Interbed thickness is specified as a fraction of the cell thickness if `CELL_FRACTION` is specified in the `OPTIONS` block.
- `rnb` is the interbed material factor equivalent number of interbeds in the interbed system represented by the interbed. `RNB` must be greater than or equal to 1 if `CDELAY` is `DELAY`. Otherwise, `RNB` can be any value.
- `ssv_cc` is the initial inelastic specific storage or compression index of the interbed. The compression index is specified if `COMPRESSION_INDICES` is specified in the `OPTIONS` block. Specified or calculated interbed inelastic specific storage values are not adjusted from initial values if `HEAD_BASED` is specified in the `OPTIONS` block.
- `sse_cr` is the initial elastic coarse-grained material specific storage or recompression index of the interbed. The recompression index is specified if `COMPRESSION_INDICES` is specified in the `OPTIONS` block. Specified or calculated interbed elastic specific storage values are not adjusted from initial values if `HEAD_BASED` is specified in the `OPTIONS` block.
- `theta` is the initial porosity of the interbed.
- `kv` is the vertical hydraulic conductivity of the delay interbed. `KV` must be greater than 0 if `CDELAY` is `DELAY`. Otherwise, `KV` can be any value.
- `h0` is the initial offset from the head in cell `cellid` or the initial head in the delay interbed. `H0` is the initial head in the delay bed if `SPECIFIED_INITIAL_INTERBED_STATE` or `SPECIFIED_INITIAL_DELAY_HEAD` are specified in the `OPTIONS` block. `H0` can be any value if `CDELAY` is `NODELAY`.
- `boundname` name of the `CSUB` cell. `BOUNDNAME` is an ASCII character variable that can contain as many as 40 characters. If `BOUNDNAME` contains spaces in it, then the entire name must be enclosed within single quotes.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the `PERIOD` block apply. `IPER` must be less than or equal to `NPER` in the `TDIS` Package and greater than zero. The `IPER` value assigned to a stress period block must be greater than the `IPER` value assigned for the previous `PERIOD` block. The information specified in the `PERIOD` block will continue to apply for all subsequent stress periods, unless the program encounters another `PERIOD` block.
- `cellid` is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the `DIS` input file, `CELLID` is the layer, row, and column. For a grid that uses the `DISV` input file, `CELLID` is the layer and `CELL2D` number. If the model uses the unstructured discretization (`DISU`) input file, `CELLID` is the node number for the cell.
- `sig0` is the stress offset for the cell. `SIG0` is added to the calculated geostatic stress for the cell. `SIG0` is specified only if `MAXSIG0` is specified to be greater than 0 in the `DIMENSIONS` block. If the `Options` block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

Example Input File

```

BEGIN OPTIONS
  COMPRESSION_INDICES
  SPECIFIED_INITIAL_INTERBED_STATE
  BOUNDNAMES
  SAVE_FLOWS
END OPTIONS

BEGIN DIMENSIONS
  NINTERBEDS 4
  MAXSIG0 1
END DIMENSIONS

BEGIN GRIDDATA
  # compression indices of coarse grained aquifer materials
  cg_ske_cr LAYERED
    CONSTANT 0.01
    CONSTANT 0.01
    CONSTANT 0.01
    CONSTANT 0.01
  # porosity of coarse grained aquifer materials
  cg_theta LAYERED
    CONSTANT 0.45
    CONSTANT 0.45
    CONSTANT 0.45
    CONSTANT 0.45
  # specific gravity of saturated sediment
  SGS LAYERED
    CONSTANT 2.0
    CONSTANT 2.0
    CONSTANT 2.0
    CONSTANT 2.0
  # specific gravity of moist sediment
  SGM LAYERED
    CONSTANT 1.7
    CONSTANT 1.7
    CONSTANT 1.7
    CONSTANT 1.7
END GRIDDATA

BEGIN PACKAGEDATA
  # icsub sno cellid cdelay pcs0 thick_frac rnb ssv_cc sse_cr theta kv h0_
  ↳boundname      1 1 1 6 delay 15.0 0.450 1.0 0.25 0.01 0.45 0.1 15.
  ↳nsystem0      2 1 1 7 nodelay 15.0 0.450 1.0 0.25 0.01 0.45 0.0 0.0
  ↳nsystem1      3 1 1 8 nodelay 15.0 0.450 1.0 0.25 0.01 0.45 0.0 0.0
  ↳nsystem1      4 1 1 9 delay 15.0 0.450 1.0 0.25 0.01 0.45 0.1 15.
  ↳nsystem2
END PACKAGEDATA

BEGIN PERIOD 1
  # stress offset for stress period 1
  1 1 6 1700.00000000
END PERIOD

```

Available Observation Types

Example Observation Input File

```
BEGIN CONTINUOUS FILEOUT my_model.csub.csv
  tcomp3      compaction-cell      1 1 7
  ibcensystem0 elastic-compaction   nsystem0
  ibcinsystem0 inelastic-compaction nsystem0
END CONTINUOUS
```

1.3.5 GWF-DIS

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [LENGTH_UNITS <length_units>]
  [NOGRB]
  [XORIGIN <xorigin>]
  [YORIGIN <yorigin>]
  [ANGROT <angrot>]
END OPTIONS
```

```
BEGIN DIMENSIONS
  NLAY <nlay>
  NROW <nrow>
  NCOL <ncol>
END DIMENSIONS
```

```
BEGIN GRIDDATA
  DELR
    <delr(ncol)> -- READARRAY
  DELC
    <delc(nrow)> -- READARRAY
  TOP
    <top(ncol, nrow)> -- READARRAY
  BOTM [LAYERED]
    <botm(ncol, nrow, nlay)> -- READARRAY
  [IDOMAIN [LAYERED]
    <idomain(ncol, nrow, nlay)> -- READARRAY]
END GRIDDATA
```

Explanation of Variables

Block: OPTIONS

- `length_units` is the length units used for this model. Values can be “FEET”, “METERS”, or “CENTIMETERS”. If not specified, the default is “UNKNOWN”.
- `NOGRB` keyword to deactivate writing of the binary grid file.

- `xorigin` x-position of the lower-left corner of the model grid. A default value of zero is assigned if not specified. The value for `XORIGIN` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- `yorigin` y-position of the lower-left corner of the model grid. If not specified, then a default value equal to zero is used. The value for `YORIGIN` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- `angrot` counter-clockwise rotation angle (in degrees) of the lower-left corner of the model grid. If not specified, then a default value of 0.0 is assigned. The value for `ANGROT` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.

Block: DIMENSIONS

- `nlay` is the number of layers in the model grid.
- `nrow` is the number of rows in the model grid.
- `ncol` is the number of columns in the model grid.

Block: GRIDDATA

- `delr` is the column spacing in the row direction.
- `delc` is the row spacing in the column direction.
- `top` is the top elevation for each cell in the top model layer.
- `botm` is the bottom elevation for each cell.
- `idomain` is an optional array that characterizes the existence status of a cell. If the `IDOMAIN` array is not specified, then all model cells exist within the solution. If the `IDOMAIN` value for a cell is 0, the cell does not exist in the simulation. Input and output values will be read and written for the cell, but internal to the program, the cell is excluded from the solution. If the `IDOMAIN` value for a cell is 1 or greater, the cell exists in the simulation. If the `IDOMAIN` value for a cell is -1, the cell does not exist in the simulation. Furthermore, the first existing cell above will be connected to the first existing cell below. This type of cell is referred to as a “vertical pass through” cell.

Example Input File

Example 1

```
#The OPTIONS block is optional
BEGIN OPTIONS
  LENGTH_UNITS METERS
END OPTIONS

#The DIMENSIONS block is required
BEGIN DIMENSIONS
  NLAY 10
  NROW 1
  NCOL 21
END DIMENSIONS

#The GRIDDATA block is required
BEGIN GRIDDATA
```

(continues on next page)

(continued from previous page)

```

DELR
  INTERNAL FACTOR 1.
    .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 0.01
DELC
  CONSTANT 1.0
TOP LAYERED
  CONSTANT 1.
BOTM LAYERED
  CONSTANT 0.9
  CONSTANT 0.8
  CONSTANT 0.7
  CONSTANT 0.6
  CONSTANT 0.5
  CONSTANT 0.4
  CONSTANT 0.3
  CONSTANT 0.2
  CONSTANT 0.1
  CONSTANT 0.0
END GRIDDATA

```

Example 2

```

BEGIN OPTIONS
  LENGTH_UNITS METERS
END OPTIONS

BEGIN DIMENSIONS
  NODES 9
  NJA 33
END DIMENSIONS

BEGIN GRIDDATA
  TOP
    CONSTANT 0.
  BOT
    CONSTANT -10
  AREA
    INTERNAL FACTOR 1
      10000 10000 10000 10000 10000 10000 10000 10000 10000
END GRIDDATA

BEGIN CONNECTIONDATA
  IHC
    CONSTANT 1
  IAC
    INTERNAL FACTOR 1
      3 4 3 4 5 4 3 4 3
  JA
    INTERNAL FACTOR 1
      1 2 4
      2 1 3 5
      3 2 6
      4 1 5 7
      5 2 4 6 8
      6 3 5 9
      7 4 8
      8 5 7 9

```

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```

    9 6 8
  CL12
    INTERNAL FACTOR 1
    0 50 50
    0 50 50 50
    0 50 50
    0 50 50 50
    0 50 50 50 50
    0 50 50 50
    0 50 50
    0 50 50 50
    0 50 50
  HWVA
    INTERNAL FACTOR 1
    0 100 100
    0 100 100 100
    0 100 100
    0 100 100 100
    0 100 100 100 100
    0 100 100 100
    0 100 100
    0 100 100 100
    0 100 100
  END CONNECTIONDATA

```

Example 3

```

#The OPTIONS block is optional
BEGIN OPTIONS
  LENGTH_UNITS METERS
END OPTIONS

#The DIMENSIONS block is required
BEGIN DIMENSIONS
  NCPL 4
  NLAY 3
  NVERT 9
END DIMENSIONS

#The GRIDDATA block is required
BEGIN GRIDDATA
  TOP
    CONSTANT 3.0
  BOTM LAYERED
    CONSTANT 2.0
    CONSTANT 1.0
    CONSTANT 0.0
  IDOMAIN LAYERED
    INTERNAL FACTOR 1
    1 1 1 0
    CONSTANT 1
    CONSTANT 1
  END GRIDDATA

#The VERTICES block is required
BEGIN VERTICES
  1 0. 1.

```

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```

2 .5 1.
3 1. 1.
4 0 .5
5 .5 .5
6 1. .5
7 0. 0.
8 .5 0.
9 1. 0.
END VERTICES

BEGIN CELL2D
1 .25 .75 4 1 2 5 4
2 .75 .75 4 2 3 6 5
3 .25 .25 4 4 5 8 7
4 .75 .25 4 5 6 9 8
END CELL2D

```

1.3.6 GWF-DISU

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN OPTIONS
  [LENGTH_UNITS <length_units>]
  [NOGRB]
  [XORIGIN <xorigin>]
  [YORIGIN <yorigin>]
  [ANGROT <angrot>]
  [VERTICAL_OFFSET_TOLERANCE <vertical_offset_tolerance>]
END OPTIONS

```

```

BEGIN DIMENSIONS
  NODES <nodes>
  NJA <nja>
  [NVERT <nvert>]
END DIMENSIONS

```

```

BEGIN GRIDDATA
  TOP
    <top(nodes)> -- READARRAY
  BOT
    <bot(nodes)> -- READARRAY
  AREA
    <area(nodes)> -- READARRAY
  [IDOMAIN
    <idomain(nodes)> -- READARRAY]
END GRIDDATA

```

```

BEGIN CONNECTIONDATA
  IAC
    <iac(nodes)> -- READARRAY
  JA

```

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```

        <j a(nja)> -- READARRAY
IHC
        <i hc(nja)> -- READARRAY
CL12
        <cl12(nja)> -- READARRAY
HWVA
        <hwva(nja)> -- READARRAY
[ANGLDEGX
        <angldegx(nja)> -- READARRAY]
END CONNECTIONDATA

```

```

BEGIN VERTICES
    <i v> <xv> <yv>
    <i v> <xv> <yv>
    ...
END VERTICES

```

```

BEGIN CELL2D
    <i cell12d> <xc> <yc> <ncvert> <icvert(ncvert)>
    <i cell12d> <xc> <yc> <ncvert> <icvert(ncvert)>
    ...
END CELL2D

```

Explanation of Variables

Block: OPTIONS

- `length_units` is the length units used for this model. Values can be “FEET”, “METERS”, or “CENTIMETERS”. If not specified, the default is “UNKNOWN”.
- `NOGRB` keyword to deactivate writing of the binary grid file.
- `xorigin` x-position of the origin used for model grid vertices. This value should be provided in a real-world coordinate system. A default value of zero is assigned if not specified. The value for `XORIGIN` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- `yorigin` y-position of the origin used for model grid vertices. This value should be provided in a real-world coordinate system. If not specified, then a default value equal to zero is used. The value for `YORIGIN` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- `angrot` counter-clockwise rotation angle (in degrees) of the model grid coordinate system relative to a real-world coordinate system. If not specified, then a default value of 0.0 is assigned. The value for `ANGROT` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- `vertical_offset_tolerance` checks are performed to ensure that the top of a cell is not higher than the bottom of an overlying cell. This option can be used to specify the tolerance that is used for checking. If top of a cell is above the bottom of an overlying cell by a value less than this tolerance, then the program will terminate with an error. The default value is zero. This option should generally not be used.

Block: DIMENSIONS

- `nodes` is the number of cells in the model grid.

- `nja` is the sum of the number of connections and `NODES`. When calculating the total number of connections, the connection between cell `n` and cell `m` is considered to be different from the connection between cell `m` and cell `n`. Thus, `NJA` is equal to the total number of connections, including `n` to `m` and `m` to `n`, and the total number of cells.
- `nvert` is the total number of (x, y) vertex pairs used to define the plan-view shape of each cell in the model grid. If `NVERT` is not specified or is specified as zero, then the `VERTICES` and `CELL2D` blocks below are not read. `NVERT` and the accompanying `VERTICES` and `CELL2D` blocks should be specified for most simulations. If the `XT3D` or `SAVE_SPECIFIC_DISCHARGE` options are specified in the `NPF` Package, then this information is required.

Block: GRIDDATA

- `top` is the top elevation for each cell in the model grid.
- `bot` is the bottom elevation for each cell.
- `area` is the cell surface area (in plan view).
- `idomain` is an optional array that characterizes the existence status of a cell. If the `IDOMAIN` array is not specified, then all model cells exist within the solution. If the `IDOMAIN` value for a cell is 0, the cell does not exist in the simulation. Input and output values will be read and written for the cell, but internal to the program, the cell is excluded from the solution. If the `IDOMAIN` value for a cell is 1 or greater, the cell exists in the simulation. `IDOMAIN` values of -1 cannot be specified for the `DISU` Package.

Block: CONNECTIONDATA

- `iac` is the number of connections (plus 1) for each cell. The sum of all the entries in `IAC` must be equal to `NJA`.
- `ja` is a list of cell number (`n`) followed by its connecting cell numbers (`m`) for each of the `m` cells connected to cell `n`. The number of values to provide for cell `n` is `IAC(n)`. This list is sequentially provided for the first to the last cell. The first value in the list must be cell `n` itself, and the remaining cells must be listed in an increasing order (sorted from lowest number to highest). Note that the cell and its connections are only supplied for the `GWF` cells and their connections to the other `GWF` cells. Also note that the `JA` list input may be divided such that every node and its connectivity list can be on a separate line for ease in readability of the file. To further ease readability of the file, the node number of the cell whose connectivity is subsequently listed, may be expressed as a negative number, the sign of which is subsequently converted to positive by the code.
- `ihc` is an index array indicating the direction between node `n` and all of its `m` connections. If `IHC = 0` then cell `n` and cell `m` are connected in the vertical direction. Cell `n` overlies cell `m` if the cell number for `n` is less than `m`; cell `m` overlies cell `n` if the cell number for `m` is less than `n`. If `IHC = 1` then cell `n` and cell `m` are connected in the horizontal direction. If `IHC = 2` then cell `n` and cell `m` are connected in the horizontal direction, and the connection is vertically staggered. A vertically staggered connection is one in which a cell is horizontally connected to more than one cell in a horizontal connection.
- `cl12` is the array containing connection lengths between the center of cell `n` and the shared face with each adjacent `m` cell.
- `hwva` is a symmetric array of size `NJA`. For horizontal connections, entries in `HWVA` are the horizontal width perpendicular to flow. For vertical connections, entries in `HWVA` are the vertical area for flow. Thus, values in the `HWVA` array contain dimensions of both length and area. Entries in the `HWVA` array have a one-to-one correspondence with the connections specified in the `JA` array. Likewise, there is a one-to-one correspondence between entries in the `HWVA` array and entries in the `IHC` array, which specifies the connection type (horizontal or vertical). Entries in the `HWVA` array must be symmetric; the program will terminate with an error if the value for `HWVA` for an `n` to `m` connection does not equal the value for `HWVA` for the corresponding `n` to `m` connection.

- `angldegx` is the angle (in degrees) between the horizontal x-axis and the outward normal to the face between a cell and its connecting cells. The angle varies between zero and 360.0 degrees, where zero degrees points in the positive x-axis direction, and 90 degrees points in the positive y-axis direction. `ANGLDEGX` is only needed if horizontal anisotropy is specified in the NPF Package, if the XT3D option is used in the NPF Package, or if the `SAVE_SPECIFIC_DISCHARGE` option is specified in the NPF Package. `ANGLDEGX` does not need to be specified if these conditions are not met. `ANGLDEGX` is of size `NJA`; values specified for vertical connections and for the diagonal position are not used. Note that `ANGLDEGX` is read in degrees, which is different from MODFLOW-USG, which reads a similar variable (`ANGLEX`) in radians.

Block: VERTICES

- `iv` is the vertex number. Records in the VERTICES block must be listed in consecutive order from 1 to `NVERT`.
- `xv` is the x-coordinate for the vertex.
- `yv` is the y-coordinate for the vertex.

Block: CELL2D

- `icell2d` is the cell2d number. Records in the CELL2D block must be listed in consecutive order from 1 to `NODES`.
- `xc` is the x-coordinate for the cell center.
- `yc` is the y-coordinate for the cell center.
- `nvert` is the number of vertices required to define the cell. There may be a different number of vertices for each cell.
- `icvert` is an array of integer values containing vertex numbers (in the VERTICES block) used to define the cell. Vertices must be listed in clockwise order.

Example Input File

```
BEGIN OPTIONS
  LENGTH_UNITS METERS
END OPTIONS

BEGIN DIMENSIONS
  NODES 9
  NJA 33
END DIMENSIONS

BEGIN GRIDDATA
  TOP
    CONSTANT 0.
  BOT
    CONSTANT -10
  AREA
    INTERNAL FACTOR 1
    10000 10000 10000 10000 10000 10000 10000 10000 10000
END GRIDDATA

BEGIN CONNECTIONDATA
  IHC
```

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```

      CONSTANT 1
IAC
      INTERNAL FACTOR 1
      3 4 3 4 5 4 3 4 3
JA
      INTERNAL FACTOR 1
      1 2 4
      2 1 3 5
      3 2 6
      4 1 5 7
      5 2 4 6 8
      6 3 5 9
      7 4 8
      8 5 7 9
      9 6 8
CL12
      INTERNAL FACTOR 1
      0 50 50
      0 50 50 50
      0 50 50
      0 50 50 50
      0 50 50 50 50
      0 50 50 50
      0 50 50
      0 50 50 50
      0 50 50
HWVA
      INTERNAL FACTOR 1
      0 100 100
      0 100 100 100
      0 100 100
      0 100 100 100
      0 100 100 100 100
      0 100 100 100
      0 100 100
      0 100 100 100
      0 100 100
END CONNECTIONDATA

```

1.3.7 GWF-DISV

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN OPTIONS
  [LENGTH_UNITS <length_units>]
  [NOGRB]
  [XORIGIN <xorigin>]
  [YORIGIN <yorigin>]
  [ANGROT <angrot>]
END OPTIONS

```

```

BEGIN DIMENSIONS
  NLAY <nlay>
  NCPL <ncpl>
  NVERT <nvert>
END DIMENSIONS

```

```

BEGIN GRIDDATA
  TOP
    <top(ncpl)> -- READARRAY
  BOTM [LAYERED]
    <botm(nlay, ncpl)> -- READARRAY
  [IDOMAIN [LAYERED]
    <idomain(nlay, ncpl)> -- READARRAY]
END GRIDDATA

```

```

BEGIN VERTICES
  <iv> <xv> <yv>
  <iv> <xv> <yv>
  ...
END VERTICES

```

```

BEGIN CELL2D
  <icell2d> <xc> <yc> <ncvert> <icvert(ncvert)>
  <icell2d> <xc> <yc> <ncvert> <icvert(ncvert)>
  ...
END CELL2D

```

Explanation of Variables

Block: OPTIONS

- `length_units` is the length units used for this model. Values can be “FEET”, “METERS”, or “CENTIMETERS”. If not specified, the default is “UNKNOWN”.
- `NOGRB` keyword to deactivate writing of the binary grid file.
- `xorigin` x-position of the origin used for model grid vertices. This value should be provided in a real-world coordinate system. A default value of zero is assigned if not specified. The value for `XORIGIN` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- `yorigin` y-position of the origin used for model grid vertices. This value should be provided in a real-world coordinate system. If not specified, then a default value equal to zero is used. The value for `YORIGIN` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- `angrot` counter-clockwise rotation angle (in degrees) of the model grid coordinate system relative to a real-world coordinate system. If not specified, then a default value of 0.0 is assigned. The value for `ANGROT` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.

Block: DIMENSIONS

- `nlay` is the number of layers in the model grid.

- `ncpl` is the number of cells per layer. This is a constant value for the grid and it applies to all layers.
- `nvert` is the total number of (x, y) vertex pairs used to characterize the horizontal configuration of the model grid.

Block: GRIDDATA

- `top` is the top elevation for each cell in the top model layer.
- `botm` is the bottom elevation for each cell.
- `idomain` is an optional array that characterizes the existence status of a cell. If the IDOMAIN array is not specified, then all model cells exist within the solution. If the IDOMAIN value for a cell is 0, the cell does not exist in the simulation. Input and output values will be read and written for the cell, but internal to the program, the cell is excluded from the solution. If the IDOMAIN value for a cell is 1 or greater, the cell exists in the simulation. If the IDOMAIN value for a cell is -1, the cell does not exist in the simulation. Furthermore, the first existing cell above will be connected to the first existing cell below. This type of cell is referred to as a “vertical pass through” cell.

Block: VERTICES

- `iv` is the vertex number. Records in the VERTICES block must be listed in consecutive order from 1 to NVERT.
- `xv` is the x-coordinate for the vertex.
- `yv` is the y-coordinate for the vertex.

Block: CELL2D

- `icell2d` is the CELL2D number. Records in the CELL2D block must be listed in consecutive order from the first to the last.
- `xc` is the x-coordinate for the cell center.
- `yc` is the y-coordinate for the cell center.
- `nvert` is the number of vertices required to define the cell. There may be a different number of vertices for each cell.
- `icvert` is an array of integer values containing vertex numbers (in the VERTICES block) used to define the cell. Vertices must be listed in clockwise order. Cells that are connected must share vertices.

Example Input File

```
#The OPTIONS block is optional
BEGIN OPTIONS
  LENGTH_UNITS METERS
END OPTIONS

#The DIMENSIONS block is required
BEGIN DIMENSIONS
  NCPL 4
  NLAY 3
  NVERT 9
END DIMENSIONS
```

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#The GRIDDATA block is required

```

BEGIN GRIDDATA
  TOP
    CONSTANT 3.0
  BOTM LAYERED
    CONSTANT 2.0
    CONSTANT 1.0
    CONSTANT 0.0
  IDOMAIN LAYERED
    INTERNAL FACTOR 1
      1 1 1 0
    CONSTANT 1
    CONSTANT 1
END GRIDDATA

```

#The VERTICES block is required

```

BEGIN VERTICES
  1 0. 1.
  2 .5 1.
  3 1. 1.
  4 0 .5
  5 .5 .5
  6 1. .5
  7 0. 0.
  8 .5 0.
  9 1. 0.
END VERTICES

```

```

BEGIN CELL2D
  1 .25 .75 4 1 2 5 4
  2 .75 .75 4 2 3 6 5
  3 .25 .25 4 4 5 8 7
  4 .75 .25 4 5 6 9 8
END CELL2D

```

1.3.8 GWF-DRN

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN OPTIONS
  [AUXILIARY <auxiliary(naux)>]
  [AUXMULTNAME <auxmultname>]
  [AUXDEPTHNAME <auxdepthname>]
  [BOUNDNAMES]
  [PRINT_INPUT]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [TS6 FILEIN <ts6_filename>]
  [OBS6 FILEIN <obs6_filename>]
  [MOVER]
END OPTIONS

```

```
BEGIN DIMENSIONS
  MAXBOUND <maxbound>
END DIMENSIONS
```

FOR ANY STRESS PERIOD

```
BEGIN PERIOD <iper>
  <cellid(ncelldim)> <elev> <cond> [<aux(naux)>] [<boundname>]
  <cellid(ncelldim)> <elev> <cond> [<aux(naux)>] [<boundname>]
  ...
END PERIOD
```

Explanation of Variables

Block: OPTIONS

- **auxiliary** defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for **naux**. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** name of auxiliary variable to be used as multiplier of drain conductance.
- **auxdepthname** name of a variable listed in AUXILIARY that defines the depth at which drainage discharge will be scaled. If a positive value is specified for the AUXDEPTHNAME AUXILIARY variable, then ELEV is the elevation at which the drain starts to discharge and ELEV + DDRN (assuming DDRN is the AUXDEPTHNAME variable) is the elevation when the drain conductance (COND) scaling factor is 1. If a negative drainage depth value is specified for DDRN, then ELEV + DDRN is the elevation at which the drain starts to discharge and ELEV is the elevation when the conductance (COND) scaling factor is 1. A linear- or cubic-scaling is used to scale the drain conductance (COND) when the Standard or Newton-Raphson Formulation is used, respectively.
- **BOUNDNAMES** keyword to indicate that boundary names may be provided with the list of drain cells.
- **PRINT_INPUT** keyword to indicate that the list of drain information will be written to the listing file immediately after it is read.
- **PRINT_FLOWS** keyword to indicate that the list of drain flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- **SAVE_FLOWS** keyword to indicate that drain flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- **TS6** keyword to specify that record corresponds to a time-series file.
- **FILEIN** keyword to specify that an input filename is expected next.
- **ts6_filename** defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- **OBS6** keyword to specify that record corresponds to an observations file.

- `obs6_filename` name of input file to define observations for the Drain package. See the “Observation utility” section for instructions for preparing observation input files. Tables `ref{table:gwf-obstypetable}` and `ref{table:gwt-obstypetable}` lists observation type(s) supported by the Drain package.
- `MOVER` keyword to indicate that this instance of the Drain Package can be used with the Water Mover (MVR) Package. When the `MOVER` option is specified, additional memory is allocated within the package to store the available, provided, and received water.

Block: DIMENSIONS

- `maxbound` integer value specifying the maximum number of drains cells that will be specified for use during any stress period.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. `IPER` must be less than or equal to `NPEN` in the TDIS Package and greater than zero. The `IPER` value assigned to a stress period block must be greater than the `IPER` value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- `cellid` is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, `CELLID` is the layer, row, and column. For a grid that uses the DISV input file, `CELLID` is the layer and `CELL2D` number. If the model uses the unstructured discretization (DISU) input file, `CELLID` is the node number for the cell.
- `elev` is the elevation of the drain. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `cond` is the hydraulic conductance of the interface between the aquifer and the drain. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `aux` represents the values of the auxiliary variables for each drain. The values of auxiliary variables must be present for each drain. The values must be specified in the order of the auxiliary variables specified in the `OPTIONS` block. If the package supports time series and the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `boundname` name of the drain cell. `BOUNDNAME` is an ASCII character variable that can contain as many as 40 characters. If `BOUNDNAME` contains spaces in it, then the entire name must be enclosed within single quotes.

Example Input File

```
#The OPTIONS block is optional
BEGIN OPTIONS
  BOUNDNAMES
  PRINT_INPUT
  PRINT_FLOWS
  SAVE_FLOWS
END OPTIONS
```

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```
#The DIMENSIONS block is required
BEGIN DIMENSIONS
  MAXBOUND 5
END DIMENSIONS

#The following block of drains will be activated for for the entire stress period
BEGIN PERIOD 1
  #node elevation conductance boundname
    73      10.2      1000.      my_drn
    76      10.2      1000.      my_drn
    79      10.2      1000.      my_drn
    80      10.2      1000.      my_drn
    81      10.2      1000.      my_drn
END PERIOD
```

Available Observation Types

Example Observation Input File

```
BEGIN OPTIONS
  DIGITS 8
  PRINT_INPUT
END OPTIONS

BEGIN CONTINUOUS FILEOUT my_model.drn01.csv
#  obsname      obstype      ID
  drn_73        DRN          73
  drn_79        DRN          79
END CONTINUOUS

BEGIN CONTINUOUS FILEOUT my_model.drn02.csv
#  obsname      obstype      ID
  drn_80        DRN          80
  drn_all       DRN          my_drn
END CONTINUOUS
```

1.3.9 GWF-EVT

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [FIXED_CELL]
  [AUXILIARY <auxiliary(naux)>]
  [AUXMULTNAME <auxmultname>]
  [BOUNDNAMES]
  [PRINT_INPUT]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [TS6 FILEIN <ts6_filename>]
  [OBS6 FILEIN <obs6_filename>]
```

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```
[SURF_RATE_SPECIFIED]
END OPTIONS
```

```
BEGIN DIMENSIONS
  MAXBOUND <maxbound>
  NSEG <nseg>
END DIMENSIONS
```

FOR ANY STRESS PERIOD

```
BEGIN PERIOD <iper>
  <cellid(ncelldim)> <surface> <rate> <depth> <pxdp(nseg-1)> <petm(nseg-1)> [
  →<petm0>] [<aux(naux)>] [<boundname>]
  <cellid(ncelldim)> <surface> <rate> <depth> <pxdp(nseg-1)> <petm(nseg-1)> [
  →<petm0>] [<aux(naux)>] [<boundname>]
  . . .
END PERIOD
```

Explanation of Variables**Block: OPTIONS**

- **FIXED_CELL** indicates that evapotranspiration will not be reassigned to a cell underlying the cell specified in the list if the specified cell is inactive.
- **auxiliary** defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for **naux**. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** name of auxiliary variable to be used as multiplier of evapotranspiration rate.
- **BOUNDNAMES** keyword to indicate that boundary names may be provided with the list of evapotranspiration cells.
- **PRINT_INPUT** keyword to indicate that the list of evapotranspiration information will be written to the listing file immediately after it is read.
- **PRINT_FLOWS** keyword to indicate that the list of evapotranspiration flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- **SAVE_FLOWS** keyword to indicate that evapotranspiration flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- **TS6** keyword to specify that record corresponds to a time-series file.
- **FILEIN** keyword to specify that an input filename is expected next.
- **ts6_filename** defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- **OBS6** keyword to specify that record corresponds to an observations file.

- `obs6_filename` name of input file to define observations for the Evapotranspiration package. See the “Observation utility” section for instructions for preparing observation input files. Tables `ref{table:gwf-obstypetable}` and `ref{table:gwt-obstypetable}` lists observation type(s) supported by the Evapotranspiration package.
- `SURF_RATE_SPECIFIED` indicates that the proportion of the evapotranspiration rate at the ET surface will be specified as `PETM0` in list input.

Block: DIMENSIONS

- `maxbound` integer value specifying the maximum number of evapotranspiration cells that will be specified for use during any stress period.
- `nseg` number of ET segments. Default is one. When `NSEG` is greater than 1, `PXDP` and `PETM` arrays must be specified `NSEG - 1` times each, in order from the uppermost segment down. `PXDP` defines the extinction-depth proportion at the bottom of a segment. `PETM` defines the proportion of the maximum ET flux rate at the bottom of a segment.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. `IPER` must be less than or equal to `NPER` in the TDIS Package and greater than zero. The `IPER` value assigned to a stress period block must be greater than the `IPER` value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- `cellid` is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, `CELLID` is the layer, row, and column. For a grid that uses the DISV input file, `CELLID` is the layer and `CELL2D` number. If the model uses the unstructured discretization (DISU) input file, `CELLID` is the node number for the cell.
- `surface` is the elevation of the ET surface (L). If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `rate` is the maximum ET flux rate (LT-1). If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `depth` is the ET extinction depth (L). If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `pxdp` is the proportion of the ET extinction depth at the bottom of a segment (dimensionless). If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `petm` is the proportion of the maximum ET flux rate at the bottom of a segment (dimensionless). If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `petm0` is the proportion of the maximum ET flux rate that will apply when head is at or above the ET surface (dimensionless). `PETM0` is read only when the `SURF_RATE_SPECIFIED` option is used. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `aux` represents the values of the auxiliary variables for each evapotranspiration. The values of auxiliary variables must be present for each evapotranspiration. The values must be specified in the order of the auxiliary

variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- **boundname** name of the evapotranspiration cell. **BOUNDNAME** is an ASCII character variable that can contain as many as 40 characters. If **BOUNDNAME** contains spaces in it, then the entire name must be enclosed within single quotes.

Example Input File

Example 1

```
# Example for structured model with list-based input
BEGIN OPTIONS
  AUXNAMES Mult
  BOUNDNAMES
  TS6 FILEIN EtRate.ts
  # Note: Time-series file EtRate.ts defines time series et_rate
  AUXMULTNAME Mult
PRINT_INPUT

BEGIN DIMENSIONS
  MAXBOUND 10
END DIMENSIONS

BEGIN PERIOD 1
# Lay Row Col SURFACE RATE DEPTH PXPDI PXPDI2 PETM1 PETM2 Mult Name
  1 1 13 110.0 et_rate 10.0 0.2 0.5 0.3 0.1 0.2 ET-1
  1 2 13 110.0 et_rate 10.0 0.2 0.5 0.3 0.1 0.4 ET-2
  1 3 13 110.0 et_rate 10.0 0.2 0.5 0.3 0.1 0.6 ET-3
  1 4 13 110.0 et_rate 10.0 0.2 0.5 0.3 0.1 0.8 ET-4
  1 5 13 110.0 2.e-2 10.0 0.2 0.5 0.3 0.1 1.0 ET-5
  1 6 13 110.0 2.e-2 10.0 0.2 0.5 0.3 0.1 1.0 ET-6
  1 7 13 110.0 2.e-2 10.0 0.2 0.5 0.3 0.1 0.7 ET-7
  1 8 13 110.0 2.e-2 10.0 0.2 0.5 0.3 0.1 0.5 ET-8
  1 9 13 110.0 2.e-2 10.0 0.2 0.5 0.3 0.1 0.3 ET-9
  1 10 13 110.0 et_rate 10.0 0.2 0.5 0.3 0.1 0.1 ET-10
END PERIOD
```

Example 2

```
BEGIN OPTIONS
  READASARRAYS
  AUXILIARY var1 var2
  PRINT_INPUT
  PRINT_FLOWS
  SAVE_FLOWS
END OPTIONS

BEGIN PERIOD 1
  #For a structured grid, IEVT defaults to model
  # layer 1, so no need to enter IEVT here.

  #ET surface elevation
  SURFACE
    constant 150.0
  #Maximum ET rate
```

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```

RATE
    constant 0.007
    #ET extinction depth
DEPTH
    constant 15.0
    #auxiliary variable (var1) array
var1
    constant 100.0
    #auxiliary variable (var2) array
var2
    constant 0.0
END PERIOD

```

Available Observation Types

Example Observation Input File

```

BEGIN OPTIONS
    PRINT_INPUT
END OPTIONS

BEGIN CONTINUOUS FILEOUT my_model.evt.csv
    et1-1    EVT    1    1    1
    et1-2    EVT    1    1    2
    et2-1    EVT    1    2    1
    et2-2    EVT    1    2    2
    et2-3    EVT    1    2    3
END CONTINUOUS

```

1.3.10 GWF-EVTA

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN OPTIONS
    READASARRAYS
    [FIXED_CELL]
    [AUXILIARY <auxiliary(naux)>]
    [AUXMULTNAME <auxmultname>]
    [PRINT_INPUT]
    [PRINT_FLOWS]
    [SAVE_FLOWS]
    [TAS6 FILEIN <tas6_filename>]
    [OBS6 FILEIN <obs6_filename>]
END OPTIONS

```

FOR ANY STRESS PERIOD

```

BEGIN PERIOD <iper>
    [IEVT
        <ievt(ncol*nrow; ncpl)> -- READARRAY]

```

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```

SURFACE
    <surface(ncol*nrow; ncpl)> -- READARRAY
RATE
    <rate(ncol*nrow; ncpl)> -- READARRAY
DEPTH
    <depth(ncol*nrow; ncpl)> -- READARRAY
AUX(IAUX)
    <aux(iaux)(ncol*nrow; ncpl)> -- READARRAY
END PERIOD

```

Explanation of Variables

Block: OPTIONS

- **READASARRAYS** indicates that array-based input will be used for the Evapotranspiration Package. This keyword must be specified to use array-based input.
- **FIXED_CELL** indicates that evapotranspiration will not be reassigned to a cell underlying the cell specified in the list if the specified cell is inactive.
- **auxiliary** defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for **naux**. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** name of auxiliary variable to be used as multiplier of evapotranspiration rate.
- **PRINT_INPUT** keyword to indicate that the list of evapotranspiration information will be written to the listing file immediately after it is read.
- **PRINT_FLOWS** keyword to indicate that the list of evapotranspiration flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- **SAVE_FLOWS** keyword to indicate that evapotranspiration flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- **TAS6** keyword to specify that record corresponds to a time-array-series file.
- **FILEIN** keyword to specify that an input filename is expected next.
- **tas6_filename** defines a time-array-series file defining a time-array series that can be used to assign time-varying values. See the Time-Variable Input section for instructions on using the time-array series capability.
- **OBS6** keyword to specify that record corresponds to an observations file.
- **obs6_filename** name of input file to define observations for the Evapotranspiration package. See the “Observation utility” section for instructions for preparing observation input files. Tables `ref{table:gwf-obstypetable}` and `ref{table:gw-obsstypetable}` lists observation type(s) supported by the Evapotranspiration package.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. IPER must be less than or equal to NPER in the TDIS Package and greater than zero. The IPER value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- `ievt` IEVT is the layer number that defines the layer in each vertical column where evapotranspiration is applied. If IEVT is omitted, evapotranspiration by default is applied to cells in layer 1. If IEVT is specified, it must be specified as the first variable in the PERIOD block or MODFLOW will terminate with an error.
- `surface` is the elevation of the ET surface (L).
- `rate` is the maximum ET flux rate (LT-1).
- `depth` is the ET extinction depth (L).
- `aux(iaux)` is an array of values for auxiliary variable AUX(IAUX), where `iaux` is a value from 1 to NAUX, and AUX(IAUX) must be listed as part of the auxiliary variables. A separate array can be specified for each auxiliary variable. If an array is not specified for an auxiliary variable, then a value of zero is assigned. If the value specified here for the auxiliary variable is the same as `auxmultname`, then the evapotranspiration rate will be multiplied by this array.

Example Input File

```
BEGIN OPTIONS
  READASARRAYS
  AUXILIARY var1 var2
  PRINT_INPUT
  PRINT_FLOWS
  SAVE_FLOWS
END OPTIONS

BEGIN PERIOD 1
  #For a structured grid, IEVT defaults to model
  # layer 1, so no need to enter IEVT here.

  #ET surface elevation
  SURFACE
    constant 150.0
  #Maximum ET rate
  RATE
    constant 0.007
  #ET extinction depth
  DEPTH
    constant 15.0
  #auxiliary variable (var1) array
  var1
    constant 100.0
  #auxiliary variable (var2) array
  var2
    constant 0.0
END PERIOD
```


1.3.11 GWF-GHB

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [AUXILIARY <auxiliary(naux)>]
  [AUXMULTNAME <auxmultname>]
  [BOUNDNAMES]
  [PRINT_INPUT]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [TS6 FILEIN <ts6_filename>]
  [OBS6 FILEIN <obs6_filename>]
  [MOVER]
END OPTIONS
```

```
BEGIN DIMENSIONS
  MAXBOUND <maxbound>
END DIMENSIONS
```

FOR ANY STRESS PERIOD

```
BEGIN PERIOD <iper>
  <cellid(ncelldim)> <bhead> <cond> [<aux(naux)>] [<boundname>]
  <cellid(ncelldim)> <bhead> <cond> [<aux(naux)>] [<boundname>]
  ...
END PERIOD
```

Explanation of Variables

Block: OPTIONS

- **auxiliary** defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for **naux**. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** name of auxiliary variable to be used as multiplier of general-head boundary conductance.
- **BOUNDNAMES** keyword to indicate that boundary names may be provided with the list of general-head boundary cells.
- **PRINT_INPUT** keyword to indicate that the list of general-head boundary information will be written to the listing file immediately after it is read.
- **PRINT_FLOWS** keyword to indicate that the list of general-head boundary flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- **SAVE_FLOWS** keyword to indicate that general-head boundary flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.

- **TS6** keyword to specify that record corresponds to a time-series file.
- **FILEIN** keyword to specify that an input filename is expected next.
- **ts6_filename** defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- **OBS6** keyword to specify that record corresponds to an observations file.
- **obs6_filename** name of input file to define observations for the General-Head Boundary package. See the “Observation utility” section for instructions for preparing observation input files. Tables [ref{table:gwf-obstypetable}](#) and [ref{table:gwt-obstypetable}](#) lists observation type(s) supported by the General-Head Boundary package.
- **MOVER** keyword to indicate that this instance of the General-Head Boundary Package can be used with the Water Mover (MVR) Package. When the MOVER option is specified, additional memory is allocated within the package to store the available, provided, and received water.

Block: DIMENSIONS

- **maxbound** integer value specifying the maximum number of general-head boundary cells that will be specified for use during any stress period.

Block: PERIOD

- **iper** integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. IPER must be less than or equal to NPER in the TDIS Package and greater than zero. The IPER value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- **cellid** is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell.
- **bhead** is the boundary head. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- **cond** is the hydraulic conductance of the interface between the aquifer cell and the boundary. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- **aux** represents the values of the auxiliary variables for each general-head boundary. The values of auxiliary variables must be present for each general-head boundary. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- **boundname** name of the general-head boundary cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

Example Input File

```

BEGIN OPTIONS
  PRINT_INPUT (echo input to listing file)
  PRINT_FLOWS (print the flows to the listing file)
  TS6 FILEIN tides.ts
  BOUNDNAMES
END OPTIONS

# Dimensions block
BEGIN DIMENSIONS
  MAXBOUND 15
END DIMENSIONS

# Stress period block(s)
BEGIN PERIOD 1
#Lay Row Col Bhead Cond boundname
  2 1 10 tides 15.0 Estuary-L2
  2 2 10 tides 15.0 Estuary-L2
  2 3 10 tides 15.0 Estuary-L2
  2 4 10 tides 15.0 Estuary-L2
  2 5 10 tides 15.0 Estuary-L2
  2 6 10 tides 15.0 Estuary-L2
  2 7 10 tides 15.0 Estuary-L2
  2 8 10 tides 15.0 Estuary-L2
  2 9 10 tides 15.0 Estuary-L2
  2 10 10 tides 15.0 Estuary-L2
  2 11 10 tides 15.0 Estuary-L2
  2 12 10 tides 15.0 Estuary-L2
  2 13 10 tides 15.0 Estuary-L2
  2 14 10 tides 15.0 Estuary-L2
  2 15 10 tides 15.0 Estuary-L2
END PERIOD

```

Available Observation Types

Example Observation Input File

```

BEGIN OPTIONS
  DIGITS 7
  PRINT_INPUT
END OPTIONS

BEGIN CONTINUOUS FILEOUT my_model.ghb.obs.csv
# obsname      obstype ID
  ghb-2-6-10   GHB      2 6 10
  ghb-2-7-10   GHB      2 7 10
END CONTINUOUS

BEGIN CONTINUOUS FILEOUT my_model.ghb.flows.csv
# obsname      obstype ID
  Estuary2     GHB      Estuary-L2
END CONTINUOUS

```

1.3.12 GWF-GNC

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [PRINT_INPUT]
  [PRINT_FLOWS]
  [EXPLICIT]
END OPTIONS
```

```
BEGIN DIMENSIONS
  NUMGNC <numgnc>
  NUMALPHAJ <numalphaj>
END DIMENSIONS
```

```
BEGIN GNCDATA
  <cellidn> <cellidm> <cellidsj(numalphaj)> <alphasj(numalphaj)>
  <cellidn> <cellidm> <cellidsj(numalphaj)> <alphasj(numalphaj)>
  ...
END GNCDATA
```

Explanation of Variables

Block: OPTIONS

- `PRINT_INPUT` keyword to indicate that the list of GNC information will be written to the listing file immediately after it is read.
- `PRINT_FLOWS` keyword to indicate that the list of GNC flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- `EXPLICIT` keyword to indicate that the ghost node correction is applied in an explicit manner on the right-hand side of the matrix. The explicit approach will likely require additional outer iterations. If the keyword is not specified, then the correction will be applied in an implicit manner on the left-hand side. The implicit approach will likely converge better, but may require additional memory. If the `EXPLICIT` keyword is not specified, then the `BICGSTAB` linear acceleration option should be specified within the `LINEAR` block of the Sparse Matrix Solver.

Block: DIMENSIONS

- `numgnc` is the number of GNC entries.
- `numalphaj` is the number of contributing factors.

Block: GNCDATA

- `cellidn` is the cellid of the cell, *n*, in which the ghost node is located. For a structured grid that uses the DIS input file, `CELLIDN` is the layer, row, and column numbers of the cell. For a grid that uses the DISV input file, `CELLIDN` is the layer number and `CELL2D` number for the two cells. If the model uses the unstructured discretization (DISU) input file, then `CELLIDN` is the node number for the cell.

- `cellidm` is the cellid of the connecting cell, `m`, to which flow occurs from the ghost node. For a structured grid that uses the DIS input file, `CELLIDM` is the layer, row, and column numbers of the cell. For a grid that uses the DISV input file, `CELLIDM` is the layer number and `CELL2D` number for the two cells. If the model uses the unstructured discretization (DISU) input file, then `CELLIDM` is the node number for the cell.
- `cellidsj` is the array of `CELLIDS` for the contributing `j` cells, which contribute to the interpolated head value at the ghost node. This item contains one `CELLID` for each of the contributing cells of the ghost node. Note that if the number of actual contributing cells needed by the user is less than `NUMALPHAJ` for any ghost node, then a dummy `CELLID` of zero(s) should be inserted with an associated contributing factor of zero. For a structured grid that uses the DIS input file, `CELLID` is the layer, row, and column numbers of the cell. For a grid that uses the DISV input file, `CELLID` is the layer number and `cell2d` number for the two cells. If the model uses the unstructured discretization (DISU) input file, then `CELLID` is the node number for the cell.
- `alphasj` is the contributing factors for each contributing node in `CELLIDSJ`. Note that if the number of actual contributing cells is less than `NUMALPHAJ` for any ghost node, then dummy `CELLIDS` should be inserted with an associated contributing factor of zero. The sum of `ALPHASJ` should be less than one. This is because one minus the sum of `ALPHASJ` is equal to the alpha term (alpha `n` in equation 4-61 of the GWF Model report) that is multiplied by the head in cell `n`.

Example Input File

```

BEGIN OPTIONS
  PRINT_INPUT
  PRINT_FLOWS
END OPTIONS

BEGIN DIMENSIONS
  NUMGNC 24
  NUMALPHAJ 1
END DIMENSIONS

BEGIN GNCDATA
  10 41 9 0.333333333333
  10 43 11 0.333333333333
  11 44 10 0.333333333333
  11 46 12 0.333333333333
  12 47 11 0.333333333333
  12 49 13 0.333333333333
  16 41 9 0.333333333333
  16 59 20 0.333333333333
  17 49 13 0.333333333333
  17 67 21 0.333333333333
  20 68 16 0.333333333333
  20 86 24 0.333333333333
  21 76 17 0.333333333333
  21 94 25 0.333333333333
  24 95 20 0.333333333333
  24 113 28 0.333333333333
  25 103 21 0.333333333333
  25 121 32 0.333333333333
  29 113 28 0.333333333333
  29 115 30 0.333333333333
  30 116 29 0.333333333333
  30 118 31 0.333333333333
  31 119 30 0.333333333333
  31 121 32 0.333333333333

```

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```
END  GNCDATA
```

1.3.13 GWF-HFB

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [PRINT_INPUT]
END OPTIONS
```

```
BEGIN DIMENSIONS
  MAXHFB <maxhfb>
END DIMENSIONS
```

FOR ANY STRESS PERIOD

```
BEGIN PERIOD <iper>
  <cellid1(ncellldim)> <cellid2(ncellldim)> <hydchr>
  <cellid1(ncellldim)> <cellid2(ncellldim)> <hydchr>
  . . .
END PERIOD
```

Explanation of Variables

Block: OPTIONS

- `PRINT_INPUT` keyword to indicate that the list of horizontal flow barriers will be written to the listing file immediately after it is read.

Block: DIMENSIONS

- `maxhfb` integer value specifying the maximum number of horizontal flow barriers that will be entered in this input file. The value of `MAXHFB` is used to allocate memory for the horizontal flow barriers.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the `PERIOD` block apply. `IPER` must be less than or equal to `NPER` in the `TDIS` Package and greater than zero. The `IPER` value assigned to a stress period block must be greater than the `IPER` value assigned for the previous `PERIOD` block. The information specified in the `PERIOD` block will continue to apply for all subsequent stress periods, unless the program encounters another `PERIOD` block.
- `cellid1` identifier for the first cell. For a structured grid that uses the `DIS` input file, `CELLID1` is the layer, row, and column numbers of the cell. For a grid that uses the `DISV` input file, `CELLID1` is the layer number and `CELL2D` number for the two cells. If the model uses the unstructured discretization (`DISU`) input file, then `CELLID1` is the node numbers for the cell. The barrier is located between cells designated as `CELLID1` and `CELLID2`. For models that use the `DIS` and `DISV` grid types, the layer number for `CELLID1` and `CELLID2`

must be the same. For all grid types, cells must be horizontally adjacent or the program will terminate with an error.

- `cellid2` identifier for the second cell. See `CELLID1` for description of how to specify.
- `hydchr` is the hydraulic characteristic of the horizontal-flow barrier. The hydraulic characteristic is the barrier hydraulic conductivity divided by the width of the horizontal-flow barrier. If the hydraulic characteristic is negative, then the absolute value of `HYDCHR` acts as a multiplier to the conductance between the two model cells specified as containing the barrier. For example, if the value for `HYDCHR` was specified as -1.5, the conductance calculated for the two cells would be multiplied by 1.5.

Example Input File

```
BEGIN OPTIONS
  PRINT_INPUT
END OPTIONS

BEGIN DIMENSIONS
  MAXHFB 1
END DIMENSIONS

BEGIN PERIOD 1
  #L1 R1 C1 L2 R2 C2 HYDCHR
  1 1 4 1 1 5 0.1
END PERIOD 1
```

1.3.14 GWF-IC

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN GRIDDATA
  STRT [LAYERED]
    <strt(nodes)> -- READARRAY
END GRIDDATA
```

Explanation of Variables

Block: GRIDDATA

- `strt` is the initial (starting) head—that is, head at the beginning of the GWF Model simulation. `STRT` must be specified for all simulations, including steady-state simulations. One value is read for every model cell. For simulations in which the first stress period is steady state, the values used for `STRT` generally do not affect the simulation (exceptions may occur if cells go dry and (or) rewet). The execution time, however, will be less if `STRT` includes hydraulic heads that are close to the steady-state solution. A head value lower than the cell bottom can be provided if a cell should start as dry.

Example Input File

```
#The OPTIONS block is optional
BEGIN OPTIONS
END OPTIONS

#The GRIDDATA block is required
BEGIN GRIDDATA
  STRT LAYERED
    CONSTANT 0.0 Initial Head layer 1
    CONSTANT 0.0 Initial Head layer 2
  END GRIDDATA
```

1.3.15 GWF-LAK

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [AUXILIARY <auxiliary(naux)>]
  [BOUNDNAMES]
  [PRINT_INPUT]
  [PRINT_STAGE]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [STAGE FILEOUT <stagefile>]
  [BUDGET FILEOUT <budgetfile>]
  [PACKAGE_CONVERGENCE FILEOUT <package_convergence_filename>]
  [TS6 FILEIN <ts6_filename>]
  [OBS6 FILEIN <obs6_filename>]
  [MOVER]
  [SURFDEP <surfdep>]
  [TIME_CONVERSION <time_conversion>]
  [LENGTH_CONVERSION <length_conversion>]
END OPTIONS
```

```
BEGIN DIMENSIONS
  NLAKES <nlakes>
  NOUTLETS <noutlets>
  NTABLES <ntables>
END DIMENSIONS
```

```
BEGIN PACKAGEDATA
  <lakeno> <strt> <nlakeconn> [<aux(naux)>] [<boundname>]
  <lakeno> <strt> <nlakeconn> [<aux(naux)>] [<boundname>]
  ...
END PACKAGEDATA
```

```
BEGIN CONNECTIONDATA
  <lakeno> <iconn> <cellid(ncellldim)> <claktype> <bedleak> <belev> <telev>
  ↳<connlen> <connwidth>
  <lakeno> <iconn> <cellid(ncellldim)> <claktype> <bedleak> <belev> <telev>
  ↳<connlen> <connwidth>
  ...
END CONNECTIONDATA
```



```

BEGIN TABLES
  <lakeno> TAB6 FILEIN <tab6_filename>
  <lakeno> TAB6 FILEIN <tab6_filename>
  ...
END TABLES

```

```

BEGIN OUTLETS
  <outletno> <lakein> <lakeout> <couttype> <invert> <width> <rough> <slope>
  <outletno> <lakein> <lakeout> <couttype> <invert> <width> <rough> <slope>
  ...
END OUTLETS

```

FOR ANY STRESS PERIOD

```

BEGIN PERIOD <iper>
  <number> <laksetting>
  <number> <laksetting>
  ...
END PERIOD

```

Explanation of Variables

Block: OPTIONS

- `auxiliary` defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for `naux`. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- `BOUNDNAMES` keyword to indicate that boundary names may be provided with the list of lake cells.
- `PRINT_INPUT` keyword to indicate that the list of lake information will be written to the listing file immediately after it is read.
- `PRINT_STAGE` keyword to indicate that the list of lake stages will be printed to the listing file for every stress period in which “HEAD PRINT” is specified in Output Control. If there is no Output Control option and `PRINT_STAGE` is specified, then stages are printed for the last time step of each stress period.
- `PRINT_FLOWS` keyword to indicate that the list of lake flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- `SAVE_FLOWS` keyword to indicate that lake flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- `STAGE` keyword to specify that record corresponds to stage.
- `stagefile` name of the binary output file to write stage information.
- `BUDGET` keyword to specify that record corresponds to the budget.
- `FILEOUT` keyword to specify that an output filename is expected next.
- `budgetfile` name of the binary output file to write budget information.

- `PACKAGE_CONVERGENCE` keyword to specify that record corresponds to the package convergence comma spaced values file.
- `package_convergence_filename` name of the comma spaced values output file to write package convergence information.
- `TS6` keyword to specify that record corresponds to a time-series file.
- `FILEIN` keyword to specify that an input filename is expected next.
- `ts6_filename` defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- `OBS6` keyword to specify that record corresponds to an observations file.
- `obs6_filename` name of input file to define observations for the LAK package. See the “Observation utility” section for instructions for preparing observation input files. Tables `ref{table:gwf-obstypetable}` and `ref{table:gwt-obstypetable}` lists observation type(s) supported by the LAK package.
- `MOVER` keyword to indicate that this instance of the LAK Package can be used with the Water Mover (MVR) Package. When the `MOVER` option is specified, additional memory is allocated within the package to store the available, provided, and received water.
- `surfdep` real value that defines the surface depression depth for VERTICAL lake-GWF connections. If specified, `SURFDEP` must be greater than or equal to zero. If `SURFDEP` is not specified, a default value of zero is used for all vertical lake-GWF connections.
- `time_conversion` value that is used in converting outlet flow terms that use Manning’s equation or gravitational acceleration to consistent time units. `TIME_CONVERSION` should be set to 1.0, 60.0, 3,600.0, 86,400.0, and 31,557,600.0 when using time units (`TIME_UNITS`) of seconds, minutes, hours, days, or years in the simulation, respectively. `CONVTIME` does not need to be specified if no lake outlets are specified or `TIME_UNITS` are seconds.
- `length_conversion` real value that is used in converting outlet flow terms that use Manning’s equation or gravitational acceleration to consistent length units. `LENGTH_CONVERSION` should be set to 3.28081, 1.0, and 100.0 when using length units (`LENGTH_UNITS`) of feet, meters, or centimeters in the simulation, respectively. `LENGTH_CONVERSION` does not need to be specified if no lake outlets are specified or `LENGTH_UNITS` are meters.

Block: DIMENSIONS

- `nlakes` value specifying the number of lakes that will be simulated for all stress periods.
- `noutlets` value specifying the number of outlets that will be simulated for all stress periods. If `NOUTLETS` is not specified, a default value of zero is used.
- `ntables` value specifying the number of lakes tables that will be used to define the lake stage, volume relation, and surface area. If `NTABLES` is not specified, a default value of zero is used.

Block: PACKAGEDATA

- `lakeno` integer value that defines the lake number associated with the specified `PACKAGEDATA` data on the line. `LAKENO` must be greater than zero and less than or equal to `NLAKES`. Lake information must be specified for every lake or the program will terminate with an error. The program will also terminate with an error if information for a lake is specified more than once.
- `strt` real value that defines the starting stage for the lake.

- `nlakeconn` integer value that defines the number of GWF cells connected to this (LAKENO) lake. There can only be one vertical lake connection to each GWF cell. NLAKECONN must be greater than zero.
- `aux` represents the values of the auxiliary variables for each lake. The values of auxiliary variables must be present for each lake. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `boundname` name of the lake cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

Block: CONNECTIONDATA

- `lakeno` integer value that defines the lake number associated with the specified CONNECTIONDATA data on the line. LAKENO must be greater than zero and less than or equal to NLAKES. Lake connection information must be specified for every lake connection to the GWF model (NLAKECONN) or the program will terminate with an error. The program will also terminate with an error if connection information for a lake connection to the GWF model is specified more than once.
- `iconn` integer value that defines the GWF connection number for this lake connection entry. ICONN must be greater than zero and less than or equal to NLAKECONN for lake LAKENO.
- `cellid` is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell.
- `claktype` character string that defines the lake-GWF connection type for the lake connection. Possible lake-GWF connection type strings include: VERTICAL—character keyword to indicate the lake-GWF connection is vertical and connection conductance calculations use the hydraulic conductivity corresponding to the $K_{\{33\}}$ tensor component defined for CELLID in the NPF package. HORIZONTAL—character keyword to indicate the lake-GWF connection is horizontal and connection conductance calculations use the hydraulic conductivity corresponding to the $K_{\{11\}}$ tensor component defined for CELLID in the NPF package. EMBEDDEDH—character keyword to indicate the lake-GWF connection is embedded in a single cell and connection conductance calculations use the hydraulic conductivity corresponding to the $K_{\{11\}}$ tensor component defined for CELLID in the NPF package. EMBEDDEDV—character keyword to indicate the lake-GWF connection is embedded in a single cell and connection conductance calculations use the hydraulic conductivity corresponding to the $K_{\{33\}}$ tensor component defined for CELLID in the NPF package. Embedded lakes can only be connected to a single cell (NLAKECONN = 1) and there must be a lake table associated with each embedded lake.
- `bedleak` character string or real value that defines the bed leakance for the lake-GWF connection. BEDLEAK must be greater than or equal to zero or specified to be NONE. If BEDLEAK is specified to be NONE, the lake-GWF connection conductance is solely a function of aquifer properties in the connected GWF cell and lakebed sediments are assumed to be absent.
- `belev` real value that defines the bottom elevation for a HORIZONTAL lake-GWF connection. Any value can be specified if CLAKTYPE is VERTICAL, EMBEDDEDH, or EMBEDDEDV. If CLAKTYPE is HORIZONTAL and BELEV is not equal to TELEV, BELEV must be greater than or equal to the bottom of the GWF cell CELLID. If BELEV is equal to TELEV, BELEV is reset to the bottom of the GWF cell CELLID.
- `telev` real value that defines the top elevation for a HORIZONTAL lake-GWF connection. Any value can be specified if CLAKTYPE is VERTICAL, EMBEDDEDH, or EMBEDDEDV. If CLAKTYPE is HORIZONTAL and TELEV is not equal to BELEV, TELEV must be less than or equal to the top of the GWF cell CELLID. If TELEV is equal to BELEV, TELEV is reset to the top of the GWF cell CELLID.

- `connlen` real value that defines the distance between the connected GWF CELLID node and the lake for a HORIZONTAL, EMBEDDEDH, or EMBEDDEDV lake-GWF connection. CONLENN must be greater than zero for a HORIZONTAL, EMBEDDEDH, or EMBEDDEDV lake-GWF connection. Any value can be specified if CLAKTYPE is VERTICAL.
- `connwidth` real value that defines the connection face width for a HORIZONTAL lake-GWF connection. CONNWIDTH must be greater than zero for a HORIZONTAL lake-GWF connection. Any value can be specified if CLAKTYPE is VERTICAL, EMBEDDEDH, or EMBEDDEDV.

Block: TABLES

- `lakeno` integer value that defines the lake number associated with the specified TABLES data on the line. LAKENO must be greater than zero and less than or equal to NLAKES. The program will terminate with an error if table information for a lake is specified more than once or the number of specified tables is less than NTABLES.
- `TAB6` keyword to specify that record corresponds to a table file.
- `FILEIN` keyword to specify that an input filename is expected next.
- `tab6_filename` character string that defines the path and filename for the file containing lake table data for the lake connection. The TAB6_FILENAME file includes the number of entries in the file and the relation between stage, volume, and surface area for each entry in the file. Lake table files for EMBEDDEDH and EMBEDDEDV lake-GWF connections also include lake-GWF exchange area data for each entry in the file. Instructions for creating the TAB6_FILENAME input file are provided in Lake Table Input File section.

Block: OUTLETS

- `outletno` integer value that defines the outlet number associated with the specified OUTLETS data on the line. OUTLETNO must be greater than zero and less than or equal to NOUTLETS. Outlet information must be specified for every outlet or the program will terminate with an error. The program will also terminate with an error if information for a outlet is specified more than once.
- `lakein` integer value that defines the lake number that outlet is connected to. LAKEIN must be greater than zero and less than or equal to NLAKES.
- `lakeout` integer value that defines the lake number that outlet discharge from lake outlet OUTLETNO is routed to. LAKEOUT must be greater than or equal to zero and less than or equal to NLAKES. If LAKEOUT is zero, outlet discharge from lake outlet OUTLETNO is discharged to an external boundary.
- `couttype` character string that defines the outlet type for the outlet OUTLETNO. Possible COUTTYPE strings include: SPECIFIED—character keyword to indicate the outlet is defined as a specified flow. MANNING—character keyword to indicate the outlet is defined using Manning’s equation. WEIR—character keyword to indicate the outlet is defined using a sharp weir equation.
- `invert` real value that defines the invert elevation for the lake outlet. Any value can be specified if COUTTYPE is SPECIFIED. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `width` real value that defines the width of the lake outlet. Any value can be specified if COUTTYPE is SPECIFIED. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `rough` real value that defines the roughness coefficient for the lake outlet. Any value can be specified if COUTTYPE is not MANNING. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- `slope` real value that defines the bed slope for the lake outlet. Any value can be specified if `COUTTYPE` is not `MANNING`. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. `IPER` must be less than or equal to `NPER` in the TDIS Package and greater than zero. The `IPER` value assigned to a stress period block must be greater than the `IPER` value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- `number` integer value that defines the lake or outlet number associated with the specified PERIOD data on the line. `NUMBER` must be greater than zero and less than or equal to `NLAKES` for a lake number and less than or equal to `NOUTLETS` for an outlet number.
- `laksetting` line of information that is parsed into a keyword and values. Keyword values that can be used to start the `LAKSETTING` string include both keywords for lake settings and keywords for outlet settings. Keywords for lake settings include: `STATUS`, `STAGE`, `RAINFALL`, `EVAPORATION`, `RUNOFF`, `INFLOW`, `WITHDRAWAL`, and `AUXILIARY`. Keywords for outlet settings include `RATE`, `INVERT`, `WIDTH`, `SLOPE`, and `ROUGH`.

```
STATUS <status>
STAGE <stage>
RAINFALL <rainfall>
EVAPORATION <evaporation>
RUNOFF <runoff>
INFLOW <inflow>
WITHDRAWAL <withdrawal>
RATE <rate>
INVERT <invert>
WIDTH <width>
SLOPE <slope>
ROUGH <rough>
AUXILIARY <auxname> <auxval>
```

- `status` keyword option to define lake status. `STATUS` can be `ACTIVE`, `INACTIVE`, or `CONSTANT`. By default, `STATUS` is `ACTIVE`.
- `stage` real or character value that defines the stage for the lake. The specified `STAGE` is only applied if the lake is a constant stage lake. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `rainfall` real or character value that defines the rainfall rate (LT-1) for the lake. Value must be greater than or equal to zero. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `evaporation` real or character value that defines the maximum evaporation rate (LT-1) for the lake. Value must be greater than or equal to zero. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `runoff` real or character value that defines the runoff rate (L3 T-1) for the lake. Value must be greater than or equal to zero. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- **inflow** real or character value that defines the volumetric inflow rate (L3 T-1) for the lake. Value must be greater than or equal to zero. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value. By default, inflow rates are zero for each lake.
- **withdrawal** real or character value that defines the maximum withdrawal rate (L3 T-1) for the lake. Value must be greater than or equal to zero. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- **rate** real or character value that defines the extraction rate for the lake outflow. A positive value indicates inflow and a negative value indicates outflow from the lake. RATE only applies to active (IBOUND > 0) lakes. A specified RATE is only applied if COUTTYPE for the OUTLETNO is SPECIFIED. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value. By default, the RATE for each SPECIFIED lake outlet is zero.
- **invert** real or character value that defines the invert elevation for the lake outlet. A specified INVERT value is only used for active lakes if COUTTYPE for lake outlet OUTLETNO is not SPECIFIED. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- **rough** real value that defines the roughness coefficient for the lake outlet. Any value can be specified if COUTTYPE is not MANNING. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- **width** real or character value that defines the width of the lake outlet. A specified WIDTH value is only used for active lakes if COUTTYPE for lake outlet OUTLETNO is not SPECIFIED. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- **slope** real or character value that defines the bed slope for the lake outlet. A specified SLOPE value is only used for active lakes if COUTTYPE for lake outlet OUTLETNO is MANNING. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- **AUXILIARY** keyword for specifying auxiliary variable.
- **auxname** name for the auxiliary variable to be assigned AUXVAL. AUXNAME must match one of the auxiliary variable names defined in the OPTIONS block. If AUXNAME does not match one of the auxiliary variable names defined in the OPTIONS block the data are ignored.
- **auxval** value for the auxiliary variable. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

Example Input File

```
BEGIN OPTIONS
  PRINT_INPUT
  BOUNDNAMES
  PRINT_STAGE
  PRINT_FLOWS
  STAGE FILEOUT lak-1.stage.bin
  BUDGET FILEOUT lak-1.cbc
END OPTIONS
```

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BEGIN DIMENSIONS

NLAKES 1

NOUTLETS 1

END DIMENSIONS

BEGIN PACKAGEDATA

lakeno strt lakeconn boundname

1 110.00 57 LAKE_1

END PACKAGEDATA

BEGIN CONNECTIONDATA

| # | <i>lakeno</i> | <i>iconn</i> | <i>layer</i> | <i>row</i> | <i>column</i> | <i>ctype</i> | <i>bedleak</i> | <i>belev</i> | <i>telev</i> | <i>dx</i> | <i>width</i> |
|---|---------------|--------------|--------------|------------|---------------|--------------|----------------|--------------|--------------|-----------|--------------|
| 1 | 1 | 1 | 7 | 6 | HORIZONTAL | 0.1 | 0 | 0 | 500 | 500 | |
| 1 | 2 | 1 | 8 | 6 | HORIZONTAL | 0.1 | 0 | 0 | 500 | 500 | |
| 1 | 3 | 1 | 9 | 6 | HORIZONTAL | 0.1 | 0 | 0 | 500 | 500 | |
| 1 | 4 | 1 | 10 | 6 | HORIZONTAL | 0.1 | 0 | 0 | 500 | 500 | |
| 1 | 5 | 1 | 11 | 6 | HORIZONTAL | 0.1 | 0 | 0 | 500 | 500 | |
| 1 | 6 | 1 | 6 | 7 | HORIZONTAL | 0.1 | 0 | 0 | 500 | 500 | |
| 1 | 7 | 2 | 7 | 7 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 8 | 2 | 8 | 7 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 9 | 2 | 8 | 7 | HORIZONTAL | 0.1 | 0 | 0 | 250 | 500 | |
| 1 | 10 | 2 | 9 | 7 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 11 | 2 | 9 | 7 | HORIZONTAL | 0.1 | 0 | 0 | 250 | 500 | |
| 1 | 12 | 2 | 10 | 7 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 13 | 2 | 10 | 7 | HORIZONTAL | 0.1 | 0 | 0 | 250 | 500 | |
| 1 | 14 | 2 | 11 | 7 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 15 | 1 | 12 | 7 | HORIZONTAL | 0.1 | 0 | 0 | 500 | 500 | |
| 1 | 16 | 1 | 6 | 8 | HORIZONTAL | 0.1 | 0 | 0 | 500 | 500 | |
| 1 | 17 | 2 | 7 | 8 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 18 | 2 | 7 | 8 | HORIZONTAL | 0.1 | 0 | 0 | 250 | 500 | |
| 1 | 19 | 3 | 8 | 8 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 20 | 3 | 9 | 8 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 21 | 3 | 10 | 8 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 22 | 2 | 11 | 8 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 23 | 2 | 11 | 8 | HORIZONTAL | 0.1 | 0 | 0 | 250 | 500 | |
| 1 | 24 | 1 | 12 | 8 | HORIZONTAL | 0.1 | 0 | 0 | 500 | 500 | |
| 1 | 25 | 1 | 6 | 9 | HORIZONTAL | 0.1 | 0 | 0 | 500 | 500 | |
| 1 | 26 | 2 | 7 | 9 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 27 | 2 | 7 | 9 | HORIZONTAL | 0.1 | 0 | 0 | 250 | 500 | |
| 1 | 28 | 3 | 8 | 9 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 29 | 3 | 9 | 9 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 30 | 3 | 10 | 9 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 31 | 2 | 11 | 9 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 32 | 2 | 11 | 9 | HORIZONTAL | 0.1 | 0 | 0 | 250 | 500 | |
| 1 | 33 | 1 | 12 | 9 | HORIZONTAL | 0.1 | 0 | 0 | 500 | 500 | |
| 1 | 34 | 1 | 6 | 10 | HORIZONTAL | 0.1 | 0 | 0 | 500 | 500 | |
| 1 | 35 | 2 | 7 | 10 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 36 | 2 | 7 | 10 | HORIZONTAL | 0.1 | 0 | 0 | 250 | 500 | |
| 1 | 37 | 3 | 8 | 10 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 38 | 3 | 9 | 10 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 39 | 3 | 10 | 10 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 40 | 2 | 11 | 10 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |
| 1 | 41 | 2 | 11 | 10 | HORIZONTAL | 0.1 | 0 | 0 | 250 | 500 | |
| 1 | 42 | 1 | 12 | 10 | HORIZONTAL | 0.1 | 0 | 0 | 500 | 500 | |
| 1 | 43 | 1 | 6 | 11 | HORIZONTAL | 0.1 | 0 | 0 | 500 | 500 | |
| 1 | 44 | 2 | 7 | 11 | VERTICAL | 0.1 | 0 | 0 | 0 | 0 | |

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```

1  45  2  8  11  VERTICAL  0.1  0  0  0  0
1  46  2  8  11  HORIZONTAL 0.1  0  0 250 500
1  47  2  9  11  VERTICAL  0.1  0  0  0  0
1  48  2  9  11  HORIZONTAL 0.1  0  0 250 500
1  49  2 10  11  VERTICAL  0.1  0  0  0  0
1  50  2 10  11  HORIZONTAL 0.1  0  0 250 500
1  51  2 11  11  VERTICAL  0.1  0  0  0  0
1  52  1 12  11  HORIZONTAL 0.1  0  0 500 500
1  53  1  7  12  HORIZONTAL 0.1  0  0 500 500
1  54  1  8  12  HORIZONTAL 0.1  0  0 500 500
1  55  1  9  12  HORIZONTAL 0.1  0  0 500 500
1  56  1 10  12  HORIZONTAL 0.1  0  0 500 500
1  57  1 11  12  HORIZONTAL 0.1  0  0 500 500
END CONNECTIONDATA

BEGIN OUTLETS
# outletno lakein lakeout couttype invert width rough slope
1 1 0 SPECIFIED 0 0 0 0
END OUTLETS

BEGIN PERIOD 1
1 RAINFALL 0.0116
1 EVAPORATION 0.0103
END PERIOD

BEGIN PERIOD 100
1 STATUS CONSTANT
1 STAGE 110.
END PERIOD

```

Available Observation Types

Example Observation Input File

```

BEGIN OPTIONS
  DIGITS 10
  PRINT_INPUT
END OPTIONS

BEGIN CONTINUOUS FILEOUT my_model.lak.csv
  llstage stage 1
  llvol volume 1
  vflow lak 1 1
  hflow1 lak 1 2
  hflow2 lak 1 3
  hflow3 lak 1 4
  hflow4 lak 1 5
  lakflow lak lake_1
END CONTINUOUS

```

1.3.16 GWF-MAW

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [AUXILIARY <auxiliary(naux)>]
  [BOUNDNAMES]
  [PRINT_INPUT]
  [PRINT_HEAD]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [HEAD FILEOUT <headfile>]
  [BUDGET FILEOUT <budgetfile>]
  [NO_WELL_STORAGE]
  [FLOW_CORRECTION]
  [FLOWING_WELLS]
  [SHUTDOWN_THETA <shutdown_theta>]
  [SHUTDOWN_KAPPA <shutdown_kappa>]
  [TS6 FILEIN <ts6_filename>]
  [OBS6 FILEIN <obs6_filename>]
  [MOVER]
END OPTIONS
```

```
BEGIN DIMENSIONS
  NMAWWELLS <nmawwells>
END DIMENSIONS
```

```
BEGIN PACKAGEDATA
  <wellno> <radius> <bottom> <strt> <condeqn> <ngwfnodes> [<aux(naux)>] [
↪<boundname>]
  <wellno> <radius> <bottom> <strt> <condeqn> <ngwfnodes> [<aux(naux)>] [
↪<boundname>]
  ...
END PACKAGEDATA
```

```
BEGIN CONNECTIONDATA
  <wellno> <icon> <cellid(ncelldim)> <scrn_top> <scrn_bot> <hk_skin> <radius_skin>
  <wellno> <icon> <cellid(ncelldim)> <scrn_top> <scrn_bot> <hk_skin> <radius_skin>
  ...
END CONNECTIONDATA
```

FOR ANY STRESS PERIOD

```
BEGIN PERIOD <iper>
  <wellno> <mawsetting>
  <wellno> <mawsetting>
  ...
END PERIOD
```

Explanation of Variables

Block: OPTIONS

- **auxiliary** defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks

must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for `naux`. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.

- **BOUNDNAMES** keyword to indicate that boundary names may be provided with the list of multi-aquifer well cells.
- **PRINT_INPUT** keyword to indicate that the list of multi-aquifer well information will be written to the listing file immediately after it is read.
- **PRINT_HEAD** keyword to indicate that the list of multi-aquifer well heads will be printed to the listing file for every stress period in which “HEAD PRINT” is specified in Output Control. If there is no Output Control option and **PRINT_HEAD** is specified, then heads are printed for the last time step of each stress period.
- **PRINT_FLOWS** keyword to indicate that the list of multi-aquifer well flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- **SAVE_FLOWS** keyword to indicate that multi-aquifer well flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- **HEAD** keyword to specify that record corresponds to head.
- `headfile` name of the binary output file to write head information.
- **BUDGET** keyword to specify that record corresponds to the budget.
- **FILEOUT** keyword to specify that an output filename is expected next.
- `budgetfile` name of the binary output file to write budget information.
- **NO_WELL_STORAGE** keyword that deactivates inclusion of well storage contributions to the multi-aquifer well package continuity equation.
- **FLOW_CORRECTION** keyword that activates flow corrections in cases where the head in a multi-aquifer well is below the bottom of the screen for a connection or the head in a convertible cell connected to a multi-aquifer well is below the cell bottom. When flow corrections are activated, unit head gradients are used to calculate the flow between a multi-aquifer well and a connected GWF cell. By default, flow corrections are not made.
- **FLOWING_WELLS** keyword that activates the flowing wells option for the multi-aquifer well package.
- `shutdown_theta` value that defines the weight applied to discharge rate for wells that limit the water level in a discharging well (defined using the **HEAD_LIMIT** keyword in the stress period data). **SHUTDOWN_THETA** is used to control discharge rate oscillations when the flow rate from the aquifer is less than the specified flow rate from the aquifer to the well. Values range between 0.0 and 1.0, and larger values increase the weight (decrease under-relaxation) applied to the well discharge rate. The **HEAD_LIMIT** option has been included to facilitate backward compatibility with previous versions of MODFLOW but use of the **RATE_SCALING** option instead of the **HEAD_LIMIT** option is recommended. By default, **SHUTDOWN_THETA** is 0.7.
- `shutdown_kappa` value that defines the weight applied to discharge rate for wells that limit the water level in a discharging well (defined using the **HEAD_LIMIT** keyword in the stress period data). **SHUTDOWN_KAPPA** is used to control discharge rate oscillations when the flow rate from the aquifer is less than the specified flow rate from the aquifer to the well. Values range between 0.0 and 1.0, and larger values increase the weight applied to the well discharge rate. The **HEAD_LIMIT** option has been included to facilitate backward compatibility with previous versions of MODFLOW but use of the **RATE_SCALING** option instead of the **HEAD_LIMIT** option is recommended. By default, **SHUTDOWN_KAPPA** is 0.0001.
- **TS6** keyword to specify that record corresponds to a time-series file.

- `FILEIN` keyword to specify that an input filename is expected next.
- `ts6_filename` defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- `OBS6` keyword to specify that record corresponds to an observations file.
- `obs6_filename` name of input file to define observations for the MAW package. See the “Observation utility” section for instructions for preparing observation input files. Tables `ref{table:gwf-obstypetable}` and `ref{table:gwt-obstypetable}` lists observation type(s) supported by the MAW package.
- `MOVER` keyword to indicate that this instance of the MAW Package can be used with the Water Mover (MVR) Package. When the `MOVER` option is specified, additional memory is allocated within the package to store the available, provided, and received water.

Block: DIMENSIONS

- `nmauwells` integer value specifying the number of multi-aquifer wells that will be simulated for all stress periods.

Block: PACKAGEDATA

- `wellno` integer value that defines the well number associated with the specified `PACKAGEDATA` data on the line. `WELLNO` must be greater than zero and less than or equal to `NMAUWELLS`. Multi-aquifer well information must be specified for every multi-aquifer well or the program will terminate with an error. The program will also terminate with an error if information for a multi-aquifer well is specified more than once.
- `radius` radius for the multi-aquifer well. The program will terminate with an error if the radius is less than or equal to zero.
- `bottom` bottom elevation of the multi-aquifer well. If `CONDEQN` is `SPECIFIED`, `THIEM`, `SKIN`, or `COMPOSITE`, `BOTTOM` is set to the cell bottom in the lowermost GWF cell connection in cases where the specified well bottom is above the bottom of this GWF cell. If `CONDEQN` is `MEAN`, `BOTTOM` is set to the lowermost GWF cell connection screen bottom in cases where the specified well bottom is above this value. The bottom elevation defines the lowest well head that will be simulated when the `NEWTON UNDER_RELAXATION` option is specified in the GWF model name file. The bottom elevation is also used to calculate volumetric storage in the well.
- `strt` starting head for the multi-aquifer well. The program will terminate with an error if the starting head is less than the specified well bottom.
- `condeqn` character string that defines the conductance equation that is used to calculate the saturated conductance for the multi-aquifer well. Possible multi-aquifer well `CONDEQN` strings include: `SPECIFIED`—character keyword to indicate the multi-aquifer well saturated conductance will be specified. `THIEM`—character keyword to indicate the multi-aquifer well saturated conductance will be calculated using the Thiem equation, which considers the cell top and bottom, aquifer hydraulic conductivity, and effective cell and well radius. `SKIN`—character keyword to indicate that the multi-aquifer well saturated conductance will be calculated using the cell top and bottom, aquifer and screen hydraulic conductivity, and well and skin radius. `CUMULATIVE`—character keyword to indicate that the multi-aquifer well saturated conductance will be calculated using a combination of the Thiem and `SKIN` equations. `MEAN`—character keyword to indicate the multi-aquifer well saturated conductance will be calculated using the aquifer and screen top and bottom, aquifer and screen hydraulic conductivity, and well and skin radius. The `CUMULATIVE` conductance equation is identical to the `SKIN LOSSTYPE` in the Multi-Node Well (MNW2) package for MODFLOW-2005. The program will terminate with an error condition if `CONDEQN` is `SKIN` or `CUMULATIVE` and the calculated saturated conductance is less than zero; if an error condition occurs, it is suggested that the `THEIM` or `MEAN` conductance equations be used for these multi-aquifer wells.

- `ngwfnodes` integer value that defines the number of GWF nodes connected to this (WELLNO) multi-aquifer well. NGWFNODES must be greater than zero.
- `aux` represents the values of the auxiliary variables for each multi-aquifer well. The values of auxiliary variables must be present for each multi-aquifer well. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `boundname` name of the multi-aquifer well cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

Block: CONNECTIONDATA

- `wellno` integer value that defines the well number associated with the specified CONNECTIONDATA data on the line. WELLNO must be greater than zero and less than or equal to NMAWWELLS. Multi-aquifer well connection information must be specified for every multi-aquifer well connection to the GWF model (NGWFNODES) or the program will terminate with an error. The program will also terminate with an error if connection information for a multi-aquifer well connection to the GWF model is specified more than once.
- `icon` integer value that defines the GWF connection number for this multi-aquifer well connection entry. ICONN must be greater than zero and less than or equal to NGWFNODES for multi-aquifer well WELLNO.
- `cellid` is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. One or more screened intervals can be connected to the same CELLID if CONDEQN for a well is MEAN. The program will terminate with an error if MAW wells using SPECIFIED, THIEM, SKIN, or CUMULATIVE conductance equations have more than one connection to the same CELLID.
- `scrn_top` value that defines the top elevation of the screen for the multi-aquifer well connection. If CONDEQN is SPECIFIED, THIEM, SKIN, or COMPOSITE, SCRN_TOP can be any value and is set to the top of the cell. If CONDEQN is MEAN, SCRN_TOP is set to the multi-aquifer well connection cell top if the specified value is greater than the cell top. The program will terminate with an error if the screen top is less than the screen bottom.
- `scrn_bot` value that defines the bottom elevation of the screen for the multi-aquifer well connection. If CONDEQN is SPECIFIED, THIEM, SKIN, or COMPOSITE, SCRN_BOT can be any value is set to the bottom of the cell. If CONDEQN is MEAN, SCRN_BOT is set to the multi-aquifer well connection cell bottom if the specified value is less than the cell bottom. The program will terminate with an error if the screen bottom is greater than the screen top.
- `hk_skin` value that defines the skin (filter pack) hydraulic conductivity (if CONDEQN for the multi-aquifer well is SKIN, CUMULATIVE, or MEAN) or conductance (if CONDEQN for the multi-aquifer well is SPECIFIED) for each GWF node connected to the multi-aquifer well (NGWFNODES). If CONDEQN is SPECIFIED, HK_SKIN must be greater than or equal to zero. HK_SKIN can be any value if CONDEQN is THIEM. Otherwise, HK_SKIN must be greater than zero. If CONDEQN is SKIN, the contrast between the cell transmissivity (the product of geometric mean horizontal hydraulic conductivity and the cell thickness) and the well transmissivity (the product of HK_SKIN and the screen thicknesses) must be greater than one in node CELLID or the program will terminate with an error condition; if an error condition occurs, it is suggested that the HK_SKIN be reduced to a value less than K11 and K22 in node CELLID or the THEIM or MEAN conductance equations be used for these multi-aquifer wells.
- `radius_skin` real value that defines the skin radius (filter pack radius) for the multi-aquifer well. RADIUS_SKIN can be any value if CONDEQN is SPECIFIED or THIEM. If CONDEQN is SKIN, CUMU-

LATIVE, or MEAN, the program will terminate with an error if RADIUS_SKIN is less than or equal to the RADIUS for the multi-aquifer well.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. IPER must be less than or equal to NPER in the TDIS Package and greater than zero. The IPER value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- `wellno` integer value that defines the well number associated with the specified PERIOD data on the line. WELLNO must be greater than zero and less than or equal to NMAWWELLS.
- `mawsetting` line of information that is parsed into a keyword and values. Keyword values that can be used to start the MAWSETTING string include: STATUS, FLOWING_WELL, RATE, WELL_HEAD, HEAD_LIMIT, SHUT_OFF, RATE_SCALING, and AUXILIARY.

```
STATUS <status>
FLOWING_WELL <fwelev> <fwcond> <fwrlen>
RATE <rate>
WELL_HEAD <well_head>
HEAD_LIMIT <head_limit>
SHUT_OFF <minrate> <maxrate>
RATE_SCALING <pump_elevation> <scaling_length>
AUXILIARY <auxname> <auxval>
```

- `status` keyword option to define well status. STATUS can be ACTIVE, INACTIVE, or CONSTANT. By default, STATUS is ACTIVE.
- `FLOWING_WELL` keyword to indicate the well is a flowing well. The FLOWING_WELL option can be used to simulate flowing wells when the simulated well head exceeds the specified drainage elevation.
- `fwelev` elevation used to determine whether or not the well is flowing.
- `fwcond` conductance used to calculate the discharge of a free flowing well. Flow occurs when the head in the well is above the well top elevation (FWELEV).
- `fwrlen` length used to reduce the conductance of the flowing well. When the head in the well drops below the well top plus the reduction length, then the conductance is reduced. This reduction length can be used to improve the stability of simulations with flowing wells so that there is not an abrupt change in flowing well rates.
- `rate` is the volumetric pumping rate for the multi-aquifer well. A positive value indicates recharge and a negative value indicates discharge (pumping). RATE only applies to active (IBOUND > 0) multi-aquifer wells. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value. By default, the RATE for each multi-aquifer well is zero.
- `well_head` is the head in the multi-aquifer well. WELL_HEAD is only applied to constant head (STATUS is CONSTANT) and inactive (STATUS is INACTIVE) multi-aquifer wells. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value. The program will terminate with an error if WELL_HEAD is less than the bottom of the well.
- `head_limit` is the limiting water level (head) in the well, which is the minimum of the well RATE or the well inflow rate from the aquifer. HEAD_LIMIT can be applied to extraction wells (RATE < 0) or injection wells (RATE > 0). HEAD_LIMIT can be deactivated by specifying the text string “OFF”. The HEAD_LIMIT

option is based on the HEAD_LIMIT functionality available in the MNW2 package for MODFLOW-2005. The HEAD_LIMIT option has been included to facilitate backward compatibility with previous versions of MODFLOW but use of the RATE_SCALING option instead of the HEAD_LIMIT option is recommended. By default, HEAD_LIMIT is “OFF”.

- SHUT_OFF keyword for activating well shut off capability. Subsequent values define the minimum and maximum pumping rate that a well must exceed to shutoff or reactivate a well, respectively, during a stress period. SHUT_OFF is only applied to injection wells (RATE<0) and if HEAD_LIMIT is specified (not set to “OFF”). If HEAD_LIMIT is specified, SHUT_OFF can be deactivated by specifying a minimum value equal to zero. The SHUT_OFF option is based on the SHUT_OFF functionality available in the MNW2 package for MODFLOW-2005. The SHUT_OFF option has been included to facilitate backward compatibility with previous versions of MODFLOW but use of the RATE_SCALING option instead of the SHUT_OFF option is recommended. By default, SHUT_OFF is not used.
- minrate is the minimum rate that a well must exceed to shutoff a well during a stress period. The well will shut down during a time step if the flow rate to the well from the aquifer is less than MINRATE. If a well is shut down during a time step, reactivation of the well cannot occur until the next time step to reduce oscillations. MINRATE must be less than maxrate.
- maxrate is the maximum rate that a well must exceed to reactivate a well during a stress period. The well will reactivate during a timestep if the well was shutdown during the previous time step and the flow rate to the well from the aquifer exceeds maxrate. Reactivation of the well cannot occur until the next time step if a well is shutdown to reduce oscillations. maxrate must be greater than MINRATE.
- RATE_SCALING activate rate scaling. If RATE_SCALING is specified, both PUMP_ELEVATION and SCALING_LENGTH must be specified. RATE_SCALING cannot be used with HEAD_LIMIT. RATE_SCALING can be used for extraction or injection wells. For extraction wells, the extraction rate will start to decrease once the head in the well lowers to a level equal to the pump elevation plus the scaling length. If the head in the well drops below the pump elevation, then the extraction rate is calculated to be zero. For an injection well, the injection rate will begin to decrease once the head in the well rises above the specified pump elevation. If the head in the well rises above the pump elevation plus the scaling length, then the injection rate will be set to zero.
- pump_elevation is the elevation of the multi-aquifer well pump (PUMP_ELEVATION). PUMP_ELEVATION should not be less than the bottom elevation (BOTTOM) of the multi-aquifer well.
- scaling_length height above the pump elevation (SCALING_LENGTH). If the simulated well head is below this elevation (pump elevation plus the scaling length), then the pumping rate is reduced.
- AUXILIARY keyword for specifying auxiliary variable.
- auxname name for the auxiliary variable to be assigned AUXVAL. AUXNAME must match one of the auxiliary variable names defined in the OPTIONS block. If AUXNAME does not match one of the auxiliary variable names defined in the OPTIONS block the data are ignored.
- auxval value for the auxiliary variable. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

Example Input File

Example 1

```
begin options
  print_input
  print_head
  print_flows
  boundnames
  head fileout maw-1.head.bin
```

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(continued from previous page)

```

    budget fileout maw-1.cbc
end options

begin dimensions
    nmawwells 2
end dimensions

begin packagedata
#  wellno radius bottom strt  condeqn ngwnodes name
    1    0.15 -100.0 9.14   thiem      2 pwell
    2    0.25 -100.0 9.14   thiem      1 iwell
end packagedata

begin connectiondata
#  wellno conn 1  r  c  stop  sbot  k  rskin
    1    1 1 51 51    0    0 0    0
    1    2 2 51 51    0    0 0    0
    2    1 2 2 2      0    0 0    0
end connectiondata

begin period 1
    1 rate_scaling -90. 5.
    1 rate -1767.
    2 status inactive
end period

begin period 100
    2 status active
    2 rate 529.
    1 rate -2767.
end period

```

Example 2

```

begin options
    print_input
    print_head
    print_flows
    boundnames
end options

begin dimensions
    nmawwells 2
end dimensions

begin packagedata
#  wellno radius bottom strt  condeqn ngwnodes name
    1    0.15 -100.0 9.14   mean      2 pwell
    2    0.25 -100.0 9.14   mean      1 iwell
end packagedata

begin connectiondata
#  wellno conn 1  r  c  stop  sbot  k  rskin
    1    1 1 51 51    0. -100. 361.  .25
    1    2 2 51 51    0. -100. 361.  .25
    2    1 2 2 2   -50. -100. 361  .50
end connectiondata

```

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```
begin period 1
  1 rate_scaling -90. 5.
  1 rate -1767.
  2 status inactive
end period

begin period 100
  2 status active
  2 rate 529.
  1 rate -2767.
end period
```

Example 3

```
begin options
  print_input
  print_head
  print_flows
  boundnames
  flowing_wells
end options

begin dimensions
  nmawwells 1
end dimensions

begin packagedata
  # wellno radius bottom strt condeqn ngwnodes name
    1 0.15 -514.9 9.14 specified 2 ntwell
end packagedata

begin connectiondata
  # wellno conn l r c stop sbot k rskin
    1 1 1 51 51 -50 -514.9 111.3763 0
    1 2 2 51 51 -50 -514.9 445.9849 0
end connectiondata

begin period 1
  1 rate 0
  1 flowing_well 0. 7500. 0.5
end period
```

Available Observation Types

Example Observation Input File

```
BEGIN OPTIONS
  DIGITS 10
  PRINT_INPUT
END OPTIONS

BEGIN CONTINUOUS FILEOUT my_model.maw.csv
  mlhead head 1
```

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(continued from previous page)

```

mlrate01 maw 1 1
mlrate02 maw 1 2
mlrate    maw well-1
m2rate01 maw well-2
END CONTINUOUS

```

1.3.17 GWF-MVR

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN OPTIONS
  [PRINT_INPUT]
  [PRINT_FLOWS]
  [MODELNAMES]
  [BUDGET FILEOUT <budgetfile>]
END OPTIONS

```

```

BEGIN DIMENSIONS
  MAXMVR <maxmvr>
  MAXPACKAGES <maxpackages>
END DIMENSIONS

```

```

BEGIN PACKAGES
  [<mname>] <pname>
  [<mname>] <pname>
  ...
END PACKAGES

```

FOR ANY STRESS PERIOD

```

BEGIN PERIOD <iper>
  [<mname1>] <pname1> <id1> [<mname2>] <pname2> <id2> <mvrtype> <value>
  [<mname1>] <pname1> <id1> [<mname2>] <pname2> <id2> <mvrtype> <value>
  ...
END PERIOD

```

Explanation of Variables

Block: OPTIONS

- **PRINT_INPUT** keyword to indicate that the list of MVR information will be written to the listing file immediately after it is read.
- **PRINT_FLOWS** keyword to indicate that the list of MVR flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- **MODELNAMES** keyword to indicate that all package names will be preceded by the model name for the package. Model names are required when the Mover Package is used with a GWF-GWF Exchange. The MODELNAME keyword should not be used for a Mover Package that is for a single GWF Model.

- `BUDGET` keyword to specify that record corresponds to the budget.
- `FILEOUT` keyword to specify that an output filename is expected next.
- `budgetfile` name of the output file to write budget information.

Block: DIMENSIONS

- `maxmvr` integer value specifying the maximum number of water mover entries that will be specified for any stress period.
- `maxpackages` integer value specifying the number of unique packages that are included in this water mover input file.

Block: PACKAGES

- `mname` name of model containing the package. Model names are assigned by the user in the simulation name file.
- `pname` is the name of a package that may be included in a subsequent stress period block. The package name is assigned in the name file for the GWF Model. Package names are optionally provided in the name file. If they are not provided by the user, then packages are assigned a default value, which is the package acronym followed by a hyphen and the package number. For example, the first Drain Package is named DRN-1. The second Drain Package is named DRN-2, and so forth.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. IPER must be less than or equal to NPER in the TDIS Package and greater than zero. The IPER value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- `mname1` name of model containing the package, PNAME1.
- `pname1` is the package name for the provider. The package PNAME1 must be designated to provide water through the MVR Package by specifying the keyword “MOVER” in its OPTIONS block.
- `id1` is the identifier for the provider. For the standard boundary packages, the provider identifier is the number of the boundary as it is listed in the package input file. (Note that the order of these boundaries may change by stress period, which must be accounted for in the Mover Package.) So the first well has an identifier of one. The second is two, and so forth. For the advanced packages, the identifier is the reach number (SFR Package), well number (MAW Package), or UZF cell number. For the Lake Package, ID1 is the lake outlet number. Thus, outflows from a single lake can be routed to different streams, for example.
- `mname2` name of model containing the package, PNAME2.
- `pname2` is the package name for the receiver. The package PNAME2 must be designated to receive water from the MVR Package by specifying the keyword “MOVER” in its OPTIONS block.
- `id2` is the identifier for the receiver. The receiver identifier is the reach number (SFR Package), Lake number (LAK Package), well number (MAW Package), or UZF cell number.
- `mvrtype` is the character string signifying the method for determining how much water will be moved. Supported values are “FACTOR” “EXCESS” “THRESHOLD” and “UPTO”. These four options determine how the receiver flow rate, Q_R , is calculated. These options mirror the options defined for the `cprior` variable in the SFR package, with the term “FACTOR” being functionally equivalent to the “FRACTION” option for `cprior`.

- value is the value to be used in the equation for calculating the amount of water to move. For the “FACTOR” option, VALUE is the alpha factor. For the remaining options, VALUE is the specified flow rate, Q_S.

Example Input File

```

BEGIN OPTIONS
  PRINT_INPUT
  PRINT_FLOWS
END OPTIONS

BEGIN DIMENSIONS
  MAXMVR 16
  MAXPACKAGES 5
END DIMENSIONS

BEGIN PACKAGES
  MAW-1
  MAW-2
  SFR-1
  LAK-1
  UZF-1
END PACKAGES

BEGIN PERIOD 1
# ***PROVIDER***      ***RECEIVER***      ***FLOW INFO**
#  PAK1  PAK1RCH      PAK2  PAK2RCH  TYPE      VALUE
  MAW-1      1  MAW-2      21  EXCESS      5.00
  MAW-1      11  SFR-1      77  FACTOR      0.25
  MAW-1      21  UZF-1      93  FACTOR      0.01
  MAW-1      21  LAK-1       3  FACTOR      1.00

  SFR-1     1021  MAW-1      21  THRESHOLD 10.0
  SFR-1     441  SFR-1      77  FACTOR      0.10
  SFR-1     56   UZF-1      93  FACTOR      0.10
  SFR-1    4587  LAK-1       3  FACTOR      1.00

  UZF-1       4  MAW-1      11  FACTOR      1.00
  UZF-1       5  SFR-1      22  FACTOR      1.00
  UZF-1       6  UZF-1      45  FACTOR      1.00
  UZF-1       7  LAK-1       3  FACTOR      1.00

  LAK-1       1  MAW-1      11  EXCESS     1000.
  LAK-1       2  SFR-1      22  UPTO       2000.
  LAK-1       3  UZF-1      45  UPTO       3000.
  LAK-1       4  LAK-1       3  UPTO       3000.
END PERIOD 1

```

1.3.18 GWF-NAM

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [LIST <list>]
  [PRINT_INPUT]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [NEWTON [UNDER_RELAXATION]]
END OPTIONS
```

```
BEGIN PACKAGES
  <ftype> <fname> [<pname>]
  <ftype> <fname> [<pname>]
  ...
END PACKAGES
```

Explanation of Variables

Block: OPTIONS

- `list` is name of the listing file to create for this GWF model. If not specified, then the name of the list file will be the basename of the GWF model name file and the `.lst` extension. For example, if the GWF name file is called `“my.model.nam”` then the list file will be called `“my.model.lst”`.
- `PRINT_INPUT` keyword to indicate that the list of all model stress package information will be written to the listing file immediately after it is read.
- `PRINT_FLOWS` keyword to indicate that the list of all model package flow rates will be printed to the listing file for every stress period time step in which `“BUDGET PRINT”` is specified in Output Control. If there is no Output Control option and `“PRINT_FLOWS”` is specified, then flow rates are printed for the last time step of each stress period.
- `SAVE_FLOWS` keyword to indicate that all model package flow terms will be written to the file specified with `“BUDGET FILEOUT”` in Output Control.
- `NEWTON` keyword that activates the Newton-Raphson formulation for groundwater flow between connected, convertible groundwater cells and stress packages that support calculation of Newton-Raphson terms for groundwater exchanges. Cells will not dry when this option is used. By default, the Newton-Raphson formulation is not applied.
- `UNDER_RELAXATION` keyword that indicates whether the groundwater head in a cell will be under-relaxed when water levels fall below the bottom of the model below any given cell. By default, Newton-Raphson `UNDER_RELAXATION` is not applied.

Block: PACKAGES

- `ftype` is the file type, which must be one of the following character values shown in table ref{table:ftype}. `Ftype` may be entered in any combination of uppercase and lowercase.
- `fname` is the name of the file containing the package input. The path to the file should be included if the file is not located in the folder where the program was run.
- `pname` is the user-defined name for the package. `PNAME` is restricted to 16 characters. No spaces are allowed in `PNAME`. `PNAME` character values are read and stored by the program for stress packages only. These names may be useful for labeling purposes when multiple stress packages of the same type are located within a single GWF Model. If `PNAME` is specified for a stress package, then `PNAME` will be used in the flow budget table in

the listing file; it will also be used for the text entry in the cell-by-cell budget file. PNAME is case insensitive and is stored in all upper case letters.

Example Input File

```
# This block is optional
BEGIN OPTIONS
  PRINT_INPUT
  PRINT_FLOWS
  SAVE_FLOWS
END OPTIONS

# List of packages. List can be listed in any order.
BEGIN PACKAGES
  IC6          bcf2ss.ic
  NPF6         bcf2ss.npf
  WEL6         bcf2ss.wel  WEL-COUNTY
  RIV6         bcf2ss.riv
  RCH6         bcf2ss.rch
  OC6          bcf2ss.oc
  DIS6         bcf2ss.dis
END PACKAGES
```

1.3.19 GWF-NPF

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [SAVE_FLOWS]
  [ALTERNATIVE_CELL_AVERAGING <alternative_cell_averaging>]
  [THICKSTR]
  [VARIABLECV [DEWATERED]]
  [PERCHED]
  [REWET WETFACT <wetfct> IWETIT <iwetit> IHDWET <ihdwet>]
  [XT3D [RHS]]
  [SAVE_SPECIFIC_DISCHARGE]
  [SAVE_SATURATION]
  [K22OVERK]
  [K33OVERK]
END OPTIONS
```

```
BEGIN GRIDDATA
  ICELLTYPE [LAYERED]
    <icelltype(nodes)> -- READARRAY
  K [LAYERED]
    <k(nodes)> -- READARRAY
  [K22 [LAYERED]
    <k22(nodes)> -- READARRAY]
  [K33 [LAYERED]
    <k33(nodes)> -- READARRAY]
  [ANGLE1 [LAYERED]
    <angle1(nodes)> -- READARRAY]
```

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```

[ANGLE2 [LAYERED]
    <angle2(nodes)> -- READARRAY]
[ANGLE3 [LAYERED]
    <angle3(nodes)> -- READARRAY]
[WETDRY [LAYERED]
    <wetdry(nodes)> -- READARRAY]
END GRIDDATA

```

Explanation of Variables

Block: OPTIONS

- **SAVE_FLOWS** keyword to indicate that budget flow terms will be written to the file specified with “BUDGET SAVE FILE” in Output Control.
- **alternative_cell_averaging** is a text keyword to indicate that an alternative method will be used for calculating the conductance for horizontal cell connections. The text value for **ALTERNATIVE_CELL_AVERAGING** can be “LOGARITHMIC”, “AMT-LMK”, or “AMT-HMK”. “AMT-LMK” signifies that the conductance will be calculated using arithmetic-mean thickness and logarithmic-mean hydraulic conductivity. “AMT-HMK” signifies that the conductance will be calculated using arithmetic-mean thickness and harmonic-mean hydraulic conductivity. If the user does not specify a value for **ALTERNATIVE_CELL_AVERAGING**, then the harmonic-mean method will be used. This option cannot be used if the **XT3D** option is invoked.
- **THICKSTRT** indicates that cells having a negative **ICELLTYPE** are confined, and their cell thickness for conductance calculations will be computed as **STRT-BOT** rather than **TOP-BOT**.
- **VARIABLECV** keyword to indicate that the vertical conductance will be calculated using the saturated thickness and properties of the overlying cell and the thickness and properties of the underlying cell. If the **DEWATERED** keyword is also specified, then the vertical conductance is calculated using only the saturated thickness and properties of the overlying cell if the head in the underlying cell is below its top. If these keywords are not specified, then the default condition is to calculate the vertical conductance at the start of the simulation using the initial head and the cell properties. The vertical conductance remains constant for the entire simulation.
- **DEWATERED** If the **DEWATERED** keyword is specified, then the vertical conductance is calculated using only the saturated thickness and properties of the overlying cell if the head in the underlying cell is below its top.
- **PERCHED** keyword to indicate that when a cell is overlying a dewatered convertible cell, the head difference used in Darcy’s Law is equal to the head in the overlying cell minus the bottom elevation of the overlying cell. If not specified, then the default is to use the head difference between the two cells.
- **REWET** activates model rewetting. Rewetting is off by default.
- **wetfct** is a keyword and factor that is included in the calculation of the head that is initially established at a cell when that cell is converted from dry to wet.
- **iwetit** is a keyword and iteration interval for attempting to wet cells. Wetting is attempted every **IWETIT** iteration. This applies to outer iterations and not inner iterations. If **IWETIT** is specified as zero or less, then the value is changed to 1.
- **ihdwet** is a keyword and integer flag that determines which equation is used to define the initial head at cells that become wet. If **IHDWET** is 0, $h = \text{BOT} + \text{WETFCT}(\text{hm} - \text{BOT})$. If **IHDWET** is not 0, $h = \text{BOT} + \text{WETFCT}(\text{THRESH})$.
- **XT3D** keyword indicating that the **XT3D** formulation will be used. If the **RHS** keyword is also included, then the **XT3D** additional terms will be added to the right-hand side. If the **RHS** keyword is excluded, then the **XT3D** terms will be put into the coefficient matrix. Use of **XT3D** will substantially increase the computational effort,

but will result in improved accuracy for anisotropic conductivity fields and for unstructured grids in which the CVFD requirement is violated. XT3D requires additional information about the shapes of grid cells. If XT3D is active and the DISU Package is used, then the user will need to provide in the DISU Package the angldegx array in the CONNECTIONDATA block and the VERTICES and CELL2D blocks.

- **RHS** If the RHS keyword is also included, then the XT3D additional terms will be added to the right-hand side. If the RHS keyword is excluded, then the XT3D terms will be put into the coefficient matrix.
- **SAVE_SPECIFIC_DISCHARGE** keyword to indicate that x, y, and z components of specific discharge will be calculated at cell centers and written to the budget file, which is specified with “BUDGET SAVE FILE” in Output Control. If this option is activated, then additional information may be required in the discretization packages and the GWF Exchange package (if GWF models are coupled). Specifically, ANGLDEGX must be specified in the CONNECTIONDATA block of the DISU Package; ANGLDEGX must also be specified for the GWF Exchange as an auxiliary variable.
- **SAVE_SATURATION** keyword to indicate that cell saturation will be written to the budget file, which is specified with “BUDGET SAVE FILE” in Output Control. Saturation will be saved to the budget file as an auxiliary variable saved with the DATA-SAT text label. Saturation is a cell variable that ranges from zero to one and can be used by post processing programs to determine how much of a cell volume is saturated. If ICELLTYPE is 0, then saturation is always one.
- **K22OVERK** keyword to indicate that specified K22 is a ratio of K22 divided by K. If this option is specified, then the K22 array entered in the NPF Package will be multiplied by K after being read.
- **K33OVERK** keyword to indicate that specified K33 is a ratio of K33 divided by K. If this option is specified, then the K33 array entered in the NPF Package will be multiplied by K after being read.

Block: GRIDDATA

- **icelltype** flag for each cell that specifies how saturated thickness is treated. 0 means saturated thickness is held constant; >0 means saturated thickness varies with computed head when head is below the cell top; <0 means saturated thickness varies with computed head unless the THICKSTRT option is in effect. When THICKSTRT is in effect, a negative value of icelltype indicates that saturated thickness will be computed as STRT-BOT and held constant.
- **k** is the hydraulic conductivity. For the common case in which the user would like to specify the horizontal hydraulic conductivity and the vertical hydraulic conductivity, then K should be assigned as the horizontal hydraulic conductivity, K33 should be assigned as the vertical hydraulic conductivity, and K22 and the three rotation angles should not be specified. When more sophisticated anisotropy is required, then K corresponds to the K11 hydraulic conductivity axis. All included cells (IDOMAIN > 0) must have a K value greater than zero.
- **k22** is the hydraulic conductivity of the second ellipsoid axis (or the ratio of K22/K if the K22OVERK option is specified); for an unrotated case this is the hydraulic conductivity in the y direction. If K22 is not included in the GRIDDATA block, then K22 is set equal to K. For a regular MODFLOW grid (DIS Package is used) in which no rotation angles are specified, K22 is the hydraulic conductivity along columns in the y direction. For an unstructured DISU grid, the user must assign principal x and y axes and provide the angle for each cell face relative to the assigned x direction. All included cells (IDOMAIN > 0) must have a K22 value greater than zero.
- **k33** is the hydraulic conductivity of the third ellipsoid axis (or the ratio of K33/K if the K33OVERK option is specified); for an unrotated case, this is the vertical hydraulic conductivity. When anisotropy is applied, K33 corresponds to the K33 tensor component. All included cells (IDOMAIN > 0) must have a K33 value greater than zero.
- **angle1** is a rotation angle of the hydraulic conductivity tensor in degrees. The angle represents the first of three sequential rotations of the hydraulic conductivity ellipsoid. With the K11, K22, and K33 axes of the ellipsoid initially aligned with the x, y, and z coordinate axes, respectively, ANGLE1 rotates the ellipsoid about its K33 axis (within the x - y plane). A positive value represents counter-clockwise rotation when viewed from any

point on the positive K33 axis, looking toward the center of the ellipsoid. A value of zero indicates that the K11 axis lies within the x - z plane. If ANGLE1 is not specified, default values of zero are assigned to ANGLE1, ANGLE2, and ANGLE3, in which case the K11, K22, and K33 axes are aligned with the x, y, and z axes, respectively.

- `angle2` is a rotation angle of the hydraulic conductivity tensor in degrees. The angle represents the second of three sequential rotations of the hydraulic conductivity ellipsoid. Following the rotation by ANGLE1 described above, ANGLE2 rotates the ellipsoid about its K22 axis (out of the x - y plane). An array can be specified for ANGLE2 only if ANGLE1 is also specified. A positive value of ANGLE2 represents clockwise rotation when viewed from any point on the positive K22 axis, looking toward the center of the ellipsoid. A value of zero indicates that the K11 axis lies within the x - y plane. If ANGLE2 is not specified, default values of zero are assigned to ANGLE2 and ANGLE3; connections that are not user-designated as vertical are assumed to be strictly horizontal (that is, to have no z component to their orientation); and connection lengths are based on horizontal distances.
- `angle3` is a rotation angle of the hydraulic conductivity tensor in degrees. The angle represents the third of three sequential rotations of the hydraulic conductivity ellipsoid. Following the rotations by ANGLE1 and ANGLE2 described above, ANGLE3 rotates the ellipsoid about its K11 axis. An array can be specified for ANGLE3 only if ANGLE1 and ANGLE2 are also specified. An array must be specified for ANGLE3 if ANGLE2 is specified. A positive value of ANGLE3 represents clockwise rotation when viewed from any point on the positive K11 axis, looking toward the center of the ellipsoid. A value of zero indicates that the K22 axis lies within the x - y plane.
- `wetdry` is a combination of the wetting threshold and a flag to indicate which neighboring cells can cause a cell to become wet. If WETDRY < 0, only a cell below a dry cell can cause the cell to become wet. If WETDRY > 0, the cell below a dry cell and horizontally adjacent cells can cause a cell to become wet. If WETDRY is 0, the cell cannot be wetted. The absolute value of WETDRY is the wetting threshold. When the sum of BOT and the absolute value of WETDRY at a dry cell is equaled or exceeded by the head at an adjacent cell, the cell is wetted. WETDRY must be specified if "REWET" is specified in the OPTIONS block. If "REWET" is not specified in the options block, then WETDRY can be entered, and memory will be allocated for it, even though it is not used.

Example Input File

```
BEGIN OPTIONS
  SAVE_FLOWS
END OPTIONS

BEGIN GRIDDATA
  #
  #icelltype(nodes) is 0:confined, 1:convertible
  ICELLTYPE
    constant 0
  #
  # horizontal hydraulic conductivity
  K
    constant 1.0
  #
  # vertical hydraulic conductivity
  K33
    constant 0.1
END GRIDDATA
```

1.3.20 GWF-OC

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [BUDGET FILEOUT <budgetfile>]
  [HEAD FILEOUT <headfile>]
  [HEAD PRINT_FORMAT COLUMNS <columns> WIDTH <width> DIGITS <digits> <format>]
END OPTIONS
```

FOR ANY STRESS PERIOD

```
BEGIN PERIOD <iper>
  [SAVE <rtype> <ocsetting>]
  [PRINT <rtype> <ocsetting>]
END PERIOD
```

Explanation of Variables

Block: OPTIONS

- **BUDGET** keyword to specify that record corresponds to the budget.
- **FILEOUT** keyword to specify that an output filename is expected next.
- `budgetfile` name of the output file to write budget information.
- **HEAD** keyword to specify that record corresponds to head.
- `headfile` name of the output file to write head information.
- **PRINT_FORMAT** keyword to specify format for printing to the listing file.
- `columns` number of columns for writing data.
- `width` width for writing each number.
- `digits` number of digits to use for writing a number.
- `format` write format can be EXPONENTIAL, FIXED, GENERAL, or SCIENTIFIC.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. IPER must be less than or equal to NPER in the TDIS Package and greater than zero. The IPER value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- **SAVE** keyword to indicate that information will be saved this stress period.
- **PRINT** keyword to indicate that information will be printed this stress period.
- `rtype` type of information to save or print. Can be BUDGET or HEAD.
- `ocsetting` specifies the steps for which the data will be saved.

```
ALL
FIRST
LAST
FREQUENCY <frequency>
STEPS <steps (<nstp>)>
```

- ALL keyword to indicate save for all time steps in period.
- FIRST keyword to indicate save for first step in period. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.
- LAST keyword to indicate save for last step in period. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.
- frequency save at the specified time step frequency. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.
- steps save for each step specified in STEPS. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

Example Input File

```
BEGIN OPTIONS
  HEAD FILEOUT AdvGW_tidal.hds
  BUDGET FILEOUT AdvGW_tidal.cbc
  HEAD PRINT_FORMAT COLUMNS 100 WIDTH 15 DIGITS 4 GENERAL
END OPTIONS

BEGIN PERIOD 1
  PRINT HEAD FIRST
  PRINT HEAD LAST
  PRINT BUDGET LAST
  SAVE HEAD ALL
  SAVE BUDGET ALL
END PERIOD

# No output for stress periods 2 through 24
BEGIN PERIOD 2
END PERIOD

BEGIN PERIOD 25
  PRINT HEAD STEPS 6 12 23
  SAVE BUDGET FIRST
  SAVE BUDGET LAST
  SAVE BUDGET FREQUENCY 5
END PERIOD
```

1.3.21 GWF-RCH

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [FIXED_CELL]
```

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```

[AUXILIARY <auxiliary(naux)>]
[AUXMULTNAME <auxmultname>]
[BOUNDNAMES]
[PRINT_INPUT]
[PRINT_FLOWS]
[SAVE_FLOWS]
[TS6 FILEIN <ts6_filename>]
[OBS6 FILEIN <obs6_filename>]
END OPTIONS

```

```

BEGIN DIMENSIONS
    MAXBOUND <maxbound>
END DIMENSIONS

```

FOR ANY STRESS PERIOD

```

BEGIN PERIOD <iper>
    <cellid(ncelldim)> <recharge> [<aux(naux)>] [<boundname>]
    <cellid(ncelldim)> <recharge> [<aux(naux)>] [<boundname>]
    ...
END PERIOD

```

Explanation of Variables**Block: OPTIONS**

- **FIXED_CELL** indicates that recharge will not be reassigned to a cell underlying the cell specified in the list if the specified cell is inactive.
- **auxiliary** defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for **naux**. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** name of auxiliary variable to be used as multiplier of recharge.
- **BOUNDNAMES** keyword to indicate that boundary names may be provided with the list of recharge cells.
- **PRINT_INPUT** keyword to indicate that the list of recharge information will be written to the listing file immediately after it is read.
- **PRINT_FLOWS** keyword to indicate that the list of recharge flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- **SAVE_FLOWS** keyword to indicate that recharge flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- **TS6** keyword to specify that record corresponds to a time-series file.
- **FILEIN** keyword to specify that an input filename is expected next.
- **ts6_filename** defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.

- OBS6 keyword to specify that record corresponds to an observations file.
- obs6_filename name of input file to define observations for the Recharge package. See the “Observation utility” section for instructions for preparing observation input files. Tables [ref{table:gwf-obstypetable}](#) and [ref{table:gwt-obstypetable}](#) lists observation type(s) supported by the Recharge package.

Block: DIMENSIONS

- maxbound integer value specifying the maximum number of recharge cells that will be specified for use during any stress period.

Block: PERIOD

- iper integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. IPER must be less than or equal to NPER in the TDIS Package and greater than zero. The IPER value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- cellid is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell.
- recharge is the recharge flux rate (LT-1). This rate is multiplied inside the program by the surface area of the cell to calculate the volumetric recharge rate. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- aux represents the values of the auxiliary variables for each recharge. The values of auxiliary variables must be present for each recharge. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- boundname name of the recharge cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

Example Input File

Example 1

```
BEGIN OPTIONS
  AUXILIARY var1 var2 mult
  PRINT_INPUT
  PRINT_FLOWS
  SAVE_FLOWS
  BOUNDNAMES
  TS6 FILEIN recharge_rates.ts
  # Note: Time-series file recharge_rates.ts defines time series rch_1
  AUXMULTNAME mult
END OPTIONS
```

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```

BEGIN DIMENSIONS
  MAXBOUND 10
END DIMENSIONS

BEGIN PERIOD 1
  RECHARGE
    # Lay  Row  Col  Rate  Var1  Var2  mult  BoundName
      1    1    1  rch_1  1.0   2.0   1.0      Rch-1-1
      1    1    2  rch_1  1.1   2.1   1.0      Rch-1-2
      1    1    3  rch_1  1.2   2.2   0.5
      1    2    1  rch_1  1.3   2.3   1.0      Rch-2-1
      1    2    2  rch_1  1.4   2.4   1.0      Rch-2-2
      1    2    3  rch_1  1.5   2.5   1.0
      1    2    4  rch_1  1.6   2.6   0.5
      1    3    1  rch_1  1.7   2.7   1.0
      1    3    2  rch_1  1.8   2.8   1.0
      1    3    3  rch_1  1.9   2.9   1.0
  END PERIOD

```

Example 2

```

BEGIN OPTIONS
  AUXILIARY var1 var2 mymult
  READASARRAYS
  PRINT_INPUT
  PRINT_FLOWS
  SAVE_FLOWS
  AUXMULTNAME mymult
END OPTIONS

BEGIN PERIOD 1

  # For this model, the absence of an IRCH array causes
  # recharge to apply to model layer 1. To make recharge
  # apply to layer 2 instead, the following lines
  # (uncommented) could be used:
  # IRCH
  #   constant 2

  # recharge rate
  RECHARGE
    constant 0.0040

  # auxiliary variable (var1) array
  var1
    constant 100.

  # auxiliary variable (var2) array
  var2
    constant 0.

  # auxiliary variable (mymult) array
  # Because ``AUXMULTNAME mymult`` was specified in the
  # options block, the MYMULT array will be used to multiply
  # the values in the RECHARGE array
  MYMULT
    INTERNAL FACTOR 1.0

```

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```

0.5  1.0  1.0  0.5
1.0  1.0  1.0  1.0
0.5  1.0  1.0  0.5

END PERIOD

```

Available Observation Types

Example Observation Input File

```

BEGIN OPTIONS
  PRINT_INPUT
END OPTIONS

BEGIN CONTINUOUS FILEOUT my_model.rch.csv
  rch1-1    RCH    Rch-1-1
  rch1-2    RCH    Rch-1-2
  rch2-1    RCH    Rch-2-1
  rch2-2    RCH    Rch-2-2
  rch2-3    RCH    1  2  3
END CONTINUOUS

```

1.3.22 GWF-RCHA

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN OPTIONS
  READASARRAYS
  [FIXED_CELL]
  [AUXILIARY <auxiliary(naux)>]
  [AUXMULTNAME <auxmultname>]
  [PRINT_INPUT]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [TAS6 FILEIN <tas6_filename>]
  [OBS6 FILEIN <obs6_filename>]
END OPTIONS

```

FOR ANY STRESS PERIOD

```

BEGIN PERIOD <iper>
  [IRCH
    <irch(ncol*nrow; ncpl)> -- READARRAY]
  RECHARGE
    <recharge(ncol*nrow; ncpl)> -- READARRAY
  [AUX
    <aux(ncol*nrow; ncpl)> -- READARRAY]
END PERIOD

```

Explanation of Variables

Block: OPTIONS

- `READASARRAYS` indicates that array-based input will be used for the Recharge Package. This keyword must be specified to use array-based input.
- `FIXED_CELL` indicates that recharge will not be reassigned to a cell underlying the cell specified in the list if the specified cell is inactive.
- `auxiliary` defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for `naux`. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- `auxmultname` name of auxiliary variable to be used as multiplier of recharge.
- `PRINT_INPUT` keyword to indicate that the list of recharge information will be written to the listing file immediately after it is read.
- `PRINT_FLOWS` keyword to indicate that the list of recharge flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- `SAVE_FLOWS` keyword to indicate that recharge flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- `TAS6` keyword to specify that record corresponds to a time-array-series file.
- `FILEIN` keyword to specify that an input filename is expected next.
- `tas6_filename` defines a time-array-series file defining a time-array series that can be used to assign time-varying values. See the Time-Variable Input section for instructions on using the time-array series capability.
- `OBS6` keyword to specify that record corresponds to an observations file.
- `obs6_filename` name of input file to define observations for the Recharge package. See the “Observation utility” section for instructions for preparing observation input files. Tables `ref{table:gwf-obstypetable}` and `ref{table:gwt-obstypetable}` lists observation type(s) supported by the Recharge package.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. `IPER` must be less than or equal to `NPER` in the TDIS Package and greater than zero. The `IPER` value assigned to a stress period block must be greater than the `IPER` value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- `irch` `IRCH` is the layer number that defines the layer in each vertical column where recharge is applied. If `IRCH` is omitted, recharge by default is applied to cells in layer 1. `IRCH` can only be used if `READASARRAYS` is specified in the OPTIONS block. If `IRCH` is specified, it must be specified as the first variable in the PERIOD block or MODFLOW will terminate with an error.
- `recharge` is the recharge flux rate (LT-1). This rate is multiplied inside the program by the surface area of the cell to calculate the volumetric recharge rate. The recharge array may be defined by a time-array series (see the “Using Time-Array Series in a Package” section).

- `aux` is an array of values for auxiliary variable `aux(iaux)`, where `iaux` is a value from 1 to `naux`, and `aux(iaux)` must be listed as part of the auxiliary variables. A separate array can be specified for each auxiliary variable. If an array is not specified for an auxiliary variable, then a value of zero is assigned. If the value specified here for the auxiliary variable is the same as `auxmultname`, then the recharge array will be multiplied by this array.

Example Input File

```
BEGIN OPTIONS
  AUXILIARY var1 var2 mymult
  READASARRAYS
  PRINT_INPUT
  PRINT_FLOWS
  SAVE_FLOWS
  AUXMULTNAME mymult
END OPTIONS

BEGIN PERIOD 1

  # For this model, the absence of an IRCH array causes
  # recharge to apply to model layer 1. To make recharge
  # apply to layer 2 instead, the following lines
  # (uncommented) could be used:
  # IRCH
  #   constant 2

  # recharge rate
  RECHARGE
    constant 0.0040

  # auxiliary variable (var1) array
  var1
    constant 100.

  # auxiliary variable (var2) array
  var2
    constant 0.

  # auxiliary variable (mymult) array
  # Because ``AUXMULTNAME mymult'' was specified in the
  # options block, the MYMULT array will be used to multiply
  # the values in the RECHARGE array
  MYMULT
    INTERNAL FACTOR  1.0
      0.5  1.0  1.0  0.5
      1.0  1.0  1.0  1.0
      0.5  1.0  1.0  0.5

END PERIOD
```

1.3.23 GWF-RIV

Structure of Blocks

FOR EACH SIMULATION


```

BEGIN OPTIONS
  [AUXILIARY <auxiliary(naux)>]
  [AUXMULTNAME <auxmultname>]
  [BOUNDNAMES]
  [PRINT_INPUT]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [TS6 FILEIN <ts6_filename>]
  [OBS6 FILEIN <obs6_filename>]
  [MOVER]
END OPTIONS

```

```

BEGIN DIMENSIONS
  MAXBOUND <maxbound>
END DIMENSIONS

```

FOR ANY STRESS PERIOD

```

BEGIN PERIOD <iper>
  <cellid(ncellldim)> <stage> <cond> <rbot> [<aux(naux)>] [<boundname>]
  <cellid(ncellldim)> <stage> <cond> <rbot> [<aux(naux)>] [<boundname>]
  ...
END PERIOD

```

Explanation of Variables

Block: OPTIONS

- `auxiliary` defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for `naux`. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- `auxmultname` name of auxiliary variable to be used as multiplier of riverbed conductance.
- `BOUNDNAMES` keyword to indicate that boundary names may be provided with the list of river cells.
- `PRINT_INPUT` keyword to indicate that the list of river information will be written to the listing file immediately after it is read.
- `PRINT_FLOWS` keyword to indicate that the list of river flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- `SAVE_FLOWS` keyword to indicate that river flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- `TS6` keyword to specify that record corresponds to a time-series file.
- `FILEIN` keyword to specify that an input filename is expected next.
- `ts6_filename` defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- `OBS6` keyword to specify that record corresponds to an observations file.

- `obs6_filename` name of input file to define observations for the River package. See the “Observation utility” section for instructions for preparing observation input files. Tables `ref{table:gwf-obstypetable}` and `ref{table:gwt-obstypetable}` lists observation type(s) supported by the River package.
- `MOVER` keyword to indicate that this instance of the River Package can be used with the Water Mover (MVR) Package. When the `MOVER` option is specified, additional memory is allocated within the package to store the available, provided, and received water.

Block: DIMENSIONS

- `maxbound` integer value specifying the maximum number of rivers cells that will be specified for use during any stress period.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. `IPER` must be less than or equal to `NPER` in the TDIS Package and greater than zero. The `IPER` value assigned to a stress period block must be greater than the `IPER` value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- `cellid` is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, `CELLID` is the layer, row, and column. For a grid that uses the DISV input file, `CELLID` is the layer and `CELL2D` number. If the model uses the unstructured discretization (DISU) input file, `CELLID` is the node number for the cell.
- `stage` is the head in the river. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `cond` is the riverbed hydraulic conductance. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `rbot` is the elevation of the bottom of the riverbed. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `aux` represents the values of the auxiliary variables for each river. The values of auxiliary variables must be present for each river. The values must be specified in the order of the auxiliary variables specified in the `OPTIONS` block. If the package supports time series and the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `boundname` name of the river cell. `BOUNDNAME` is an ASCII character variable that can contain as many as 40 characters. If `BOUNDNAME` contains spaces in it, then the entire name must be enclosed within single quotes.

Example Input File

```
BEGIN OPTIONS
  PRINT_INPUT
  PRINT_FLOWS
  SAVE_FLOWS
```

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```

BOUNDNAMES
  TS6 FILEIN river_stages.ts
END OPTIONS

begin dimensions
  MAXBOUND 20
end dimensions

BEGIN PERIOD 1
# layer  row  col  stage      cond  rbot  BoundName
   1     3    1   river_stage_1  1001.  35.9
   1     4    2   river_stage_1  1002.  35.8
   1     5    3   river_stage_1  1003.  35.7
   1     5    4   river_stage_1  1004.  35.6
   1     6    5   river_stage_1  1005.  35.5
   1     6    6   river_stage_1  1006.  35.4  riv1_c6
   1     6    7   river_stage_1  1007.  35.3  riv1_c7
   1     5    8   river_stage_1  1008.  35.2
   1     5    9   river_stage_1  1009.  35.1
   1     5   10   river_stage_1  1010.  35.0
   1    10    1   river_stage_2  1001.  36.9  riv2_upper
   1     9    2   river_stage_2  1002.  36.8  riv2_upper
   1     8    3   river_stage_2  1003.  36.7  riv2_upper
   1     7    4   river_stage_2  1004.  36.6
   1     7    5   river_stage_2  1005.  36.5
   1     6    6   river_stage_2  1006.  36.4  riv2_c6
   1     6    7   river_stage_2  1007.  36.3  riv2_c7
   1     7    8   river_stage_2  1008.  36.2
   1     7    9   river_stage_2  1009.  36.1
   1     7   10   river_stage_2  1010.  36.0
END PERIOD

```

Available Observation Types

Example Observation Input File

```

BEGIN OPTIONS
  DIGITS 7
  PRINT_INPUT
END OPTIONS

BEGIN CONTINUOUS FILEOUT my_model.riv.csv
# obsname      type  ID
rv1-5-4        RIV   1   5   4
rv1-6-5        RIV   1   6   5
rv1-c7         RIV   riv1_c7   # flow at boundary "riv1_c7"
rv2-7-4        RIV   1   7   4
rv2-8-5        RIV   1   7   5
rv2-9-6        RIV   1   6   6
END CONTINUOUS

BEGIN CONTINUOUS FILEOUT my_model.riv.flows.csv
# obsname      type  ID
rv1-3-1        RIV   1   3   1
rv1-4-2        RIV   1   4   2

```

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```

rv1-5-3      RIV  1   5   3
rv1-c6       RIV  riv1_c6
rv2-upper    RIV  riv2_upper
END CONTINUOUS

```

1.3.24 GWF-SFR

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN OPTIONS
  [AUXILIARY <auxiliary(naux)>]
  [BOUNDNAMES]
  [PRINT_INPUT]
  [PRINT_STAGE]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [STAGE FILEOUT <stagefile>]
  [BUDGET FILEOUT <budgetfile>]
  [PACKAGE_CONVERGENCE FILEOUT <package_convergence_filename>]
  [TS6 FILEIN <ts6_filename>]
  [OBS6 FILEIN <obs6_filename>]
  [MOVER]
  [MAXIMUM_PICARD_ITERATIONS <maximum_picard_iterations>]
  [MAXIMUM_ITERATIONS <maximum_iterations>]
  [MAXIMUM_DEPTH_CHANGE <maximum_depth_change>]
  [UNIT_CONVERSION <unit_conversion>]
END OPTIONS

```

```

BEGIN DIMENSIONS
  NREACHES <nreaches>
END DIMENSIONS

```

```

BEGIN PACKAGEDATA
  <rno> <cellid(ncelldim)> <rlen> <rwid> <rgrd> <rtp> <rbth> <rhk> <man> <ncon>
  ↳<ustrf> <ndv> [<aux(naux)>] [<boundname>]
  <rno> <cellid(ncelldim)> <rlen> <rwid> <rgrd> <rtp> <rbth> <rhk> <man> <ncon>
  ↳<ustrf> <ndv> [<aux(naux)>] [<boundname>]
  ...
END PACKAGEDATA

```

```

BEGIN CONNECTIONDATA
  <rno> [<ic(ncon(rno))>]
  <rno> [<ic(ncon(rno))>]
  ...
END CONNECTIONDATA

```

```

BEGIN DIVERSIONS
  <rno> <idv> <iconr> <cprior>
  <rno> <idv> <iconr> <cprior>
  ...
END DIVERSIONS

```

FOR ANY STRESS PERIOD

```

BEGIN PERIOD <iper>
  <rno> <sfrsetting>
  <rno> <sfrsetting>
  ...
END PERIOD

```

Explanation of Variables**Block: OPTIONS**

- `auxiliary` defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for `naux`. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- `BOUNDNAMES` keyword to indicate that boundary names may be provided with the list of stream reach cells.
- `PRINT_INPUT` keyword to indicate that the list of stream reach information will be written to the listing file immediately after it is read.
- `PRINT_STAGE` keyword to indicate that the list of stream reach stages will be printed to the listing file for every stress period in which “HEAD PRINT” is specified in Output Control. If there is no Output Control option and `PRINT_STAGE` is specified, then stages are printed for the last time step of each stress period.
- `PRINT_FLOWS` keyword to indicate that the list of stream reach flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- `SAVE_FLOWS` keyword to indicate that stream reach flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- `STAGE` keyword to specify that record corresponds to stage.
- `stagefile` name of the binary output file to write stage information.
- `BUDGET` keyword to specify that record corresponds to the budget.
- `FILEOUT` keyword to specify that an output filename is expected next.
- `budgetfile` name of the binary output file to write budget information.
- `PACKAGE_CONVERGENCE` keyword to specify that record corresponds to the package convergence comma spaced values file.
- `package_convergence_filename` name of the comma spaced values output file to write package convergence information.
- `TS6` keyword to specify that record corresponds to a time-series file.
- `FILEIN` keyword to specify that an input filename is expected next.
- `ts6_filename` defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- `OBS6` keyword to specify that record corresponds to an observations file.

- `obs6_filename` name of input file to define observations for the SFR package. See the “Observation utility” section for instructions for preparing observation input files. Tables [ref{table:gwf-obstypetable}](#) and [ref{table:gwt-obstypetable}](#) lists observation type(s) supported by the SFR package.
- `MOVER` keyword to indicate that this instance of the SFR Package can be used with the Water Mover (MVR) Package. When the `MOVER` option is specified, additional memory is allocated within the package to store the available, provided, and received water.
- `maximum_picard_iterations` value that defines the maximum number of Streamflow Routing picard iterations allowed when solving for reach stages and flows as part of the GWF formulate step. Picard iterations are used to minimize differences in SFR package results between subsequent GWF picard (non-linear) iterations as a result of non-optimal reach numbering. If reaches are numbered in order, from upstream to downstream, `MAXIMUM_PICARD_ITERATIONS` can be set to 1 to reduce model run time. By default, `MAXIMUM_PICARD_ITERATIONS` is equal to 100.
- `maximum_iterations` value that defines the maximum number of Streamflow Routing Newton-Raphson iterations allowed for a reach. By default, `MAXIMUM_ITERATIONS` is equal to 100.
- `maximum_depth_change` value that defines the depth closure tolerance. By default, `DMAXCHG` is equal to 1×10^{-5} .
- `unit_conversion` value (or conversion factor) that is used in calculating stream depth for stream reach. 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.

Block: DIMENSIONS

- `nreaches` integer value specifying the number of stream reaches. There must be `NREACHES` entries in the `PACKAGEDATA` block.

Block: PACKAGEDATA

- `rno` integer value that defines the reach number associated with the specified `PACKAGEDATA` data on the line. `RNO` must be greater than zero and less than or equal to `NREACHES`. Reach information must be specified for every reach or the program will terminate with an error. The program will also terminate with an error if information for a reach is specified more than once.
- `cellid` The keyword “NONE” must be specified for reaches that are not connected to an underlying GWF cell. The keyword “NONE” is used for reaches that are in cells that have `IDOMAIN` values less than one or are in areas not covered by the GWF model grid. Reach-aquifer flow is not calculated if the keyword “NONE” is specified.
- `rln` real value that defines the reach length. `RLEN` must be greater than zero.
- `rwid` real value that defines the reach width. `RWID` must be greater than zero.
- `rgrd` real value that defines the stream gradient (slope) across the reach. `RGRD` must be greater than zero.
- `rtp` real value that defines the top elevation of the reach streambed.
- `rbth` real value that defines the thickness of the reach streambed. `RBTH` can be any value if `CELLID` is “NONE”. Otherwise, `RBTH` must be greater than zero.
- `rhk` real value that defines the hydraulic conductivity of the reach streambed. `RHK` can be any positive value if `CELLID` is “NONE”. Otherwise, `RHK` must be greater than zero.
- `man` real or character value that defines the Manning’s roughness coefficient for the reach. `MAN` must be greater than zero. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- `ncon` integer value that defines the number of reaches connected to the reach. If a value of zero is specified for `NCON` an entry for `RNO` is still required in the subsequent `CONNECTIONDATA` block.
- `ustrf` real value that defines the fraction of upstream flow from each upstream reach that is applied as upstream inflow to the reach. The sum of all `USTRF` values for all reaches connected to the same upstream reach must be equal to one and `USTRF` must be greater than or equal to zero. If the Options block includes a `TIMESERIES-FILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `ndv` integer value that defines the number of downstream diversions for the reach.
- `aux` represents the values of the auxiliary variables for each stream reach. The values of auxiliary variables must be present for each stream reach. The values must be specified in the order of the auxiliary variables specified in the `OPTIONS` block. If the package supports time series and the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `boundname` name of the stream reach cell. `BOUNDNAME` is an ASCII character variable that can contain as many as 40 characters. If `BOUNDNAME` contains spaces in it, then the entire name must be enclosed within single quotes.

Block: CONNECTIONDATA

- `rno` integer value that defines the reach number associated with the specified `CONNECTIONDATA` data on the line. `RNO` must be greater than zero and less than or equal to `NREACHES`. Reach connection information must be specified for every reach or the program will terminate with an error. The program will also terminate with an error if connection information for a reach is specified more than once.
- `ic` integer value that defines the reach number of the reach connected to the current reach and whether it is connected to the upstream or downstream end of the reach. Negative `IC` numbers indicate connected reaches are connected to the downstream end of the current reach. Positive `IC` numbers indicate connected reaches are connected to the upstream end of the current reach. The absolute value of `IC` must be greater than zero and less than or equal to `NREACHES`. `IC` should not be specified when `NCON` is zero but must be specified otherwise.

Block: DIVERSIONS

- `rno` integer value that defines the reach number associated with the specified `DIVERSIONS` data on the line. `RNO` must be greater than zero and less than or equal to `NREACHES`. Reach diversion information must be specified for every reach with a `NDV` value greater than 0 or the program will terminate with an error. The program will also terminate with an error if diversion information for a given reach diversion is specified more than once.
- `idv` integer value that defines the downstream diversion number for the diversion for reach `RNO`. `IDV` must be greater than zero and less than or equal to `NDV` for reach `RNO`.
- `iconr` integer value that defines the downstream reach that will receive the diverted water. `IDV` must be greater than zero and less than or equal to `NREACHES`. Furthermore, reach `ICONR` must be a downstream connection for reach `RNO`.
- `cprior` character string value that defines the prioritization system for the diversion, such as when insufficient water is available to meet all diversion stipulations, and is used in conjunction with the value of `FLOW` value specified in the `STRESS_PERIOD_DATA` section. Available diversion options include: (1) `CPRIOR` = “`FRACTION`”, then the amount of the diversion is computed as a fraction of the streamflow leaving reach `RNO` (Q_{DS}); in this case, `0.0 DIVFLOW 1.0`. (2) `CPRIOR` = “`EXCESS`”, a diversion is made only if Q_{DS} for reach `RNO` exceeds the value of `DIVFLOW`. If this occurs, then the quantity of water diverted is the excess

flow ($Q_{DS} - \text{DIVFLOW}$) and Q_{DS} from reach RNO is set equal to DIVFLOW. This represents a flood-control type of diversion, as described by Danskin and Hanson (2002). (3) CPRIOR = "THRESHOLD", then if Q_{DS} in reach RNO is less than the specified diversion flow DIVFLOW, no water is diverted from reach RNO. If Q_{DS} in reach RNO is greater than or equal to DIVFLOW, DIVFLOW is diverted and Q_{DS} is set to the remainder ($Q_{DS} - \text{DIVFLOW}$). 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). (4) CPRIOR = "UPTO" – if Q_{DS} in reach RNO is greater than or equal to the specified diversion flow DIVFLOW, Q_{DS} is reduced by DIVFLOW. If Q_{DS} in reach RNO is less than DIVFLOW, DIVFLOW is set to Q_{DS} and there will be no flow available for reaches connected to downstream end of reach RNO.

Block: PERIOD

- **iper** integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. IPER must be less than or equal to NPER in the TDIS Package and greater than zero. The IPER value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- **rno** integer value that defines the reach number associated with the specified PERIOD data on the line. RNO must be greater than zero and less than or equal to NREACHES.
- **sfrsetting** line of information that is parsed into a keyword and values. Keyword values that can be used to start the SFRSETTING string include: STATUS, MANNING, STAGE, INFLOW, RAINFALL, EVAPORATION, RUNOFF, DIVERSION, UPSTREAM_FRACTION, and AUXILIARY.

```
STATUS <status>
MANNING <manning>
STAGE <stage>
INFLOW <inflow>
RAINFALL <rainfall>
EVAPORATION <evaporation>
RUNOFF <runoff>
DIVERSION <idv> <divflow>
UPSTREAM_FRACTION <upstream_fraction>
AUXILIARY <auxname> <auxval>
```

- **status** keyword option to define stream reach status. STATUS can be ACTIVE, INACTIVE, or SIMPLE. The SIMPLE STATUS option simulates streamflow using a user-specified stage for a reach or a stage set to the top of the reach (depth = 0). In cases where the simulated leakage calculated using the specified stage exceeds the sum of inflows to the reach, the stage is set to the top of the reach and leakage is set equal to the sum of inflows. Upstream fractions should be changed using the UPSTREAM_FRACTION SFRSETTING if the status for one or more reaches is changed to ACTIVE or INACTIVE. For example, if one of two downstream connections for a reach is inactivated, the upstream fraction for the active and inactive downstream reach should be changed to 1.0 and 0.0, respectively, to ensure that the active reach receives all of the downstream outflow from the upstream reach. By default, STATUS is ACTIVE.
- **manning** real or character value that defines the Manning's roughness coefficient for the reach. MANNING must be greater than zero. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- **stage** real or character value that defines the stage for the reach. The specified STAGE is only applied if the reach uses the simple routing option. If STAGE is not specified for reaches that use the simple routing option, the specified stage is set to the top of the reach. If the Options block includes a TIMESERIESFILE entry (see

the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- `inflow` real or character value that defines the volumetric inflow rate for the streamflow routing reach. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value. By default, inflow rates are zero for each reach.
- `rainfall` real or character value that defines the volumetric rate per unit area of water added by precipitation directly on the streamflow routing reach. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value. By default, rainfall rates are zero for each reach.
- `evaporation` real or character value that defines the volumetric rate per unit area of water subtracted by evaporation from the streamflow routing reach. A positive evaporation rate should be provided. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value. If the volumetric evaporation rate for a reach exceeds the sources of water to the reach (upstream and specified inflows, rainfall, and runoff but excluding groundwater leakage into the reach) the volumetric evaporation rate is limited to the sources of water to the reach. By default, evaporation rates are zero for each reach.
- `runoff` real or character value that defines the volumetric rate of diffuse overland runoff that enters the streamflow routing reach. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value. If the volumetric runoff rate for a reach is negative and exceeds inflows to the reach (upstream and specified inflows, and rainfall but excluding groundwater leakage into the reach) the volumetric runoff rate is limited to inflows to the reach and the volumetric evaporation rate for the reach is set to zero. By default, runoff rates are zero for each reach.
- `DIVERSION` keyword to indicate diversion record.
- `idv` an integer value specifying which diversion of reach `RNO` that `DIVFLOW` is being specified for. Must be less or equal to `ndv` for the current reach (`RNO`).
- `divflow` real or character value that defines the volumetric diversion (`DIVFLOW`) rate for the streamflow routing reach. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `upstream_fraction` real value that defines the fraction of upstream flow (`USTRF`) from each upstream reach that is applied as upstream inflow to the reach. The sum of all `USTRF` values for all reaches connected to the same upstream reach must be equal to one.
- `AUXILIARY` keyword for specifying auxiliary variable.
- `auxname` name for the auxiliary variable to be assigned `AUXVAL`. `AUXNAME` must match one of the auxiliary variable names defined in the `OPTIONS` block. If `AUXNAME` does not match one of the auxiliary variable names defined in the `OPTIONS` block the data are ignored.
- `auxval` value for the auxiliary variable. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

Example Input File

```
BEGIN OPTIONS
  UNIT_CONVERSION 1.486
  BOUNDNAMES
  PRINT_STAGE
```

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```

PRINT_FLOWS
STAGE FILEOUT sfr-1.stage.bin
BUDGET FILEOUT sfr-1.cbc
END OPTIONS

#dimension block is required
BEGIN DIMENSIONS
NREACHES 37
END DIMENSIONS

BEGIN PACKAGEDATA
#rno k i j rlen rwid      rgrd      rtp      rbth      rhk      man      ncon      ustrf      ndv
↳boundname
  1 1 1 1 4500. 12      8.67E-04 1093.048      3.0 0.00003 0.03      1 1.0 0
↳ reach1
  2 1 2 2 7000. 12      8.67E-04 1088.059      3.0 0.00003 0.03      2 1.0 0
↳ reach2
  3 1 3 3 6000. 12      8.67E-04 1082.419      3.0 0.00003 0.03      2 1.0 0
↳ reach3
  4 1 3 4 5550. 12      8.67E-04 1077.408      3.0 0.00003 0.03      3 1.0 1
↳ reach4
  5 1 4 5 6500. 12      9.43E-04 1071.934      3.0 0.00003 0.03      2 1.0 0
  6 1 5 6 5000. 12      9.43E-04 1066.509      3.0 0.00003 0.03      2 1.0 0
  7 1 6 6 5000. 12      9.43E-04 1061.792      3.0 0.00003 0.03      2 1.0 0
  8 1 7 6 5000. 12      9.43E-04 1057.075      3.0 0.00003 0.03      2 1.0 0
  9 1 8 6 5000. 12      9.43E-04 1052.359      3.0 0.00003 0.03      2 1.0 0
 10 1 3 5 5000. 10      5.45E-04 1073.636      2.0 0.00003 0.03      2 0.0 0
↳ canal
 11 1 3 6 5000. 10      5.45E-04 1070.909      2.0 0.00003 0.03      2 1.0 0
↳ canal
 12 1 3 7 4500. 10      5.45E-04 1068.318      2.0 0.00003 0.03      2 1.0 0
↳ canal
 13 1 4 8 6000. 10      5.45E-04 1065.455      2.0 0.00003 0.03      2 1.0 0
↳ canal
 14 1 5 8 5000. 10      5.45E-04 1062.455      2.0 0.00003 0.03      2 1.0 0
↳ canal
 15 1 6 8 2000. 10      5.45E-04 1060.545      2.0 0.00003 0.03      2 1.0 0
↳ canal
 16 1 510 2500. 10      1.81E-03 1077.727      3.0 0.00003 0.03      1 1.0 0
 17 1 5 9 5000. 10      1.81E-03 1070.909      3.0 0.00003 0.03      2 1.0 0
 18 1 6 8 3500. 10      1.81E-03 1063.182      3.0 0.00003 0.03      2 1.0 0
 19 1 6 8 4000. 15      1.00E-03 1058.000      3.0 0.00003 0.03      3 1.0 0
 20 1 7 7 5000. 15      1.00E-03 1053.500      3.0 0.00003 0.03      2 1.0 0
 21 1 8 7 3500. 15      1.00E-03 1049.250      3.0 0.00003 0.03      2 1.0 0
 22 1 8 6 2500. 15      1.00E-03 1046.250      3.0 0.00003 0.03      2 1.0 0
 23 1 9 6 5000. 12      9.09E-04 1042.727      3.0 0.00003 0.03      3 1.0 0
 24 1 10 7 5000. 12      9.09E-04 1038.182      3.0 0.00003 0.03      2 1.0 0
 25 1 11 7 5000. 12      9.09E-04 1033.636      3.0 0.00003 0.03      2 1.0 0
 26 1 12 7 5000. 12      9.09E-04 1029.091      3.0 0.00003 0.03      2 1.0 0
 27 1 13 7 2000. 12      9.09E-04 1025.909      3.0 0.00003 0.03      2 1.0 0
 28 1 14 9 5000. 55      9.67E-04 1037.581      3.0 0.00006 0.025      1 1.0 0
 29 1 13 8 5500. 55      9.67E-04 1032.500      3.0 0.00006 0.025      2 1.0 0
 30 1 13 7 5000. 55      9.67E-04 1027.419      3.0 0.00006 0.025      2 1.0 0
 31 1 13 6 5000. 40      1.25E-03 1021.875      3.0 0.00006 0.025      3 1.0 0
 32 1 13 5 5000. 40      1.25E-03 1015.625      3.0 0.00006 0.025      2 1.0 0
 33 1 13 4 5000. 40      1.25E-03 1009.375      3.0 0.00006 0.025      2 1.0 0
 34 1 13 3 5000. 40      1.25E-03 1003.125      3.0 0.00006 0.025      2 1.0 0

```

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```

35 1 13 2 5000. 40 1.25E-03 996.8750 3.0 0.00006 0.025 2 1.0 0
36 1 13 1 3000. 40 1.25E-03 991.8750 3.0 0.00006 0.025 2 1.0 0
37 none 5000. 40 1.25E-03 985.6250 3.0 0.00006 0.025 1 1.0 0
END PACKAGEDATA

BEGIN CONNECTIONDATA
#rno ic1 ic2 ic3
1 -2
2 1 -3
3 2 -4
4 3 -5 -10
5 4 -6
6 5 -7
7 6 -8
8 7 -9
9 8 -23
10 4 -11
11 10 -12
12 11 -13
13 12 -14
14 13 -15
15 14 -19
16 -17
17 16 -18
18 17 -19
19 15 18 -20
20 19 -21
21 20 -22
22 21 -23
23 9 22 -24
24 23 -25
25 24 -26
26 25 -27
27 26 -31
28 -29
29 28 -30
30 29 -31
31 27 30 -32
32 31 -33
33 32 -34
34 33 -35
35 34 -36
36 35 -37
37 36
END CONNECTIONDATA

BEGIN DIVERSIONS
# rno idv iconr cprior
4 1 10 UPTO
END DIVERSIONS

BEGIN PERIOD 1
# rno sfrsetting
1 inflow 25.
16 inflow 10.
28 inflow 150.
4 diversion 1 10.

```

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```

10 status simple
11 status simple
12 status simple
13 status simple
14 status simple
15 status simple
10 stage 1075.5454
11 stage 1072.6363
12 stage 1069.8727
13 stage 1066.8181
14 stage 1063.6181
15 stage 1061.5818
END PERIOD

```

Available Observation Types

Example Observation Input File

```

BEGIN OPTIONS
  DIGITS 8
  PRINT_INPUT
END OPTIONS

BEGIN CONTINUOUS FILEOUT my_model.sfr.csv
#  obsname      obstype      id
  gage1stage    STAGE         reach4
  gage2stage    STAGE         7
  gage2inflow   INFLOW        7
  gage2disch    DOWNSTREAM-FLOW 7
  gage3stage    STAGE         14
END CONTINUOUS

BEGIN CONTINUOUS FILEOUT my_model.sfr.leakage.csv
#  obsname      obstype      id
  leak1         SFR           reach1
  leak10        SFR           10
  leak11        SFR           11
  leak12        SFR           12
  leak13        SFR           13
  leak14        SFR           14
  leak15        SFR           15
  leakcanal     SFR           canal  #Sum of flows between canal reaches and
↳groundwater
END CONTINUOUS

```

1.3.25 GWF-STO

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN OPTIONS
  [SAVE_FLOWS]
  [STORAGECOEFFICIENT]
  [SS_CONFINED_ONLY]
END OPTIONS

```

```

BEGIN GRIDDATA
  ICONVERT [LAYERED]
    <iconvert(nodes)> -- READARRAY
  SS [LAYERED]
    <ss(nodes)> -- READARRAY
  SY [LAYERED]
    <sy(nodes)> -- READARRAY
END GRIDDATA

```

FOR ANY STRESS PERIOD

```

BEGIN PERIOD <iper>
  [STEADY-STATE]
  [TRANSIENT]
END PERIOD

```

Explanation of Variables

Block: OPTIONS

- **SAVE_FLOWS** keyword to indicate that cell-by-cell flow terms will be written to the file specified with “BUDGET SAVE FILE” in Output Control.
- **STORAGECOEFFICIENT** keyword to indicate that the SS array is read as storage coefficient rather than specific storage.
- **SS_CONFINED_ONLY** keyword to indicate that specific storage is only calculated when a cell is under confined conditions (head greater than or equal to the top of the cell). This option is identical to the approach used to calculate storage changes under confined conditions in MODFLOW-2005.

Block: GRIDDATA

- **iconvert** is a flag for each cell that specifies whether or not a cell is convertible for the storage calculation. 0 indicates confined storage is used. >0 indicates confined storage is used when head is above cell top and a mixed formulation of unconfined and confined storage is used when head is below cell top.
- **ss** is specific storage (or the storage coefficient if **STORAGECOEFFICIENT** is specified as an option). Specific storage values must be greater than or equal to 0. If the CSUB Package is included in the GWF model, specific storage must be zero for every cell.
- **sy** is specific yield. Specific yield values must be greater than or equal to 0. Specific yield does not have to be specified if there are no convertible cells (**ICONVERT**=0 in every cell).

Block: PERIOD

- **iper** integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. **IPER** must be less than or equal to **NPER** in the TDIS Package and greater than zero. The **IPER**

value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.

- **STEADY-STATE** keyword to indicate that stress period IPER is steady-state. Steady-state conditions will apply until the **TRANSIENT** keyword is specified in a subsequent **BEGIN PERIOD** block. If the CSUB Package is included in the GWF model, only the first and last stress period can be steady-state.
- **TRANSIENT** keyword to indicate that stress period IPER is transient. Transient conditions will apply until the **STEADY-STATE** keyword is specified in a subsequent **BEGIN PERIOD** block.

Example Input File

```
BEGIN OPTIONS
  SAVE_FLOWS
END OPTIONS

BEGIN GRIDDATA
  #cell storage conversion 0:confined, 1:convertible
  ICONVERT
    constant 1
    #specific storage (for all model cells)
  SS
    constant 1.e-5
    #specific yield (specified by layer because of LAYERED keyword)
  SY LAYERED
    constant 0.2
    constant 0.15
    constant 0.15
END GRIDDATA

BEGIN PERIOD 1
  STEADY-STATE
END PERIOD

BEGIN PERIOD 2
  TRANSIENT
END PERIOD

#stress period 3 will be transient because
#a BEGIN PERIOD block is not provided.

BEGIN PERIOD 4
  STEADY-STATE
END PERIOD
```

1.3.26 GWF-UZF

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [AUXILIARY <auxiliary(naux)>]
  [AUXMULTNAME <auxmultname>]
```

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```

[BOUNDNAMES]
[PRINT_INPUT]
[PRINT_FLOWS]
[SAVE_FLOWS]
[WATER_CONTENT FILEOUT <wcfile>]
[BUDGET FILEOUT <budgetfile>]
[PACKAGE_CONVERGENCE FILEOUT <package_convergence_filename>]
[TS6 FILEIN <ts6_filename>]
[OBS6 FILEIN <obs6_filename>]
[MOVER]
[SIMULATE_ET]
[LINEAR_GWET]
[SQUARE_GWET]
[SIMULATE_GWSEEP]
[UNSAT_ETWC]
[UNSAT_ETAE]
END OPTIONS

```

```

BEGIN DIMENSIONS
  NUZFCELLS <nuzfcells>
  NTRAILWAVES <ntrailwaves>
  NWAVESETS <nwavesets>
END DIMENSIONS

```

```

BEGIN PACKAGEDATA
  <iuzno> <cellid(ncellldim)> <landflag> <ivertcon> <surfdep> <vks> <thtr> <thts>
  ↪<thti> <eps> [<boundname>]
  <iuzno> <cellid(ncellldim)> <landflag> <ivertcon> <surfdep> <vks> <thtr> <thts>
  ↪<thti> <eps> [<boundname>]
  ...
END PACKAGEDATA

```

FOR ANY STRESS PERIOD

```

BEGIN PERIOD <iper>
  <iuzno> <finf> <pet> <extdp> <extwc> <ha> <hroot> <rootact> [<aux(naux)>]
  <iuzno> <finf> <pet> <extdp> <extwc> <ha> <hroot> <rootact> [<aux(naux)>]
  ...
END PERIOD

```

Explanation of Variables**Block: OPTIONS**

- **auxiliary** defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for **naux**. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** name of auxiliary variable to be used as multiplier of GWF cell area used by UZF cell.
- **BOUNDNAMES** keyword to indicate that boundary names may be provided with the list of UZF cells.

- `PRINT_INPUT` keyword to indicate that the list of UZF information will be written to the listing file immediately after it is read.
- `PRINT_FLOWS` keyword to indicate that the list of UZF flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- `SAVE_FLOWS` keyword to indicate that UZF flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- `WATER_CONTENT` keyword to specify that record corresponds to unsaturated zone water contents.
- `wcfile` name of the binary output file to write water content information.
- `BUDGET` keyword to specify that record corresponds to the budget.
- `FILEOUT` keyword to specify that an output filename is expected next.
- `budgetfile` name of the binary output file to write budget information.
- `PACKAGE_CONVERGENCE` keyword to specify that record corresponds to the package convergence comma spaced values file.
- `package_convergence_filename` name of the comma spaced values output file to write package convergence information.
- `TS6` keyword to specify that record corresponds to a time-series file.
- `FILEIN` keyword to specify that an input filename is expected next.
- `ts6_filename` defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- `OBS6` keyword to specify that record corresponds to an observations file.
- `obs6_filename` name of input file to define observations for the UZF package. See the “Observation utility” section for instructions for preparing observation input files. Tables `ref{table:gwf-obstypetable}` and `ref{table:gwt-obstypetable}` lists observation type(s) supported by the UZF package.
- `MOVER` keyword to indicate that this instance of the UZF Package can be used with the Water Mover (MVR) Package. When the `MOVER` option is specified, additional memory is allocated within the package to store the available, provided, and received water.
- `SIMULATE_ET` keyword specifying that ET in the unsaturated (UZF) and saturated zones (GWF) will be simulated. ET can be simulated in the UZF cell and not the GWF cell by omitting keywords `LINEAR_GWET` and `SQUARE_GWET`.
- `LINEAR_GWET` keyword specifying that groundwater ET will be simulated using the original ET formulation of MODFLOW-2005.
- `SQUARE_GWET` keyword specifying that groundwater ET will be simulated by assuming a constant ET rate for groundwater levels between land surface (TOP) and land surface minus the ET extinction depth (TOP-EXTDP). Groundwater ET is smoothly reduced from the PET rate to zero over a nominal interval at TOP-EXTDP.
- `SIMULATE_GWSEEP` keyword specifying that groundwater discharge (GWSEEP) to land surface will be simulated. Groundwater discharge is nonzero when groundwater head is greater than land surface.
- `UNSAT_ETWC` keyword specifying that ET in the unsaturated zone will be simulated as a function of the specified PET rate while the water content (THETA) is greater than the ET extinction water content (EXTWC).
- `UNSAT_ETAE` keyword specifying that ET in the unsaturated zone will be simulated using a capillary pressure based formulation. Capillary pressure is calculated using the Brooks-Corey retention function.

Block: DIMENSIONS

- `nuzfcells` is the number of UZF cells. More than one UZF cell can be assigned to a GWF cell; however, only one GWF cell can be assigned to a single UZF cell. If more than one UZF cell is assigned to a GWF cell, then an auxiliary variable should be used to reduce the surface area of the UZF cell with the AUXMULTNAME option.
- `ntrailwaves` is the number of trailing waves. A recommended value of 7 can be used for NTRAILWAVES. This value can be increased to lower mass balance error in the unsaturated zone.
- `nwavesets` is the number of wave sets. A recommended value of 40 can be used for NWAVESETS. This value can be increased if more waves are required to resolve variations in water content within the unsaturated zone.

Block: PACKAGEDATA

- `iuzno` integer value that defines the UZF cell number associated with the specified PACKAGEDATA data on the line. IUZNO must be greater than zero and less than or equal to NUZFCELLS. UZF information must be specified for every UZF cell or the program will terminate with an error. The program will also terminate with an error if information for a UZF cell is specified more than once.
- `cellid` is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell.
- `landflag` integer value set to one for land surface cells indicating that boundary conditions can be applied and data can be specified in the PERIOD block. A value of 0 specifies a non-land surface cell.
- `invertcon` integer value set to specify underlying UZF cell that receives water flowing to bottom of cell. If unsaturated zone flow reaches the water table before the cell bottom, then water is added to the GWF cell instead of flowing to the underlying UZF cell. A value of 0 indicates the UZF cell is not connected to an underlying UZF cell.
- `surfdep` is the surface depression depth of the UZF cell.
- `vks` is the saturated vertical hydraulic conductivity of the UZF cell. This value is used with the Brooks-Corey function and the simulated water content to calculate the partially saturated hydraulic conductivity.
- `thtr` is the residual (irreducible) water content of the UZF cell. This residual water is not available to plants and will not drain into underlying aquifer cells.
- `thts` is the saturated water content of the UZF cell. The values for saturated and residual water content should be set in a manner that is consistent with the specific yield value specified in the Storage Package. The saturated water content must be greater than the residual content.
- `thti` is the initial water content of the UZF cell. The value must be greater than or equal to the residual water content and less than or equal to the saturated water content.
- `eps` is the exponent used in the Brooks-Corey function. The Brooks-Corey function is used by UZF to calculate hydraulic conductivity under partially saturated conditions as a function of water content and the user-specified saturated hydraulic conductivity.
- `boundname` name of the UZF cell cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. IPER must be less than or equal to NPER in the TDIS Package and greater than zero. The IPER value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- `iuzno` integer value that defines the UZF cell number associated with the specified PERIOD data on the line.
- `finf` real or character value that defines the applied infiltration rate of the UZF cell (LT-1). If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `pet` real or character value that defines the potential evapotranspiration rate of the UZF cell and specified GWF cell. Evapotranspiration is first removed from the unsaturated zone and any remaining potential evapotranspiration is applied to the saturated zone. If IVERTCON is greater than zero then residual potential evapotranspiration not satisfied in the UZF cell is applied to the underlying UZF and GWF cells. PET is always specified, but is only used if SIMULATE_ET is specified in the OPTIONS block. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `extdp` real or character value that defines the evapotranspiration extinction depth of the UZF cell. If IVERTCON is greater than zero and EXTDP extends below the GWF cell bottom then remaining potential evapotranspiration is applied to the underlying UZF and GWF cells. EXTDP is always specified, but is only used if SIMULATE_ET is specified in the OPTIONS block. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `extwc` real or character value that defines the evapotranspiration extinction water content of the UZF cell. EXTWC is always specified, but is only used if SIMULATE_ET and UNSAT_ETWC are specified in the OPTIONS block. The evapotranspiration rate from the unsaturated zone will be set to zero when the calculated water content is at or less than this value. The value for EXTWC cannot be less than the residual water content, and if it is specified as being less than the residual water content it is set to the residual water content. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `ha` real or character value that defines the air entry potential (head) of the UZF cell. HA is always specified, but is only used if SIMULATE_ET and UNSAT_ETAE are specified in the OPTIONS block. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `hroot` real or character value that defines the root potential (head) of the UZF cell. HROOT is always specified, but is only used if SIMULATE_ET and UNSAT_ETAE are specified in the OPTIONS block. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `rootact` real or character value that defines the root activity function of the UZF cell. ROOTACT is the length of roots in a given volume of soil divided by that volume. Values range from 0 to about 3 cm⁻², depending on the plant community and its stage of development. ROOTACT is always specified, but is only used if SIMULATE_ET and UNSAT_ETAE are specified in the OPTIONS block. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `aux` represents the values of the auxiliary variables for each UZF. The values of auxiliary variables must be present for each UZF. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry

(see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

Example Input File

```

BEGIN OPTIONS
  OBS6 UZF.obs
  SIMULATE_ET
  UNSAT_ETWC
  LINEAR_GWET
END OPTIONS

BEGIN DIMENSIONS
  NUZFCELLS    10
  NTRAILWAVES  7
  NWAVESETS    40
END DIMENSIONS

BEGIN PACKAGEDATA
  1  1  1  1  1  1.0 1.0 0.05 0.35 0.1 4.0
  2  1  1  2  1  1.0 1.0 0.05 0.35 0.1 4.0
  3  1  1  3  1  1.0 1.0 0.05 0.35 0.1 4.0
  4  1  1  4  1  1.0 1.0 0.05 0.35 0.1 4.0
  5  1  1  5  1  1.0 1.0 0.05 0.35 0.1 4.0
  6  1  1  6  1  1.0 1.0 0.05 0.35 0.1 4.0
  7  1  1  7  1  1.0 1.0 0.05 0.35 0.1 4.0
  8  1  1  8  1  1.0 1.0 0.05 0.35 0.1 4.0
  9  1  1  9  1  1.0 1.0 0.05 0.35 0.1 4.0
  10 1  1 10  1  1.0 1.0 0.05 0.35 0.1 4.0
END PACKAGEDATA

BEGIN PERIOD 1
  2 0.00005 0.00002 2.0 0.10
  3 0.00008 0.00002 2.0 0.10
  4 0.00009 0.00002 2.0 0.10
  5 0.0001  0.00002 2.0 0.10
  6 0.0001  0.00002 2.0 0.10
  7 0.00009 0.00002 2.0 0.10
  8 0.00008 0.00002 2.0 0.10
  9 0.00005 0.00002 2.0 0.10
END PERIOD

BEGIN PERIOD 2
  2 0.00009 0.00003 2.0 0.10
  3 0.0001  0.00003 2.0 0.10
  4 0.0001  0.00003 2.0 0.10
  5 0.00015 0.00003 2.0 0.10
  6 0.00015 0.00003 2.0 0.10
  7 0.0001  0.00003 2.0 0.10
  8 0.0001  0.00003 2.0 0.10
  9 0.00009 0.00003 2.0 0.10
END PERIOD

```

Available Observation Types

Example Observation Input File

```

BEGIN CONTINUOUS FILEOUT my_model.obs.uzf.csv
  id26_infil      infiltration      26
  id126_infil     infiltration      126
  id26_dpth=20    water-content     26 20.0
  id126_dpth=51   water-content     126 1.0    #depth is below celtop
  id126_rch       uzf-gwrch        126
END CONTINUOUS

BEGIN CONTINUOUS FILEOUT my_model.uzf.budget.uzf.csv
  sinf            infiltration      uzfcells
  frommvr         from-mvr         uzfcells
  rejinf          rej-inf          uzfcells
  rejinfmvr       rej-inf-to-mvr   uzfcells
  uzet            uzet            uzfcells
  storage         storage          uzfcells
  net-inf         net-infiltration uzfcells
END CONTINUOUS

BEGIN CONTINUOUS FILEOUT my_model.uzf.budget.gwf.csv
  gwrch          uzf-gwrch        uzfcells
  gwd            uzf-gwd          uzfcells
  gwdbtomvr      uzf-gwd-to-mvr   uzfcells
  gwet           uzf-gwet         uzfcells
END CONTINUOUS

```

1.3.27 GWF-WEL

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN OPTIONS
  [AUXILIARY <auxiliary(naux)>]
  [AUXMULTNAME <auxmultname>]
  [BOUNDNAMES]
  [PRINT_INPUT]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [AUTO_FLOW_REDUCE <auto_flow_reduce>]
  [TS6 FILEIN <ts6_filename>]
  [OBS6 FILEIN <obs6_filename>]
  [MOVER]
END OPTIONS

```

```

BEGIN DIMENSIONS
  MAXBOUND <maxbound>
END DIMENSIONS

```

FOR ANY STRESS PERIOD

```

BEGIN PERIOD <iper>
  <cellid(ncelldim)> <q> [<aux(naux)>] [<boundname>]
  <cellid(ncelldim)> <q> [<aux(naux)>] [<boundname>]
  ...
END PERIOD

```

Explanation of Variables

Block: OPTIONS

- **auxiliary** defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for **naux**. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** name of auxiliary variable to be used as multiplier of well flow rate.
- **BOUNDNAMES** keyword to indicate that boundary names may be provided with the list of well cells.
- **PRINT_INPUT** keyword to indicate that the list of well information will be written to the listing file immediately after it is read.
- **PRINT_FLOWS** keyword to indicate that the list of well flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- **SAVE_FLOWS** keyword to indicate that well flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- **auto_flow_reduce** keyword and real value that defines the fraction of the cell thickness used as an interval for smoothly adjusting negative pumping rates to 0 in cells with head values less than or equal to the bottom of the cell. Negative pumping rates are adjusted to 0 or a smaller negative value when the head in the cell is equal to or less than the calculated interval above the cell bottom. **AUTO_FLOW_REDUCE** is set to 0.1 if the specified value is less than or equal to zero. By default, negative pumping rates are not reduced during a simulation.
- **TS6** keyword to specify that record corresponds to a time-series file.
- **FILEIN** keyword to specify that an input filename is expected next.
- **ts6_filename** defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- **OBS6** keyword to specify that record corresponds to an observations file.
- **obs6_filename** name of input file to define observations for the Well package. See the “Observation utility” section for instructions for preparing observation input files. Tables [ref{table:gwf-obstypetable}](#) and [ref{table:gwt-obstypetable}](#) lists observation type(s) supported by the Well package.
- **MOVER** keyword to indicate that this instance of the Well Package can be used with the Water Mover (MVR) Package. When the MOVER option is specified, additional memory is allocated within the package to store the available, provided, and received water.

Block: DIMENSIONS

- **maxbound** integer value specifying the maximum number of wells cells that will be specified for use during any stress period.

Block: PERIOD

- **iper** integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. IPER must be less than or equal to NPER in the TDIS Package and greater than zero. The IPER value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- **cellid** is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell.
- **q** is the volumetric well rate. A positive value indicates recharge (injection) and a negative value indicates discharge (extraction). If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- **aux** represents the values of the auxiliary variables for each well. The values of auxiliary variables must be present for each well. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- **boundname** name of the well cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

Example Input File

```
#The OPTIONS block is optional
BEGIN OPTIONS
  AUXILIARY depth screen_length
  BOUNDNAMES
  PRINT_INPUT
  PRINT_FLOWS
  SAVE_FLOWS
END OPTIONS

#The DIMENSIONS block is required
BEGIN DIMENSIONS
  MAXBOUND 5
END DIMENSIONS

#The following block of wells will be activated for stress periods
#2 and 3. No wells are present in stress period 1 due to an
#absence of a block for that period.
BEGIN PERIOD 2
  #layer row col      Q    depth screen_length boundname

  #wells 1 and 2
```

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```

      7 102 17 -19000 275.9 17.6 CW_1
      9 192 44 -13000 280.0 24.0 CW_2

      #wells 3 through 5
      9 109 67 -24000 295.1 12.1 CW_3
     10 43 17 -12000 301.3 9.6 CW_4
     11 12 17 -17000 315.0 18.6 CW_5

END PERIOD

#Turn off all wells for stress period 4
BEGIN PERIOD 4
  #An empty block indicates that there are no wells.
END PERIOD

#For stress period 5, turn on wells 1 and 4,
#and add three wells that are grouped in a well field
BEGIN PERIOD 5
  #layer row col Q depth screen_length boundname
      7 102 17 -19000 275.9 17.6 CW_1
     10 43 17 -12000 301.3 9.6 CW_4

  #wells in well field
      5 27 50 -11000 190.0 20.0 well_field
      5 27 51 -10000 185.0 20.0 well_field
      5 28 50 -12000 187.3 15.0 well_field

END PERIOD

#Use a list of wells in ASCII file wells_sp6.txt for stress period 6.
#Use these wells until the end of the simulation.
BEGIN PERIOD 6
  OPEN/CLOSE wells_sp6.txt
END PERIOD

```

Available Observation Types

Example Observation Input File

```

BEGIN OPTIONS
  DIGITS 7
  PRINT_INPUT
END OPTIONS

BEGIN CONTINUOUS FILEOUT my_model.wel.obs.csv
# obsname          obstype ID
  wel-7-102-17      WEL      7 102 17
  wel-7-102-17      WEL      CW_1
  well-field        WEL      well_field
END CONTINUOUS

```

1.4 Groundwater Transport

1.4.1 GWT-ADV

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [SCHEME <scheme>]
END OPTIONS
```

Explanation of Variables

Block: OPTIONS

- `scheme` scheme used to solve the advection term. Can be upstream, central, or TVD. If not specified, upstream weighting is the default weighting scheme.

Example Input File

```
BEGIN OPTIONS
  SCHEME UPSTREAM
END OPTIONS
```

1.4.2 GWT-API

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [BOUNDNAMES]
  [PRINT_INPUT]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [OBS6 FILEIN <obs6_filename>]
  [MOVER]
END OPTIONS
```

```
BEGIN DIMENSIONS
  MAXBOUND <maxbound>
END DIMENSIONS
```

Explanation of Variables

Block: OPTIONS

- `BOUNDNAMES` keyword to indicate that boundary names may be provided with the list of api boundary cells.

- `PRINT_INPUT` keyword to indicate that the list of api boundary information will be written to the listing file immediately after it is read.
- `PRINT_FLOWS` keyword to indicate that the list of api boundary flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- `SAVE_FLOWS` keyword to indicate that api boundary flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- `OBS6` keyword to specify that record corresponds to an observations file.
- `FILEIN` keyword to specify that an input filename is expected next.
- `obs6_filename` name of input file to define observations for the api boundary package. See the “Observation utility” section for instructions for preparing observation input files. Tables [ref{table:gwf-obstypetable}](#) and [ref{table:gwt-obstypetable}](#) lists observation type(s) supported by the api boundary package.
- `MOVER` keyword to indicate that this instance of the api boundary Package can be used with the Water Mover (MVR) Package. When the `MOVER` option is specified, additional memory is allocated within the package to store the available, provided, and received water.

Block: DIMENSIONS

- `maxbound` integer value specifying the maximum number of api boundary cells that will be specified for use during any stress period.

1.4.3 GWT-CNC

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [AUXILIARY <auxiliary(naux)>]
  [AUXMULTNAME <auxmultname>]
  [BOUNDNAMES]
  [PRINT_INPUT]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [TS6 FILEIN <ts6_filename>]
  [OBS6 FILEIN <obs6_filename>]
END OPTIONS
```

```
BEGIN DIMENSIONS
  MAXBOUND <maxbound>
END DIMENSIONS
```

FOR ANY STRESS PERIOD

```
BEGIN PERIOD <iper>
  <cellid(ncelldim)> <conc> [<aux(naux)>] [<boundname>]
  <cellid(ncelldim)> <conc> [<aux(naux)>] [<boundname>]
  ...
END PERIOD
```

Explanation of Variables

Block: OPTIONS

- `auxiliary` defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for `naux`. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- `auxmultname` name of auxiliary variable to be used as multiplier of concentration value.
- `BOUNDNAMES` keyword to indicate that boundary names may be provided with the list of constant concentration cells.
- `PRINT_INPUT` keyword to indicate that the list of constant concentration information will be written to the listing file immediately after it is read.
- `PRINT_FLOWS` keyword to indicate that the list of constant concentration flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- `SAVE_FLOWS` keyword to indicate that constant concentration flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- `TS6` keyword to specify that record corresponds to a time-series file.
- `FILEIN` keyword to specify that an input filename is expected next.
- `ts6_filename` defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- `OBS6` keyword to specify that record corresponds to an observations file.
- `obs6_filename` name of input file to define observations for the Constant Concentration package. See the “Observation utility” section for instructions for preparing observation input files. Tables `ref{table:gwf-obstypetable}` and `ref{table:gwt-obstypetable}` lists observation type(s) supported by the Constant Concentration package.

Block: DIMENSIONS

- `maxbound` integer value specifying the maximum number of constant concentrations cells that will be specified for use during any stress period.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. IPER must be less than or equal to NPER in the TDIS Package and greater than zero. The IPER value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- `cellid` is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file,

CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell.

- `conc` is the constant concentration value. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `aux` represents the values of the auxiliary variables for each constant concentration. The values of auxiliary variables must be present for each constant concentration. The values must be specified in the order of the auxiliary variables specified in the `OPTIONS` block. If the package supports time series and the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `boundname` name of the constant concentration cell. `BOUNDNAME` is an ASCII character variable that can contain as many as 40 characters. If `BOUNDNAME` contains spaces in it, then the entire name must be enclosed within single quotes.

Example Input File

```
BEGIN OPTIONS
  PRINT_FLOWS
  PRINT_INPUT
  SAVE_FLOWS
END OPTIONS

BEGIN DIMENSIONS
  MAXBOUND 1
END DIMENSIONS

BEGIN PERIOD 1
  1 1 1 1.0
END PERIOD
```

Available Observation Types

Example Observation Input File

```
BEGIN OPTIONS
  DIGITS 8
  PRINT_INPUT
END OPTIONS

BEGIN CONTINUOUS FILEOUT my_model.cnc01.csv
# obsname  obstype  ID
cnc_2_1  CNC      1 1 2
cnc_2_2  CNC      1 2 2
cnc_2_3  CNC      1 3 2
cnc_2_4  CNC      1 4 2
END CONTINUOUS

BEGIN CONTINUOUS FILEOUT my_model.chd02.csv
# obsname  obstype  ID
cnc_3_flow CNC      CNC_1_3
END CONTINUOUS
```

1.4.4 GWT-DIS

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [LENGTH_UNITS <length_units>]
  [NOGRB]
  [XORIGIN <xorigin>]
  [YORIGIN <yorigin>]
  [ANGROT <angrot>]
END OPTIONS
```

```
BEGIN DIMENSIONS
  NLAY <nlay>
  NROW <nrow>
  NCOL <ncol>
END DIMENSIONS
```

```
BEGIN GRIDDATA
  DELR
    <delr(ncol)> -- READARRAY
  DELC
    <delc(nrow)> -- READARRAY
  TOP
    <top(ncol, nrow)> -- READARRAY
  BOTM [LAYERED]
    <botm(ncol, nrow, nlay)> -- READARRAY
  [IDOMAIN [LAYERED]
    <idomain(ncol, nrow, nlay)> -- READARRAY]
END GRIDDATA
```

Explanation of Variables

Block: OPTIONS

- `length_units` is the length units used for this model. Values can be “FEET”, “METERS”, or “CENTIMETERS”. If not specified, the default is “UNKNOWN”.
- `NOGRB` keyword to deactivate writing of the binary grid file.
- `xorigin` x-position of the lower-left corner of the model grid. A default value of zero is assigned if not specified. The value for `XORIGIN` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- `yorigin` y-position of the lower-left corner of the model grid. If not specified, then a default value equal to zero is used. The value for `YORIGIN` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- `angrot` counter-clockwise rotation angle (in degrees) of the lower-left corner of the model grid. If not specified, then a default value of 0.0 is assigned. The value for `ANGROT` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.

Block: DIMENSIONS

- `nlay` is the number of layers in the model grid.
- `nrow` is the number of rows in the model grid.
- `ncol` is the number of columns in the model grid.

Block: GRIDDATA

- `delr` is the column spacing in the row direction.
- `delc` is the row spacing in the column direction.
- `top` is the top elevation for each cell in the top model layer.
- `botm` is the bottom elevation for each cell.
- `idomain` is an optional array that characterizes the existence status of a cell. If the IDOMAIN array is not specified, then all model cells exist within the solution. If the IDOMAIN value for a cell is 0, the cell does not exist in the simulation. Input and output values will be read and written for the cell, but internal to the program, the cell is excluded from the solution. If the IDOMAIN value for a cell is 1, the cell exists in the simulation. If the IDOMAIN value for a cell is -1, the cell does not exist in the simulation. Furthermore, the first existing cell above will be connected to the first existing cell below. This type of cell is referred to as a “vertical pass through” cell.

1.4.5 GWT-DISU**Structure of Blocks***FOR EACH SIMULATION*

```
BEGIN OPTIONS
  [LENGTH_UNITS <length_units>]
  [NOGRB]
  [XORIGIN <xorigin>]
  [YORIGIN <yorigin>]
  [ANGROT <angrot>]
  [VERTICAL_OFFSET_TOLERANCE <vertical_offset_tolerance>]
END OPTIONS
```

```
BEGIN DIMENSIONS
  NODES <nodes>
  NJA <nja>
  [NVERT <nvert>]
END DIMENSIONS
```

```
BEGIN GRIDDATA
  TOP
    <top(nodes)> -- READARRAY
  BOT
    <bot(nodes)> -- READARRAY
  AREA
    <area(nodes)> -- READARRAY
  [IDOMAIN
```

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```

        <idomain(nodes)> -- READARRAY]
END GRIDDATA

```

```

BEGIN CONNECTIONDATA
  IAC
    <iac(nodes)> -- READARRAY
  JA
    <ja(nja)> -- READARRAY
  IHC
    <ihc(nja)> -- READARRAY
  CL12
    <cl12(nja)> -- READARRAY
  HWVA
    <hwva(nja)> -- READARRAY
  [ANGLDEGX
    <angldegx(nja)> -- READARRAY]
END CONNECTIONDATA

```

```

BEGIN VERTICES
  <iv> <xv> <yv>
  <iv> <xv> <yv>
  ...
END VERTICES

```

```

BEGIN CELL2D
  <icell12d> <xc> <yc> <ncvert> <icvert(ncvert)>
  <icell12d> <xc> <yc> <ncvert> <icvert(ncvert)>
  ...
END CELL2D

```

Explanation of Variables

Block: OPTIONS

- `length_units` is the length units used for this model. Values can be “FEET”, “METERS”, or “CENTIMETERS”. If not specified, the default is “UNKNOWN”.
- `NOGRB` keyword to deactivate writing of the binary grid file.
- `xorigin` x-position of the origin used for model grid vertices. This value should be provided in a real-world coordinate system. A default value of zero is assigned if not specified. The value for `XORIGIN` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- `yorigin` y-position of the origin used for model grid vertices. This value should be provided in a real-world coordinate system. If not specified, then a default value equal to zero is used. The value for `YORIGIN` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- `angrot` counter-clockwise rotation angle (in degrees) of the model grid coordinate system relative to a real-world coordinate system. If not specified, then a default value of 0.0 is assigned. The value for `ANGROT` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- `vertical_offset_tolerance` checks are performed to ensure that the top of a cell is not higher than the bottom of an overlying cell. This option can be used to specify the tolerance that is used for checking. If top

of a cell is above the bottom of an overlying cell by a value less than this tolerance, then the program will not terminate with an error. The default value is zero. This option should generally not be used.

Block: DIMENSIONS

- `nodes` is the number of cells in the model grid.
- `nja` is the sum of the number of connections and `NODES`. When calculating the total number of connections, the connection between cell `n` and cell `m` is considered to be different from the connection between cell `m` and cell `n`. Thus, `NJA` is equal to the total number of connections, including `n` to `m` and `m` to `n`, and the total number of cells.
- `nvert` is the total number of (x, y) vertex pairs used to define the plan-view shape of each cell in the model grid. If `NVERT` is not specified or is specified as zero, then the `VERTICES` and `CELL2D` blocks below are not read. `NVERT` and the accompanying `VERTICES` and `CELL2D` blocks should be specified for most simulations. If the `XT3D` or `SAVE_SPECIFIC_DISCHARGE` options are specified in the `NPF` Package, then this information is required.

Block: GRIDDATA

- `top` is the top elevation for each cell in the model grid.
- `bot` is the bottom elevation for each cell.
- `area` is the cell surface area (in plan view).
- `idomain` is an optional array that characterizes the existence status of a cell. If the `IDOMAIN` array is not specified, then all model cells exist within the solution. If the `IDOMAIN` value for a cell is 0, the cell does not exist in the simulation. Input and output values will be read and written for the cell, but internal to the program, the cell is excluded from the solution. If the `IDOMAIN` value for a cell is 1 or greater, the cell exists in the simulation. `IDOMAIN` values of -1 cannot be specified for the `DISU` Package.

Block: CONNECTIONDATA

- `iac` is the number of connections (plus 1) for each cell. The sum of all the entries in `IAC` must be equal to `NJA`.
- `ja` is a list of cell number (`n`) followed by its connecting cell numbers (`m`) for each of the `m` cells connected to cell `n`. The number of values to provide for cell `n` is `IAC(n)`. This list is sequentially provided for the first to the last cell. The first value in the list must be cell `n` itself, and the remaining cells must be listed in an increasing order (sorted from lowest number to highest). Note that the cell and its connections are only supplied for the `GWT` cells and their connections to the other `GWT` cells. Also note that the `JA` list input may be divided such that every node and its connectivity list can be on a separate line for ease in readability of the file. To further ease readability of the file, the node number of the cell whose connectivity is subsequently listed, may be expressed as a negative number, the sign of which is subsequently converted to positive by the code.
- `ihc` is an index array indicating the direction between node `n` and all of its `m` connections. If `IHC` = 0 then cell `n` and cell `m` are connected in the vertical direction. Cell `n` overlies cell `m` if the cell number for `n` is less than `m`; cell `m` overlies cell `n` if the cell number for `m` is less than `n`. If `IHC` = 1 then cell `n` and cell `m` are connected in the horizontal direction. If `IHC` = 2 then cell `n` and cell `m` are connected in the horizontal direction, and the connection is vertically staggered. A vertically staggered connection is one in which a cell is horizontally connected to more than one cell in a horizontal connection.
- `cl12` is the array containing connection lengths between the center of cell `n` and the shared face with each adjacent `m` cell.

- `hwva` is a symmetric array of size `NJA`. For horizontal connections, entries in `HWVA` are the horizontal width perpendicular to flow. For vertical connections, entries in `HWVA` are the vertical area for flow. Thus, values in the `HWVA` array contain dimensions of both length and area. Entries in the `HWVA` array have a one-to-one correspondence with the connections specified in the `JA` array. Likewise, there is a one-to-one correspondence between entries in the `HWVA` array and entries in the `IHC` array, which specifies the connection type (horizontal or vertical). Entries in the `HWVA` array must be symmetric; the program will terminate with an error if the value for `HWVA` for an `n` to `m` connection does not equal the value for `HWVA` for the corresponding `n` to `m` connection.
- `angldegx` is the angle (in degrees) between the horizontal `x`-axis and the outward normal to the face between a cell and its connecting cells. The angle varies between zero and 360.0 degrees, where zero degrees points in the positive `x`-axis direction, and 90 degrees points in the positive `y`-axis direction. `ANGLDEGX` is only needed if horizontal anisotropy is specified in the NPF Package, if the `XT3D` option is used in the NPF Package, or if the `SAVE_SPECIFIC_DISCHARGE` option is specified in the NPF Package. `ANGLDEGX` does not need to be specified if these conditions are not met. `ANGLDEGX` is of size `NJA`; values specified for vertical connections and for the diagonal position are not used. Note that `ANGLDEGX` is read in degrees, which is different from MODFLOW-USG, which reads a similar variable (`ANGLEX`) in radians.

Block: VERTICES

- `iv` is the vertex number. Records in the `VERTICES` block must be listed in consecutive order from 1 to `NVERT`.
- `xv` is the `x`-coordinate for the vertex.
- `yv` is the `y`-coordinate for the vertex.

Block: CELL2D

- `icell2d` is the `cell2d` number. Records in the `CELL2D` block must be listed in consecutive order from 1 to `NODES`.
- `xc` is the `x`-coordinate for the cell center.
- `yc` is the `y`-coordinate for the cell center.
- `nvert` is the number of vertices required to define the cell. There may be a different number of vertices for each cell.
- `icvert` is an array of integer values containing vertex numbers (in the `VERTICES` block) used to define the cell. Vertices must be listed in clockwise order.

1.4.6 GWT-DISV

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [LENGTH_UNITS <length_units>]
  [NOGRB]
  [XORIGIN <xorigin>]
  [YORIGIN <yorigin>]
  [ANGROT <angrot>]
END OPTIONS
```



```

BEGIN DIMENSIONS
  NLAY <nlay>
  NCPL <ncpl>
  NVERT <nvert>
END DIMENSIONS

```

```

BEGIN GRIDDATA
  TOP
    <top(ncpl)> -- READARRAY
  BOTM [LAYERED]
    <botm(nlay, ncpl)> -- READARRAY
  [IDOMAIN [LAYERED]
    <idomain(nlay, ncpl)> -- READARRAY]
END GRIDDATA

```

```

BEGIN VERTICES
  <iv> <xv> <yv>
  <iv> <xv> <yv>
  ...
END VERTICES

```

```

BEGIN CELL2D
  <icell2d> <xc> <yc> <ncvert> <icvert(ncvert)>
  <icell2d> <xc> <yc> <ncvert> <icvert(ncvert)>
  ...
END CELL2D

```

Explanation of Variables

Block: OPTIONS

- `length_units` is the length units used for this model. Values can be “FEET”, “METERS”, or “CENTIMETERS”. If not specified, the default is “UNKNOWN”.
- `NOGRB` keyword to deactivate writing of the binary grid file.
- `xorigin` x-position of the origin used for model grid vertices. This value should be provided in a real-world coordinate system. A default value of zero is assigned if not specified. The value for `XORIGIN` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- `yorigin` y-position of the origin used for model grid vertices. This value should be provided in a real-world coordinate system. If not specified, then a default value equal to zero is used. The value for `YORIGIN` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- `angrot` counter-clockwise rotation angle (in degrees) of the model grid coordinate system relative to a real-world coordinate system. If not specified, then a default value of 0.0 is assigned. The value for `ANGROT` does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.

Block: DIMENSIONS

- `nlay` is the number of layers in the model grid.

- `ncpl` is the number of cells per layer. This is a constant value for the grid and it applies to all layers.
- `nvert` is the total number of (x, y) vertex pairs used to characterize the horizontal configuration of the model grid.

Block: GRIDDATA

- `top` is the top elevation for each cell in the top model layer.
- `botm` is the bottom elevation for each cell.
- `idomain` is an optional array that characterizes the existence status of a cell. If the IDOMAIN array is not specified, then all model cells exist within the solution. If the IDOMAIN value for a cell is 0, the cell does not exist in the simulation. Input and output values will be read and written for the cell, but internal to the program, the cell is excluded from the solution. If the IDOMAIN value for a cell is 1, the cell exists in the simulation. If the IDOMAIN value for a cell is -1, the cell does not exist in the simulation. Furthermore, the first existing cell above will be connected to the first existing cell below. This type of cell is referred to as a “vertical pass through” cell.

Block: VERTICES

- `iv` is the vertex number. Records in the VERTICES block must be listed in consecutive order from 1 to NVERT.
- `xv` is the x-coordinate for the vertex.
- `yv` is the y-coordinate for the vertex.

Block: CELL2D

- `icell2d` is the CELL2D number. Records in the CELL2D block must be listed in consecutive order from the first to the last.
- `xc` is the x-coordinate for the cell center.
- `yc` is the y-coordinate for the cell center.
- `nvert` is the number of vertices required to define the cell. There may be a different number of vertices for each cell.
- `icvert` is an array of integer values containing vertex numbers (in the VERTICES block) used to define the cell. Vertices must be listed in clockwise order. Cells that are connected must share vertices.

1.4.7 GWT-DSP

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [XT3D_OFF]
  [XT3D_RHS]
END OPTIONS
```

```

BEGIN GRIDDATA
  [DIFFC [LAYERED]
    <diffc(nodes)> -- READARRAY]
  [ALH [LAYERED]
    <alh(nodes)> -- READARRAY]
  [ALV [LAYERED]
    <alv(nodes)> -- READARRAY]
  [ATH1 [LAYERED]
    <ath1(nodes)> -- READARRAY]
  [ATH2 [LAYERED]
    <ath2(nodes)> -- READARRAY]
  [ATV [LAYERED]
    <atv(nodes)> -- READARRAY]
END GRIDDATA

```

Explanation of Variables

Block: OPTIONS

- **XT3D_OFF** deactivate the xt3d method and use the faster and less accurate approximation. This option may provide a fast and accurate solution under some circumstances, such as when flow aligns with the model grid, there is no mechanical dispersion, or when the longitudinal and transverse dispersivities are equal. This option may also be used to assess the computational demand of the XT3D approach by noting the run time differences with and without this option on.
- **XT3D_RHS** add xt3d terms to right-hand side, when possible. This option uses less memory, but may require more iterations.

Block: GRIDDATA

- **diffc** effective molecular diffusion coefficient.
- **alh** longitudinal dispersivity in horizontal direction. If flow is strictly horizontal, then this is the longitudinal dispersivity that will be used. If flow is not strictly horizontal or strictly vertical, then the longitudinal dispersivity is a function of both ALH and ALV. If mechanical dispersion is represented (by specifying any dispersivity values) then this array is required.
- **alv** longitudinal dispersivity in vertical direction. If flow is strictly vertical, then this is the longitudinal dispersivity value that will be used. If flow is not strictly horizontal or strictly vertical, then the longitudinal dispersivity is a function of both ALH and ALV. If this value is not specified and mechanical dispersion is represented, then this array is set equal to ALH.
- **ath1** transverse dispersivity in horizontal direction. This is the transverse dispersivity value for the second ellipsoid axis. If flow is strictly horizontal and directed in the x direction (along a row for a regular grid), then this value controls spreading in the y direction. If mechanical dispersion is represented (by specifying any dispersivity values) then this array is required.
- **ath2** transverse dispersivity in horizontal direction. This is the transverse dispersivity value for the third ellipsoid axis. If flow is strictly horizontal and directed in the x direction (along a row for a regular grid), then this value controls spreading in the z direction. If this value is not specified and mechanical dispersion is represented, then this array is set equal to ATH1.
- **atv** transverse dispersivity when flow is in vertical direction. If flow is strictly vertical and directed in the z direction, then this value controls spreading in the x and y directions. If this value is not specified and mechanical dispersion is represented, then this array is set equal to ATH2.

Example Input File

```
BEGIN OPTIONS
END OPTIONS

BEGIN GRIDDATA
  DIFFC
    CONSTANT 1.e-9
  ALH
    CONSTANT 1.
  ALV
    CONSTANT 1.
  ATH1
    CONSTANT 0.1
  ATH2
    CONSTANT 0.1
  ATV
    CONSTANT 0.1
END GRIDDATA
```

1.4.8 GWT-FMI

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [SAVE_FLOWS]
  [FLOW_IMBALANCE_CORRECTION]
END OPTIONS
```

```
BEGIN PACKAGEDATA
  <flowtype> FILEIN <fname>
  <flowtype> FILEIN <fname>
  ...
END PACKAGEDATA
```

Explanation of Variables

Block: OPTIONS

- **SAVE_FLOWS** keyword to indicate that FMI flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- **FLOW_IMBALANCE_CORRECTION** correct for an imbalance in flows by assuming that any residual flow error comes in or leaves at the concentration of the cell. When this option is activated, the GWT Model budget written to the listing file will contain two additional entries: **FLOW-ERROR** and **FLOW-CORRECTION**. These two entries will be equal but opposite in sign. The **FLOW-CORRECTION** term is a mass flow that is added to offset the error caused by an imprecise flow balance. If these terms are not relatively small, the flow model should be rerun with stricter convergence tolerances.

Block: PACKAGEDATA

- `flowtype` is the word GWFBUDGET, GWFHEAD, GWFMOVER or the name of an advanced GWF stress package. If GWFBUDGET is specified, then the corresponding file must be a budget file from a previous GWF Model run. If an advanced GWF stress package name appears then the corresponding file must be the budget file saved by a LAK, SFR, MAW or UZF Package.
- `FILEIN` keyword to specify that an input filename is expected next.
- `fname` is the name of the file containing flows. The path to the file should be included if the file is not located in the folder where the program was run.

Example Input File

```

BEGIN OPTIONS
  FLOW_IMBALANCE_CORRECTION
END OPTIONS

BEGIN PACKAGEDATA
  GWFBUDGET FILEIN ../flow/mygwmodel.bud
  GWFHEAD FILEIN   ../flow/mygwmodel.hds
  GWFMOVER FILEIN  ../flow/mygwmodel.hds
  LAK-1 FILEIN     ../flow/mygwmodel.lak.bud
  SFR-1 FILEIN     ../flow/mygwmodel.sfr.bud
  MAW-1 FILEIN     ../flow/mygwmodel.maw.bud
  UZF-1 FILEIN     ../flow/mygwmodel.uzf.bud
  LAK-2 FILEIN     ../flow/mygwmodel-2.lak.bud
END PACKAGEDATA

```

1.4.9 GWT-IC**Structure of Blocks***FOR EACH SIMULATION*

```

BEGIN GRIDDATA
  STRT [LAYERED]
    <strt(nodes)> -- READARRAY
END GRIDDATA

```

Explanation of Variables**Block: GRIDDATA**

- `strt` is the initial (starting) concentration—that is, concentration at the beginning of the GWT Model simulation. `STRT` must be specified for all GWT Model simulations. One value is read for every model cell.

Example Input File

```
#The OPTIONS block is optional
BEGIN OPTIONS
END OPTIONS

#The GRIDDATA block is required
BEGIN GRIDDATA
  STRT LAYERED
    CONSTANT 0.0 Initial Concentration layer 1
    CONSTANT 0.0 Initial Concentration layer 2
  END GRIDDATA
```

1.4.10 GWT-IST

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [SAVE_FLOWS]
  [SORPTION]
  [FIRST_ORDER_DECAY]
  [ZERO_ORDER_DECAY]
  [CIM FILEOUT <cimfile>]
  [CIM PRINT_FORMAT COLUMNS <columns> WIDTH <width> DIGITS <digits> <format>]
END OPTIONS
```

```
BEGIN GRIDDATA
  [CIM [LAYERED]
    <cim(nodes)> -- READARRAY]
  THETAIM [LAYERED]
    <thetaim(nodes)> -- READARRAY
  ZETAIM [LAYERED]
    <zetaim(nodes)> -- READARRAY
  [DECAY [LAYERED]
    <decay(nodes)> -- READARRAY]
  [DECAY_SORBED [LAYERED]
    <decay_sorbed(nodes)> -- READARRAY]
  BULK_DENSITY [LAYERED]
    <bulk_density(nodes)> -- READARRAY
  DISTCOEF [LAYERED]
    <distcoef(nodes)> -- READARRAY
  END GRIDDATA
```

Explanation of Variables

Block: OPTIONS

- SAVE_FLOWS keyword to indicate that IST flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- SORPTION is a text keyword to indicate that sorption will be activated. Use of this keyword requires that BULK_DENSITY and DISTCOEF are specified in the GRIDDATA block. The linear sorption isotherm is the only isotherm presently supported in the IST Package.

- `FIRST_ORDER_DECAY` is a text keyword to indicate that first-order decay will occur. Use of this keyword requires that `DECAY` and `DECAY_SORBED` (if sorption is active) are specified in the `GRIDDATA` block.
- `ZERO_ORDER_DECAY` is a text keyword to indicate that zero-order decay will occur. Use of this keyword requires that `DECAY` and `DECAY_SORBED` (if sorption is active) are specified in the `GRIDDATA` block.
- `CIM` keyword to specify that record corresponds to immobile concentration.
- `FILEOUT` keyword to specify that an output filename is expected next.
- `cimfile` name of the output file to write immobile concentrations. This file is a binary file that has the same format and structure as a binary head and concentration file. The value for the text variable written to the file is `CIM`. Immobile domain concentrations will be written to this file at the same interval as mobile domain concentrations are saved, as specified in the `GWT Model Output Control` file.
- `PRINT_FORMAT` keyword to specify format for printing to the listing file.
- `columns` number of columns for writing data.
- `width` width for writing each number.
- `digits` number of digits to use for writing a number.
- `format` write format can be `EXPONENTIAL`, `FIXED`, `GENERAL`, or `SCIENTIFIC`.

Block: GRIDDATA

- `cim` initial concentration of the immobile domain in mass per length cubed. If `CIM` is not specified, then it is assumed to be zero.
- `thetaim` porosity of the immobile domain specified as the volume of immobile pore space per total volume (dimensionless).
- `zetaim` mass transfer rate coefficient between the mobile and immobile domains, in dimensions of per time.
- `decay` is the rate coefficient for first or zero-order decay for the aqueous phase of the immobile domain. A negative value indicates solute production. The dimensions of decay for first-order decay is one over time. The dimensions of decay for zero-order decay is mass per length cubed per time. Decay will have no effect on simulation results unless either first- or zero-order decay is specified in the options block.
- `decay_sorbed` is the rate coefficient for first or zero-order decay for the sorbed phase of the immobile domain. A negative value indicates solute production. The dimensions of `decay_sorbed` for first-order decay is one over time. The dimensions of `decay_sorbed` for zero-order decay is mass of solute per mass of aquifer per time. If `decay_sorbed` is not specified and both `decay` and sorption are active, then the program will terminate with an error. `decay_sorbed` will have no effect on simulation results unless the `SORPTION` keyword and either first- or zero-order decay are specified in the options block.
- `bulk_density` is the bulk density of the aquifer in mass per length cubed. `bulk_density` will have no effect on simulation results unless the `SORPTION` keyword is specified in the options block.
- `distcoef` is the distribution coefficient for the equilibrium-controlled linear sorption isotherm in dimensions of length cubed per mass. `distcoef` will have no effect on simulation results unless the `SORPTION` keyword is specified in the options block.

Example Input File

```
BEGIN OPTIONS
  SORPTION
  FIRST_ORDER_DECAY
```

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```

    CIM FILEOUT gwtmodel.imd1.ucn
END OPTIONS

BEGIN GRIDDATA
    ZETAIM
        CONSTANT 0.01
    THETAIM
        CONSTANT 0.025
    BULK_DENSITY
        CONSTANT 0.25000000
    DISTCOEF
        CONSTANT 0.01000000
    DECAY
        CONSTANT 0.01000000
    DECAY_SORBED
        CONSTANT 0.01000000
END GRIDDATA

```

1.4.11 GWT-LKT

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN OPTIONS
    [FLOW_PACKAGE_NAME <flow_package_name>]
    [AUXILIARY <auxiliary(naux)>]
    [FLOW_PACKAGE_AUXILIARY_NAME <flow_package_auxiliary_name>]
    [BOUNDNAMES]
    [PRINT_INPUT]
    [PRINT_CONCENTRATION]
    [PRINT_FLOWS]
    [SAVE_FLOWS]
    [CONCENTRATION FILEOUT <concfile>]
    [BUDGET FILEOUT <budgetfile>]
    [TS6 FILEIN <ts6_filename>]
    [OBS6 FILEIN <obs6_filename>]
END OPTIONS

```

```

BEGIN PACKAGEDATA
    <lakeno> <strt> [<aux(naux)>] [<boundname>]
    <lakeno> <strt> [<aux(naux)>] [<boundname>]
    ...
END PACKAGEDATA

```

FOR ANY STRESS PERIOD

```

BEGIN PERIOD <iper>
    <lakeno> <laksetting>
    <lakeno> <laksetting>
    ...
END PERIOD

```


Explanation of Variables

Block: OPTIONS

- `flow_package_name` keyword to specify the name of the corresponding flow package. If not specified, then the corresponding flow package must have the same name as this advanced transport package (the name associated with this package in the GWT name file).
- `auxiliary` defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for `naux`. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- `flow_package_auxiliary_name` keyword to specify the name of an auxiliary variable in the corresponding flow package. If specified, then the simulated concentrations from this advanced transport package will be copied into the auxiliary variable specified with this name. Note that the flow package must have an auxiliary variable with this name or the program will terminate with an error. If the flows for this advanced transport package are read from a file, then this option will have no effect.
- `BOUNDNAMES` keyword to indicate that boundary names may be provided with the list of lake cells.
- `PRINT_INPUT` keyword to indicate that the list of lake information will be written to the listing file immediately after it is read.
- `PRINT_CONCENTRATION` keyword to indicate that the list of lake concentration will be printed to the listing file for every stress period in which “HEAD PRINT” is specified in Output Control. If there is no Output Control option and `PRINT_CONCENTRATION` is specified, then concentration are printed for the last time step of each stress period.
- `PRINT_FLOWS` keyword to indicate that the list of lake flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “`PRINT_FLOWS`” is specified, then flow rates are printed for the last time step of each stress period.
- `SAVE_FLOWS` keyword to indicate that lake flow terms will be written to the file specified with “`BUDGET FILEOUT`” in Output Control.
- `CONCENTRATION` keyword to specify that record corresponds to concentration.
- `concfile` name of the binary output file to write concentration information.
- `BUDGET` keyword to specify that record corresponds to the budget.
- `FILEOUT` keyword to specify that an output filename is expected next.
- `budgetfile` name of the binary output file to write budget information.
- `TS6` keyword to specify that record corresponds to a time-series file.
- `FILEIN` keyword to specify that an input filename is expected next.
- `ts6_filename` defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- `OBS6` keyword to specify that record corresponds to an observations file.
- `obs6_filename` name of input file to define observations for the LKT package. See the “Observation utility” section for instructions for preparing observation input files. Tables `ref{table:gwf-obstypetable}` and `ref{table:gwt-obstypetable}` lists observation type(s) supported by the LKT package.

Block: PACKAGEDATA

- `lakeno` integer value that defines the lake number associated with the specified PACKAGEDATA data on the line. LAKENO must be greater than zero and less than or equal to NLAKES. Lake information must be specified for every lake or the program will terminate with an error. The program will also terminate with an error if information for a lake is specified more than once.
- `strt` real value that defines the starting concentration for the lake.
- `aux` represents the values of the auxiliary variables for each lake. The values of auxiliary variables must be present for each lake. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `boundname` name of the lake cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. IPER must be less than or equal to NPER in the TDIS Package and greater than zero. The IPER value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- `lakeno` integer value that defines the lake number associated with the specified PERIOD data on the line. LAKENO must be greater than zero and less than or equal to NLAKES.
- `laksetting` line of information that is parsed into a keyword and values. Keyword values that can be used to start the LAKSETTING string include: STATUS, CONCENTRATION, RAINFALL, EVAPORATION, RUNOFF, and AUXILIARY. These settings are used to assign the concentration of associated with the corresponding flow terms. Concentrations cannot be specified for all flow terms. For example, the Lake Package supports a “WITHDRAWAL” flow term. If this withdrawal term is active, then water will be withdrawn from the lake at the calculated concentration of the lake.

```
STATUS <status>
CONCENTRATION <concentration>
RAINFALL <rainfall>
EVAPORATION <evaporation>
RUNOFF <runoff>
EXT-INFLOW <ext-inflow>
AUXILIARY <auxname> <auxval>
```

- `status` keyword option to define lake status. STATUS can be ACTIVE, INACTIVE, or CONSTANT. By default, STATUS is ACTIVE, which means that concentration will be calculated for the lake. If a lake is inactive, then there will be no solute mass fluxes into or out of the lake and the inactive value will be written for the lake concentration. If a lake is constant, then the concentration for the lake will be fixed at the user specified value.
- `concentration` real or character value that defines the concentration for the lake. The specified CONCENTRATION is only applied if the lake is a constant concentration lake. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- `rainfall` real or character value that defines the rainfall solute concentration (ML-3) for the lake. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `evaporation` real or character value that defines the concentration of evaporated water (ML-3) for the lake. If this concentration value is larger than the simulated concentration in the lake, then the evaporated water will be removed at the same concentration as the lake. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `runoff` real or character value that defines the concentration of runoff (ML-3) for the lake. Value must be greater than or equal to zero. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `ext-inflow` real or character value that defines the concentration of external inflow (ML-3) for the lake. Value must be greater than or equal to zero. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `AUXILIARY` keyword for specifying auxiliary variable.
- `auxname` name for the auxiliary variable to be assigned `AUXVAL`. `AUXNAME` must match one of the auxiliary variable names defined in the `OPTIONS` block. If `AUXNAME` does not match one of the auxiliary variable names defined in the `OPTIONS` block the data are ignored.
- `auxval` value for the auxiliary variable. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

Example Input File

```

BEGIN OPTIONS
  AUXILIARY  aux1  aux2
  BOUNDNAMES
  PRINT_INPUT
  PRINT_CONCENTRATION
  PRINT_FLOWS
  SAVE_FLOWS
  CONCENTRATION  FILEOUT  gwt_lkt_02.lkt.bin
  BUDGET  FILEOUT  gwt_lkt_02.lkt.bud
  OBS6  FILEIN  gwt_lkt_02.lkt.obs
END OPTIONS

BEGIN PACKAGEDATA
#  L          STRT          aux1          aux2          bname
1      0.00000000      99.00000000      999.00000000  MYLAKE1
2      0.00000000      99.00000000      999.00000000  MYLAKE2
3      0.00000000      99.00000000      999.00000000  MYLAKE3
END PACKAGEDATA

BEGIN PERIOD  1
  1  STATUS  ACTIVE
  2  STATUS  ACTIVE
  3  STATUS  ACTIVE
END PERIOD  1

```

Available Observation Types

Example Observation Input File

```

BEGIN options
  DIGITS 7
  PRINT_INPUT
END options

BEGIN continuous FILEOUT gwt_lkt02.lkt.obs.csv
  lkt-1-conc CONCENTRATION 1
  lkt-1-extinflow EXT-INFLOW 1
  lkt-1-rain RAINFALL 1
  lkt-1-roff RUNOFF 1
  lkt-1-evap EVAPORATION 1
  lkt-1-wdr1 WITHDRAWAL 1
  lkt-1-stor STORAGE 1
  lkt-1-const CONSTANT 1
  lkt-1-gwt1 LKT 1 1
  lkt-1-gwt2 LKT 1 2
  lkt-2-gwt1 LKT 2 1
  lkt-1-mylake1 LKT MYLAKE1
  lkt-1-fjf FLOW-JA-FACE 1 2
  lkt-2-fjf FLOW-JA-FACE 2 1
  lkt-3-fjf FLOW-JA-FACE 2 3
  lkt-4-fjf FLOW-JA-FACE 3 2
  lkt-5-fjf FLOW-JA-FACE MYLAKE1
  lkt-6-fjf FLOW-JA-FACE MYLAKE2
  lkt-7-fjf FLOW-JA-FACE MYLAKE3
END continuous

```

1.4.12 GWT-MST

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN OPTIONS
  [SAVE_FLOWS]
  [FIRST_ORDER_DECAY]
  [ZERO_ORDER_DECAY]
  [SORPTION <sorption>]
END OPTIONS

```

```

BEGIN GRIDDATA
  POROSITY [LAYERED]
    <porosity(nodes)> -- READARRAY
  [DECAY [LAYERED]
    <decay(nodes)> -- READARRAY]
  [DECAY_SORBED [LAYERED]
    <decay_sorbed(nodes)> -- READARRAY]
  [BULK_DENSITY [LAYERED]
    <bulk_density(nodes)> -- READARRAY]
  [DISTCOEF [LAYERED]
    <distcoef(nodes)> -- READARRAY]

```

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```
[SP2 [LAYERED]
      <sp2 (nodes)> -- READARRAY]
END GRIDDATA
```

Explanation of Variables

Block: OPTIONS

- **SAVE_FLOWS** keyword to indicate that MST flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- **FIRST_ORDER_DECAY** is a text keyword to indicate that first-order decay will occur. Use of this keyword requires that **DECAY** and **DECAY_SORBED** (if sorption is active) are specified in the **GRIDDATA** block.
- **ZERO_ORDER_DECAY** is a text keyword to indicate that zero-order decay will occur. Use of this keyword requires that **DECAY** and **DECAY_SORBED** (if sorption is active) are specified in the **GRIDDATA** block.
- **sorption** is a text keyword to indicate that sorption will be activated. Valid sorption options include **LINEAR**, **FREUNDLICH**, and **LANGMUIR**. Use of this keyword requires that **BULK_DENSITY** and **DISTCOEF** are specified in the **GRIDDATA** block. If sorption is specified as **FREUNDLICH** or **LANGMUIR** then **SP2** is also required in the **GRIDDATA** block.

Block: GRIDDATA

- **porosity** is the aquifer porosity.
- **decay** is the rate coefficient for first or zero-order decay for the aqueous phase of the mobile domain. A negative value indicates solute production. The dimensions of decay for first-order decay is one over time. The dimensions of decay for zero-order decay is mass per length cubed per time. decay will have no effect on simulation results unless either first- or zero-order decay is specified in the options block.
- **decay_sorbed** is the rate coefficient for first or zero-order decay for the sorbed phase of the mobile domain. A negative value indicates solute production. The dimensions of decay_sorbed for first-order decay is one over time. The dimensions of decay_sorbed for zero-order decay is mass of solute per mass of aquifer per time. If decay_sorbed is not specified and both decay and sorption are active, then the program will terminate with an error. decay_sorbed will have no effect on simulation results unless the **SORPTION** keyword and either first- or zero-order decay are specified in the options block.
- **bulk_density** is the bulk density of the aquifer in mass per length cubed. bulk_density is not required unless the **SORPTION** keyword is specified.
- **distcoef** is the distribution coefficient for the equilibrium-controlled linear sorption isotherm in dimensions of length cubed per mass. distcoef is not required unless the **SORPTION** keyword is specified.
- **sp2** is the exponent for the Freundlich isotherm and the sorption capacity for the Langmuir isotherm.

Example Input File

```
BEGIN OPTIONS
  SORPTION linear
  FIRST_ORDER_DECAY
END OPTIONS
```

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```
BEGIN GRIDDATA
  POROSITY
    CONSTANT 0.1
  DECAY
    CONSTANT 0.001
  DECAY_SORBED
    CONSTANT 0.001
  BULK_DENSITY
    CONSTANT 1.
  DISTCOEF
    CONSTANT 0.01
END GRIDDATA
```

1.4.13 GWT-MVT

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [PRINT_INPUT]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [BUDGET FILEOUT <budgetfile>]
END OPTIONS
```

Explanation of Variables

Block: OPTIONS

- **PRINT_INPUT** keyword to indicate that the list of mover information will be written to the listing file immediately after it is read.
- **PRINT_FLOWS** keyword to indicate that the list of lake flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- **SAVE_FLOWS** keyword to indicate that lake flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- **BUDGET** keyword to specify that record corresponds to the budget.
- **FILEOUT** keyword to specify that an output filename is expected next.
- **budgetfile** name of the binary output file to write budget information.

Example Input File

```
BEGIN OPTIONS
  PRINT_INPUT
  PRINT_FLOWS
  SAVE_FLOWS
```

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```
BUDGET FILEOUT mygwtmodel.mvt.bud
END OPTIONS
```

1.4.14 GWT-MWT

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
[FLOW_PACKAGE_NAME <flow_package_name>]
[AUXILIARY <auxiliary(naux)>]
[FLOW_PACKAGE_AUXILIARY_NAME <flow_package_auxiliary_name>]
[BOUNDNAMES]
[PRINT_INPUT]
[PRINT_CONCENTRATION]
[PRINT_FLOWS]
[SAVE_FLOWS]
[CONCENTRATION FILEOUT <concfile>]
[BUDGET FILEOUT <budgetfile>]
[TS6 FILEIN <ts6_filename>]
[OBS6 FILEIN <obs6_filename>]
END OPTIONS
```

```
BEGIN PACKAGEDATA
<mawno> <strt> [<aux(naux)>] [<boundname>]
<mawno> <strt> [<aux(naux)>] [<boundname>]
...
END PACKAGEDATA
```

FOR ANY STRESS PERIOD

```
BEGIN PERIOD <iper>
<mawno> <mwtsetting>
<mawno> <mwtsetting>
...
END PERIOD
```

Explanation of Variables

Block: OPTIONS

- `flow_package_name` keyword to specify the name of the corresponding flow package. If not specified, then the corresponding flow package must have the same name as this advanced transport package (the name associated with this package in the GWT name file).
- `auxiliary` defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for `naux`. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.

- `flow_package_auxiliary_name` keyword to specify the name of an auxiliary variable in the corresponding flow package. If specified, then the simulated concentrations from this advanced transport package will be copied into the auxiliary variable specified with this name. Note that the flow package must have an auxiliary variable with this name or the program will terminate with an error. If the flows for this advanced transport package are read from a file, then this option will have no effect.
- `BOUNDNAMES` keyword to indicate that boundary names may be provided with the list of well cells.
- `PRINT_INPUT` keyword to indicate that the list of well information will be written to the listing file immediately after it is read.
- `PRINT_CONCENTRATION` keyword to indicate that the list of well concentration will be printed to the listing file for every stress period in which “HEAD PRINT” is specified in Output Control. If there is no Output Control option and `PRINT_CONCENTRATION` is specified, then concentration are printed for the last time step of each stress period.
- `PRINT_FLOWS` keyword to indicate that the list of well flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “`PRINT_FLOWS`” is specified, then flow rates are printed for the last time step of each stress period.
- `SAVE_FLOWS` keyword to indicate that well flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- `CONCENTRATION` keyword to specify that record corresponds to concentration.
- `concfile` name of the binary output file to write concentration information.
- `BUDGET` keyword to specify that record corresponds to the budget.
- `FILEOUT` keyword to specify that an output filename is expected next.
- `budgetfile` name of the binary output file to write budget information.
- `TS6` keyword to specify that record corresponds to a time-series file.
- `FILEIN` keyword to specify that an input filename is expected next.
- `ts6_filename` defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- `OBS6` keyword to specify that record corresponds to an observations file.
- `obs6_filename` name of input file to define observations for the MWT package. See the “Observation utility” section for instructions for preparing observation input files. Tables `ref{table:gwf-obstypetable}` and `ref{table:gwt-obstypetable}` lists observation type(s) supported by the MWT package.

Block: PACKAGEDATA

- `mawno` integer value that defines the well number associated with the specified `PACKAGEDATA` data on the line. `MAWNO` must be greater than zero and less than or equal to `NMAWWELLS`. Well information must be specified for every well or the program will terminate with an error. The program will also terminate with an error if information for a well is specified more than once.
- `strt` real value that defines the starting concentration for the well.
- `aux` represents the values of the auxiliary variables for each well. The values of auxiliary variables must be present for each well. The values must be specified in the order of the auxiliary variables specified in the `OPTIONS` block. If the package supports time series and the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- `boundname` name of the well cell. `BOUNDNAME` is an ASCII character variable that can contain as many as 40 characters. If `BOUNDNAME` contains spaces in it, then the entire name must be enclosed within single quotes.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. `IPER` must be less than or equal to `NPER` in the TDIS Package and greater than zero. The `IPER` value assigned to a stress period block must be greater than the `IPER` value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- `mawno` integer value that defines the well number associated with the specified PERIOD data on the line. `MAWNO` must be greater than zero and less than or equal to `NMAWWELLS`.
- `mwtsetting` line of information that is parsed into a keyword and values. Keyword values that can be used to start the MWTSETTING string include: `STATUS`, `CONCENTRATION`, `RAINFALL`, `EVAPORATION`, `RUNOFF`, and `AUXILIARY`. These settings are used to assign the concentration of associated with the corresponding flow terms. Concentrations cannot be specified for all flow terms. For example, the Multi-Aquifer Well Package supports a “WITHDRAWAL” flow term. If this withdrawal term is active, then water will be withdrawn from the well at the calculated concentration of the well.

```
STATUS <status>
CONCENTRATION <concentration>
RATE <rate>
AUXILIARY <auxname> <auxval>
```

- `status` keyword option to define well status. `STATUS` can be `ACTIVE`, `INACTIVE`, or `CONSTANT`. By default, `STATUS` is `ACTIVE`, which means that concentration will be calculated for the well. If a well is inactive, then there will be no solute mass fluxes into or out of the well and the inactive value will be written for the well concentration. If a well is constant, then the concentration for the well will be fixed at the user specified value.
- `concentration` real or character value that defines the concentration for the well. The specified `CONCENTRATION` is only applied if the well is a constant concentration well. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `rate` real or character value that defines the injection solute concentration (ML-3) for the well. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `AUXILIARY` keyword for specifying auxiliary variable.
- `auxname` name for the auxiliary variable to be assigned `AUXVAL`. `AUXNAME` must match one of the auxiliary variable names defined in the `OPTIONS` block. If `AUXNAME` does not match one of the auxiliary variable names defined in the `OPTIONS` block the data are ignored.
- `auxval` value for the auxiliary variable. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

Example Input File

```

BEGIN OPTIONS
  AUXILIARY  aux1  aux2
  BOUNDNAMES
  PRINT_INPUT
  PRINT_CONCENTRATION
  PRINT_FLOWS
  SAVE_FLOWS
  CONCENTRATION  FILEOUT  gwt_mwt_02.mwt.bin
  BUDGET  FILEOUT  gwt_mwt_02.mwt.bud
  OBS6  FILEIN  gwt_mwt_02.mwt.obs
END OPTIONS

BEGIN PACKAGEDATA
#  L          STRT          aux1          aux2          bname
  1          0.00000000      99.00000000      999.00000000  MYWELL1
  2          0.00000000      99.00000000      999.00000000  MYWELL2
  3          0.00000000      99.00000000      999.00000000  MYWELL3
END PACKAGEDATA

BEGIN PERIOD  1
  1  STATUS  ACTIVE
  2  STATUS  ACTIVE
  3  STATUS  ACTIVE
END PERIOD  1

```

Available Observation Types

Example Observation Input File

```

BEGIN options
  DIGITS  12
  PRINT_INPUT
END options

BEGIN continuous  FILEOUT  gwt_mwt_02.mwt.obs.csv
mwt1mwt  MWT  1  1
mwt2mwt  MWT  2  1
mwt3mwt  MWT  3  1
mwt4mwt  MWT  4  1
mwt1conc  CONCENTRATION  1
mwt2conc  CONCENTRATION  2
mwt3conc  CONCENTRATION  3
mwt4conc  CONCENTRATION  4
mwt1stor  STORAGE  1
mwt2stor  STORAGE  2
mwt3stor  STORAGE  3
mwt4stor  STORAGE  4
mwt1cnst  CONSTANT  1
mwt2cnst  CONSTANT  2
mwt3cnst  CONSTANT  3
mwt4cnst  CONSTANT  4
mwt1fmvr  FROM-MVR  1
mwt2fmvr  FROM-MVR  2
mwt3fmvr  FROM-MVR  3
mwt4fmvr  FROM-MVR  4

```

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```

mwt1rate  RATE  1
mwt2rate  RATE  2
mwt3rate  RATE  3
mwt4rate  RATE  4
mwt1rtmv  RATE-TO-MVR  1
mwt2rtmv  RATE-TO-MVR  2
mwt3rtmv  RATE-TO-MVR  3
mwt4rtmv  RATE-TO-MVR  4
mwt1fwrt  FW-RATE  1
mwt2fwrt  FW-RATE  2
mwt3fwrt  FW-RATE  3
mwt4fwrt  FW-RATE  4
mwt1frtm  FW-RATE-TO-MVR  1
mwt2frtm  FW-RATE-TO-MVR  2
mwt3frtm  FW-RATE-TO-MVR  3
mwt4frtm  FW-RATE-TO-MVR  4
END continuous  FILEOUT  gwt_mwt_02.mwt.obs.csv

```

1.4.15 GWT-NAM

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN OPTIONS
  [LIST <list>]
  [PRINT_INPUT]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
END OPTIONS

```

```

BEGIN PACKAGES
  <ftype> <fname> [<pname>]
  <ftype> <fname> [<pname>]
  ...
END PACKAGES

```

Explanation of Variables

Block: OPTIONS

- `list` is name of the listing file to create for this GWT model. If not specified, then the name of the list file will be the basename of the GWT model name file and the '.lst' extension. For example, if the GWT name file is called "my.model.nam" then the list file will be called "my.model.lst".
- `PRINT_INPUT` keyword to indicate that the list of all model stress package information will be written to the listing file immediately after it is read.
- `PRINT_FLOWS` keyword to indicate that the list of all model package flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.

- `SAVE_FLOWS` keyword to indicate that all model package flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.

Block: PACKAGES

- `ftype` is the file type, which must be one of the following character values shown in table ref{table:f_{type}}. `Ftype` may be entered in any combination of uppercase and lowercase.
- `fname` is the name of the file containing the package input. The path to the file should be included if the file is not located in the folder where the program was run.
- `pname` is the user-defined name for the package. `PNAME` is restricted to 16 characters. No spaces are allowed in `PNAME`. `PNAME` character values are read and stored by the program for stress packages only. These names may be useful for labeling purposes when multiple stress packages of the same type are located within a single GWT Model. If `PNAME` is specified for a stress package, then `PNAME` will be used in the flow budget table in the listing file; it will also be used for the text entry in the cell-by-cell budget file. `PNAME` is case insensitive and is stored in all upper case letters.

Example Input File

```
# This block is optional
BEGIN OPTIONS
END OPTIONS

BEGIN PACKAGES
  DIS6      transport.dis
  IC6       transport.ic
  MST6      transport.mst
  ADV6      transport.adv
  DSP6      transport.dsp
  SSM6      transport.ssm
  CNC6      transport01.cnc LEFT
  CNC6      transport02.cnc RIGHT
  SRC6      transport01.src LAY1
  SRC6      transport02.src LAY2
  SRC6      transport03.src LAY3
  IST6      transport01.ist CLAY
  IST6      transport02.ist SILT
  OC6       transport.oc
END PACKAGES
```

1.4.16 GWT-OC

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [BUDGET FILEOUT <budgetfile>]
  [CONCENTRATION FILEOUT <concentrationfile>]
  [CONCENTRATION PRINT_FORMAT COLUMNS <columns> WIDTH <width> DIGITS <digits>
↪<format>]
END OPTIONS
```

FOR ANY STRESS PERIOD

```

BEGIN PERIOD <iper>
  [SAVE <rtype> <ocsetting>]
  [PRINT <rtype> <ocsetting>]
END PERIOD

```

Explanation of Variables**Block: OPTIONS**

- BUDGET keyword to specify that record corresponds to the budget.
- FILEOUT keyword to specify that an output filename is expected next.
- budgetfile name of the output file to write budget information.
- CONCENTRATION keyword to specify that record corresponds to concentration.
- concentrationfile name of the output file to write conc information.
- PRINT_FORMAT keyword to specify format for printing to the listing file.
- columns number of columns for writing data.
- width width for writing each number.
- digits number of digits to use for writing a number.
- format write format can be EXPONENTIAL, FIXED, GENERAL, or SCIENTIFIC.

Block: PERIOD

- iper integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. IPER must be less than or equal to NPER in the TDIS Package and greater than zero. The IPER value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- SAVE keyword to indicate that information will be saved this stress period.
- PRINT keyword to indicate that information will be printed this stress period.
- rtype type of information to save or print. Can be BUDGET or CONCENTRATION.
- ocsetting specifies the steps for which the data will be saved.

```

ALL
FIRST
LAST
FREQUENCY <frequency>
STEPS <steps(<nstp>)>

```

- ALL keyword to indicate save for all time steps in period.
- FIRST keyword to indicate save for first step in period. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.
- LAST keyword to indicate save for last step in period. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

- frequency save at the specified time step frequency. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.
- steps save for each step specified in STEPS. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

Example Input File

```
BEGIN OPTIONS
  CONCENTRATION FILEOUT  transport.ucn
  CONCENTRATION PRINT_FORMAT  COLUMNS 15  WIDTH 7  DIGITS 2  FIXED
END OPTIONS

BEGIN PERIOD 1
  PRINT BUDGET ALL
  SAVE CONCENTRATION ALL
  PRINT CONCENTRATION ALL
END PERIOD
```

1.4.17 GWT-SFT

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [FLOW_PACKAGE_NAME <flow_package_name>]
  [AUXILIARY <auxiliary(naux)>]
  [FLOW_PACKAGE_AUXILIARY_NAME <flow_package_auxiliary_name>]
  [BOUNDNAMES]
  [PRINT_INPUT]
  [PRINT_CONCENTRATION]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [CONCENTRATION FILEOUT <concfile>]
  [BUDGET FILEOUT <budgetfile>]
  [TS6 FILEIN <ts6_filename>]
  [OBS6 FILEIN <obs6_filename>]
END OPTIONS
```

```
BEGIN PACKAGEDATA
  <rno> <strt> [<aux(naux)>] [<boundname>]
  <rno> <strt> [<aux(naux)>] [<boundname>]
  ...
END PACKAGEDATA
```

FOR ANY STRESS PERIOD

```
BEGIN PERIOD <iper>
  <rno> <reachsetting>
  <rno> <reachsetting>
  ...
END PERIOD
```

Explanation of Variables

Block: OPTIONS

- `flow_package_name` keyword to specify the name of the corresponding flow package. If not specified, then the corresponding flow package must have the same name as this advanced transport package (the name associated with this package in the GWT name file).
- `auxiliary` defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for `naux`. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- `flow_package_auxiliary_name` keyword to specify the name of an auxiliary variable in the corresponding flow package. If specified, then the simulated concentrations from this advanced transport package will be copied into the auxiliary variable specified with this name. Note that the flow package must have an auxiliary variable with this name or the program will terminate with an error. If the flows for this advanced transport package are read from a file, then this option will have no effect.
- `BOUNDNAMES` keyword to indicate that boundary names may be provided with the list of reach cells.
- `PRINT_INPUT` keyword to indicate that the list of reach information will be written to the listing file immediately after it is read.
- `PRINT_CONCENTRATION` keyword to indicate that the list of reach stages will be printed to the listing file for every stress period in which “HEAD PRINT” is specified in Output Control. If there is no Output Control option and `PRINT_STAGE` is specified, then stages are printed for the last time step of each stress period.
- `PRINT_FLOWS` keyword to indicate that the list of reach flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- `SAVE_FLOWS` keyword to indicate that reach flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- `CONCENTRATION` keyword to specify that record corresponds to concentration.
- `concfile` name of the binary output file to write concentration information.
- `BUDGET` keyword to specify that record corresponds to the budget.
- `FILEOUT` keyword to specify that an output filename is expected next.
- `budgetfile` name of the binary output file to write budget information.
- `TS6` keyword to specify that record corresponds to a time-series file.
- `FILEIN` keyword to specify that an input filename is expected next.
- `ts6_filename` defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- `OBS6` keyword to specify that record corresponds to an observations file.
- `obs6_filename` name of input file to define observations for the SFT package. See the “Observation utility” section for instructions for preparing observation input files. Tables [ref{table:gwf-obstypetable}](#) and [ref{table:gwt-obstypetable}](#) lists observation type(s) supported by the SFT package.

Block: PACKAGEDATA

- `rno` integer value that defines the reach number associated with the specified PACKAGEDATA data on the line. RNO must be greater than zero and less than or equal to NREACHES. Reach information must be specified for every reach or the program will terminate with an error. The program will also terminate with an error if information for a reach is specified more than once.
- `strt` real value that defines the starting concentration for the reach.
- `aux` represents the values of the auxiliary variables for each reach. The values of auxiliary variables must be present for each reach. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `boundname` name of the reach cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. IPER must be less than or equal to NPER in the TDIS Package and greater than zero. The IPER value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- `rno` integer value that defines the reach number associated with the specified PERIOD data on the line. RNO must be greater than zero and less than or equal to NREACHES.
- `reachsetting` line of information that is parsed into a keyword and values. Keyword values that can be used to start the REACHSETTING string include: STATUS, CONCENTRATION, RAINFALL, EVAPORATION, RUNOFF, and AUXILIARY. These settings are used to assign the concentration of associated with the corresponding flow terms. Concentrations cannot be specified for all flow terms. For example, the Streamflow Package supports a “DIVERSION” flow term. Diversion water will be routed using the calculated concentration of the reach.

```
STATUS <status>
CONCENTRATION <concentration>
RAINFALL <rainfall>
EVAPORATION <evaporation>
RUNOFF <runoff>
INFLOW <inflow>
AUXILIARY <auxname> <auxval>
```

- `status` keyword option to define reach status. STATUS can be ACTIVE, INACTIVE, or CONSTANT. By default, STATUS is ACTIVE, which means that concentration will be calculated for the reach. If a reach is inactive, then there will be no solute mass fluxes into or out of the reach and the inactive value will be written for the reach concentration. If a reach is constant, then the concentration for the reach will be fixed at the user specified value.
- `concentration` real or character value that defines the concentration for the reach. The specified CONCENTRATION is only applied if the reach is a constant concentration reach. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- `rainfall` real or character value that defines the rainfall solute concentration (ML-3) for the reach. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `evaporation` real or character value that defines the concentration of evaporated water (ML-3) for the reach. If this concentration value is larger than the simulated concentration in the reach, then the evaporated water will be removed at the same concentration as the reach. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `runoff` real or character value that defines the concentration of runoff (ML-3) for the reach. Value must be greater than or equal to zero. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `inflow` real or character value that defines the concentration of inflow (ML-3) for the reach. Value must be greater than or equal to zero. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `AUXILIARY` keyword for specifying auxiliary variable.
- `auxname` name for the auxiliary variable to be assigned `AUXVAL`. `AUXNAME` must match one of the auxiliary variable names defined in the `OPTIONS` block. If `AUXNAME` does not match one of the auxiliary variable names defined in the `OPTIONS` block the data are ignored.
- `auxval` value for the auxiliary variable. If the Options block includes a `TIMESERIESFILE` entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

Example Input File

```

BEGIN OPTIONS
  AUXILIARY  aux1  aux2
  BOUNDNAMES
  PRINT_INPUT
  PRINT_CONCENTRATION
  PRINT_FLOWS
  SAVE_FLOWS
  CONCENTRATION  FILEOUT  gwt_sft_02.sft.bin
  BUDGET  FILEOUT  gwt_sft_02.sft.bud
  OBS6  FILEIN  gwt_sft_02.sft.obs
END OPTIONS

BEGIN PACKAGEDATA
#  L          STRT          aux1          aux2          bname
1      0.00000000      99.00000000      999.00000000  REACH1
2      0.00000000      99.00000000      999.00000000  REACH2
3      0.00000000      99.00000000      999.00000000  REACH3
END PACKAGEDATA

BEGIN PERIOD  1
  1  STATUS  ACTIVE
  2  STATUS  ACTIVE
  3  STATUS  ACTIVE
END PERIOD  1

```

Available Observation Types

Example Observation Input File

```

BEGIN options
  DIGITS 7
  PRINT_INPUT
END options

BEGIN continuous  FILEOUT  gwt_lkt02.lkt.obs.csv
  sft-1-conc  CONCENTRATION  1
  sft-1-extinflow  EXT-INFLOW  1
  sft-1-rain  RAINFALL  1
  sft-1-roff  RUNOFF  1
  sft-1-evap  EVAPORATION  1
  sft-1-stor  STORAGE  1
  sft-1-const  CONSTANT  1
  sft-1-gwt1  SFT  1  1
  sft-1-gwt2  SFT  1  2
  sft-2-gwt1  SFT  2  1
  sft-1-mylake1  SFT  MYREACHES
  sft-1-fjf  FLOW-JA-FACE  1  2
  sft-2-fjf  FLOW-JA-FACE  2  1
  sft-3-fjf  FLOW-JA-FACE  2  3
  sft-4-fjf  FLOW-JA-FACE  3  2
  sft-5-fjf  FLOW-JA-FACE  MYREACH1
  sft-6-fjf  FLOW-JA-FACE  MYREACH2
  sft-7-fjf  FLOW-JA-FACE  MYREACH3
END continuous

```

1.4.18 GWT-SRC

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN OPTIONS
  [AUXILIARY <auxiliary(naux)>]
  [AUXMULTNAME <auxmultname>]
  [BOUNDNAMES]
  [PRINT_INPUT]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [TS6 FILEIN <ts6_filename>]
  [OBS6 FILEIN <obs6_filename>]
END OPTIONS

```

```

BEGIN DIMENSIONS
  MAXBOUND <maxbound>
END DIMENSIONS

```

FOR ANY STRESS PERIOD

```

BEGIN PERIOD <iper>
  <cellid(ncelldim)> <smassrate> [<aux(naux)>] [<boundname>]

```

(continues on next page)

(continued from previous page)

```

<cellid(ncellldim)> <smassrate> [<aux(naux)>] [<boundname>]
...
END PERIOD

```

Explanation of Variables

Block: OPTIONS

- `auxiliary` defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for `naux`. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- `auxmultname` name of auxiliary variable to be used as multiplier of mass loading rate.
- `BOUNDNAMES` keyword to indicate that boundary names may be provided with the list of mass source cells.
- `PRINT_INPUT` keyword to indicate that the list of mass source information will be written to the listing file immediately after it is read.
- `PRINT_FLOWS` keyword to indicate that the list of mass source flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- `SAVE_FLOWS` keyword to indicate that mass source flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- `TS6` keyword to specify that record corresponds to a time-series file.
- `FILEIN` keyword to specify that an input filename is expected next.
- `ts6_filename` defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- `OBS6` keyword to specify that record corresponds to an observations file.
- `obs6_filename` name of input file to define observations for the Mass Source package. See the “Observation utility” section for instructions for preparing observation input files. Tables `ref{table:gwf-obstypetable}` and `ref{table:gwt-obstypetable}` lists observation type(s) supported by the Mass Source package.

Block: DIMENSIONS

- `maxbound` integer value specifying the maximum number of sources cells that will be specified for use during any stress period.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. IPER must be less than or equal to NPER in the TDIS Package and greater than zero. The IPER value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD

block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.

- `cellid` is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell.
- `smassrate` is the mass source loading rate. A positive value indicates addition of solute mass and a negative value indicates removal of solute mass. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `aux` represents the values of the auxiliary variables for each mass source. The values of auxiliary variables must be present for each mass source. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `boundname` name of the mass source cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

Example Input File

```
BEGIN OPTIONS
  PRINT_FLOWS
  PRINT_INPUT
  SAVE_FLOWS
END OPTIONS

BEGIN DIMENSIONS
  MAXBOUND 1
END DIMENSIONS

BEGIN PERIOD 1
  1 1 1 1.0
END PERIOD
```

Available Observation Types

Example Observation Input File

```
BEGIN OPTIONS
  DIGITS 7
  PRINT_INPUT
END OPTIONS

BEGIN CONTINUOUS FILEOUT my_model.src.obs.csv
# obsname          obstype ID
src-7-102-17      SRC      7 102 17
src-7-102-17      SRC      CW_1
sources           SRC      sources
END CONTINUOUS
```

1.4.19 GWT-SSM

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [PRINT_FLOWS]
  [SAVE_FLOWS]
END OPTIONS
```

```
BEGIN SOURCES
  <pname> <srctype> <auxname>
  <pname> <srctype> <auxname>
  . . .
END SOURCES
```

Explanation of Variables

Block: OPTIONS

- **PRINT_FLOWS** keyword to indicate that the list of SSM flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.
- **SAVE_FLOWS** keyword to indicate that SSM flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.

Block: SOURCES

- **pname** name of the flow package for which an auxiliary variable contains a source concentration. If this flow package is represented using an advanced transport package (SFT, LKT, MWT, or UZT), then the advanced transport package will override SSM terms specified here.
- **srctype** keyword indicating how concentration will be assigned for sources and sinks. Keyword must be specified as either **AUX** or **AUXMIXED**. For both options the user must provide an auxiliary variable in the corresponding flow package. The auxiliary variable must have the same name as the **AUXNAME** value that follows. If the **AUX** keyword is specified, then the auxiliary variable specified by the user will be assigned as the concentration value for groundwater sources (flows with a positive sign). For negative flow rates (sinks), groundwater will be withdrawn from the cell at the simulated concentration of the cell. The **AUXMIXED** option provides an alternative method for how to determine the concentration of sinks. If the cell concentration is larger than the user-specified auxiliary concentration, then the concentration of groundwater withdrawn from the cell will be assigned as the user-specified concentration. Alternatively, if the user-specified auxiliary concentration is larger than the cell concentration, then groundwater will be withdrawn at the cell concentration. Thus, the **AUXMIXED** option is designed to work with the Evapotranspiration (EVT) and Recharge (RCH) Packages where water may be withdrawn at a concentration that is less than the cell concentration.
- **auxname** name of the auxiliary variable in the package **PNAME**. This auxiliary variable must exist and be specified by the user in that package. The values in this auxiliary variable will be used to set the concentration associated with the flows for that boundary package.

Example Input File

```
BEGIN SOURCES
# pname      srctype      auxname
WEL-1        AUX    CONCENTRATION
LAK-1        AUX    CONCENTRATION
EVT-1    AUXMIXED      ETCONC
END SOURCES
```

1.4.20 GWT-UZT

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
[FLOW_PACKAGE_NAME <flow_package_name>]
[AUXILIARY <auxiliary(naux)>]
[FLOW_PACKAGE_AUXILIARY_NAME <flow_package_auxiliary_name>]
[BOUNDNAMES]
[PRINT_INPUT]
[PRINT_CONCENTRATION]
[PRINT_FLOWS]
[SAVE_FLOWS]
[CONCENTRATION FILEOUT <concfile>]
[BUDGET FILEOUT <budgetfile>]
[TS6 FILEIN <ts6_filename>]
[OBS6 FILEIN <obs6_filename>]
END OPTIONS
```

```
BEGIN PACKAGEDATA
<uzfno> <strt> [<aux(naux)>] [<boundname>]
<uzfno> <strt> [<aux(naux)>] [<boundname>]
...
END PACKAGEDATA
```

FOR ANY STRESS PERIOD

```
BEGIN PERIOD <iper>
<uzfno> <uztsetting>
<uzfno> <uztsetting>
...
END PERIOD
```

Explanation of Variables

Block: OPTIONS

- `flow_package_name` keyword to specify the name of the corresponding flow package. If not specified, then the corresponding flow package must have the same name as this advanced transport package (the name associated with this package in the GWT name file).
- `auxiliary` defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks

must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for `naux`. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.

- `flow_package_auxiliary_name` keyword to specify the name of an auxiliary variable in the corresponding flow package. If specified, then the simulated concentrations from this advanced transport package will be copied into the auxiliary variable specified with this name. Note that the flow package must have an auxiliary variable with this name or the program will terminate with an error. If the flows for this advanced transport package are read from a file, then this option will have no effect.
- `BOUNDNAMES` keyword to indicate that boundary names may be provided with the list of unsaturated zone flow cells.
- `PRINT_INPUT` keyword to indicate that the list of unsaturated zone flow information will be written to the listing file immediately after it is read.
- `PRINT_CONCENTRATION` keyword to indicate that the list of UZF cell concentration will be printed to the listing file for every stress period in which “HEAD PRINT” is specified in Output Control. If there is no Output Control option and `PRINT_CONCENTRATION` is specified, then concentration are printed for the last time step of each stress period.
- `PRINT_FLOWS` keyword to indicate that the list of unsaturated zone flow rates will be printed to the listing file for every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “`PRINT_FLOWS`” is specified, then flow rates are printed for the last time step of each stress period.
- `SAVE_FLOWS` keyword to indicate that unsaturated zone flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- `CONCENTRATION` keyword to specify that record corresponds to concentration.
- `concfile` name of the binary output file to write concentration information.
- `BUDGET` keyword to specify that record corresponds to the budget.
- `FILEOUT` keyword to specify that an output filename is expected next.
- `budgetfile` name of the binary output file to write budget information.
- `TS6` keyword to specify that record corresponds to a time-series file.
- `FILEIN` keyword to specify that an input filename is expected next.
- `ts6_filename` defines a time-series file defining time series that can be used to assign time-varying values. See the “Time-Variable Input” section for instructions on using the time-series capability.
- `OBS6` keyword to specify that record corresponds to an observations file.
- `obs6_filename` name of input file to define observations for the UZT package. See the “Observation utility” section for instructions for preparing observation input files. Tables `ref{table:gwf-obstypetable}` and `ref{table:gwt-obstypetable}` lists observation type(s) supported by the UZT package.

Block: PACKAGEDATA

- `uzfno` integer value that defines the UZF cell number associated with the specified PACKAGEDATA data on the line. UZFNO must be greater than zero and less than or equal to `NUZFCELLS`. Unsaturated zone flow information must be specified for every UZF cell or the program will terminate with an error. The program will also terminate with an error if information for a UZF cell is specified more than once.

- `strt` real value that defines the starting concentration for the unsaturated zone flow cell.
- `aux` represents the values of the auxiliary variables for each unsaturated zone flow. The values of auxiliary variables must be present for each unsaturated zone flow. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `boundname` name of the unsaturated zone flow cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

Block: PERIOD

- `iper` integer value specifying the starting stress period number for which the data specified in the PERIOD block apply. IPER must be less than or equal to NPER in the TDIS Package and greater than zero. The IPER value assigned to a stress period block must be greater than the IPER value assigned for the previous PERIOD block. The information specified in the PERIOD block will continue to apply for all subsequent stress periods, unless the program encounters another PERIOD block.
- `uzfno` integer value that defines the UZF cell number associated with the specified PERIOD data on the line. UZFNO must be greater than zero and less than or equal to NUZFCELLS.
- `uztsetting` line of information that is parsed into a keyword and values. Keyword values that can be used to start the UZTSETTING string include: STATUS, CONCENTRATION, INFILTRATION, UZET, and AUXILIARY. These settings are used to assign the concentration of associated with the corresponding flow terms. Concentrations cannot be specified for all flow terms.

```
STATUS <status>
CONCENTRATION <concentration>
INFILTRATION <infiltration>
UZET <uzet>
AUXILIARY <auxname> <auxval>
```

- `status` keyword option to define UZF cell status. STATUS can be ACTIVE, INACTIVE, or CONSTANT. By default, STATUS is ACTIVE, which means that concentration will be calculated for the UZF cell. If a UZF cell is inactive, then there will be no solute mass fluxes into or out of the UZF cell and the inactive value will be written for the UZF cell concentration. If a UZF cell is constant, then the concentration for the UZF cell will be fixed at the user specified value.
- `concentration` real or character value that defines the concentration for the unsaturated zone flow cell. The specified CONCENTRATION is only applied if the unsaturated zone flow cell is a constant concentration cell. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `infiltration` real or character value that defines the infiltration solute concentration (ML-3) for the UZF cell. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- `uzet` real or character value that defines the concentration of unsaturated zone evapotranspiration water (ML-3) for the UZF cell. If this concentration value is larger than the simulated concentration in the UZF cell, then the unsaturated zone ET water will be removed at the same concentration as the UZF cell. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- AUXILIARY keyword for specifying auxiliary variable.

- `auxname` name for the auxiliary variable to be assigned AUXVAL. AUXNAME must match one of the auxiliary variable names defined in the OPTIONS block. If AUXNAME does not match one of the auxiliary variable names defined in the OPTIONS block the data are ignored.
- `auxval` value for the auxiliary variable. If the Options block includes a TIMESERIESFILE entry (see the “Time-Variable Input” section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

Example Input File

```

BEGIN OPTIONS
  AUXILIARY  aux1  aux2
  BOUNDNAMES
  PRINT_INPUT
  PRINT_CONCENTRATION
  PRINT_FLOWS
  SAVE_FLOWS
  CONCENTRATION  FILEOUT  gwt_02.uzt.bin
  BUDGET  FILEOUT  gwt_02.uzt.bud
  OBS6  FILEIN  gwt_02.uzt.obs
END OPTIONS

BEGIN PACKAGEDATA
#  L          STRT          aux1          aux2          bname
1      0.00000000      99.00000000      999.00000000  MYUZFCCELL1
2      0.00000000      99.00000000      999.00000000  MYUZFCCELL2
3      0.00000000      99.00000000      999.00000000  MYUZFCCELL3
END PACKAGEDATA

BEGIN PERIOD  1
1  STATUS  ACTIVE
2  STATUS  ACTIVE
3  STATUS  ACTIVE
END PERIOD  1

```

Available Observation Types

Example Observation Input File

```

BEGIN options
  DIGITS  7
  PRINT_INPUT
END options

BEGIN continuous  FILEOUT  gwt_02.uzt.obs.csv
mwt-1-conc  CONCENTRATION  1
mwt-1-stor  STORAGE  1
mwt-1-gwt1  UZT  1  1
mwt-1-gwt2  UZT  2  2
mwt-2-gwt1  UZT  3  3
END continuous

```

1.5 Model Exchanges

1.5.1 EXG-GWFGWF

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [AUXILIARY <auxiliary (naux)>]
  [PRINT_INPUT]
  [PRINT_FLOWS]
  [SAVE_FLOWS]
  [CELL_AVERAGING <cell_averaging>]
  [VARIABLECV [DEWATERED]]
  [NEWTON]
  [GNC6 FILEIN <gnc6_filename>]
  [MVR6 FILEIN <mvr6_filename>]
  [OBS6 FILEIN <obs6_filename>]
END OPTIONS
```

```
BEGIN DIMENSIONS
  NEXG <nexg>
END DIMENSIONS
```

```
BEGIN EXCHANGEDATA
  <cellidm1> <cellidm2> <ihc> <cl1> <cl2> <hwva> [<aux (naux)>]
  <cellidm1> <cellidm2> <ihc> <cl1> <cl2> <hwva> [<aux (naux)>]
  ...
END EXCHANGEDATA
```

Explanation of Variables

Block: OPTIONS

- **auxiliary** an array of auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided. Most auxiliary variables will not be used by the GWF-GWF Exchange, but they will be available for use by other parts of the program. If an auxiliary variable with the name “ANGLDEGX” is found, then this information will be used as the angle (provided in degrees) between the connection face normal and the x axis, where a value of zero indicates that a normal vector points directly along the positive x axis. The connection face normal is a normal vector on the cell face shared between the cell in model 1 and the cell in model 2 pointing away from the model 1 cell. Additional information on “ANGLDEGX” is provided in the description of the DISU Package. If an auxiliary variable with the name “CDIST” is found, then this information will be used as the straight-line connection distance, including the vertical component, between the two cell centers. Both ANGLDEGX and CDIST are required if specific discharge is calculated for either of the groundwater models.
- **PRINT_INPUT** keyword to indicate that the list of exchange entries will be echoed to the listing file immediately after it is read.
- **PRINT_FLOWS** keyword to indicate that the list of exchange flow rates will be printed to the listing file for every stress period in which “SAVE BUDGET” is specified in Output Control.
- **SAVE_FLOWS** keyword to indicate that cell-by-cell flow terms will be written to the budget file for each model provided that the Output Control for the models are set up with the “BUDGET SAVE FILE” option.

- `cell_averaging` is a keyword and text keyword to indicate the method that will be used for calculating the conductance for horizontal cell connections. The text value for `CELL_AVERAGING` can be “HARMONIC”, “LOGARITHMIC”, or “AMT-LMK”, which means “arithmetic-mean thickness and logarithmic-mean hydraulic conductivity”. If the user does not specify a value for `CELL_AVERAGING`, then the harmonic-mean method will be used.
- `VARIABLECV` keyword to indicate that the vertical conductance will be calculated using the saturated thickness and properties of the overlying cell and the thickness and properties of the underlying cell. If the `DEWATERED` keyword is also specified, then the vertical conductance is calculated using only the saturated thickness and properties of the overlying cell if the head in the underlying cell is below its top. If these keywords are not specified, then the default condition is to calculate the vertical conductance at the start of the simulation using the initial head and the cell properties. The vertical conductance remains constant for the entire simulation.
- `DEWATERED` If the `DEWATERED` keyword is specified, then the vertical conductance is calculated using only the saturated thickness and properties of the overlying cell if the head in the underlying cell is below its top.
- `NEWTON` keyword that activates the Newton-Raphson formulation for groundwater flow between connected, convertible groundwater cells. Cells will not dry when this option is used.
- `FILEIN` keyword to specify that an input filename is expected next.
- `GNC6` keyword to specify that record corresponds to a ghost-node correction file.
- `gnc6_filename` is the file name for ghost node correction input file. Information for the ghost nodes are provided in the file provided with these keywords. The format for specifying the ghost nodes is the same as described for the GNC Package of the GWF Model. This includes specifying `OPTIONS`, `DIMENSIONS`, and `GNCDATA` blocks. The order of the ghost nodes must follow the same order as the order of the cells in the `EXCHANGEDATA` block. For the `GNCDATA`, `noden` and all of the `nodej` values are assumed to be located in model 1, and `nodem` is assumed to be in model 2.
- `MVR6` keyword to specify that record corresponds to a mover file.
- `mvr6_filename` is the file name of the water mover input file to apply to this exchange. Information for the water mover are provided in the file provided with these keywords. The format for specifying the water mover information is the same as described for the Water Mover (MVR) Package of the GWF Model, with two exceptions. First, in the `PACKAGES` block, the model name must be included as a separate string before each package. Second, the appropriate model name must be included before package name 1 and package name 2 in the `BEGIN PERIOD` block. This allows providers and receivers to be located in both models listed as part of this exchange.
- `OBS6` keyword to specify that record corresponds to an observations file.
- `obs6_filename` is the file name of the observations input file for this exchange. See the “Observation utility” section for instructions for preparing observation input files. Table [ref{table:gwf-obstypetable}](#) lists observation type(s) supported by the GWF-GWF package.

Block: DIMENSIONS

- `nextg` keyword and integer value specifying the number of GWF-GWF exchanges.

Block: EXCHANGEDATA

- `cellidm1` is the cellid of the cell in model 1 as specified in the simulation name file. For a structured grid that uses the `DIS` input file, `CELLIDM1` is the layer, row, and column numbers of the cell. For a grid that uses the `DISV` input file, `CELLIDM1` is the layer number and `CELL2D` number for the two cells. If the model uses the unstructured discretization (`DISU`) input file, then `CELLIDM1` is the node number for the cell.

- `cellidm2` is the cellid of the cell in model 2 as specified in the simulation name file. For a structured grid that uses the DIS input file, `CELLIDM2` is the layer, row, and column numbers of the cell. For a grid that uses the DISV input file, `CELLIDM2` is the layer number and `CELL2D` number for the two cells. If the model uses the unstructured discretization (DISU) input file, then `CELLIDM2` is the node number for the cell.
- `ihc` is an integer flag indicating the direction between node `n` and all of its `m` connections. If `IHC = 0` then the connection is vertical. If `IHC = 1` then the connection is horizontal. If `IHC = 2` then the connection is horizontal for a vertically staggered grid.
- `cl1` is the distance between the center of cell 1 and the its shared face with cell 2.
- `cl2` is the distance between the center of cell 2 and the its shared face with cell 1.
- `hwva` is the horizontal width of the flow connection between cell 1 and cell 2 if `IHC > 0`, or it is the area perpendicular to flow of the vertical connection between cell 1 and cell 2 if `IHC = 0`.
- `aux` represents the values of the auxiliary variables for each GWFGWF Exchange. The values of auxiliary variables must be present for each exchange. The values must be specified in the order of the auxiliary variables specified in the `OPTIONS` block.

Example Input File

```

BEGIN OPTIONS
  PRINT_INPUT
  PRINT_FLOWS
  SAVE_FLOWS
  AUXILIARY testaux
  GNC6 FILEIN simulation.gnc
  MVR6 FILEIN simulation.mvr
END OPTIONS

BEGIN DIMENSIONS
  NEXG 36
END DIMENSIONS

  # nodem1 nodem2 ihc cl1 cl2 fahl testaux
BEGIN EXCHANGEDATA
#
#      left side
16      1      1 50. 16.67 33.33 100.99
16     10      1 50. 16.67 33.33 100.99
16     19      1 50. 16.67 33.33 100.99
23     28      1 50. 16.67 33.33 100.99
23     37      1 50. 16.67 33.33 100.99
23     46      1 50. 16.67 33.33 100.99
30     55      1 50. 16.67 33.33 100.99
30     64      1 50. 16.67 33.33 100.99
30     73      1 50. 16.67 33.33 100.99
#
#      right side
20      9      1 50. 16.67 33.33 100.99
20     18      1 50. 16.67 33.33 100.99
20     27      1 50. 16.67 33.33 100.99
27     36      1 50. 16.67 33.33 100.99
27     45      1 50. 16.67 33.33 100.99
27     54      1 50. 16.67 33.33 100.99
34     63      1 50. 16.67 33.33 100.99
34     72      1 50. 16.67 33.33 100.99

```

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```

      34      81      1  50. 16.67 33.33  100.99
#
#      back
      10      1      1  50. 17.67 33.33  100.99
      10      2      1  50. 17.67 33.33  100.99
      10      3      1  50. 17.67 33.33  100.99
      11      4      1  50. 17.67 33.33  100.99
      11      5      1  50. 17.67 33.33  100.99
      11      6      1  50. 17.67 33.33  100.99
      12      7      1  50. 17.67 33.33  100.99
      12      8      1  50. 17.67 33.33  100.99
      12      9      1  50. 17.67 33.33  100.99
#
#      front
      38      73      1  50. 17.67 33.33  100.99
      38      74      1  50. 17.67 33.33  100.99
      38      75      1  50. 17.67 33.33  100.99
      39      76      1  50. 17.67 33.33  100.99
      39      77      1  50. 17.67 33.33  100.99
      39      78      1  50. 17.67 33.33  100.99
      40      79      1  50. 17.67 33.33  100.99
      40      80      1  50. 17.67 33.33  100.99
      40      81      1  50. 17.67 33.33  100.99
END EXCHANGEDATA

```

Example Observation Input File

```

BEGIN OPTIONS
  DIGITS 10
  PRINT_INPUT
END OPTIONS

# Block defining continuous observations
BEGIN CONTINUOUS FILEOUT simulation.obs.csv
# obsname      obstype
  exg1          flow-ja-face    1
END CONTINUOUS

```

1.5.2 EXG-GWFGWT

Structure of Blocks

FOR EACH SIMULATION

Explanation of Variables

1.6 Utilities

1.6.1 UTL-ATS

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN DIMENSIONS
  MAXATS <maxats>
END DIMENSIONS
```

FOR ANY STRESS PERIOD

```
BEGIN PERIODDATA
  <iperats> <dt0> <dtmin> <dtmax> <dtadj> <dtfailadj>
  <iperats> <dt0> <dtmin> <dtmax> <dtadj> <dtfailadj>
  ...
END PERIODDATA
```

Explanation of Variables

Block: DIMENSIONS

- `maxats` is the number of records in the subsequent perioddata block that will be used for adaptive time stepping.

Block: PERIODDATA

- `iperats` is the period number to designate for adaptive time stepping. The remaining ATS values on this line will apply to period `iperats`. `iperats` must be greater than zero. A warning is printed if `iperats` is greater than `nper`.
- `dt0` is the initial time step length for period `iperats`. If `dt0` is zero, then the final step from the previous stress period will be used as the initial time step. The program will terminate with an error message if `dt0` is negative.
- `dtmin` is the minimum time step length for this period. This value must be greater than zero and less than `dtmax`. `dtmin` must be a small value in order to ensure that simulation times end at the end of stress periods and the end of the simulation. A small value, such as 1.e-5, is recommended.
- `dtmax` is the maximum time step length for this period. This value must be greater than `dtmin`.
- `dtadj` is the time step multiplier factor for this period. If the number of outer solver iterations are less than the product of the maximum number of outer iterations (`OUTER_MAXIMUM`) and `ATS_OUTER_MAXIMUM_FRACTION` (an optional variable in the IMS input file with a default value of 1/3), then the time step length is multiplied by `dtadj`. If the number of outer solver iterations are greater than the product of the maximum number of outer iterations and `ATS_OUTER_MAXIMUM_FRACTION`, then the time step length is divided by `dtadj`. `dtadj` must be zero, one, or greater than one. If `dtadj` is zero or one, then it has no effect on the simulation. A value between 2.0 and 5.0 can be used as an initial estimate.
- `dtfailadj` is the divisor of the time step length when a time step fails to converge. If there is solver failure, then the time step will be tried again with a shorter time step length calculated as the previous time step length divided by `dtfailadj`. `dtfailadj` must be zero, one, or greater than one. If `dtfailadj` is zero or one, then time steps will not be retried with shorter lengths. In this case, the program will terminate with an error, or it will continue if the `CONTINUE` option is set in the simulation name file. Initial tests with this variable should be set to 5.0 or larger to determine if convergence can be achieved.

Example Input File

```
# ATS input file

BEGIN dimensions
  MAXATS 2
END dimensions

BEGIN perioddata
# per    dt0    dtmin    dtmax    dtadj    dtfailadj
  2  100.0  1.0E-5  1000.0    2.0        5.0
  7   10.0  1.0E-5   100.0    1.7        2.0
END perioddata
```

1.6.2 UTL-LAK-TAB

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN DIMENSIONS
  NROW <nrow>
  NCOL <ncol>
END DIMENSIONS
```

```
BEGIN TABLE
  <stage> <volume> <sarea> [<barea>]
  <stage> <volume> <sarea> [<barea>]
  ...
END TABLE
```

Explanation of Variables

Block: DIMENSIONS

- `nrow` integer value specifying the number of rows in the lake table. There must be `NROW` rows of data in the TABLE block.
- `ncol` integer value specifying the number of columns in the lake table. There must be `NCOL` columns of data in the TABLE block. For lakes with HORIZONTAL and/or VERTICAL CTYPE connections, `NCOL` must be equal to 3. For lakes with EMBEDDEDH or EMBEDDEDV CTYPE connections, `NCOL` must be equal to 4.

Block: TABLE

- `stage` real value that defines the stage corresponding to the remaining data on the line.
- `volume` real value that defines the lake volume corresponding to the stage specified on the line.
- `sarea` real value that defines the lake surface area corresponding to the stage specified on the line.
- `barea` real value that defines the lake-GWF exchange area corresponding to the stage specified on the line. `BAREA` is only specified if the `CLAKTYPE` for the lake is `EMBEDDEDH` or `EMBEDDEDV`.

Example Input File

```
begin dimensions
  nrow 11
  ncol 3
end dimensions

begin table
# stage      volume      sarea
    0         0.         0.
    1         0.5        1.
    2         1.0        2.
    3         2.0        2.
    4         3.0        2.
    5         4.0        2.
    6         5.0        2.
    7         6.0        2.
    8         7.0        2.
    9         8.0        2.
   10         9.0        2.
end table
```

1.6.3 UTL-OBS

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN OPTIONS
  [DIGITS <digits>]
  [PRINT_INPUT]
END OPTIONS
```

```
BEGIN CONTINUOUS FILEOUT <obs_output_file_name> [BINARY]
  <obsname> <obstype> <id> [<id2>]
  <obsname> <obstype> <id> [<id2>]
  ...
END CONTINUOUS
```

Explanation of Variables

Block: OPTIONS

- **digits** Keyword and an integer digits specifier used for conversion of simulated values to text on output. The default is 5 digits. When simulated values are written to a file specified as file type DATA in the Name File, the digits specifier controls the number of significant digits with which simulated values are written to the output file. The digits specifier has no effect on the number of significant digits with which the simulation time is written for continuous observations.
- **PRINT_INPUT** keyword to indicate that the list of observation information will be written to the listing file immediately after it is read.

Block: CONTINUOUS

- **FILEOUT** keyword to specify that an output filename is expected next.
- **obs_output_file_name** Name of a file to which simulated values corresponding to observations in the block are to be written. The file name can be an absolute or relative path name. A unique output file must be specified for each CONTINUOUS block. If the “BINARY” option is used, output is written in binary form. By convention, text output files have the extension “csv” (for “Comma-Separated Values”) and binary output files have the extension “bsv” (for “Binary Simulated Values”).
- **BINARY** an optional keyword used to indicate that the output file should be written in binary (unformatted) form.
- **obsname** string of 1 to 40 nonblank characters used to identify the observation. The identifier need not be unique; however, identification and post-processing of observations in the output files are facilitated if each observation is given a unique name.
- **obstype** a string of characters used to identify the observation type.
- **id** Text identifying cell where observation is located. For packages other than NPF, if boundary names are defined in the corresponding package input file, ID can be a boundary name. Otherwise ID is a cellid. If the model discretization is type DIS, cellid is three integers (layer, row, column). If the discretization is DISV, cellid is two integers (layer, cell number). If the discretization is DISU, cellid is one integer (node number).
- **id2** Text identifying cell adjacent to cell identified by ID. The form of ID2 is as described for ID. ID2 is used for intercell-flow observations of a GWF model, for three observation types of the LAK Package, for two observation types of the MAW Package, and one observation type of the UZF Package.

Example Observation Input File**Example 1**

```

BEGIN OPTIONS
  DIGITS 10
  PRINT_INPUT
END OPTIONS

BEGIN CONTINUOUS FILEOUT my_model.gwf.head.csv
# obsname  obstype  ID
  L1        HEAD      1 51 51 # heads at lay 1 row 51 col 51
  L2        HEAD      2 51 51 # heads at lay 2 row 51 col 51
END CONTINUOUS

BEGIN CONTINUOUS FILEOUT my_model.gwf.ddn.csv
# obsname  obstype  ID
  L1ddn     DRAWDOWN  1 51 51 # heads at lay 1 row 51 col 51
  L2ddn     DRAWDOWN  2 51 51 # heads at lay 2 row 51 col 51
END CONTINUOUS

BEGIN CONTINUOUS FILEOUT my_model.gwf.flow.csv
# obsname  obstype  ID      ID1
  L1rfflow  FLOW-JA-FACE  1 51 51  1 51 52
  L2rfflow  FLOW-JA-FACE  2 51 51  2 51 52
  L1-L2flow FLOW-JA-FACE  1 51 51  2 51 51
END CONTINUOUS

```

Example Observation Input File

Example 2

```

BEGIN OPTIONS
  DIGITS 10
  PRINT_INPUT
END OPTIONS

BEGIN CONTINUOUS FILEOUT my_model.gwt.conc.csv
# obsname  obstype      ID
L1          CONCENTRATION  1 51 51 # concs at lay 1 row 51 col 51
L2          CONCENTRATION  2 51 51 # concs at lay 2 row 51 col 51
END CONTINUOUS

BEGIN CONTINUOUS FILEOUT my_model.gwt.mflow.csv
# obsname  obstype      ID      ID1
L1rfflow   FLOW-JA-FACE  1 51 51  1 51 52
L2rfflow   FLOW-JA-FACE  2 51 51  2 51 52
L1-L2flow  FLOW-JA-FACE  1 51 51  2 51 51
END CONTINUOUS

```

1.6.4 UTL-TAS

Structure of Blocks

FOR EACH SIMULATION

```

BEGIN ATTRIBUTES
  NAME <time_series_nameanyld>
  NAME
    <time_series_nameanyld>
  [METHOD <interpolation_method>]
  METHOD
    <interpolation_method>
  [SFAC <sfacvaltime_series_name>]
  SFAC
    <sfacvaltime_series_name>
END ATTRIBUTES

```

```

BEGIN TIME <time_from_model_start>

    <tas_array(unknown)> -- READARRAY
END TIME

```

Explanation of Variables

Block: ATTRIBUTES

- NAME xxx
- time_series_name Name by which a package references a particular time-array series. The name must be unique among all time-array series used in a package.

- METHOD xxx
- interpolation_method Interpolation method, which is either STEPWISE or LINEAR.
- SFAC xxx
- sfacval Scale factor, which will multiply all array values in time series. SFAC is an optional attribute; if omitted, SFAC = 1.0.

Block: TIME

- time_from_model_start A numeric time relative to the start of the simulation, in the time unit used in the simulation. Times must be strictly increasing.
- tas_array An array of numeric, floating-point values, or a constant value, readable by the U2DREL array-reading utility.

1.6.5 UTL-TS

Structure of Blocks

FOR EACH SIMULATION

```
BEGIN ATTRIBUTES
  NAMES <time_series_namesanyld>
  NAMES
    <time_series_namesanyld>
  [METHODS <interpolation_methodtime_series_names>]
  METHODS
    <interpolation_methodtime_series_names>
  [METHOD <interpolation_method_single>]
  METHOD
    <interpolation_method_single>
  [SFACS <sfacval<time_series_name>]
  SFACS
    <sfacval<time_series_name>
  [<sfacval<time_series_name>]

END ATTRIBUTES
```

```
BEGIN TIMESERIES
  <ts_time> <ts_arraytime_series_names>
  <ts_time> <ts_arraytime_series_names>
  ...
  <ts_time>
  <ts_arraytime_series_names>
END TIMESERIES
```

Explanation of Variables

Block: ATTRIBUTES

- NAMES xxx

- `time_series_names` Name by which a package references a particular time-array series. The name must be unique among all time-array series used in a package.
- `METHODS xxx`
- `interpolation_method` Interpolation method, which is either STEPWISE or LINEAR.
- `METHOD xxx`
- `interpolation_method_single` Interpolation method, which is either STEPWISE or LINEAR.
- `SFACS xxx`
- `sfacval` Scale factor, which will multiply all array values in time series. SFAC is an optional attribute; if omitted, SFAC = 1.0.
- `SFAC xxx`

Block: TIMESERIES

- `ts_time` A numeric time relative to the start of the simulation, in the time unit used in the simulation. Times must be strictly increasing.
- `ts_array` A 2-D array of numeric, floating-point values, or a constant value, readable by the U2DREL array-reading utility.

Comparison of simulation run times

Comparison of run times of the current version of MODFLOW 6 (6.2.2) to the previous version (6.2.1). The current example models available from the [MODFLOW 6 Examples GitHub Repository](#) are used to compare run times. Simulations that fail are indicated by ‘–’. The percent difference, where calculated, is relative to the simulation run time for the previous version. Percent differences for example problems with short run times (less than 30 seconds) may not be significant.

MODFLOW 6 compiled Jul 30 2021 20:30:29 with GFORTRAN compiler (ver. 10.3.0).