Lake Package Input Data

Input for the Lake Package is read from the unit specified in the MODFLOW name file. The input consists of ten separate data sets, each consisting of one or more records, as described in detail below. These data are used to specify information about the physical geometry of the lakes, hydraulic properties of the lakebeds, and the degree of hydraulic stress originating from atmospheric and anthropogenic sources, as well as specifying certain output control parameters. Spatial and temporal units of input data specifications should be consistent with other data input for the MODFLOW run.

In the following section, parameters are indicated as being optional by their enclosure in brackets. All input variables are read using free formats, unless specifically indicated otherwise. In free format, variables are separated by one or more spaces, or by a comma and, optionally, one or more spaces. It is important to note that, in free format, blank spaces are not read as zeroes and a blank field cannot be used to set a parameter value to zero.

These input instructions have been modified since the publication of LAK3 (Merritt and Konikow, 2000). Modified sections are written in blue font.

For Each Simulation:

These data are read by module LAK3AL.

Record 1a. Data: {TABLEINPUT}

TABLEINPUT An optional character variable used for activating the option to specify text files containing relations among lake stage, surface area, and volume. A separate text file is specified for each lake; each file contains exactly 151 lines; and each line consists of one value for lake stage, volume, and surface area, respectively. This file must contain exactly 151 lines of data because this number of values is consistent with the number of values that are calculated internally by the Lake Package if the "TABLEINPUT" option is not used, and ensures that results will be consistent with results for simulations that calculate lake bathymetry information internally. For example, Lake Package test problems can be run without using the "TABLEINPUT" option and the Lake Package will output the lake bathymetry tables as 151 values to the List file. Bathymetry values printed to the List file can then be used directly for specifying a separate bathymetry input file using the keyword option "TABLEINPUT" and the solution will be the same. However, for difficult problems convergence can be improved by smoothing the lake bathymetry data (for example, by fitting polynomial regression equations to the original bathymetry information). If the keyword "TABLEINPUT" is entered on the first line (record) of the data set, then lake bathymetry data will be read from separate input files. These tables are used for calculating water balances within lakes; however, calculation of seepage between lakes and groundwater is unchanged from the original Lake Package on the basis of the lake and groundwater discretization (Merritt and Konikow, 2000).

Record 1b. Data: NLAKES   ILKCB

NLAKES   Number of separate lakes.

ILKCB   Whether or not to write cell-by-cell flows (yes if ILKCB> 0, no otherwise). If ILKCB< 0 and ICBCFL is not equal to 0, the cell-by-cell flows will be printed in the standard output file.

Notes:

1. Sublakes of multiple-lake systems are considered separate lakes for input purposes. The variable NLAKES is used, with certain internal assumptions and approximations, to dimension arrays for the simulation.

2. If data are being read using the fixed format mode, then each field should be entered using I10 format.

3. ICBCFL is specified in the input to the Output Control Package of MODFLOW.

Record 2. Data: THETA {NSSITR SSCNCR SURFDEP}

THETA   A new method of solving for lake stage uses only the time-weighting factor THETA (Merritt and Konikow, 2000, p. 52) for transient simulations. THETA is automatically set to a value of 1.0 for all steady-state stress periods. For transient stress periods, Explicit (THETA = 0.0), semi-implicit (0.0 < THETA < 1.0), or implicit (THETA = 1.0) solutions can be used to calculate lake stages. The option to specify negative values for THETA is supported to allow specification of additional variables (NSSITER, SSCNCR, SURFDEP) for simulations that only include transient stress periods. If THETA is specified as a negative value, then it is converted to a positive value for calculations of lake stage.

NSSITR   Maximum number of iterations for Newton's method of solution for equilibrium lake stages in each MODFLOW iteration for steady-state aquifer head solution. Only read if ISS (option flag input to DIS Package of MODFLOW indicating steady-state solution) is not zero or if THETA is specified as a negative value.

SSCNCR   Convergence criterion for equilibrium lake stage solution by Newton's method. Only read if ISS is not zero or if THETA is specified as a negative value.

SURFDEP   The height of small topological variations (undulations) in lake-bottom elevations that can affect groundwater discharge to lakes.

SURFDEPTH decreases the lakebed conductance for vertical flow across a horizontal lakebed caused both by a groundwater head that is between the lakebed and the lakebed plus SURFDEPTH and a lake stage that is also between the lakebed and the lakebed plus SURFDEPTH. This method provides a smooth transition from a condition of no groundwater discharge to a lake, when groundwater head is below the lakebed, to a condition of increasing groundwater discharge to a lake as groundwater head becomes greater than the elevation of the dry lakebed. The method also allows for the transition of seepage from a lake to groundwater when the lake stage decreases to the lakebed elevation. Values of SURFDEPTH ranging from 0.01 to 0.5 have been used successfully in test simulations. SURFDEP is read only if THETA is specified as a negative value.

Notes:

1. If data are being read using the fixed format mode, then the data should be entered using F10.4 format for floating point numbers and I10 format for integer numbers.

2. If the model simulation includes a steady-state stress period, then the number of iterations (NSSITER) and the closure tolerance (SSCNCR) defined by Merritt and Konikow (2000, p. 52) for ending the Newton iteration method is used for all subsequent transient or steady-state stress periods. If the model simulation only includes transient stress periods, a default value of 0.0001 is assigned to SSCNCR and a default value of 100 is assigned to NSSITR. An option was added in which values of SSCNCR and NSSITR can be read for a transient-only simulation by specifying a negative value for THETA. If THETA is specified as a negative value then it is converted to a positive value for calculations of lake stage.

For the First Stress Period Only:

These data are read by module LAK3RP.

Record 3. Data: STAGES {SSMN SSMX} {IUNITAB}

STAGES   The initial stage of each lake at the beginning of the run.

SSMN   Minimum stage allowed for each lake in steady-state solution. Omit for transient simulations.

SSMX   Maximum stage allowed for each lake in steady-state solution. Omit for transient simulations.

IUNITAB   The unit number of the text file containing data describing relations among lake stage, surface area, and volume. Only read if the keyword "TABLEINPUT" is entered on the first line (record) of the input file.

Notes:

1. This data set should consist of one line for each lake, where line 1 includes data for lake 1, and line n includes data for lake n. There must be exactly NLAKES lines of data.

2. SSMN and SSMX must be omitted when the solution is transient. For simulations that do not include a steady-state stress period, the minimum and maximum values of lake stage for calculated based on the lowest elevation of the lakebed and the and highest cell-top elevation for all lake cells for a particular lake, respectively.

3. If data are being read using the fixed format mode, then each field should be entered using F10.4 format.

4. IUNITAB is used to indicate that the table of values of lake stage, surface area, and volume will be read from a separate input file. These files and associated file unit numbers must be included within the MODFLOW Name file as type 'Data.'

For Each Stress Period:

These data are read by module LAK3RP.

Record 4. Data: ITMP   ITMP1   LWRT

ITMP   > 0, read lake definition data (records 5-7, and, optionally, records 8 and 9);
              = 0, no lake calculations this stress period;
              < 0, use lake definition data from last stress period.

ITMP1   > 0 or = 0, read new recharge, evaporation, runoff, and withdrawal data for each lake, and
              associated concentrations if needed for MOC3D runs;
              < 0, use recharge, evaporation, runoff, and withdrawal data, and concentrations, if
              needed, from last stress period.

LWRT   > 0, suppresses printout from the lake package.

Notes:

1. ICBCFL < 0 or = 0 also suppresses printout from the lake package. ICBCFL is specified in the input to
the Output Control Package of MODFLOW.

2. If data are being read using the fixed format mode, then each field should be entered using I10 format.

3. Lake definition data are restricted to cells for which IBOUND and WETDRY values have been set to
zero.

If ITMP > 0:

Record 5. Data: LKARR(NCOL,NROW)

A NCOL by NROW array of lake identification numbers is read for each layer in the grid by MODFLOW
module U2DINT. Record 5 is repeated for each of the NLAY layers.

LKARR   A value is read in for every grid cell. If LKARR(I,J,K) = 0, the grid cell is not a lake
              volume cell.
              If LKARR(I,J,K) > 0, its value is the identification number of the lake occupying the grid
              cell.
              LKARR(I,J,K) must not exceed the value NLAKES. If it does, or if LKARR(I,J,K) < 0,
              LKARR(I,J,K) is set to zero.
Notes:

1. Lake cells cannot be overlain by non-lake cells in a higher layer.

Record 6. Data: BDLKNC(NCOL,NROW)

A NCOL by NROW array of lakebed leakance values is read for each layer in the grid by MODFLOW
module U2DREL. Record 6 is repeated for each of the NLAY layers.

BDLKNC   A value is read in for every grid cell. The value is the lakebed leakance that will be
              assigned to lake/aquifer interfaces that occur in the corresponding grid cell.

Notes:

1. If the wet-dry option flag (IWTFLG) is not active (cells cannot rewet if they become dry), then the BDLKNC values are assumed to represent the combined leakances of the lakebed material and the aquifer material between the lake and the centers of the underlying grid cells, that is, the vertical conductance values (CV) will not be used in the computation of conductances across lake/aquifer boundary faces in the vertical direction.

2. IBOUND in the input to the Basic Package of MODFLOW and, if the IWTFLG option is active, WETDRY in the input to the BCF or other flow package of MODFLOW, should be set to zero for every cell for which LKARR is not equal to zero.

If ITMP > 0:

Record 7. Data: NSLMS

NSLMS   The number of sublake systems if coalescing/dividing lakes are to be simulated (only in transient runs). Enter 0 if no sublake systems are to be simulated.

Notes:

1. If data are being read using the fixed format mode, then NSLMS should be entered using format I5.

If ITMP > 0 and NSLMS > 0:

Record 8a. Data: IC ISUB(1)   ISUB(2)   ....   ISUB(IC)

Record 8b. Data: SILLVT(2)   ....   SILLVT(IC)

IC   The number of sublakes, including the center lake, in the sublake system being described in this record.
ISUB   The identification numbers of the sublakes in the sublake system being described in this record. The center lake number is listed first.
SILLVT   Sill elevation that determines whether the center lake is connected with a given sublake. One value is entered in this record for each sublake in the order the sublakes are listed in the previous record.

Notes:

1. A pair of records (records 8a and 8b) is read for each multiple-lake system, i.e., NSLMS pairs of records. However, IC = 0 will terminate the input.

2. If data are being read using the fixed format mode, then each field of Record 8a should be entered using I5 format and each field of Record 8b should be entered using F10.4 format.

If ITMP1 > 0 or = 0.

Record 9. Data: PRCPLK   EVAPLK   RNF   WTHDRW

PRCPLK   The rate of precipitation per unit area at the surface of a lake (L/T).

EVAPLK   The rate of evaporation per unit area from the surface of a lake (L/T).

RNF   Overland runoff from an adjacent watershed entering the lake. If RNF > 0, it is specified directly as a volumetric rate, or flux (L^3/T). If RNF < 0, its absolute value is used as a dimensionless multiplier applied to the product of the lake precipitation rate per unit area (PRCPLK) and the surface area of the lake at its full stage (occupying all layer 1 lake cells).

WTHDRW   The volumetric rate, or flux (L^3/T), of water removal from a lake by means other than rainfall, evaporation, surface outflow, or ground-water seepage. A negative value indicates augmentation. Normally, this would be used to specify the rate of artificial withdrawal from a lake for human water use, or if negative, artificial augmentation of a lake volume for esthetic or recreational purposes.

Notes:

1. When RNF is entered as a dimensionless multiplier (RNF < 0), it is considered to be the product of two proportionality factors. The first is the ratio of the area of the basin contributing runoff to the surface area of the lake when it is at full stage. The second is the fraction of the current rainfall rate that becomes runoff to the lake. This procedure provides a means for the automated computation of runoff rate from a watershed to a lake as a function of varying rainfall rate. For example, if the basin area is 10 times greater than the surface area of the lake, and 20 percent of the precipitation on the basin becomes overland runoff directly into the lake, then set RNF = -2.0.

If keyword "TABLEINPUT" is specified in item 1a then the following data are required, where 1 file is required for each lake:

Data: {STAGELAKE   VOLUMELAKE   AREALAKE}

STAGELAKE   are the lake stage values. These values should include lake stage values over the range that could occur in the simulation.

VOLUMELAKE are the lake volume values corresponding to the values specified for STAGELAKE.

AREALAKE are the lake surface area values corresponding to the values specified for STAGELAKE.

Notes:

1. Exactly 151 lines must be included within each lake bathymetry input file and each line must contain 1 value of lake stage, volume, and area (3 numbers per line) if the keyword "TABLEINPUT" is specified in item 1a. A separate file is required for each lake. Thus, if there are 4 lakes in a simulation then 4 lake bathymetry files are required. 151 values are required in each file to be consistent with the original Lake Package. See the definition of the keyword "TABLEINPUT" for more details.

Example LAK3 input file demonstrating the use of the TABLEINPUT functionality

The following is part of an example LAK3 input file that demonstrates the TABLEINPUT functionality. The example was developed from the 'l1b2k' example that is provided with the MODFLOW-2005 distribution. The example consists of 1 lake within a 2 layer groundwater model.

```
# Modified version of LAK3 test problem "l1b2k"
```

```
# Example input for specifying lake bathymetry information using
# external text files using key word option "TABLEINPUT"
TABLEINPUT                              Item 1a: KEY WORD
        1          0                    Item 1b: NLAKES,ILKCB
     0.00         50      0.001         Item 2:  THETA,NSSITER,SSCNCR
     110.       100.       170.    22 Item 3:STAGES,SSMN,SSMX,IUNITLAKTAB
        1          0          0         Item 4:  ITMP,ITMP1,LWRT
.
.
.
```

The rest of the 46 lines of 'l1b2k_bath.lak' were omitted.

The lake bathymetry file has been assigned IUNIT 22 and Fname 'l1b2k_bath.lak' in the Name File:

```
DATA 22 lak1b_bath.txt
```

File 'lak1b_bath.txt' has 151 lines of data, the first five of which are:

```
9.70000E+01   0.00000E+00   2.25000E+06      #Stage   Volume   Area
9.96867E+01   6.04500E+06   2.25000E+06
1.02373E+02   1.20900E+07   2.25000E+06
1.05060E+02   1.81350E+07   2.25000E+06
1.07747E+02   3.49267E+07   6.25000E+06
```

References

Merritt, M.L., and Konikow, L.F., 2000, Documentation of a Computer Program to Simulate Lake-Aquifer Interaction Using the MODFLOW Ground-Water Flow Model and the MOC3D Solute-Transport Model: U.S. Geological Survey Water-Resources Investigations Report 00-4167, 146 p.