# Agricultural Water Use Package for MODFLOW-NWT

The Agricultural Water-Use Package (AWU) was developed for MODFLOW-NWT in order to simulate water use for irrigation. The AWU Package works with the Streamflow-Routing (SFR2) and the Unsaturated Flow (UZF1) Packages, and includes capabilities for simulating pumping wells, similar to the WELL Package. Input required for simulating agricultural diversions, supplementary pumping, irrigation, and demand calculations are all specified within the AWU Package input file. All exchanges between different packages (SFR2, UZF1, and AWU) are calculated within the AWU Package; however, the SFR2 and UZF1 Packages must be active in order to use their capabilities in conjunction with the AWU Package. Diversion segments must be specified within the SFR2 Package in order to apply diverted water as irrigation. All data for supplementary and irrigation wells is specified within the AWU Package input file; the AWU Package calculates and applies its own boundary conditions to the groundwater flow equation for representing irrigation and/or supplementary wells.

The AWU Package is activated by specifying a file type of “AWU” within the MODFLOW-NWT Name file. The AWU input file contains 3 types of data, including 1) Options, 2) Well List, and 3) Stress Period data for specifying connectivity between segments and irrigation cells, supplemental wells and diversion segments, and irrigation wells and irrigation cells.

# Input data for the AWU Package input file

**FOR EACH SIMULATION**

AWU Package character variables can be specified in any order and must be proceeded and followed by the character variables OPTIONS and END, respectively.

OPTIONS

[NOPRINT]

[IRRIGATIONSEGMENT Numirrsegment Maxcellssegment]

[IRRIGATIONWELL Numirrwell Maxcellswell]

[SUPPLEMENTALWELL Numsupwell Maxsegment]

[MAXWELL Nummaxwell]

[TABFILES Numtab Maxval]

[PHIRAMP]

[ETDEMAND]

END

OPTIONS Character variable specified to indicate the beginning of the key word options.

NOPRINT Character variable that suppresses the printing of well lists.

IRRIGATIONSEGMENT An optional character variable. When IRRIGATESEGMENT is specified, the option to add water flowing in SFR2 diversion segments to UZF1 cells is activated.

Numirrsegment An optional integer variable. When IRRIGATESEGMENT is specified, the integer variable Numirrsegment also is specified. Numirrsegment is the maximum number of diversion segments in any stress period that will apply water to UZF1 cells.

Maxcellssegment An optional integer variable. When IRRIGATESEGMENT is specified, the integer variable Maxcellssegment also is specified. Maxcellssegment is the maximum amount of UZF1 cells associated with any single SFR2 diversion segment.

IRRIGATIONWELL An optional character variable. When IRRIGATEWELL is specified, the option to add groundwater pumped by a well to UZF1 cells is activated.

Numirrwell An optional integer variable. When IRRIGATEWELL is specified, the integer variable Numirrwell also is specified. Numirrwell is the maximum number of wells in any stress period that will apply water to UZF1 cells.

Maxcellwell An optional integer variable. When IRRIGATEWELL is specified, the integer variable Maxellwell also is specified. Maxcellwell is the maximum number of UZF1 cells associated with any single supplemental well.

SUPPLEMENTALWELL An optional character variable. When SUPPLEMENTALWELL is specified, the option to automatically pump water to supplement the difference between a specified SFR2 diversion and the actual diversion when there is a surface water shortfall.

Numsupwell An optional integer variable. When SUPPLEMENTALWELL is specified, the integer variable Numsupwell also is specified. Numsupwell is the maximum number of wells in any stress period that will pump supplementary groundwater to meet a surface water diversion shortfall.

Maxsegment An optional integer variable. When SUPPLEMENTALWELL is specified, the integer variable Maxsegment also is specified. Maxsegment is the maximum number of SFR2 segments that are supplemented by a supplemental well.

MAXWELL An optional character variable. If MAXWELL is specified then the maximum number of unique supplemental and irrigation wells used during a simulation is specified as Nummaxwell. If there are no supplemental or irrigation wells in a simulation then MAXWELL should not be specified.

Nummaxwell The total number of unique supplemental and/or irrigation wells used in the AWU Package. Well numbers and associated model cell information is input in the WELL LIST data block.

TABFILES An optional character variable. TABFILES is included in order set pumping rates using time series input files. If the irrigation demand is set using character variable ETDEMAND, or if a well is a supplemental well, then pumping rates specified in TABFILES are the maximum pumping rate, otherwise pumping rates specified in TABFILES are the irrigation demand.

Maxval An integer variable equal to the maximum number of values specified for any TABFILE.

PHIRAMP An optional character variable. PHIRAMP is included in order to specify the smoothing interval used to chnage negative pumping rates to zero when the groundwater cell dewaters. This variable only is used when the Newton solver is active.

ETDEMAND An optional character variable. ETDEMAND is included in order to activate automatic calculation of water demand for irrigation segments and irrigation wells. Demand is calculated as the difference between PET and actual ET calculated by the UZF1 Package.

END Character variable specified to indicate the end of the key word options.

Wells used for irrigation, either as a supplement to a surface water diversion or to fully satisfy an irrigation demand are defined within the WELL LIST data block. Wells must be specified in the WELL LIST using TABFILES if there are wells that are not supplemental to surface water diversions. In this case, the pumping capacity or GW demand for each times step is specified as the variable Qtab in the TABFILE. Well numbering is implicitly defined according to the order of wells in the WELL LIST, the first entry is well 1, numbered consecutively to the total number of wells used during a simulation. Wells can be made inactive during a stress period by removing all supplemental wells during a stress period. Item 1 only is read if there are AWU wells in a simulation.

Item 1: [WELL LIST]

If character variable TABFILES is specified in the OPTIONS block then item 2a is read as a space delimited list in free format. Otherwise, item 2 b is read.

Item 2a: [TABUNIT1 TABVAL1 TABLAY1 TABROW1 TABCOL1]

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[TABUNITNumtab TABVALNumtab TABLAYNumtab TABROWNumtab TABCOLNumtab]

If character variable TABFILES is not specified in the OPTIONS block then item 2b is read as a space delimited list in free format.

Item 2b: [WELLLAY1 WELLROW1 WELLCOL1 Q1]

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[LAY Maxwell ROW Maxwell COLMaxwell QMaxwell]

WELL LIST Character variable specified to indicate that AWU wells will be included in a simulation.

TABUNIT Integer variable equal to the unit number for the TABFILE used to specify pumping rates for a well.

TABVAL Integer variable equal to the maximum number of rows to be read from a TABFILE.

TABLAY Integer variable equal to the layer number of the cell containing a well.

TABROW Integer variable equal to the row number of the cell containing a well.

TABCOL Integer variable equal to the column number of the cell containing a well.

WELLLAY Integer variable equal to the layer number of the cell containing a well.

WELLROW Integer variable equal to the row number of the cell containing a well.

WELLCOL Integer variable equal to the column number of the cell containing a well.

Q Real variable equal to the maximum pumping rate or applied pumping rate.

Note 1: Well numbers are not explicitly specified and are assumed according to the order of input for items 2a or 2b. For wells that have pumping rates specified using TABFILES, pumping rates specified for well 1 correspond to the first line in item 2a, pumping rates for well 2 correspond to the second line in item 2a, and so on.

**FOR EACH STRESS PERIOD**

Stress period data must be proceeded and followed by the character variables “STRESS PERIOD” and “END,” respectively. Character variables “STRESS PERIOD” and “END” are required for each stress period. There are 3 options for specifying stress period information: 1) use stress period data for irrigation segments, irrigation wells, or supplemental wells from previous stress period; 2) specify data for all active irrigation segments, irrigation wells, or supplemental wells for stress period; or 3) set all irrigation segments, irrigation wells, or supplemental wells to inactive for a stress period. Combinations of these 3 options can be used during a stress period.

STRESS PERIOD

Item 3: [IRRSFR]

Item 4: [NUMIRRSEGSP]

Item 5: [SEGID NUMCELLSEG]

Item 6: [IRRROW1 IRRCOL1 EFF\_FACT1 FIELD\_FACT1]

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[IRRROWnumcellseg IRRCOLnumcellseg EFF\_FACTnumcellseg FIELD\_FACTnumcellseg]

Item 7: [IRRWELL]

Item 8: [NUMIRRWELLSP]

Item 9: [IRRWELLID NUMCELLWELL]

Item 10 [IRRROW1 IRRCOL1 EFF\_FACT1 FIELD\_FACT1 ~~KCROP~~~~1~~]

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[IRRROWnumcellwell IRRCOLnumcellwell EFF\_FACTnumcellwell FIELD\_FACTnumcellwell ~~KCROP~~~~numcellwell~~]

Item 10: [SUPWELL]

Item 12: [NUMSUPWELLSP]

Item 13: [SUPWELLNUM NUMSEGWELL]

Item 14: [SEGWELLID1 PCTSUP­1]

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[SEGWELLIDnumsegwell PCTSUP­numsegwell]

IRRSFR An integer variable. IRRSFR can be specified if character variable IRRGATIONSEGMENT is specified in the OPTIONS block. If IRRSFR < 0, irrigation segment data from the previous stress period will be used. If IRRSFR=0, all irrigation segments will be set to inactive. If IRRSFR>0 then IRRSFR is equal to the number of irrigation segments specified during the stress period.

NUMIRRSEGSP An integer variable equal to the number of diversion segments that will supply water to UZF cells.

SEGID An integer variable equal to the SFR2 segment number for the diversion used to divert surface water for irrigation.

NUMCELLSEG An integer variable equal to the total number of UZF1 cells that water diverted from SEGID will be applied for irrigation.

EFF\_FACT A real variable equal to the fraction of the water applied to a cell or HRU, defined by IRROW and IRRCOL that is removed from the model before being applied to a cell due to crop evapotranspiration and other field evaporation losses. If evapotranspiration is being simulated explicitly by UZF1 then set EFF\_FACT to zero.

FIELD\_FACT A real variable equal to the fraction of the diverted water applied to a cell, for example, FIELD\_FACT1 is the fraction of the diversion amount multiplied by EFF\_FACT that is applied to cell IRROW1 and IRRCOL1. The sum of all FIELD\_FACT values specified in each for a single segment should sum to 1.

~~KCROP A real variable equal to the crop coefficient (Kc) that is the ratio of the crop ET to potential ET.~~

IRRROW An integer variable equal to the UZF1 cell row number to which diverted water will be applied as irrigation.

IRRCOL An integer variable equal to the UZF1 cell column number to which diverted water will be applied as irrigation.

IRRWELLID An integer variable equal to the well identification number used to pump groundwater for irrigation. IRRWELLID is set according to the order that

NUMCELLWELL An integer variable equal to the total number of UZF1 cells that water pumped by IRRWELLID will be applied for irrigation.

EFF\_FACT A real variable equal to the fraction of the water applied to a cell, defined by IRROW and IRRCOL that is removed from the model before being applied to cell due to crop evapotranspiration and other field evaporation losses. If evapotranspiration is being simulated explicitly by UZF1 then set EFF\_FACT to zero.

FIELD\_FACT A real variable equal to the fraction of the diverted water applied to a cell, for example, FIELD\_FACT1 is the fraction of the diversion amount multiplied by EFF\_FACT1 that is applied to cell IRROW1 and IRRCOL1. The sum of all FIELD\_FACT values specified for a single well should sum to one.

IRRROW An integer variable equal to the UZF1 cell row number to which pumped water will be applied as irrigation.

IRRCOL An integer variable equal to the UZF1 cell column number to which pumped water will be applied as irrigation.

SUPWELL An optional character variable indicating that supplemental well stress period data will be specified. If SUPWELL is less than or equal to zero then no supplemental well data will be read during the stress period.

NUMSUPWELLSP An integer variable equal to the number of supplementary wells that will pump groundwater to meet the surface water shortfall for irrigation.

SUPWELLNUM An integer variable equal to the AGO well number for the well that supplements one or more surface water diversions.

NUMSEGWELL An integer variable equal to the number of SFR2 segments that will be supplemented by well SUPWELLNUM

SEGWELLID An integer variable equal to the SFR2 segment number that will be supplemented by well SUPWELLNUM

PCTSUP­ A real variable equal to the percentage of the surface water irrigation shortfall for segment SEGWELLID that will be supplemented by well SUPWELLNUM.

Note 2: If item 2, item 6, or item 10 is omitted during the first stress period of a simulation then irrigations segments, irrigation wells, or supplemental wells, respectively, are inactive during the first stress period.

Note 3: Irrigations segments, irrigation wells, or supplemental wells can be made inactive during a stress period by setting item 3, item 7, or item 11 to zero, respectively.

**Input data for TABFILES**

Item 1: [TIME1 Q1]

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[TIME TABVAL Q TABVAL]

TIME A real variable equal to the simulation time that the pumping rate Q will be used to interpolate the maximum or applied pumping rate for a time step. The pumping rate for a time step is calculated using linear interpolation. The units for TIME must be consistent with the DIS Package input variable ITMUNI.

Q A real variable equal to the maximum pumping rate for supplementary wells or for simulations that include the character variable ETDEMAND, otherwise Q is the applied pumping rate that can be used for setting the irrigation demand for wells used for irrigation (IRRWELL).