# 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) Time series, 3) Well List, and 4) 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]

[IRRIGATION\_SFR Numirrdiversions Maxcellsdiversion]

[IRRIGATION\_WELL Numirrwells Maxcellswell]

[SUPPLEMENTAL\_WELL Numsupwells Maxdiversions]

[MAXWELL Nummaxwell]

[TABFILES Numtab Maxval]

[PHIRAMP]

[ETDEMAND Accel]

[TIMESERIES\_SFR]

[TIMESERIES\_WELL]

[TIMESERIES\_SFRET]

[TIMESERIES\_WELLET]

[SFRLIST Unit\_sfrlist]

[WELLLIST Unit\_welllist]

[WELLIRRLIST Unit\_wellirrlist]

[SFRIRRLIST Unit\_sfrirrlist]

[WELLCBC Unitcbc]

END

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

NOPRINT Character variable that suppresses the printing of well lists.

IRRIGATION\_SFR An optional character variable. When IRRIGATION\_SFR is specified, the option to use surface water (SW) for irrigation is activate.

Numirrdiversions An optional integer variable. When IRRIGATION\_SFR is specified, the integer variable Numirrdiversions also is specified. Numirrdiversions is the maximum number of SFR2 diversion segments in any stress period that will be used for irrigation.

Maxcellsdiversion An optional integer variable. When IRRIGATION\_SFR is specified, the integer variable Maxcellsdiversion also is specified. Maxcellsdiversion is the maximum number of MODFLOW cells or PRMS HRUs that will receive irrigation from a single SFR2 diversion segment in any stress period.

IRRIGATION\_WELL An optional character variable. When IRRIGATION\_WELL is specified, the option to use groundwater for irrigation is activate.

Numirrwells An optional integer variable. When IRRIGATION\_WELL is specified, the integer variable Numirrwells also is specified. Numirrwells is the maximum number of AWU wells in any stress period that will be used for irrigation.

Maxcellswell An optional integer variable. When IRRIGATION\_WELL is specified, the integer variable Maxellswell also is specified. Maxcellswell is the maximum number of MODFLOW cells or PRMS HRUs that will receive irrigation from a single AWU well in any stress period.

SUPPLEMENTAL\_WELL An optional character variable. When SUPPLEMENTAL\_WELL is specified, the option to simulate supplemental groundwater for irrigation is active. The AWU Package calculates supplemental GW pumping using the difference between the irrigation demand and the surface water diversion.

Numsupwells An optional integer variable. When SUPPLEMENTAL\_WELL is specified, the integer variable Numsupwells also is specified. Numsupwells is the maximum number of supplemental wells in any stress period that will pump groundwater.

Maxdiversions An optional integer variable. When SUPPLEMENTAL\_WELL is specified, the integer variable Maxdiversions also is specified. Maxdiversions is the maximum number of SFR2 diversion segments that are supplemented by a well.

MAXWELL An optional character variable. If IRRIGATION\_WELL or SUPPLEMENTAL\_WELL is specified then MAXWELL also is specified. MAXWELL is included to indicate that the maximum number of unique supplemental and irrigation wells used during a simulation (Nummaxwell) also will be read.

Nummaxwell The maximum number of unique supplemental and irrigation wells used during a simulation.

TABFILES An optional character variable. TABFILES is included in order set pumping rates using time series input files.

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 change 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 the net irrigation water requirement.

Accel An optional real variable. Factor for accelerating nonlinear solution for the net irrigation water requirement.

TIMESERIES\_SFR An optional character variable that activates the option for outputting diversions flow rates for specified SFR2 segments used for irrigation. Additional details are specified in the time series data input.

TIMESERIES\_WELL An optional character variable for outputting well pumping rates for specified wells used for irrigation. Additional details are specified in the time series data input.

TIMESERIES\_SFRET An optional character variable for outputting irrigation applied to all cells/HRUs supplied by 1 or more specified diversion segments. Additional details are specified in the time series data input.

TIMESERIES\_WELLET An optional character variable for outputting irrigation applied to all cells/HRUs supplied by 1 or more specified wells. Additional details are specified in the time series data input.

SFRLIST An optional character variable for outputting a list of all diversion segments and diversion amounts used for irrigation in the AWU Package when "SAVE BUDGET" or a non-zero value for ICBCFL is specified in Output Control.

Unit\_sfrlist An optional integer variable that is the file unit number to which SFRLIST output is written. This unit number must correspond to a file of type Data specified in the MODFLOW Name file. A negative value indicates output will be written to the LIST file.

WELLLIST An optional character variable for outputting a list of all active wells in the AWU Package and pumped amounts when "SAVE BUDGET" or a non-zero value for ICBCFL is specified in Output Control.

Unit\_welllist An optional integer variable that is the file unit number to which WELLLIST output is written. This unit number must correspond to a file of type Data specified in the MODFLOW Name file. A negative value indicates output will be written to the LIST file.

WELLIRRLIST An optional character variable for outputting a list of MODFLOW cells or PRMS HRUs that are irrigated by AWU wells and the irrigated amounts when "SAVE BUDGET" or a non-zero value for ICBCFL is specified in Output Control.

Unit\_wellirrlist An optional integer variable that is the file unit number to which WELLIRRLIST output is written. This unit number must correspond to a file of type Data specified in the MODFLOW Name file. A negative value indicates output will be written to the LIST file.

SFRIRRLIST An optional character variable for outputting a list of MODFLOW cells or PRMS HRUs irrigated by irrigation segments and the irrigated amounts when "SAVE BUDGET" or a non-zero value for ICBCFL is specified in Output Control.

Unit\_sfrirrlist An optional integer variable that is the file unit number to which SFRIRRLIST output is written. This unit number must correspond to a file of type Data specified in the MODFLOW Name file. A negative value indicates output will be written to the LIST file.

WELLCBC An optional character variable for outputting cell-by-cell flow terms when "SAVE BUDGET" or a non-zero value for ICBCFL is specified in Output Control.

Unit\_cbc An optional integer variable that is the file unit number to which cell-by-cell unformatted list output is written. This unit number must correspond to a file of type Data(binary) specified in the MODFLOW Name file.

END Character variable specified to indicate the end of the character options.

Time series data can be written to separate formatted output files for selected SFR2 segments and AWU wells used for irrigation. These files are of type “Data” and must be included in the MODFLOW Name file. Time series data are read only if time series character variables are specified in the character options section.

[TIME SERIES]

[SFR Segmentnum1 Unit\_sfr1]

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[SFR Segmentnumnumtimeseriessfr Unit\_sfrnumtimeseriessfr]

[WELL Wellnum1 Unit\_well1]

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[WELL Wellnumnumtimeserieswell Unit\_sfrnumtimeserieswell]

[END]

TIME SERIES Character variable specified to indicate the beginning of the time series data block.

SFR Character variable indicating that irrigation information for a diversion will be written to a time series output file.

Segmentnum Integer variable that is the SFR2 segment number.

Unitsfr Integer variable that is the formatted output file unit number.

WELL Character variable indicating that irrigation information for a well will be written to a time series output file.

Segmentnum Integer variable that is the AWU well number.

Unitwell Integer variable that is the formatted output file unit number. This file is of type “Data” and is included in the MODFLOW Name file.

END Character variable specified to indicate the end of the time series data block.

Wells used for irrigation, including those used to supplement surface water diversions, are defined within the WELL LIST data block. TABFILES must be used to represent time varying pumping rates if pumping rates are not calculated by the AWU Package. 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 and irrigation wells during a stress period. Item 1 only is read if there are AWU wells, and well numbering remains the same during 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 WELLLAY1 WELLROW1 WELLCOL1]

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[TABUNITNumtab TABVALNumtab WELLLAYNumtab WELLROWNumtab WELLCOLNumtab]

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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[WELLLAY Maxwell WELLROW Maxwell WELLCOLMaxwell 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.

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 6a: [IRRROW\_SFR 1 IRRCOL\_SFR 1 EFF\_FACT\_SFR1 FIELD\_FACT\_SFR 1 KCROP1]

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[IRRROW\_SFR numcellseg IRRCOL\_SFRnumcellseg EFF\_FACT\_SFRnumcellseg FIELD\_FACT\_SFRnumcellseg KCROPnumhruseg]

Item 6b: [HRU\_ID\_SFR 1 EFF\_FACT\_SFR1 FIELD\_FACT\_SFR 1 KCROP1]

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[HRU\_ID\_SFRnumhruseg EFF\_FACT\_SFRnumhruseg FIELD\_FACT\_SFRnumhruseg KCROPnumhruseg]

Item 7: [IRRWELL]

Item 8: [NUMIRRWELLSP]

Item 9: [IRRWELLID NUMCELLWELL]

Item 10a [IRRROW\_WELL1 IRRCOL\_WELL 1 EFF\_FACT\_WELL 1 FIELD\_FACT\_WELL 1 KCROP1]

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[IRRROW\_WELL numcellwell IRRCOL\_WELL numcellwell EFF\_FACT\_WELL numcellwell FIELD\_FACT\_WELL numcellwell KCROPnumcellwell]

Item 10b [HRU\_ID\_WELL1 EFF\_FACT\_WELL 1 FIELD\_FACT\_WELL 1 KCROP1]

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[HRU\_ID\_WELL numhruwell EFF\_FACT\_WELL numhruwell FIELD\_FACT\_WELL numhruwell KCROPnumhruwell]

Item 11: [SUPWELL]

Item 12: [NUMSUPWELLSP]

Item 13: [SUPWELLNUM NUMSEGWELL]

Item 14: [SEGWELLID1 PCTSUP­1]

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[SEGWELLIDnumsegwell PCTSUP­numsegwell]

IRRSFR An optional character variable. IRRSFR can be specified if character variable IRRIGATION\_SFR is specified in the OPTIONS block.

NUMIRRSEGSP An integer variable equal to the number of SFR2 segments active during a stress period that will divert water to cells. If NUMIRRSEGSP < 0, irrigation segment data from the previous stress period will be used. If NUMIRRSEGSP =0, all irrigation segments will be set to inactive.

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

NUMCELLSEG An integer variable equal to the total number of MODFLOW cells or PRMS HRUs that will be irrigated by SFR2 diversion segment SEGID.

IRRROW\_SFR An integer variable equal to the cell row number that will be irrigated by segment SEGID.

IRRCOL\_SFR An integer variable equal to the cell column number that will be irrigated by segment SEGID.

HRU\_ID\_SFR An integer variable equal to the HRU ID number that will be irrigated by segment SEGID.

EFF\_FACT\_SFR A real variable equal to the fraction of surface water applied to a cell that can be used to represent crop evapotranspiration and other field losses. If evapotranspiration is being simulated explicitly then set EFF\_FACT to zero.

FIELD\_FACT\_SFR A real variable equal to the fraction of the diverted water applied to a cell that is used to distribute a diversion among multiple cells. The sum of all FIELD\_FACT\_SFR values for a diversion 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. This variable only is used if irrigation is applied to an HRU. If UZF1 is used to simulate ET then the crop ET is input directly into the UZF1 input file as input variable PET.

IRRWELL An optional character variable. IRRWELL can be specified if character variable IRRIGATION\_WELL is specified in the OPTIONS block.

NUMIRRWELLSP An integer variable equal to the number of AWU wells active during a stress period that will pump water for irrigation on MODFLOW cells or PRMS HRUs. If NUMIRRWELLSP < 0, irrigation well data from the previous stress period will be used. If NUMIRRWELLSP =0, all irrigation wells will be set to inactive.

IRRWELLID An integer variable equal to the well identification number used to pump groundwater for irrigation.

NUMCELLWELL An integer variable equal to the total number of MODFLOW cells or PRMS HRUs that receive water from a well.

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

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

EFF\_FACT\_WELL A real variable equal to the fraction of groundwater applied to a cell that can be used to represent crop evapotranspiration and other field losses. If evapotranspiration is being simulated explicitly then set EFF\_FACT\_WELL to zero.

FIELD\_FACT\_WELL A real variable equal to the fraction of the groundwater applied to a cell that is used to distribute water pumped from a well among multiple cells. The sum of all FIELD\_FACT\_WELL values for a well should sum to 1.

SUPWELL An optional character variable indicating that supplemental well stress period data will be specified.

NUMSUPWELLSP An integer variable equal to the number of active supplementary wells during a stress period that will pump groundwater to meet the surface water shortfall for irrigation. If NUMSUPWELLSP < 0, supplementary well data from the previous stress period will be used. If NUMSUPWELLSP =0, all supplementary wells will be set to inactive.

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

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

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

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

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.

Note 4: numhruwell is the number of HRUs irrigated by a well; numcellwell is the number of cells irrigated by a well; numhruseg is the number of HRUs irrigated by a segment; and numcellseg is the number of cells irrigated by a segment.

**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).