Documentation of StatePP
(Preparation of MODFLOW input files)

FINAL

To: File
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StatePP is short for State Pre-Processor, and name derived from the pre-processing program developed by Dewayne Schroeder for the State's AWDI model. **StatePP** takes ditch water budgets from **StateCU** via **StateFate** and converts it to cell-by-cell data needed by MODFLOW.

This document includes the following sections:

0.0 Disclaimer

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1.0 Acknowledgment

Judith Schenk of HRS developed the initial **StatePP** program. Willem A. Schreüder of Principia Mathematica re-implemented and expanded **StatePP** using funding provided by the Colorado Division of Water Resources and the Rio Grande Water Conservation District.

2.0 Overview

The **StateCU** program calculates the ditch water budget for several hundred ditches in the watershed. The **StateFate** program processes the **StateCU** output and merges it with drain flows predicted by the groundwater model. Some of the **StateFate** output serves as input to **StateCU**, but the primary output if StateFate is the ***.Xpp** file which is the primary input to **StatePP**.

The purpose of **StateFate** is to distinguish how, for example, a quantity such as spray loss is treated differently in **StateCU** and **StatePP**. In **StateCU**, spray loss is lumped in with groundwater recharge as not satisfying the crop consumptive use. In **StatePP**, spray loss is lumped in with crop consumptive use as water not returning to the groundwater system. Therefore the ***.Xpp** file contains the ditch water budgets required by **StatePP**.

StatePP itself is implemented as two discrete programs. The first is called **statepp** and is used to produce the recharge and well packages for MODFLOW. The second is called **mket** and produces Segmented ET (ETS) packages for MODFLOW. These two programs combined make up **StatePP**. The reason why this was implemented as two separate programs is that it simplifies the code.

StatePP is typically run three times: once with the historical input data (1950-2010), once with the “no pumping” input data, and once with the “recharge credit” input data. For the historical input data set, **StatePP** is used to produce input files for the steady state, average monthly, annual average and monthly transient runs. For the “no pumping” verification run, a single set of steady state input files are produced, while for the “recharge credit” data a single set of monthly transient input files are produced. The “recharge credit” transient is combined with the historical monthly transient to create the input data files for the impact runs.

In this memorandum, for consistency between sections, “pumping” is used to describe groundwater withdrawals whether the withdrawal is by a mechanical pump or if the well flows under artesian pressure.

3.0 StatePP

The **statepp** program is used to produce the recharge and well packages for MODFLOW. The following table shows the extensions used for the output files:

Extension	Type	Description
mi	Well	M&I pumping and returns
ag	Well	Agricultural well pumping
ppt	Recharge	Precipitation recharge

Extension	Type	Description
irr	Recharge	Recharge from irrigation and direct recharge
clk	Recharge	Canal leakage
rim	Recharge	Rim recharge

3.1 Statepp Inputs

The program reads a parameter file in a keyword-value format which controls the behavior of the program. The following table shows the keywords in the **statepp** input file

Key	Phase 6 Filename	Description
GRID	X6P008.grd	Grid and time period definitions
CU	../StateFate/rg2012_FactorSoUMeter.Xpp	Ditch water budget from StateFate
DF	../GIS/1998/ditch.fact	Master list of ditches
IRW	../GIS/1998/irrwell.dat	(k,i,j) of irrigation wells
IRR	../GIS/1998/divirln.dat	(i,j) of irrigated lands
CLK	../GIS/1998/divleak.dat	(i,j) of canal leakage
RF	data/rim.fact	Master list of rim recharge areas
RIM	../GIS/1998/1998.rim	(i,j) of rim recharge areas
RR	../RimRecharge/RimRecharge_2012.stm	Rim recharge volumes
RET	../StateFate/rg2012_FactorSoUMeter.Xgw	Surface returns to groundwater
PPTd	../ppt/data/	Precipitation data directory
PPTi	../GIS/1998/pptfrac.irr	Irrigation season precip fraction
PPTn	../GIS/1998/pptfrac.non	Non-irrigation season precip fraction
MIL	../MIPumping/rg2012.mi	(k,i,j) of M&I pumping
MIP	../MIPumping/MI_Pumping.stm	M&I pumping volumes
MIR	../MIPumping/MI_Return.stm	M&I return volumes
EXT	0	External Average Monthly arrays
OUT	X6P033.out	Output file name
SS	S6P033	Steady state file root
IP	I6P033	Initial period file root
AM	A6P033	Average monthly file root

Key	Phase 6 Filename	Description
CY	C6P033	Calendar year file root
MO	M6P033	Monthly transient file root
REP	*not used*	Sequence of historical years to repeat
RP	*not used*	Repeated historical period file root
TR	*not used*	Long term average transient file root

The GRID file is shared among the **statepp**, **mket** and **str/mkq** programs. The grid file defined the number of layers, rows and columns of the model, the cell dimensions and the domain offset as the first three lines in the file. The next five lines defined the starting and ending calendar years of the steady state period, the initial period, the transient period, the predictive average period and the predictive transient period. The steady state period defined the years used for the steady state, the average monthly and the no pumping simulations and is currently 1990-1998. The predictive average and transient average was used for predictive runs during Phase 4 but was not used during Phase 6. Finally the grid file references the IBOUND arrays to define active cells in the domain.

3.2 Agricultural pumping and recharge

The ditches to process are specified in the DF file. The volume in acre-feet for every month by ditch is specified in the CU file.

This DF file contains three entries per line: the WDID of the ditch, the fraction of the canal leakage that is recharged and the key words WELL or LAND. Only ditches specified in the DF file are processed. If a ditch does not appear in the CU file an error is generated.

The DitchLoss volume from the CU file is multiplied by the recharge fraction from the DF file. This recharge fraction is typically 97%, since 3% is assumed to be lost to evaporation. However, in the case of ditches that are also modeled using the stream package typically have a lower fraction. (See the **agg** program description of how this is determined.) The recharges attributed to ditch losses are distributed to cells using the CLK file. If no ditch cells are mapped to a ditch, the ditch losses are added to the return flow from surface water and distributed to the irrigated lands.

Groundwater pumping from irrigation for the ditch is read from the Pumping column in the CU file and is distributed to parcels proportional to the acreage in the IRW file. Surface water return to groundwater specified in the RET file (***.Xgw** output from StateFate) is added to this amount. For each parcel, the pumping is distributed to individual wells and layers which the well penetrates proportional to the capacity of the wells that serve a parcel. The IRW file includes the capacity of each well by layer, so this also distributes the pumping to the different aquifers.

The Recharge volume in the CU file represents managed recharge. It is distributed proportional to the groundwater irrigated lands. This step is performed by distributing the ditch wide volume to the parcels proportional to their acreage listed in the IRW file, and then to individual cells where the wells are mapped based on the capacity of the wells. Although wells have a layer associated with them, the recharge is assigned to the topmost active layer.

The RchIrrLand volume from the CU file represents the return flow from surface water irrigation to groundwater. It is distributed proportional to the irrigated parcels in the IRR coverage.

The RchGwLand represent return flows from applied groundwater. For most ditches, the DF file specifies the key word WELL, and the return flows are assigned proportional to the groundwater lands using the same procedure used to distribute managed recharge. However, for some ditches where the water is pumped into a canal, the DF file specifies the key word LAND and the return flows are distributed to the irrigated lands using the same procedure as the surface water irrigation.

In the IRW file, the starting date of every well is listed. For transient processing, the well is assigned a capacity of zero (0) prior to this starting year. Occasionally there is pumping under a ditch without any active wells specified. Similarly, there are, sometimes surface water attributed to a ditch without any irrigated lands mapped to that ditch. These volumes are printed to the screen as lost amounts because it represent pumping or recharge that appears in **StateCU** that will not appear in the MODFLOW input files because **StatePP** does not know where to assign it. These quantities were insignificant in Phase 6.

The **statepp** program ignores the remained of the data columns in the CU file.

3.3 M&I Pumping and Returns

The location of M&I pumping and returns are specified in the MIL file. This file lists the WDID and k,i,j and yield of each structure. The yield is used to proportion pumping when a WDID has multiple locations (typically layers) associated with it.

The volume pumped by month for each structure is specified by the MIP file. Pumping is proportional to the yield of each location in the MIP file.

The returned volume by month for each structure is specified in the MIR file. Note that this represents only the return to groundwater. The returns are distributed in the same way as the pumping, but are assigned to layer 1.

3.4 Rim Recharge

Rim Recharge represents recharge from small streams that deep percolate over the areas along the fan that surrounds the basin. The RF file specifies the names of all the rim inflow areas. The RF file does allow a factor to be specified to scale the rim inflow volumes, but in Phase 6 a factor of 1 was used everywhere.

The rim inflow volumes are specified by the RR file. These volumes are distributed proportional to the areas specified in the RIM file.

3.5 Precipitation Recharge

Precipitation for every month and cell is read from files named YYYYMM.ppt from the directory specified using the PPTd keyword. The PPTi file specifies the fraction of this precipitation that becomes recharge during the irrigation season (May-Sep) while the PPTn file specifies the fraction of this precipitation that becomes recharge during the non-irrigation season.

The precipitation for each month is multiplied by the corresponding precipitation fraction array. For the average monthly and monthly transient data sets, the monthly values are saved to the output. For the steady state or annual runs, the values are accumulated for the period before averaging and saving.

3.6 StatePP output

The **StatePP** program produces output for all the periods specified by the output keywords. The key words SS, IP, AM, CY, MO, TR and RP may be used to produce output for the corresponding periods.

If the repeated historical period is used, the REP file specifies the order in which historical years are repeated. This feature was last used in Phase 4.

When using the steady state, average monthly or annual average runs, **statepp** will calculate average stresses for that period based on the monthly historical data for the years specified.

The output file contains any warnings generated by **statepp**. The warnings are sorted to more easily identify the types of errors. Most of the warnings are typically that the pumping exceeds the well capacity during a particular period, and can safely be ignored.

A ***.err** file is produced which lists errors such as where well pumping is associated with a ditch while no wells are mapped to that ditch or irrigation returns should occur to a ditch with no mapped irrigated acreage in the model domain. These volumes are typically small and can be safely ignored.

A summary is produced to the screen which lists the pumping and recharge terms for the domain and the amount lost due to mapping issues. This output is typically redirected to the ***.lst** file.

4.0 mket

The **mket** program does the native ET and subirrigation computations and produces Segmented ET (ETS) packages for MODFLOW.

Just like **statepp**, the **mket** program is typically run three times to produce the data sets using different ***.Xpp** input files.

4.1 mket input

The mket input file consists of different sections. The first section describes global features such as the grid, ditch water budgets, ground surface and output periods, while subsequent sections describe native ET and different types of subirrigation. Sections are separated using one or more blank lines. Comments may be inserted anywhere in the file by beginning a line using the # symbol and does not count as blank lines.

The first section uses the following key-value entries

Keyword	Phase 6 Filename	Description
GRID	X6P008.grd	Grid and time period definitions

Keyword	Phase 6 Filename	Description
CU	../StateFate/rg2012_FactorSoUMeter.Xpp	Ditch water budget from StateFate
SURF	X6P008.surf	Ground surface file
NSUB	2+1	Number of subirrigation types
ETMAX	X6P033.etmax	Potential native ET
SS	S6P033	Steady state file root
IP	I6P033	Initial period file root
AM	A6P033	Average monthly file root
CY	C6P033	Calendar year file root
MO	M6P033	Monthly transient file root
REP	*not used*	Sequence of historical years to repeat
RP	*not used*	Repeated historical period file root
TR	*not used*	Long term average transient file root

The GRID file is shared with **statepp** and defines the model domain and time periods.

The CU file is shared with **statepp**, but **mket** ignores the data columns used by **statepp** and uses only the last three columns which list the subirrigation potential by type. The numbers of subirrigation types are given by the NSUB keyword. The 2+1 style is a historical holdover in that the third type is calculated as everything not in the first two types (meadow and alfalfa) but could also be specified as 3.

The ground surface elevation file is specified using the SURF keyword. Note that this must be specified without a full directory path. The same ground surface is used for native and all subirrigation types.

4.2 Native ET

The second section in the input file defines native ET. The first line must be the key word NATIVE followed by the GIS file specifying the spatial distribution of the different native ET types. The second line defines the monthly distribution of native ET as a sequence of 12 monthly ET multipliers. The sum of the multipliers must be 12 as the values are applied directly to individual months.

The third line in the native ET section must start with the key words DTW (for depth-to water) and is followed by a set of native ET types. Types can be combined by combining the names using a + symbol. For example,

heavy_vegetation+coniferous_trees+deciduous_trees

indicates that the heavy_vegetation and coniferous_trees and deciduous_trees types are combined and given the same depth to water curve.

Subsequent lines list the depth to water and an ET rate in feet/year for each of the groups. The first depth to water must be zero and subsequent depths must be strictly monotone increasing. The rate for the last depth must be zero.

Native ET will be written to an ETS format file. The maximum potential native ET is calculated and stored in the ETMAX file. A cell-by-cell set of curves will be calculated for each of the depths specified using the fractions of ETMAX. These values do not change from month to month. The ETS file will reference the ETMAX file for every month and use the monthly multiplier to scale the potential ET from month to month.

4.3 Subirrigation

Following the native ET section, there can be a number of subirrigation sections. Each section must start with the key word SUB, the sequence number, and a cell-by-cell file showing the cells under each ditch with this type of subirrigation.

The second line in the section must specify the peak rate of subirrigation in feet for an individual month that this type of subirrigation can be.

The third line in the section must read DTW Annual.

The forth and subsequent lines represent the annual maximum potential subirrigation with depth. The first line must have a depth of zero and the last depth must have a rate of zero.

The **mket** program will use the annual curve to represent the maximum potential amount of subirrigation that can occur. This is limited by the peak rate, as well as the subirrigation potential specified in the CU file. The subirrigation rate is determined by dividing the subirrigation potential by the acreage. When the curve exceeds the limiting values, the ET curve is limited to the limiting value, i.e. the curve is truncated.

The **mket** program will create an ETS file with the potential subirrigation for each period. A different maximum and fractional multipliers are calculated for each stress period.

4.4 mket output

The **mket** program produces output for the types of simulations using the same specifiers as the **statepp** program. For each type the root is used with ***.ets** for native ET and ***.sub1**, ***.sub2** and ***.sub3** for meadow, alfalfa and other subirrigation, respectively.

The **mket** program normally produces no output to the screen unless an error occurs.

5.0 Comments and Concerns

The current **StatePP** program input files allow only model cells with the same horizontal dimensions to be used. The internal operations of **StatePP** does not require that this be the case, but in order to make the input files as simple as possible, the input file format does not allow the grid size to be varied.

The current **StatePP** program uses a single GIS coverage for all time. This is an historical artifact dating to the time when there was a single GIS coverage. The input files therefore allow only a single GIS file name to be specified for the entire period.

During later phases, **StatePP** should be modified to allow the GIS coverages to change over time.

During Phase 6, the need to distinguish recharge from surface water irrigation, groundwater irrigation and managed recharge in the water budget became apparent. Since these terms are explicitly identified in the ***.4WB** file and the ***.Xpp** file the ability to separate these terms became possible.

During Phase 6, some model runs were performed with this level of distinction, but this was not the default. For Phases 7 and beyond it is recommended that the default would be to separate these terms. The following table shows the extensions used for the various packages.

Extension	Type	Description
mi	Well	M&I pumping and returns
ag	Well	Agricultural well pumping
ppt	Recharge	Precipitation recharge
irr	Recharge	Recharge from surface water irrigation
gwr	Recharge	Recharge from groundwater irrigation
rch	Recharge	Managed groundwater recharge
clk	Recharge	Canal leakage
rim	Recharge	Rim recharge

6.0 References

Appendix J-A4: RGDSS Ground Water, StatePP Processing Details, July 2004.

RGDSS Phase 6 Memorandum: Groundwater GIS Processing, (RGDSS_P6_GIS_Processing.pdf)