Direct Solution Algorithm

StateMod calculates the amount of water diverted according to the following Direct Solution Algorithm:

Diversion = Min (Capacity, Physically Available, Legally Available, Demand)

Where:

Capacity is self-explanatory.

Physically Available is the minimum of available flow plus immediate return flows at the diversion and all downstream nodes.

Legally Available is the water right.

Demand is self-explanatory.

Following is an example using the simple 5 node network presented in the following figure. As shown in the figure, Dem_1 returns to ISF_1. Similarly Dem_2 returns to Dem_1; Dem_ returns to ; and ISF_1 is located at –the bottom of the river system. For simplicity, this example uses average efficiency and assumes the capacity and legal availability are not limiting. Also, calculations are shown only at river nodes where a diversion or instream flows are located. Following are other key data:

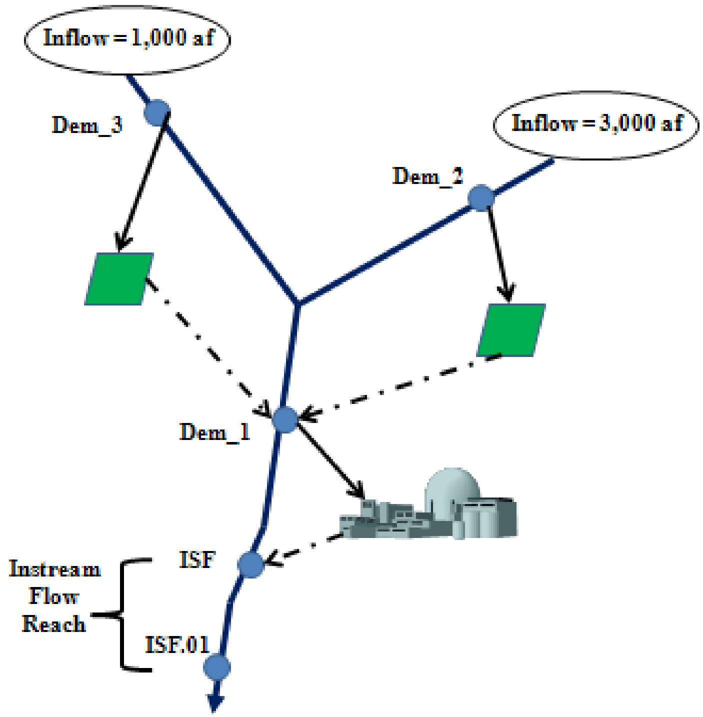

Table 7.8
Direct Solution Algorithm Data

Structure	Priority	Location	Demand	Average Efficiency (%)	Immediate Return (%)
Dem_1	1	Dem_1	2,000 ac-ft	20	40
Dem_2	2	Dem_2	3,000 ac-ft	50	50
Dem_3	3	Dem_3	1,000 ac-ft	50	50
ISF_1	4	ISF_1 to ISF.01	65 cfs	0 (1)	100 (1)

The following sequence of steps corresponds to the water right loop that occurs for each time step within StateMod. They demonstrate a key component of the Direct Allocation Algorithm that allows the diversion to be calculated directly as a function of the available flow and immediate return flows without having to iterate.

Step 1 Priority 1 M&I Diversion at Dem_1 wants 2000 AF

Because capacity and legal availability (water right) are assumed to not limit the diversion by Dem_1 is the minimum of the physically available water (available flow at Dem_1 and every other river node downstream) and the demand. Since the minimum available flow is 4,000 and the demand is 2,000, a diversion of 2,000 is allowed using the following formula:

Diversion = Min (Capacity, Physically Available, Legally Available, Demand)

Immediate return flows are then calculated and the available flow adjusted for the next priority as follows (Note as shown in Table 1 Dem_1 has an efficiency of 20% an immediate return percent of 40% and returns water to ISF_1).

Return = Divert * (1.00 - efficiency) * (immediate return)

Return = 2000 * (1.00 - .20) * (.40) = 640

Result Priority 1 (Dem_1) diverts 2000 AF and available flow is adjusted to include immediate return flows (see Available Flow-2)

River ID	Available Flow-1	Diversion (-)	Immediate Returns (+)	Available Flow-2
Dem_3	1000	0	0	1000
Dem_2	3000	0	0	3000
Dem_1	**4000 (1)**	2000	0	2000
ISF_1	4000	2000	640	2640

(1) Minimum of Available Flow plus Immediate Returns occurs at this river node

Step 2 Priority 2 Irrigation Diversion at Dem_2 wants 3000 AF

Recall that the capacity and legal availability (water right) are assumed to not limit. Therefore, the diversion by Dem_2 is the minimum of the physically available water (available flow) and the demand. Since the minimum available flow is 2,000 at Dem_1and the demand is 3,000 the diversion is limited to the available flow. This structure may benefit from immediate return flows as follows.

Divert = Min(Available Flow + Return)

Return = Divert * (1.00 - efficiency) * (immediate return)

Divert = Available Flow + Divert * (1.00-efficiency) * (immediate return)

Divert = Available Flow + Divert *.25

Divert = Available Flow / 0.75

Divert = 2000 / .75 = 2667

Immediate return flows are then calculated and the available flow adjusted for the next priority as follows (Note as shown in Table 1 Dem_2 has an efficiency of 50% an immediate return percent of 50% and returns water to River ID 60).

Return = Divert * (1.00 - efficiency) * (immediate return)

Return = 2667 * (1.00 - .50) * (.60) = 667

<u>Result Priority 2 diverts 2667 AF and available flow is adjusted to include immediate return flows (see Available Flow-2)</u>

River ID	Available Flow-1	Diversion (-)	Immediate Returns (+)	Available Flow-2
Dem_3	1000	0	0	1000
Dem_2	3000	2667	0	333
Dem_1	**2000 (1)**	2667	667	0
ISF_1	2640	2667	667	640

(1) Minimum of Available Flow plus Immediate Returns occurs at this river node

Step 3 Priority 3 Irrigation Diversion at Dem_3 wants 1000 AF

Recall the capacity and legal availability (water right) are assumed to not limit. Therefore, the diversion by Dem_1 is the minimum of the physically available water (available flow) and the demand. Since the minimum available flow is 0 at Dem_1 the diversion is zero. Note because the available flow is zero and this structure cannot benefit from any immediate return flows.

Result Priority 3 diverts 0 AF and available flow is the same (see Available Flow-2)

Note the available flow is 0 at Dem_1 that confirms the structure took the maximum possible without driving the river negative.

River ID	Available Flow-1	Diversion (-)	Immediate Returns (+)	Available Flow-2
Dem_3	1000	0	0	1000
Dem_2	333	0	0	333
Dem_1	**0 (4)**	0	0	0
ISF_1	640	0	0	640

(4) Minimum of Available Flow plus Immediate Returns occurs at this river node.

Step 4 Priority 4 Instream Flow Demand at ISF_1 wants 65 cfs (3898 AF)

Recall that the capacity and legal availability (water right) are assumed to not limit. Therefore, the diversion by ISF_1 is the minimum of the physically available water, available flow at ISF_1 and every other river node downstream and the demand. Since the minimum available flow is 640 and the demand is 3,898, a diversion of 640 is allowed using the following formula:

Diversion = Min (Capacity, Physically Available, Legally Available, Demand)

Result Priority 4 diverts 640 AF and available flow is adjusted to include immediate return flows (see Available Flow-2)

Note priority 4 diverted water while priority 3 did not. That occurs because of where the diversion is located versus where water is physically available.

River ID	Available Flow-1	Diversion (-)	Immediate Returns (+)	Available Flow-2
Dem_3	1000	0	0	1000

Dem_2	333	0	0	333
Dem_1	0	0	0	0
ISF_1	**640 (5)**	640	640	640

(5) Minimum of Available Flow plus Immediate Returns occurs at this river node.

In summary the Direct Solution Algorithm is as follows:

For every water right

1. Estimate the diversion using Available flow as a surrogate for as physically available flow using the following:

Diversion = Min (Capacity, Physically Available, Legally Available, Demand)

Where available flow is evaluated at every river node from the diversion downstream

2. If the diversion is not limited to available flow the diversion is known and goes to step 4.

3. If the diversion is limited to available flow, calculate physically available flow at every downstream node using the following:

Divert = min(Available Flow / (1.00- ((1.0-efficiency) * Immediate Return))

Where physical availability includes the location and the % of each immediate return flow to be known.

4. Calculate return flows, adjust available flow and go to next water right.

5. Go to Step 1 for next right.

Modified Direct Solution Algorithm

In order to allow StateMod to operate with a variable efficiency and soil moisture storage the Modified Direct Solution Algorithm was developed (Bennett, Ray R. December 2000). The following enhancements were required.

- StateMod must be provided a maximum efficiency value. This is implemented by setting the control file (*.ctl) variable *ieffmax* = 1 and providing maximum efficiency data for each structure for each year in the annual time series file (*.ipy). Note this file is formatted to be the same as the annual time series file used by the consumptive use model, StateCU, except annual irrigated acreage has been added to the end of the file, column 10.

- StateMod must be provided a structure's Consumptive Use Requirement (CUR). This was implemented by setting the control file (*.ctl) variable *itsfile* = 3 or 10. Note for non-agricultural water rights, the CUR is simply the consumptive, not total, demand.
- The Direct Solution Algorithm was revised as follows:

The Modified Direct Solution Algorithm is as follows:

For every water right:

1. Estimate the diversion using Available flow as a surrogate for physically available flow using the following:

Diversion = Min (Capacity, Physically Available, Legally Available, Demand)

Where available flow is evaluated at every river node from the diversion downstream

2. If the diversion is not limited by available flow the maximum diversion is known.

2a. Calculate consumptive use as the minimum (Diversion * maximum efficiency, CUR), soil moisture storage as diversion less consumptive use up to the maximum efficiency and soil moisture capacity, total return flow as the Diversion - consumptive use - soil moisture storage, immediate return flow as the total return flow * immediate return %, and adjusted available flow as available flow less the diversion plus any immediate returns.

2b. Go to Step 1 for next water right.

3. If the diversion is limited to available flow the maximum diversion could include benefit from immediate return flows.

3a. Calculate diversion at every downstream node using the following: (Note by using maximum efficiency the minimum diversion, maximum consumptive use and minimum return flow are calculated.

Divert = min(Available Flow / (1.00-max. efficiency) * (immediate return))

Where physical availability includes the location and the percent of each immediate return flow.

3b. Calculate consumptive use as the minimum (Diversion * maximum efficiency, IWR), soil moisture storage as zero, total return flow as the Diversion - consumptive use, immediate return flow as the total return flow * immediate return %, and adjusted available flow as available flow less the diversion plus any immediate returns.

3c. If the diversion is limited to available flow the maximum diversion has been calculated. Go to Step 1 for the next water right.

3d. If the diversion is not limited to the available flow, more water can be diverted but no additional CU can occur (Step 3b ensures the maximum consumptive use has occurred). Therefore the diversion can be increased as follows (Note the diversion is still limited to the water right, capacity and demand).

Divert = Divert + minimum (available flow / immediate return flow)

3e. Calculate consumptive use as the minimum (Diversion * maximum efficiency, CUR), soil moisture storage as diversion less consumptive use up to the maximum efficiency and soil moisture capacity, total return flow as the Diversion - consumptive use - soil moisture storage, immediate return flow as total return flow * immediate return %, and adjusted available flow as available flow less the diversion plus any immediate returns.

3f. Go to Step 1 for next water right.