IWFM Demand Calculator:
IDC-2015
revisions 38, 40

Theoretical Documentation
and
User's Manual

Central Valley Modeling Unit
Modeling Support Branch
Bay-Delta Office
January 2016

Table of Contents

List of Figures iv

List of Tables v

Summary of Features of the Root Zone Component Versions vi

1 Introduction 1

2 Computational Framework 5

3 Root Zone Component Version 4.0 10

3.1 Soil Moisture Routing 10

3.1.1 Precipitation, P 13

3.1.2 Direct Runoff, R_P 14

3.1.3 Applied Water, A_w 15

3.1.4 Initial Return Flow, $R_{f,ini}$ 16

3.1.5 Re-use of Return Flow, U 17

3.1.6 Net Return Flow, R_f 18

3.1.7 Generic Moisture Inflow, G 18

3.1.8 Drainage of Rice and Refuge Ponds, D_r 19

3.1.9 Deep Percolation, D 20

3.1.10 Evapotranspiration, ET 21

3.1.11 Change in Soil Moisture due to Change in Land Use Area, $\Delta\theta_a$ 23

3.1.12 Solution of the Root Zone Conservation Equation 24

3.2 Water Demand 25

3.2.1 Water Demand for Non-Ponded Crops 25

3.2.2 Water Demand for Ponded Crops 30

3.2.3 Evapotranspiration of Applied Water, ETaw 31

3.2.4 Effective Precipitation, ETp 33

3.2.5 Evapotranspiration due to Other Sources, ET_G 33

3.3 Example 1: Hypothetical Scenario 34

3.3.1 Zero Precipitation, Deep Percolation and Return Flow 35

3.3.2 Zero Deep Percolation and Return Flow 37

3.3.3 Zero Return Flow 39

3.3.4 Zero Return Flow and 1% Minimum Deep Percolation Fraction 40
3.3.5 15% Return Flow Fraction 41
3.3.6 Deficit Irrigation 42
3.3.7 Additional Comments on Test Cases 43
3.4 Example 2: A Real-World Application 46
3.4.1 Results and Discussion 51
4 Root Zone Component Version 4.1 60
4.1 Riparian Vegetation Access to Stream Flows 60
4.2 Root Water Uptake from Groundwater 62
5 Running IDC 65
5.1 Simulation Time Tracking 66
5.1.1 Length of Simulation Time Step 67
5.1.2 Time Step Format 67
5.1.3 Preparation of Time Series Data Input Files 69
5.2 Input and Output Data File Types 71
5.3 Input Files 73
5.3.1 IDC Main Input File 76
5.3.2 Element Configuration File 79
5.3.3 Nodal X-Y Coordinate File 81
5.3.4 Lake Elements Data File 83
5.3.5 Depth-to-Groundwater Data File 84
5.3.6 Precipitation File 87
5.3.7 Evapotranspiration File 90
5.3.8 Input Files for Root Zone Component Version 4.0 93
5.3.9 Input Files for Root Zone Component Version 4.1 186
5.4 Output Files 196
5.4.1 Output Files for Root Zone Component Version 4.0 197
5.4.2 Output Files for Root Zone Component Version 4.1 215
5.5 Budget Post-Processor 231
5.5.1 Budget Main Input File 233
5.6 Linking IDC to Other Models 238

5.6.1 Procedure Interfaces 239
5.6.2 Example Code That Links to IDC 253
6 References 255

List of Figures

Figure 1. Software components of IDC 8
Figure 2. Schematic representation of root zone flow processes simulated by IDC 13
Figure 3. Comparison of IDC results to CUP results for zero precipitation, deep percolation and return flow 36
Figure 4. Comparison of IDC results to CUP results for zero deep percolation and return flow 38
Figure 5. IDC results for zero return flow 40
Figure 6. IDC results for zero return flow with 1% minimum deep percolation requirement 41
Figure 7. IDC results for 15% return flow 42
Figure 8. IDC results for deficit irrigation scenario 43
Figure 9. Model area and the simulation grid for Example 2 47
Figure 10. DAUs in modeled area in Example 2 48
Figure 11. Soils map for the model area 49
Figure 12. Land-use types in the modeled area 50
Figure 13. Annual precipitation for each DAU 52
Figure 14. Seasonal irrigation water requirement versus saturated hydraulic conductivity for non-ponded crops at DAU 142 53
Figure 15. Seasonal irrigation water requirement versus saturated hydraulic conductivity for rice at DAU 163 for water year 2000 54
Figure 16. Seasonal irrigation water requirement versus pore size distribution index for non-ponded crops at DAU 142 55
Figure 17. Schematic representation of the root zone and root water uptake from groundwater 64
Figure 18. Schematic representation of the IDC input file structure 75
Figure 19. Example code demonstrating the linkage of IDC to another model 254

List of Tables

Table 1. Version numbers and simulation capabilities of each of the root zone components 10
Table 2. Summary of IDC results for the simulated scenarios (values on left are for the growing season, values in parantheses are for the entire calendar year). All values except IE are in mm. 44
Table 3. Comparison of IDC results for non-ponded crops to the values obtained from DPLA with K_{sat} values at cells with rice set to 0.01 micrometers/sec (all values are in ac-ft/ac; n/a = not applicable) 57
Table 4. Comparison of IDC results for rice to the values obtained from DPLA with K_{sat} values at cells with rice set to 0.01 micrometers/sec (all values are in ac-ft/ac; n/a = not applicable) 59
Table 5. List of allowable time step lengths in IDC simulations.....68
Table 6. Example for the representation of recycled time series data 71
Table 7. Examples of acceptable and unacceptable cases for the synchronization of time series data interval and the simulation time step 72
Table 8. File name extensions recognized by IDC 73

Summary of Features of the Root Zone Component Versions

IWFM Demand Calculator 2015 (IDC-2015) provides access to two different versions of the root zone flow computation schemes. For a given application, the user is supposed to choose one of these versions.

To aid the user in choosing the right component version, below is a summary of the simulation capabilities these root zone component versions offer.

Root Zone Component Version	Capabilities
4.0	• Simulation of non-ponded and ponded (rice and managed refuges) crops, urban lands, native and riparian vegetation at each element • Simulation of generic moisture (seepage from extra source of water, fog, etc.) • Ability to deliver water to an element, group of elements or a subregion to meet water demand • Ability to compute physical crop water demand dynamically based on crop, irrigation management, soil and atmospheric conditions or to pre-specify water demand to represent contractual demand
4.1	• All features listed for version 4.0 above • Simulation of riparian vegetation access to stream water to meet all or part of their evapotranspirative water demand • Simulation of root water uptake from groundwater

1 Introduction

In developed watersheds, the stresses on surface and subsurface water resources are generally created by groundwater pumping and stream flow diversions to satisfy agricultural and urban water requirements. The application of pumping and diversions to meet these requirements also affects the surface and subsurface water system through recharge of the aquifer and surface runoff back into the streams. The agricultural crop water requirement is a function of climate, soil and land surface physical properties as well as land use management practices which are spatially distributed and evolve in time. In almost all integrated hydrologic models pumping and diversions are specified as predefined stresses and are not included in the simulation as an integral and dynamic component of the hydrologic cycle that depend on other hydrologic components as well as water resources operational practices. On the other hand, in irrigation scheduling models that route the moisture through the root zone and compute the irrigation water requirement based on the moisture content, the root zone is completely detached from the rest of the hydrologic cycle. These models generally assume that the water demand is always met and they cannot simulate the effect of extreme hydrologic and operational conditions that may limit the pumping and diversions. Therefore, both integrated hydrologic models and irrigation scheduling models can be coupled to benefit from each other's features. This document discusses a new model developed by the California Department of Water Resources (CADWR) that estimates the irrigation water requirements and route the soil moisture through root zone in the context of integrated hydrologic modeling.

Integrated hydrologic modeling has received much attention in the last few decades. Models such as PRMS (Leavesley et al. 1983), MIKE SHE (DHI 1999), SWATMOD (Sophocleous et al. 1999), WEHY (Kavvas et al. 2004), GSFLOW (Markstrom et al. 2008), IWFM (Dogrul 2007), HydroGeoSphere (Therrien et al. 2009) and Modflow with Farm Process (Schmid et al. 2009) are developed to route the water through the components of the hydrologic cycle and to simulate the interactions between them. Integrated hydrologic models include the simulation of the land use based runoff processes and the plant consumptive use, and their effects on surface and subsurface flow dynamics. However, except for IWFM, Modflow with Farm Process and SWATMOD, they do not simulate agricultural and urban water demands and the conjunctive use of surface and subsurface water resources to meet these demands. Essentially, they are descriptive models; i.e. given all the stresses on the hydrologic system modeled, they describe where and how fast the water flows.

However, having to pre-specify the stresses such as pumping and stream diversions may pose difficulties in a modeling study. For instance, in the State of California pumping records are proprietary or not measured and often are unavailable. Therefore, for a historical or a calibration model run, the modeler is required to estimate the historical pumping rates to meet an externally computed demand. For instance, Williamson et al. (1989) used electric power records to estimate the historical groundwater pumping in the Central Valley of California. However, such approaches may introduce additional uncertainties to the simulation. On the other hand, in a projection model run where future hydrologic and water resources operational conditions are simulated, pre-specifying pumping and diversions is almost impossible. First, the agricultural and urban water requirements that pumping and

diversions are used to meet are not known until after the future conditions are actually simulated. Second, amount of pumping and diversions may be limited by physical (aquifer storage, stream flow capacity, etc.) and contractual limitations which will affect agricultural and urban water requirements, in turn affecting the flow dynamics. This suggests that pumping and diversions in a projection model run are dynamic and depend on other components of hydrologic cycle simulated. They cannot be pre-specified and can only be simulated as an integral part of the evolving hydrologic cycle, and irrigation and urban water requirements that depend on the cycle.

Another type of modeling tool, irrigation-scheduling-type models, treats the root zone component of the hydrologic cycle as detached from other components. Given the climatic, soil and crop properties, these models simulate the evolution of the soil moisture in the root zone and the agricultural water requirement that depends on the soil moisture content (Kincaid and Heerman 1974, Camp et al. 1988, Smith 1991, George et al. 2000, Orang et al. 2004, Snyder et al. 2004, Raes et al. 2009). Generally, these models include a complex representation of the flow dynamics in the root zone and solve a soil moisture balance equation. Some of these models can also be used in evaluating the effect of different farm management scenarios such as regulated deficit irrigation on crops and in computing leaching requirements (Tayfur et al. 1995, Corwin et al. 2007, Heng et al. 2009).

Because of the treatment of the root zone as a component disconnected from the rest of the hydrologic cycle, irrigation-scheduling-type models cannot address situations where applied water is different than the crop irrigation water requirement in a dynamic sense. Similar to the integrated hydrologic models, they require applied water to be pre-defined. The pre-defined applied water can be assumed equal to the crop irrigation requirement, it can

be pre-defined as being less than the irrigation requirement to simulate deficit irrigation conditions, or it can be defined to be greater than the irrigation requirement. However, it is not possible to simulate conditions where, throughout the simulation period, aquifer storage or stream flows are depleted such that the pre-defined applied water cannot be met. Another drawback of irrigation-scheduling-type models is that they cannot be calibrated or verified when they are used in regional scale applications. Since they are not connected to the stream network or the underlying aquifer system, it is generally not possible to verify the accuracy of the simulated deep percolation or the simulated surface runoff due to irrigation and precipitation.

In general, the two types of modeling approaches, integrated hydrologic and the irrigation-scheduling-type models, can benefit from each other's capabilities if they are coupled. Integrated hydrologic models need a root zone component that is developed in an irrigation-scheduling-type approach that responds to the hydrologic and farm operational conditions, and compute corresponding water demands. On the other hand, irrigation-scheduling-type models need to be connected to the rest of the hydrologic cycle through coupling with an integrated hydrologic model to receive feedback from the aquifer system and the stream network in terms of simulated pumping and diversions that are actually available.

CADWR has been developing and maintaining the Integrated Water Flow Model (IWFM), a surface-subsurface hydrologic model that couples the integrated hydrologic modeling approach with a root zone component that uses the irrigation-scheduling-type approach (CADWR 2009). Over the years, both IWFM as a whole and its root zone component have evolved to incorporate accurate simulation techniques and to address the

issues CADWR have been facing. The root zone simulation engine of IWFM is designed such that it can either be used as a stand-alone irrigation-scheduling-type model or can easily be linked to integrated hydrologic models other than IWFM.

The stand-alone root zone modeling tool is named as IWFM Demand Calculator (IDC). As a stand-alone modeling tool, IDC assumes that the applied water is equal to the computed irrigation water requirements. When IDC's underlying root zone simulation engine is linked to IWFM or any other integrated hydrologic model, applied water is defined as the sum of simulated pumping and stream diversions computed by the integrated hydrologic model. In this case, depending on the state of the aquifer and the stream flows, the applied water can be equal or less than the water demand computed by the root zone simulation engine. The deep percolation, surface runoff due to precipitation and irrigation return flow computed by the root zone simulation engine are passed to the integrated hydrologic model as stresses to the aquifer and the stream network.

This document describes the methods used in IDC (the stand-alone version of the root zone simulation engine) to solve the soil moisture balance in the root zone and to compute agricultural and urban water demands. However, this document should also serve as a guide for the simulation engine when linked to integrated hydrologic models since the methods as well as the input and output data files remain exactly the same.

2 Computational Framework

A computational grid is required when using IDC to compute irrigation water requirements and route moisture through the root zone. This computational grid can be a regular grid (such as a finite difference grid) or an irregular grid (e.g. a finite element grid).

However, IDC expects the computational grid to be defined in a manner similar to a finite element grid; i.e. cells and the node numbers that surround each cell should be listed along with the coordinates of the nodes (it should be noted that finite difference grids can easily be defined in this manner). Grid cells are grouped into subregions that are defined by the user. These subregions may represent different types of boundaries and scales (e.g. hydrologic regions, water districts, counties, regions where irrigation and water management data are collected, etc.) depending on the requirements of the IDC application. Although IDC requires a computational grid to be defined, it does not use the finite element or the finite difference approach to solve the conservation equation for the soil moisture in the root zone. The reasons for and benefits of using a computational grid are explained later in this section.

Each grid cell area is distributed between native and riparian vegetation, urban, rice, refuge (specifically wetland refuges for waterfowl) and user-specified number of non-ponded agricultural crop lands. Rice lands are further distributed between lands where rice residue is decomposed by flooding (flooded decomp), where it is decomposed without any flooding (non-flooded decomp) and where it is not decomposed at all. Refuges are divided into two groups of seasonal and permanent refuges. Rice and refuge lands are collectively referred to as ponded crop lands. Even though refuges are not agricultural crops, the refuge ponds are managed in a way that is similar to rice ponds, allowing the simulation methods for rice fields to be used for refuges as well. For this reason, refuges are included in the ponded-crop category in IDC. Non-ponded crops are agricultural crops that are not grown in standing water like rice. The number of non-ponded crops simulated in an IDC application is specified by the user. Therefore, in an IDC application where there are N number of non-ponded crops, the total number of land use types that are simulated at each grid cell will be

equal to N+8 (N for non-ponded crops, 5 for ponded crops, 1 for urban, 1 for native vegetation and 1 for riparian vegetation). Even though N+8 land use types are simulated, a grid cell can have the area of one or more land use types set to zero. This tells IDC that those land use types do not exist in that grid cell and the simulation of these land use types is skipped. IDC allows time series land use areas defined for each grid cell, so a particular land use type that does not exist in a grid cell in earlier times of the simulation period can exist in the same cell in the later times, or an existing land use type can disappear from a cell (this feature allows, for instance, to simulate the effects of agricultural lands and native vegetation areas being converted into urban lands).

IDC computes applied water demands for ponded and non-ponded crops at each grid cell under user-specified climatic and irrigation management settings. Urban water demand is computed based on user-specified population and per-capita water usage. Native and riparian vegetations are not irrigated; therefore applied water demands for these land use types are not computed.

For all land-use types precipitation as well as applied water, if any, is routed through the root zone. Any surface runoff due to precipitation and irrigation generated at each cell is routed to a subregion, to another grid cell or to outside the model area, depending on the choice of the user. Any surface runoff that is routed to a subregion or grid cell becomes part of the applied water in that subregion or cell.

IDC is written in Fortran 2003 using an object-oriented programming approach. It consists of i) input data files, ii) output data files, iii) the numerical engine that reads data from input files, computes applied water demands, routes water through the root zone and prints out the results to output files, and iv) a user interface that utilizes an ASCII text file

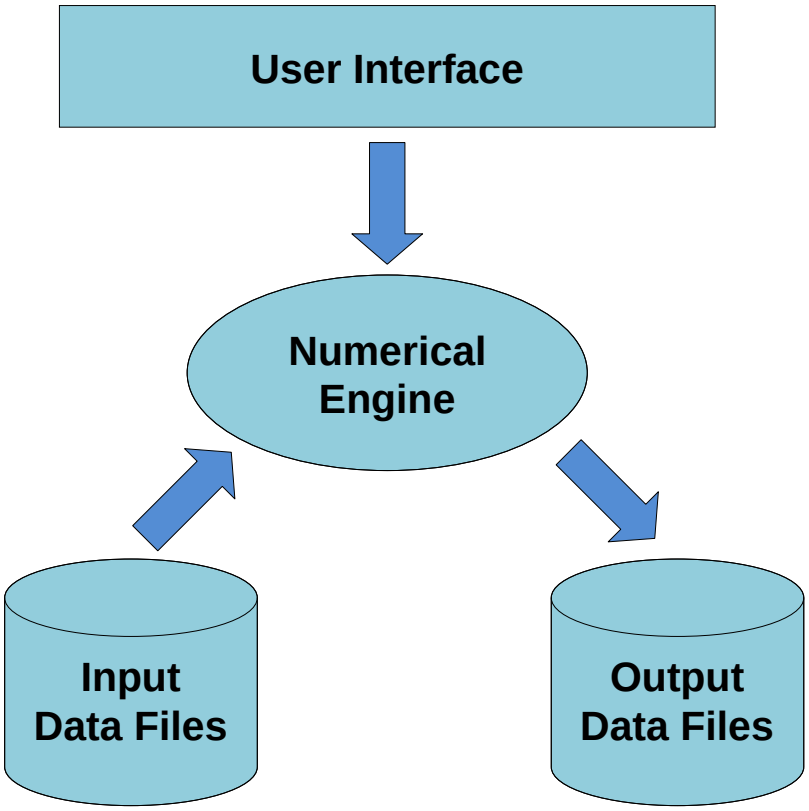


Figure 1. Software components of IDC

that allows the user to define input and output files and simulation control data for the numerical engine (Figure 1).

Although IDC does not use finite difference or finite element methods to solve the conservation equation in the root zone, being able to operate on a grid as well as its object-oriented design brings several advantages:

i. The computational grid allows better representation of spatially-distributed data such as potential evapotranspiration, precipitation, soil characteristics, etc.

ii. Being able to operate on computational grids allows IDC to easily couple with other numerical engines that operate on computational grids such as groundwater models.

iii. The object-oriented design allows easy re-compilation of the numerical engine into a dynamic link library (DLL) which allows easy coupling to other hydrologic, biological and environmental numerical engines such as those that comply with Open Modeling Interface (OpenMI) standards (Gregersen et al. 2007, Goodall et al. 2007).

iv. Easy coupling to numerical engines that simulate other components of the hydrologic cycle allows calibration of model parameters (e.g. soil hydraulic conductivity, soil and irrigation management parameters that play a role in the generation of surface runoff, etc.) through the use of widely available observation data (e.g. groundwater elevations and stream flows).

The methods used by IDC to compute water demand and route moisture through root zone at a regional level, and the design of the computational framework make IDC a unique tool.

IDC currently provides two different versions of root zone component with slightly different simulation features. Table 1 lists the simulation capabilities included with each version of the root zone components. It is expected that as the need for different simulation capabilities arises in the future, IDC will be extended to provide more versions of root zone components with the desired features. It should be noted that some of the features listed in Table 1 are available only when IDC is linked to an integrated hydrologic model such as IWFM (CADWR 2009).

Table 1. Version numbers and simulation capabilities of each of the root zone components

Version	Capabilities
4.0	• Flow routing and demand calculation at each grid cell • Simulation of ponded and non-ponded agricultural crops, urban lands, native and riparian vegetation • Explicit simulation of rice and refuge (i.e. ponded crops) operations • Simulation of generic soil moisture (seepage from extra source of water, fog, etc.) • Simulation of regulated deficit irrigation • Ability to specify water demands (i.e. contractual demands) instead of computing them dynamically • Explicit representation of effective precipitation and ETaw
4.1	• All capabilities of version 4.0 listed above • Simulation of riparian vegetation access to stream flows to meet ET requirements (applicable only when IDC is linked to an integrated hydrologic model such as IWFM) • Simulation of root water uptake from groundwater (applicable only when IDC is linked to an integrated hydrologic model such as IWFM)

In the following sections, flow routing and water demand calculations as well as the input and output data files in each version of root zone component will be explained.

3 Root Zone Component Version 4.0

3.1 Soil Moisture Routing

Precipitation is generally the natural source for the soil moisture in the root zone. Precipitation that falls on the ground surface infiltrates into the soil at a rate dictated by the type of ground cover, physical characteristics of the soil and the moisture that is already available in the soil. The portion of the precipitation that is in excess of the infiltration rate

generates a surface flow. In IDC, this surface flow is termed as *direct runoff*. Irrigation of agricultural lands and urban outdoors such as lawns and parks can also generate surface flows. Surface flows due to irrigation are termed as *return flows* in IDC. Part of the precipitation and irrigation evaporate before infiltrating into the soil. Infiltration due to precipitation and irrigation replenish the soil moisture in the root zone which is also depleted through plant root uptake for transpiration and additional evaporation from the top layers of the soil. The transpiration through the plants and evaporation from the land surface as well as the top layers of the soil are all simulated as a single *evapotranspiration* term in IDC. In general, moisture in the root zone can move in horizontal as well as the vertical directions. In IDC, it is assumed that the horizontal movement of the moisture is negligible compared to the vertical movement. Therefore only the flow of the moisture in the vertical direction is addressed. The moisture that leaves the root zone through its bottom boundary is termed as *deep percolation*.

IDC uses a physically-based approach to compute the flow terms mentioned above and to route the soil moisture through the root zone. For a particular land use type at a grid cell, the conservation equation for the soil moisture discretized in time is

$$\theta^{t+1}Z^{t+1} = \theta^{t}Z^{t} + \Delta t\left(P^{t+1} - R_P^{t+1} + A_w^{t+1} - R_f^{t+1} + G^{t+1}Z^{t+1} - D_r^{t+1} - D^{t+1} - ET^{t+1}\right) + \Delta\theta_a^{t+1} \quad (1)$$

and

$$\theta^{t+1} = \theta_P^{t+1} + \theta_{A_w}^{t+1} + \theta_G^{t+1} \quad (2)$$

$$\theta^{t} = \theta_P^{t} + \theta_{A_w}^{t} + \theta_G^{t} \quad (3)$$

$$R_f^{t+1} = R_{f,ini}^{t+1} - U^{t+1} \quad (4)$$

where

θ_P = soil moisture content due to precipitation (L/L),

θ_{A_w} = soil moisture content due to applied water (L/L),

θ_G = soil moisture content due to a generic, user-defined moisture inflow (L/L),

θ = total soil moisture content (L/L),

Z = rooting depth (L);

P = rate of precipitation (L/T),

R_P = direct runoff (L/T),

A_w = applied water, i.e. irrigation (L/T),

$R_{f,ini}$ = initial return flow (L/T),

U = re-used portion of the initial return flow (L/T),

R_f = net return flow after re-use takes place (L/T),

G = a generic, user-defined moisture inflow to represent any source of moisture other than precipitation or irrigation (L/L/T),

D_r = outflow due to the draining of rice and refuge ponds (L/T),

D = deep percolation (L/T),

ET = evapotranspiration (L/T),

$\Delta\theta_a$ = change in soil moisture due to change in land use area (L),

t = the time step index (dimensionless),

Δt = simulation time step length (T).

These flow terms are depicted in Figure 2. The soil moisture in equation (1) is represented as a summation of moisture due to precipitation and applied water in order to keep track of the contribution of applied water to crop evapotranspiration which is termed as ET of applied water (ETaw) by irrigation practitioners.

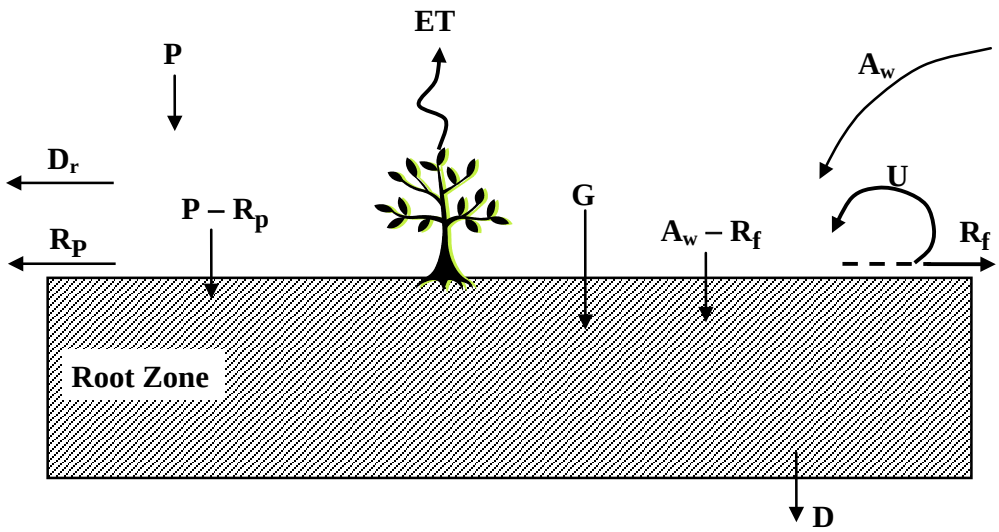


Figure 2. Schematic representation of root zone flow processes simulated by IDC

Equation (1) is solved for each land use type at each grid cell. In equation (1), θ^{t+1} and θ^t are generally less than the total porosity, θ_T, except for rice and refuge lands where ponding is possible. In these areas, it is assumed that the rooting depth is constant ($Z^{t+1} = Z^t$), that θ can be computed to be greater than θ_T, and the difference between the θ and θ_T represents the depth of the pond. Therefore, for rice and refuge areas, θZ is not truly the stored soil moisture in the root zone; it represents the sum of the soil moisture and the depth of the ponded water.

In the following sections, the simulation of the flow processes illustrated in Figure 2 will be discussed. For simplicity, time indices t and t+1 are dropped, when appropriate, from the flow notations in the rest of this document.

3.1.1 Precipitation, P

Precipitation is a user-input time series data for each grid cell.

3.1.2 Direct Runoff, R_P

IDC uses a modified version of SCS curve number (SCS-CN) method (USDA 2004) described by Schroeder at al. (1994):

$$R_p = \frac{1}{\Delta t}\frac{\left(P\Delta t - 0.2S\right)}{P\Delta t + 0.8S} \tag{5}$$

$$S = \begin{cases} S_{max}\left[1 - \dfrac{\theta^t - \dfrac{\theta_f}{2}}{\theta_T - \dfrac{\theta_f}{2}}\right] & \text{for } \theta^t > \dfrac{\theta_f}{2} \\ S_{max} & \text{for } \theta^t \le \dfrac{\theta_f}{2} \end{cases} \tag{6}$$

$$S_{max} = \frac{1000}{CN} - 10 \tag{7}$$

where CN is the curve number specified for a combination of land use type, soil type and management practice (dimensionless), S_{max} is the soil retention parameter for dry antecedent moisture conditions (L), S is the soil retention parameter at a given moisture content (L), θ_f is the field capacity (L/L) and θ_T is the total porosity (L/L). Equations (5) - (7) state that when root zone moisture is below half of field capacity direct runoff is at a minimum as computed by the SCS-CN method. As the soil moisture increases above half of field capacity the retention capacity of the soil decreases and direct runoff increases.

Equations (5) - (7) are not used for areas such as rice and refuge ponds, and impervious urban areas (parking lots, roof tops, etc) where the infiltration of precipitation is not possible. For these areas entire precipitation becomes direct runoff. For rice lands and seasonal refuges, the ponds are temporary. Therefore, equations (5) - (7) are used during the

period when ponds do not exist whereas the entire precipitation is converted into direct runoff during ponding season.

The total direct runoff that leaves a grid cell is the summation of direct runoff from all the agricultural and urban areas at the cell.

3.1.3 Applied Water, A_w

The main purpose of IDC is to compute dynamically the applied water for agricultural lands that will meet the crop evapotranspirative requirements in climatic and agricultural management settings defined by user-input parameters. The detailed discussion for the computation of applied water is given later in this document. Aside from being able to calculate it, IDC also allows the user to specify applied water. For instance, the amount of applied water may be dictated by contractual agreements rather than the crop evapotranspirative requirements. In a historical simulation, the amount of applied water may be available as historical records whereas in a projection run it will need to be computed. To be able to address such situations, IDC allows the user to specify some or all of the applied water amounts for each agricultural land use at each grid cell as time series input data. Applied water for any agricultural land use that is not assigned user specified values is computed by IDC.

In general, urban applied water to meet municipal and industrial water demand as well as demand for urban outdoors is calculated in terms of rate of water use per capita (e.g. CADWR 2005). For this reason, IDC does not attempt to compute the applied water for urban lands; instead, it is always a user-specified time series input data for urban lands at each grid cell. Urban areas are divided into pervious (lawns, parks and any unpaved outdoor areas) and impervious (roof tops, paved areas such as parking lots) areas. Applied water for

urban areas is divided into two parts through user-specified time series fractions to meet the urban outdoors water demand at pervious urban lands, and municipal and industrial water demand at impervious urban lands.

Native and riparian vegetation rely on precipitation alone (the contribution of groundwater to ET of riparian vegetation is not simulated in IDC). Therefore, applied water for these areas is always taken to be zero.

Applied water is computed by IDC or specified by the user for each agricultural and urban land use at each grid cell. It consists of two components: i) surface runoff (combination of return flows due to irrigation, direct runoff due to precipitation, and drainage from rice and refuge ponds) that is generated at an upstream grid cell and used as irrigation water at the grid cell in consideration, and ii) water acquired from other sources such as streams and groundwater (stream flows and groundwater system are not simulated by IDC since IDC only considers the domain that consists of the root zone and the land surface that is separated from the rest of the hydrologic cycle). Another component that can be used to meet the crop evapotranspirative requirements as well as the urban indoors and outdoors water requirements is the re-use of captured return flow, U, in a grid cell (see Figure 2). This component is not included in the definition of the applied water to properly satisfy the statement of conservation of mass. To make a distinction between applied water with and without the re-use component, the applied water without the re-use component, U, is termed as *prime applied water* (i.e. A_w as discussed in this section), and the applied water that includes U is termed as the *total applied water*.

3.1.4 Initial Return Flow, $R_{f,ini}$

Initial return flow is specified by the user as a time series fraction of the prime

applied water, A_w, for each non-ponded agricultural crop and urban land use area at each grid cell:

$$R_{f,ini} = A_w f_{R_{f,ini}} \tag{8}$$

where $f_{R_{f,ini}}$ is the initial return flow fraction (dimensionless). For urban lands, the initial return flow fraction only applies to the portion of the applied water that is allocated for the urban outdoors. The applied water that is allocated for urban indoors usage is assumed to become return flow completely.

For rice and refuge areas initial return flow is specified by the user as a time series unit flow rate. Generally, irrigation methods for rice require an additional amount of water to be applied to sustain flow-through type irrigation systems (Williams 2004) where water supplied to the top-most rice field sequentially floods each successive field as it makes its way to the lowermost basin. For refuges, additional water may be necessary to keep the water in the refuge ponds moving to control water quality and algae growth.

For areas with native and riparian vegetation, $R_{f,ini}$ is zero since applied water for these areas is zero.

3.1.5 Re-use of Return Flow, U

Re-use of return flow is specified by the user as a time series fraction of the prime applied water, A_w, for each non-ponded agricultural crop and urban land use area at each grid cell:

$$U = A_w f_U \tag{9}$$

where f_U is the re-used return flow fraction (dimensionless). Since re-used amount of return flow cannot be larger than the return flow itself, the re-use fraction must be less than or equal

to the initial return flow fraction.

Similar to initial return flow, re-use is specified as time series unit flow rate for rice and refuge areas.

U simulates the re-use that occurs in a single grid cell. In an IDC application, a single grid cell can be large enough to cover multiple farms. In this case, U represents the total return flow from upstream farms that is captured and re-used by the downstream farms in the same grid cell. Another type of re-use occurs when the return flow from a grid cell crosses the cell boundary and flows into a downstream grid cell where it is captured and re-used. This type of re-use is not included in the term U. Instead, as discussed earlier, it becomes part of the prime applied water, A_w, for the downstream grid cell.

3.1.6 Net Return Flow, R_f

As shown in equation (4), the net return flow, R_f, is the difference between the initial return flow, $R_{f,ini}$ and the re-used return flow, U. Substituting equations (8) and (9) into equation (4), R_f can also be represented as

$$R_f = A_w \left(f_{R_{f,ini}} - f_U \right) \tag{10}$$

Equation (10) is valid for non-ponded agricultural lands as well as urban areas. Equation (10) is not used for ponded crops since re-use and initial return flows are specified explicitly.

The total net return flow that leaves a grid cell is the summation of all return flows from all the agricultural and urban land areas at that cell.

3.1.7 Generic Moisture Inflow, G

Generic moisture inflow, G, is included in equation (1) to represent any moisture

inflow into the root zone due to a source other than precipitation or irrigation. It is a user-defined time-series data set specified for each computational grid cell. It is given as a unit rate of inflow per unit length of the rooting depth (L/L/T) of the land use type that is being considered. IDC multiplies G by the rooting depth and the length of the simulation time step to convert it into units of length.

It is expected that G will be set to zero in most IDC applications. However, it can be used in cases where the user has estimates of moisture inflow into the root zone from sources other than precipitation and irrigation. For instance, seepage through the levees into the islands of California's Sacramento-San Joaquin Delta can be represented through G. Another possibility to utilize G is to simulate the effects of fog on meeting the evapotranspirative crop demands.

3.1.8 Drainage of Rice and Refuge Ponds, D_r

Rice ponds and seasonal refuges are drained during certain periods of the year. Rice ponds are drained for harvesting at the end of the growing season. Some rice fields may be re-flooded to decompose the rice residue as well as to create habitat for wildlife. Before the growing season begins, these fields are drained again. Similarly, seasonal refuge ponds can be periodically drained to create space for other types of land usage such as farming during growing season. IDC allows the user to simulate such land management practices by requiring time series ponding depths for rice and refuge areas. Any time the ponding depth specified for a time step is less than that specified for the previous time step, IDC computes a unit rate of pond drainage as

$$D_r^{t+1} = \frac{P_D^t - P_D^{t+1}}{\Delta t} \geq 0 \qquad (11)$$

For land use types other than rice and refuges, pond drainage is equal to zero.

3.1.9 Deep Percolation, D

Deep percolation is the amount of vertical moisture flow that leaves the root zone through its lower boundary. IDC uses a one-dimensional physically-based routing approach to compute D:

$$D^{t+1} = K\left(\theta^{t+1} Z^{t+1}\right) \frac{dh\left(\theta^{t+1} Z^{t+1}\right)}{dz} \tag{12}$$

where K is the unsaturated hydraulic conductivity as a function of soil moisture (L/T), h is the pressure head (L), and z is the vertical distance measured from land surface (L). Assuming that the vertical head gradient is unity, using van Genuchten-Mualem equation (Mualem 1976, van Genuchten 1980) and assuming residual moisture content is negligible, equation (12) can be re-written as

$$D^{t+1} = D_{rdc}^{t+1} + K_s \left(\frac{\theta^{t+1}}{\theta_T}\right)^{1/2} \left\{1 - \left[1 - \left(\frac{\theta^{t+1}}{\theta_T}\right)^{1/m}\right]^m\right\}^2 \tag{13}$$

and

$$m = \frac{\lambda}{\lambda + 1} \tag{14}$$

$$D_{rdc}^{t+1} = \begin{cases} \theta^t \left(Z^t - Z^{t+1}\right) & \text{if } Z^t > Z^{t+1} \\ 0 & \text{otherwise} \end{cases} \tag{15}$$

where K_s is the saturated hydraulic conductivity (L/T) and λ is the pore size distribution index (dimensionless).

Equation (15) shows that when the rooting depth is decreasing, generally at the harvest time, any moisture that falls outside the rooting depth is converted into deep percolation. However, it should be noted that setting the rooting depth, Z, to zero outside of cropping season will cause incorrect results as IDC will assume that soil has zero storage capacity and will convert all precipitation to either deep percolation or direct runoff. Therefore, it is important to specify a non-zero rooting depth even outside the growing season to properly represent the moisture storage capacity of the soil. Alternatively, one can assume constant rooting depth throughout the entire simulation period. Preliminary tests have shown that although changing rooting depth has an impact on the flow terms as well as the computed water demands at short time periods that are on the order of a few days, over the entire cropping season its cumulative impact is small.

As an alternative to the van Genuchten-Mualem equation, IDC can use Campbell's approach (Campbell 1974) to represent the unsaturated hydraulic conductivity:

$$D^{t+1} = D_{rdc}^{t+1} + K_s \left(\frac{\theta^{t+1}}{\theta_T} \right)^{3+\frac{2}{\lambda}} \tag{16}$$

where the assumption of negligible residual moisture content is applied.

3.1.10 Evapotranspiration, ET

Calculations of ET are based on the potential ET, ET_{pot}, values specified by the user as time series data for each land use and grid cell combination. Although ET_{pot} values can be taken as the crop ET under standard conditions, ET_c, described by Allen et al. (1998), they can also be taken as the crop ET under non-standard conditions, ET_{cadj}, also described by Allen et al. (1998), to incorporate conditions such as non-uniform irrigation, low soil fertility, salt toxicity, pests, diseases, etc (except the case where the plants are water stressed because

of lack of sufficient water; this situation is simulated dynamically in IDC as discussed below).

IDC computes ET as a function of the soil moisture in the root zone:

$$ET^{t+1} = \begin{cases} ET_{pot}^{t+1} & \text{if} \quad \dfrac{\theta^{t+1} - \theta_{wp}}{\left(\dfrac{\theta_f - \theta_{wp}}{2}\right)} > 1 \\ \dfrac{\theta^{t+1} - \theta_{wp}}{\left(\dfrac{\theta_f - \theta_{wp}}{2}\right)} ET_{pot}^{t+1} & \text{if} \quad 0 \le \dfrac{\theta^{t+1} - \theta_{wp}}{\left(\dfrac{\theta_f - \theta_{wp}}{2}\right)} \le 1 \\ 0 & \text{if} \quad \dfrac{\theta^{t+1} - \theta_{wp}}{\left(\dfrac{\theta_f - \theta_{wp}}{2}\right)} < 0 \end{cases} \tag{17}$$

where θ_{wp} is the wilting point (L/L) and $\theta_f - \theta_{wp}$ is the total available water (TAW) (Allen et al. 1998). Equation (17) suggests that if the soil moisture at a given time step is greater than half of TAW, ET will be equal to ET_{pot}. If the soil moisture falls below half of TAW, plants will start experiencing water stress and ET will be less than ET_{pot}. Below wilting point, the ET rate will be zero. The method described by equation (17) is similar to the method described in Allen et al. (1998) to compute a non-standard crop ET under water stress conditions. In Allen et al. (1998), a water stress parameter, p, is defined for each crop which represents the soil moisture content below which the crop starts experiencing water stress. In equation (17), p is taken as 0.5 regardless of the plant type.

3.1.11 Change in Soil Moisture due to Change in Land Use Area, $\Delta\theta_a$

IDC allows the user to specify areas for each land use type at each grid cell as time series data. Equation (1) is solved and soil moisture is tracked for each land use type at each cell. Due to different crop characteristics and management practices for each land use, soil moisture will be different for different land use types. To satisfy the global conservation of mass at the modeled domain, it is necessary to keep track of the soil moisture that is exchanged between different land use types as the areas change through the simulation period. $\Delta\theta_a$ is the term that represents this exchange of soil moisture between different land use types.

As an example consider a total of n land use types defined for a grid cell with corresponding areas defined at time step t and t+1 as A_i^t and A_i^{t+1}, respectively, where i=1,…,n. For land use types whose areas decline or stay the same $\Delta\theta_a$ will be zero (volumetric soil moisture storage will be less for land use types whose areas decrease, but soil moisture depth will be the same for these land use types). On the other hand, land use types whose areas increase will adopt new soil moisture from land use types whose areas diminish. For a land use type j whose area increases by

$$A_j^e = A_j^{t+1} - A_j^t > 0 \tag{18}$$

the change in soil moisture due to area change, $\Delta\theta_{a,j}$, is computed as

$$\Delta\theta_{a,j} = \frac{A_j^t\theta_j^t Z_j^t + A_j^e \dfrac{\sum_i A_i^r \theta_i^t Z_i^t}{\sum_i A_i^r}}{A_j^{t+1}} - \theta_j^t Z_j^t \tag{19}$$

where A_i^r is the decrease in the area of land use i:

$$A_i^r = A_i^t - A_i^{t+1} > 0 \tag{20}$$

Equation (19) suggests that after adopting the soil moisture from land use types whose areas decrease, the new soil moisture computed for the land use j is uniformly distributed over the land use area.

In certain situations, the new soil moisture with the adopted moisture from reduced land use areas can be numerically greater than the total porosity. For instance such a case can occur when the area of a crop with short rooting depth extends into the area of a crop with much deeper rooting depth. In this case the new soil moisture is set to total porosity and the moisture above total porosity is converted into deep percolation.

3.1.12 Solution of the Root Zone Conservation Equation

Equation (1) is non-linear with respect to θ^{t+1}. IDC uses an iterative method that is a combination of bisection and Newton's methods (Gerald and Wheatley 1994) to solve equation (1). The iterative solution methodology starts and continues with Newton iterations until the estimate for the soil moisture goes above total porosity less 10% of the user-defined convergence tolerance for the iterative solver. At this point, bisection method is used as the iterative method. The reason for this switch between the two methods is that the gradient of the van Genuchten-Mualem equation near saturation becomes very large and this causes problems for Newton's method. Bisection method has slower convergence but is more robust; therefore it is preferred when soil moisture is close to or above saturation. The switch between Newton's and bisection methods occurs mostly for rice and refuge areas where soil moisture can be at or numerically above total porosity (representing the ponding conditions).

3.2 Water Demand

From a plants perspective, water demand (also referred to as the physical water demand in this document) is the amount of irrigation water to satisfy the crop's evapotranspirative requirement under a specified irrigation management setting that is not met by precipitation. From a water management perspective, it is the amount of irrigation water that needs to be delivered to farms dictated by contractual agreements. This amount may or may not be the same as the physical water demand of the crops.

IDC is designed to address both types of water demands under user-specified climatic and irrigation management settings in regional scale applications. The physical water demand is computed by utilizing the root zone conservation equation (1), whereas the contractual water demands are specified by the user. Physical water demand is calculated only for agricultural crops, refuges and urban lands; water demand is zero for native and riparian vegetation since they are not irrigated.

Below, the methods used by IDC to compute applied water demand for non-ponded and ponded (rice and refuge lands) land use areas are explained.

3.2.1 Water Demand for Non-Ponded Crops

IDC utilizes an irrigation-scheduling-type approach in computing the water demand for non-ponded crops. Each non-ponded crop at each grid cell is associated with a time series data of irrigation period flag, irrigation trigger minimum soil moisture, irrigation target soil moisture, minimum deep percolation requirement as a fraction of infiltrated applied water, return flow fraction and re-use fraction. IDC also requires the user to specify if the soil moisture at the beginning or at the end of a time step will be used to compute irrigation water demand. For a short simulation time step such as a day using the soil moisture at the

beginning of the time step is appropriate, whereas for a long time step such as a month, it is better to use the soil moisture at the end of the time step. The real-world analogy is that a farmer may check the soil moisture conditions in the morning and decide if the crops need irrigation, while he never bases his decision of irrigating over an entire month on the moisture conditions at the beginning of that month.

The irrigation period flag tells IDC when to compute irrigation water demand for a non-ponded crop. An irrigation period flag of 0 means that it is outside the cropping season and IDC will not compute the irrigation water demand, whereas 1 means that it is growing season and the irrigation water demand will be computed.

First, the water demand calculations in the case when the soil moisture at the beginning of a time step is used will be explained.

At the beginning of a time step, if irrigation period flag is 1, IDC checks if the soil moisture, $\theta^t Z^t$, is less than the irrigation trigger minimum soil moisture, $\theta_{min}^{t+1} Z^{t+1}$, where θ_{min}^{t+1} is represented in terms of the Total Available Water (TAW):

$$\theta_{min}^{t+1} = \theta_{wp} + f_{\theta min}^{t+1} TAW \tag{21}$$

$$TAW = \theta_f - \theta_{wp} \tag{22}$$

where $f_{\theta min}^{t+1}$ is a fraction of TAW specified as time series data by the user. θ_{min}^{t+1} is the soil moisture content that corresponds to the maximum allowable depletion (Allen et al. 1998). If $\theta^t Z^t$ is less than $\theta_{min}^{t+1} Z^{t+1}$, the irrigation amount to raise the soil moisture up to irrigation target moisture, $\theta_{trg}^{t+1} Z^{t+1}$ is computed by setting θ^{t+1} in equation (1) to θ_{trg}^{t+1} and re-writing it

for A_w (in IDC irrigation water demand is equivalent to the applied water since IDC assumes that water is available to meet the irrigation water demand at all times):

$$A_w^{t+1} = \begin{cases} \dfrac{\dfrac{\theta_{trg}^{t+1} Z^{t+1} - \theta^t Z^t - \Delta\theta_a^{t+1}}{\Delta t} - P^{t+1} + R_p^{t+1} - G^{t+1} Z^{t+1} + D_{trg}^{t+1} + ET_{trg}^{t+1}}{1 - \left(f_{R_{f,ini}}^{t+1} - f_U^{t+1} \right)} & \text{if} \quad \theta^t Z^t < \theta_{min}^{t+1} Z^{t+1} \\ 0 & \text{if} \quad \theta^t Z^t \geq \theta_{min}^{t+1} Z^{t+1} \end{cases} \tag{23}$$

Several points need to be highlighted for equation (23):

1. Pond drainage flow, D_r, is set to zero since equation (23) is written for non-ponded crops.
2. ET_{trg}^{t+1} and D_{trg}^{t+1} represent the ET and deep percolation rates, respectively, at the target soil moisture.
3. Equation (10) is substituted for return flow, R_f.

Equation (23) is the expression for the amount of applied water that will raise the soil moisture up to target soil moisture while taking into account the contribution of precipitation, irrigation efficiency measures $f_{R_{f,ini}}$ and f_U as well as the moisture depleting effects of deep percolation and ET.

By default, IDC uses field capacity as the target soil moisture. However, the user can optionally specify a fraction of the field capacity as the target soil moisture during irrigation to simulate the effects of deficit irrigation (Fereres and Soriano, 2007; Kirda, 2002). By setting the irrigation trigger minimum soil moisture and the irrigation target soil moisture to values that are lower than those for optimal irrigation, the user can simulate the deficit irrigation practices.

In the case where the soil moisture at the end of a time step is used for water demand calculations, IDC initially assumes that A_w^{t+1} is zero, and solves equation (1) for θ^{t+1}. If $\theta^{t+1}Z^{t+1}$ is less than $\theta_{min}^{t+1}Z^{t+1}$, there is irrigation water demand and IDC uses equation (23) to compute this demand.

It is common practice to apply additional irrigation water on the fields to flush the salts from the soil. To simulate this practice, IDC allows the user to specify an optional time-series minimum deep percolation factor for each non-ponded crop at each grid cell. The deep percolation factor is defined as a fraction of the infiltrated applied water:

$$D_{min} = f_D\left(A_w - R_f\right) \tag{24}$$

where D_{min} is the minimum deep percolation required (L/T) and f_D is the minimum deep percolation fraction (dimensionless). It should be noted that f_D is different than leaching fraction in that leaching fraction is defined for a set of irrigation events after which the soil salinity and water flow in the root zone reaches an equilibrium (Ayers and Westcot, 1985; Dudley et al., 2008) whereas f_D in IDC is valid only for the time step when the irrigation event takes place.

After water demand is computed using equation (23), IDC checks if deep percolation is greater than the minimum deep percolation, if f_D is supplied. If minimum deep percolation is not achieved, it computes a new water demand that will raise the soil moisture to the irrigation target soil moisture while generating minimum deep percolation. This is achieved by writing equation (24) for $A_w - R_f$, substituting it into equation (1), and solving the resulting non-linear equation for θ^{t+1}:

$$\theta^{t+1}Z^{t+1} = \theta^{t}Z^{t} + \Delta t\left[P^{t+1} - R_p^{t+1} + G^{t+1}Z^{t+1} - D_{min}^{t+1}\left(1 - \frac{1}{f_D^{t+1}}\right) - ET^{t+1}\right] + \Delta\theta_a^{t+1} \quad (25)$$

In writing equation (25), pond drainage, D_r, is set to zero since the equation is written for non-ponded crops only and ET^{t+1} is the ET rate at θ^{t+1}. It should also be noted that D_{min} is a function of θ^{t+1} in equation (25).

Equation (25) is solved for θ^{t+1} iteratively using Newton's method. Once the solution is obtained, the water demand is computed as

$$A_w^{t+1} = \frac{D_{min}^{t+1}}{f_D^{t+1}\left[1 - \left(f_{R_{f,ini}}^{t+1} - f_U^{t+1}\right)\right]} \quad (26)$$

where D_{min}^{t+1} is computed at θ^{t+1} that is obtained by solving equation (25).

Deep percolation has an upper limit that is equal in magnitude to the saturated hydraulic conductivity, K_s, of the soil (see equation (13)). Therefore, D_{min} is limited by K_s. If it is computed to be larger than K_s, it is adjusted down to K_s and the user-specified minimum deep percolation factor, f_D, is overridden.

Alternatively, IDC allows the user to specify water demand to address the contractual rather than the physical water demands. In this case, equations (23) and (26) are bypassed and user-specified water demands are used. However, it is likely that the specified water demands will be less than or greater than the physical water demands. In either case, IDC uses the specified values in equation (1) to route the moisture through the root zone. In the case that the specified demands are less than their physical counterparts, IDC will allow ET to fall below ET_{pot}, assuming that the target irrigation soil moisture is equal to the field

capacity. If they are greater than the physical demands, IDC computes increased soil moisture, deep percolation and return flow, again by the use of equation (1).

The inclusion of deep percolation in equation (23) shows that the water demand, among other factors, depends also on the soil type where the crops are planted. The same crop under the same management factors and for the same yield will require more water if it was planted on a sandy soil than it was planted on a clayey soil.

3.2.2 Water Demand for Ponded Crops

The water demand computations for ponded crops are driven by the pond depths specified by the user except during decomposition periods for rice lands where non-flooded decomposition practices are followed. For the periods when a non-zero ponding depth is specified, IDC computes the applied water demand that will completely saturate the soil and crate a pond with the specified depth after taking into account the contribution of precipitation in a user-specified crop management setting. First an initial estimate of water demand is computed by setting drainage flow and net return flow to zero, deep percolation to saturated hydraulic conductivity, ET to ET_{pot}, θ^{t+1} to total porosity plus the pond depth in equation (1) and rearranging the equation for A_w:

$$A_{w,ini}^{t+1} = \frac{\theta_T Z + P_D^{t+1} - \theta^t Z - \Delta\theta_a^{t+1}}{\Delta t} - P^{t+1} + R_p^{t+1} - G^{t+1} Z + K_s + ET_{pot}^{t+1} + D_r^{t+1} \quad > \quad 0 \quad (27)$$

where $A_{w,ini}$ is the initial estimate of the applied water demand (L/T) and P_D is the pond depth (L). As stated previously, IDC assumes constant rooting depth for ponded crops, therefore the time index for Z in equation (27) does not appear. There is water demand only if the result of equation (27) is greater than zero. As the second step, the drainage flow is computed using equation (11). Then, the final applied water demand is computed as

$$A_w^{t+1} = A_{w,ini}^{t+1} + R_{f,ini}^{t+1} - U^{t+1} \quad > \quad 0 \tag{28}$$

where, as mentioned earlier, $R_{f,ini}$ and U are specified as unit flow rates for rice lands and refuges.

Equations (27) and (28) are used for seasonal and permanent refuge areas as well as for rice lands where flooded decomposition practices are followed. For rice lands where non-flooded decomposition practices are followed, the same approach is used during growing season; during decomposition period user specified water application amounts are utilized.

As with non-ponded crops, if the user specifies water demand IDC bypasses its computation and substitutes the specified value into equation (1).

3.2.3 Evapotranspiration of Applied Water, ETaw

The portion of the crop evapotranspiration that is satisfied by irrigation water is referred to as the evapotranspiration of applied water (ETaw). The crop evapotranspiration can be satisfied by moisture storage already available in the soil, precipitation, applied water, and if available, other sources of moisture, G. Moisture storage is comprised of previous precipitation events and irrigation activities as well as moisture inflows from other sources. Therefore, one can view ETaw as having two components: one where the irrigation satisfies the crop ET requirement almost instantaneously (e.g. over a period of few minutes or hours), and one where a portion of the applied water is stored in the soil and satisfies the crop ET over an extended period of time (e.g. over a period of few days or weeks).

For proper prediction, IDC keeps track of the portion of soil moisture that is supplied by irrigation and effectively simulates both components of ETaw. After equation (1) is solved and all flow components are calculated, ETaw and the soil moisture storage due to irrigation are computed using the following set of expressions:

$$\alpha_{A_w} = \frac{\theta^t_{A_w} Z^t + \Delta t\left(A^{t+1}_w - R^{t+1}_f\right)}{\left(\theta^t_P + \theta^t_{A_w} + \theta^t_G\right)Z^t + \Delta t\left(P^{t+1} - R^{t+1} + A^{t+1}_w - R^{t+1}_f + G^{t+1}Z^{t+1}\right)} \tag{29}$$

$$ETaw^{t+1} = \alpha_{A_w} ET^{t+1} \tag{30}$$

$$\theta^{t+1}_{A_w} Z^{t+1} = \theta^t_{A_w} Z^t + \Delta t\left[A^{t+1}_w - R^{t+1}_f - \alpha_{A_w}\left(D^{t+1}_r + D^{t+1}\right) - ETaw^{t+1}\right] + \Delta\theta^{t+1}_{a,A_w} \tag{31}$$

where α_{A_w} is the ratio of stored applied water plus the infiltrated applied water to the total moisture storage plus total infiltration, and $\Delta\theta_{a,A_w}$ is the moisture storage due to irrigation that is acquired from adjacent land use areas because of change in land use area. Equations (29) - (31) suggest that all root zone flow components are proportioned between flow due to precipitation, flow due to applied water and flow due to other sources of moisture using the fraction defined in equation (29), which are used to compute the moisture storage due to irrigation.

α_{A_w} represents both the instantaneous and the long-term contributions of irrigation to ETaw and other flow terms. The part with $\Delta t\left(A^{t+1}_w - R^{t+1}_f\right)$ at the numerator represents the instantaneous contribution, whereas the part with $\theta^t_{A_w} Z^t$ represents its contribution that takes place over an extended period of time. Here, the term “instantaneous” refers to any event that takes place over a single simulation time step, Δt.

When irrigation period flag is 0 representing out-of-growing-season, ETaw is still computed to track θ_{A_w} (see equation (31)). This is because evapotranspiration continues to occur outside the irrigation period due to soil evaporation and transpiration from non-agricultural crops such as weeds.

3.2.4 Effective Precipitation, ETp

Effective precipitation, ETp, is the portion of precipitation that is available to meet crop evapotranspiration. It does not include direct runoff, deep percolation or evaporation before the crop can use it (USDA 1997). Similar to ETaw, ETp represents the instantaneous contribution of precipitation to satisfy the crop evapotranspiration as well as its contribution over an extended period of time. IDC uses the following expressions to compute ETp:

$$\alpha_P = \frac{\theta_P^t Z^t + \Delta t\left(P^{t+1} - R^{t+1}\right)}{\left(\theta_P^t + \theta_{A_w}^t + \theta_G^t\right)Z^t + \Delta t\left(P^{t+1} - R^{t+1} + A_w^{t+1} - R_f^{t+1} + G^{t+1}Z^{t+1}\right)} \tag{32}$$

$$ETp^{t+1} = \alpha_P ET^{t+1} \tag{33}$$

$$\theta_P^{t+1} Z^{t+1} = \theta_P^t Z^t + \Delta t\left[P^{t+1} - R^{t+1} - \alpha_P\left(D_r^{t+1} + D^{t+1}\right) - ETp^{t+1}\right] + \Delta\theta_{a,P}^{t+1} \tag{34}$$

where α_P is the ratio of stored precipitation plus the infiltration of precipitation to the total moisture storage plus the total infiltration, and $\Delta\theta_{a,P}$ is the moisture storage due to precipitation that is acquired from adjacent land use areas because of change in land use area.

3.2.5 Evapotranspiration due to Other Sources, ET_G

ET_G is the portion of the generic, user-defined source of moisture that is available to meet the evapotranspirative demand. Similar to ETaw and ETp, it represents the instantaneous contribution of the generic source of moisture to satisfy the crop evapotranspiration as well as its contribution over an extended period of time. IDC uses the following set of expressions to compute ET_G:

$$\alpha_G = \frac{\theta_G^t Z^t + \Delta t\left(G^{t+1}Z^{t+1}\right)}{\left(\theta_P^t + \theta_{A_w}^t + \theta_G^t\right)Z^t + \Delta t\left(P^{t+1} - R^{t+1} + A_w^{t+1} - R_f^{t+1} + G^{t+1}Z^{t+1}\right)} \tag{35}$$

$$ET_G^{t+1} = \alpha_G ET^{t+1} \tag{36}$$

$$\theta_G^{t+1}Z^{t+1} = \theta_G^t Z^t + \Delta t\left[G^{t+1}Z^{t+1} - \alpha_G\left(D_r^{t+1} + D^{t+1}\right) - ET_G^{t+1}\right] + \Delta\theta_{a,G}^{t+1} \tag{37}$$

where α_G is the ratio of stored moisture due to generic source plus the infiltration of the generic moisture to the total moisture storage plus the total infiltration, and $\Delta\theta_{a,G}$ is the moisture storage due to the generic moisture source that is acquired from adjacent land use areas because of change in land use area.

3.3 Example 1: Hypothetical Scenario

To test and analyze its results, IDC was run for a hypothetical case where tomatoes were the irrigated crop. Additionally, to test the irrigation scheduling logic built into IDC, it was compared, when applicable, to the CUP model developed jointly by DWR and UC Davis (Orang et al. 2004). CUP is a graphical user interface driven spreadsheet application that was developed to improve the dissemination of crop evapotranspiration (ET_c) information to California growers and water purveyors. The program uses monthly means of solar radiation, maximum and minimum temperature, dew point temperature, wind speed, and daily rainfall data to compute and apply ET_c values on a daily basis to determine crop water requirements.

The testing and analysis of IDC results were performed in several stages. The first stage included a very simple test case with minimum amount of IDC features included. In

each consecutive stage another feature of IDC was included in the test and the effects of the feature on the results were analyzed.

For this example, tomatoes were chosen as the crop for which irrigation water requirements were calculated from January 1, 1996 to December 31, 1996. The growing season for tomatoes was April 1 to August 31. The generic source of moisture was set to zero. For a specified set of weather data, CUP computed daily ET_c values that were input into IDC. Available water holding capacity (the difference between field capacity and wilting point) was 0.14 mm/mm, the rooting depth was set to 1524 mm and the maximum allowable soil moisture depletion was set to 50% of the field capacity. Using soil properties and crop specific information, CUP computed yield threshold depletion and the corresponding allowable moisture depletion (Snyder et al. 2004). The moisture content that corresponded to the allowable soil moisture depletion computed by CUP was input as the irrigation trigger moisture content into IDC. In IDC, the wilting point, field capacity, total porosity and pore size distribution index are taken to be 0.000 mm/mm, 0.270 mm/mm, 0.463 mm/mm and 0.418, respectively. These values were taken from data published by Rawls et al. (1982) for a loam soil. The initial soil moisture content was set equal to field capacity. It was also assumed in IDC that 50% of the initial soil moisture was due to precipitation.

3.3.1 Zero Precipitation, Deep Percolation and Return Flow

CUP computes runoff due to precipitation differently than IDC. It also doesn't incorporate deep percolation and agricultural return flow into the computation of applied water. To simulate the similar processes, the precipitation in both programs, and saturated hydraulic conductivity and return flow factor in IDC were all set to zero. Figure 3 shows a

comparison of IDC and CUP results for this case. In Figure 3, FC is the field capacity, SMmin is the irrigation trigger minimum soil moisture computed by CUP and used as input to IDC, AW_IDC is the applied water computed by IDC, AW_CUP is the applied water computed by CUP, SM_IDC is the soil moisture computed by IDC, SM_CUP is the soil moisture computed by CUP, and ET_c is the crop ET that is computed by CUP and used as input to IDC.

In both models, initial soil moisture is at field capacity. Until April 1, ET_c for bare soil and non-agricultural plants deplete the soil moisture below the irrigation trigger minimum soil moisture. However, since growing season does not start until April 1, irrigation is not triggered. On April 1, when the growing season starts, the first irrigation

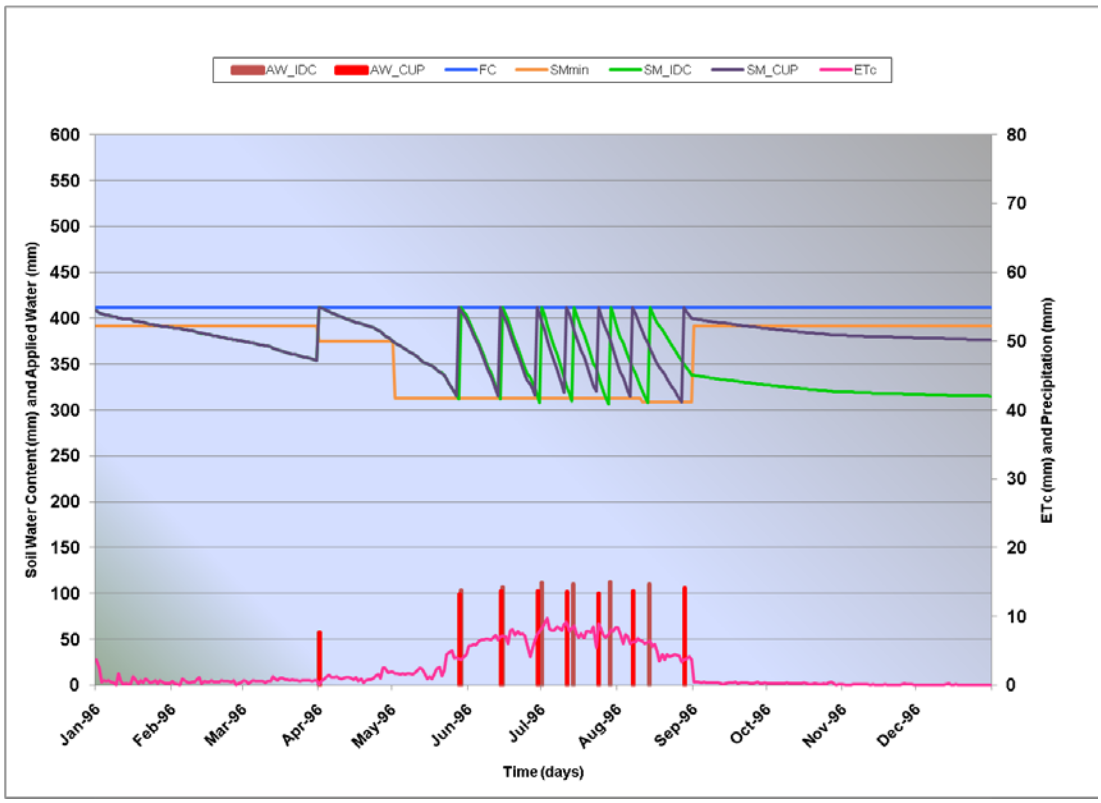


Figure 3. Comparison of IDC results to CUP results for zero precipitation, deep percolation and return flow

event is triggered and both models raise the soil moisture up to field capacity. Soil moisture and the magnitude of applied water are almost exactly the same until the second irrigation event towards the end of May. Here, a difference between IDC and CUP becomes apparent. The second irrigation event occurs on May 28 for CUP and on May 29 for IDC. At the beginning of May 28 both models have soil moisture that is above the irrigation trigger minimum soil moisture. CUP predicts that soil moisture at the end of the day will be less than the minimum moisture and initiates an irrigation event. IDC, on the other hand, initiates an irrigation event only based on the soil moisture at the beginning of the day. At the begging of May 29, the soil moisture is less than the minimum moisture in IDC and this is when IDC initiates an irrigation event. The effect of this difference between the two models in deciding when to irrigate accumulates throughout the growing season until the simulated soil moistures are visibly different. In fact, CUP initiates a total of 8 irrigation events that amounts to 774 mm of applied water throughout the growing season whereas IDC initiates 7 events that amounts to 712 mm.

Although there are some differences between IDC and CUP results, in general, this comparison shows that the irrigation scheduling logic built into IDC works properly. IDC allows the depletion of soil moisture until it becomes less than the irrigation trigger moisture. This is when it initiates an irrigation event to raise the moisture up to the target moisture level (field capacity, in this case).

3.3.2 Zero Deep Percolation and Return Flow

At this stage of testing IDC, daily precipitation data for calendar year 1996 was used. With the inclusion of this data, CUP computed a new set of ET_c and irrigation trigger minimum soil moisture which were used as input to IDC. The results for this stage are

shown in Figure 4.

In this stage, another difference between IDC and CUP is shown. CUP never allows the soil moisture to go above field capacity; the infiltration of precipitation is adjusted so that soil moisture stays below or at the field capacity. IDC uses SCS curve number method (USDA 2004) to compute the direct runoff and, consequently, infiltration from precipitation (a curve number of 82 was used for this example). It also allows soil moisture to go above field capacity. This is because past CADWR experiences in coupled root zone, groundwater and stream flow modeling showed that forcing the soil moisture to be at or below field capacity at every time step required increasing direct runoff or deep percolation. This approach had adverse effects on the timing of recharge into groundwater and surface runoff

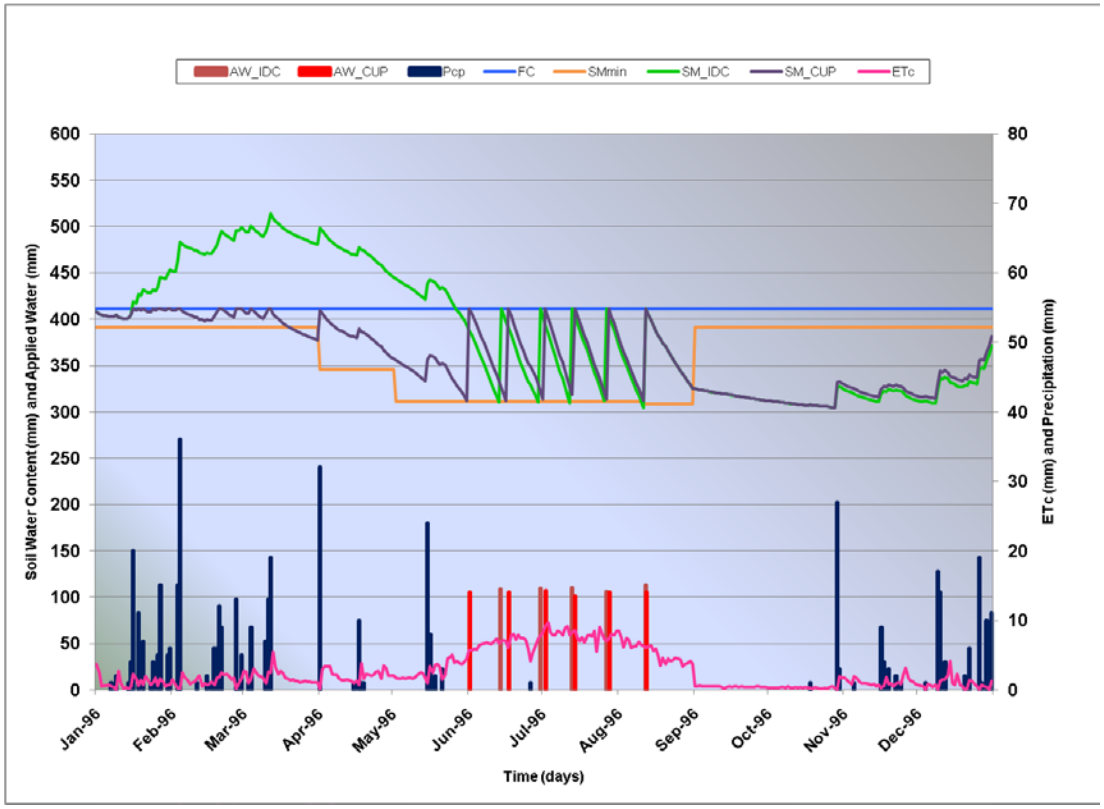


Figure 4. Comparison of IDC results to CUP results for zero deep percolation and return flow

into the streams. Furthermore, it has been observed in the field that considerable root zone drainage can occur beyond three days (Ritchie, 1981) suggesting that the soil moisture stays above field capacity for as long as the drainage continues.

Figure 4 shows that the soil moisture in IDC rises above field capacity with the winter rains whereas CUP limits it with field capacity by decreasing the infiltration of precipitation. For the entire year, IDC and CUP generate 69 mm and 141 mm of direct runoff, respectively, out of 465 mm of precipitation. Although, with different values for curve number, the direct runoff can be changed in IDC, this example shows the effect of allowing the soil moisture to rise above field capacity. With the higher moisture content at the beginning of the growing season, IDC does not initiate an irrigation until June 14, whereas CUP initiates the first irrigation on June 1. For the entire season, the application water for IDC and CUP are 547 mm and 628 mm, respectively.

3.3.3 Zero Return Flow

At this stage of testing, hydraulic conductivity of the loam soil was set to 1.32 cm/hour (Rawls et al. 1982) to simulate the deep percolation from the root zone. Since deep percolation is not simulated in CUP, the IDC results were compared to the IDC results from previous stage.

Figure 5 shows the results for this test case. The annual deep percolation is 135 mm. When compared to Figure 4, it can be seen that the soil moisture increase during the winter months is less due to the moisture depleting effects of deep percolation.

Inclusion of the deep percolation in the simulation also decreases the direct runoff from precipitation; 57 mm annually in this case versus 69 mm with zero deep percolation. This result is expected since depleting the soil moisture through deep percolation leads to

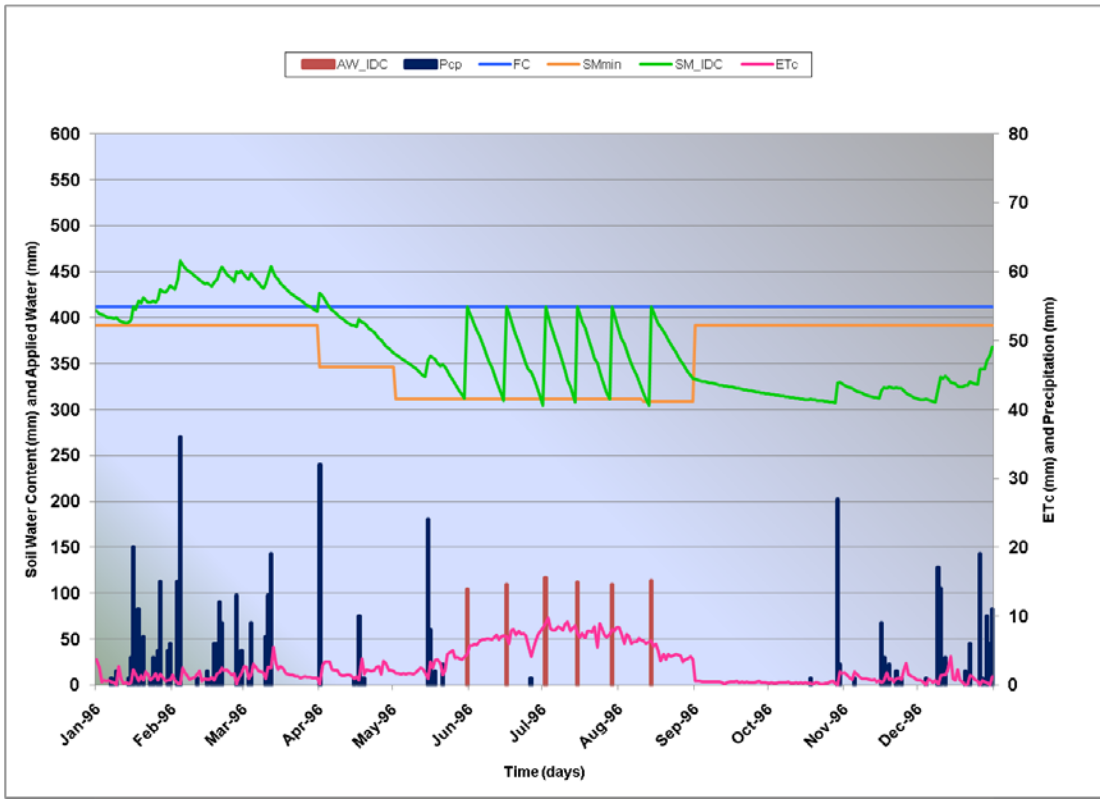


Figure 5. IDC results for zero return flow

increased empty storage to be filled by precipitation.

The annual applied water in this case is 666 mm compared to 547 mm with no deep percolation. This result is also in line with expectations that increasing the deep percolation should also increase the amount of applied water to achieve the same crop yield. In this case, when raising the moisture to field capacity, applied water not only counter-balances the moisture depleting effect of evapotranspiration but also that of deep percolation.

3.3.4 Zero Return Flow and 1% Minimum Deep Percolation Fraction

In this stage, a minimum deep percolation of 1% of infiltrated applied water is imposed. Figure 6 shows that every time an irrigation event is triggered, the soil moisture is raised above field capacity to a moisture that will create a deep percolation that is equal to

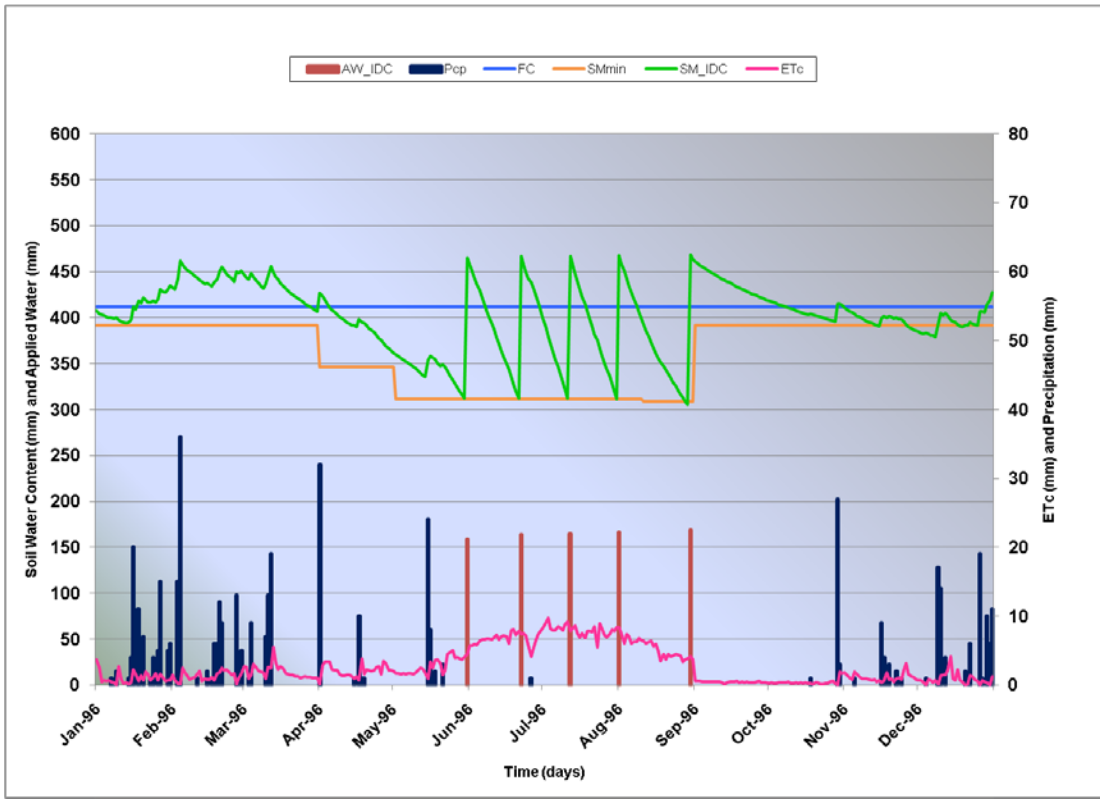


Figure 6. IDC results for zero return flow with 1% minimum deep percolation requirement

1% of the infiltrated applied water on that day. Since the deep percolation continues beyond the day of the irrigation, the total deep percolation from irrigation is larger than 1%. During the growing season, the total deep percolation amounts to 70 mm with 822 mm of applied water. Assuming that the deep percolation is entirely due to irrigation during the growing season, this leads to a leaching fraction of 9%.

3.3.5 15% Return Flow Fraction

In this case, the minimum deep percolation fraction was set to zero but the return flow fraction was set to 15% of applied water. The results for this case are shown in Figure 7. When compared to Figure 5 of section 3.3.3 (zero return flow with zero minimum deep percolation fraction), it can be seen that the only difference is in the amount of applied water.

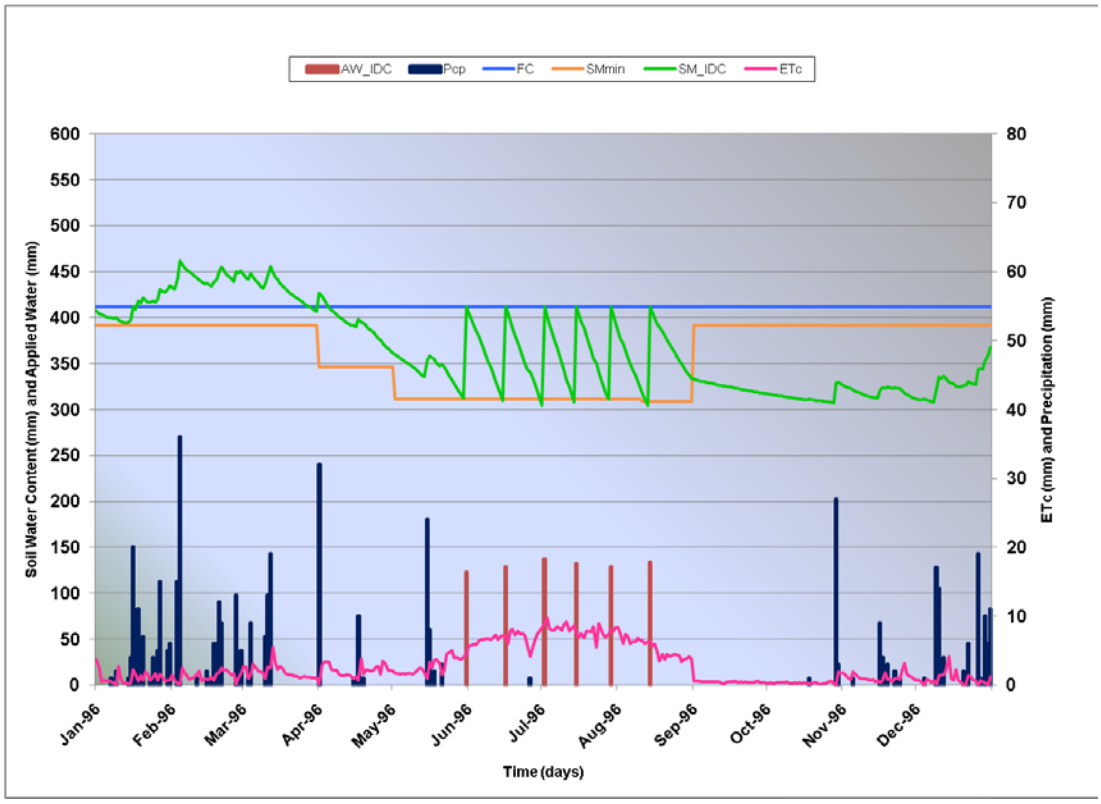


Figure 7. IDC results for 15% return flow

The total applied water in this case was 783 mm compared to 666 mm in the case with zero return flow and minimum deep percolation fraction (see section 3.3.3). The return flow amount was 117 mm, equal to the difference between the applied water in two test cases. The return flow is taken out of the total applied water and it does not affect the soil moisture dynamics.

3.3.6 Deficit Irrigation

As a final test case, deficit irrigation conditions were simulated by setting the irrigation target moisture to 60% of field capacity and the irrigation trigger minimum soil moisture to 50% of those used in previous test case (see section 3.3.5). The results for this case are shown in Figure 8. SMtarget and ET in Figure 8 represent the irrigation target soil

moisture and the actual ET, respectively. Deficit irrigation is generally recommended when the losses due to the decrease in the crop yield because of unmet crop ET is surpassed by the gains fromconserving irrigation water (Kirda, 2002). In this test case, the total applied water and crop ET were 594 mm and 718 mm, respectively, compared to 783 mm and 764 mm, respectively, in the non-deficit irrigation scenario simulated in section 3.3.5. These results show that a 24% reduction in applied water only caused a 6% reduction in the crop ET.

3.3.7 Additional Comments on Test Cases

Some of the important seasonal (values on the left) and annual (values in parentheses) flow terms from each simulated scenario are listed in Table 2. The scenario simulated in section 3.3.1 (zero precipitation, deep percolation and return flow) is not included in the table

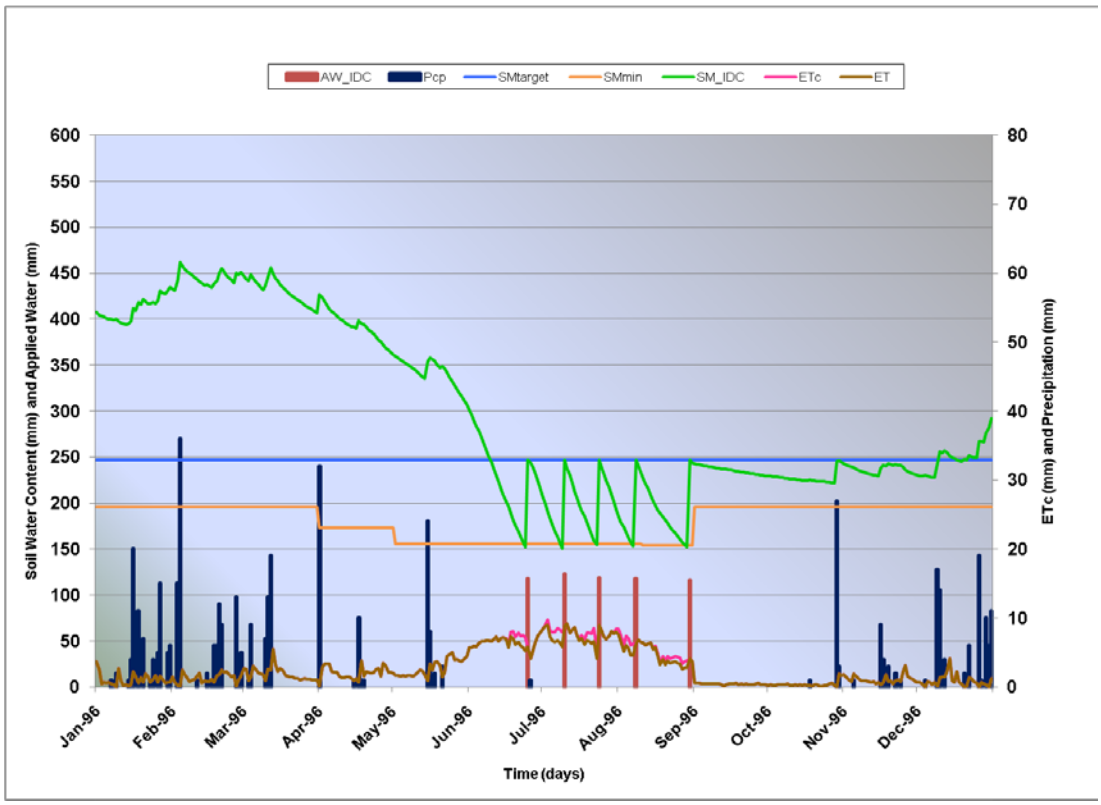


Figure 8. IDC results for deficit irrigation scenario

since the crop ET is different than the other scenarios and it would be difficult to make meaningful comparisons with other scenarios. In Table 2, AW is the applied water, ET is the actual ET, Rp is the direct runoff, Rf is the net return flow, D is the deep percolation, ETaw is the ET of applied water, ETp is the effective precipitation and IE is the irrigation efficiency expressed as ETaw divided by AW.

The following are several comments and conclusions based on the values listed in Table 2:

1. Deep percolation has a direct impact on the irrigation requirement, higher the deep percolation more applied water is needed to meet the crop ET (see AW values for scenarios simulated in sections 3.3.2, 3.3.3 and 3.3.4). However, deep percolation and applied water are not linearly related since a portion of the applied water is stored in the soil.
2. Direct runoff from precipitation decreases as deep percolation increases (see Rp values for sections 3.3.2 and 3.3.3). This is because deep percolation depletes the soil moisture storage allowing more precipitation to infiltrate. However, as more water is

Table 2. Summary of IDC results for the simulated scenarios (values on left are for the growing season, values in parantheses are for the entire calendar year). All values except IE are in mm.

	Scenario				
	5.2	**5.3**	**5.4**	**5.5**	**5.6**
Flow Term	**D=0;Rf=0**	**Rf=0**	**Rf=0;Dmin=1%**	**Rf=15%**	**Deficit Irrig.**
AW	546 (546)	666 (666)	822 (822)	783 (783)	594 (594)
ET	764 (983)	764 (983)	764 (983)	764 (983)	718 (936)
Rp	21 (69)	16 (57)	16 (62)	16 (57)	16 (53)
Rf	0 (0)	0 (0)	0 (0)	117 (117)	89 (89)
D	0 (0)	43 (135)	69 (226)	43 (135)	19 (100)
ETaw	428 (428)	475 (475)	484 (484)	475 (475)	397 (397)
ETp	336 (336)	289 (289)	280 (280)	289 (289)	321 (321)
IE	78%	71%	59%	61%	67%

applied to increase the soil moisture above field capacity, increasing the deep percolation for leaching of salts, higher values of direct runoff are observed due to soil moisture being above field capacity at the end of growing season (see Figure 6 and annual Rp values for sections 3.3.3 and 3.3.4).

3. Return flow affects the irrigation requirement but not the ET, deep percolation, ETaw and ETp (see relevant flow terms for sections 3.3.3 and 3.3.5). As expected, increasing return flow decreases irrigation efficiency.
4. Comparing IE values for sections 3.3.3 and 3.3.4, it can be seen that applying more irrigation water for the purposes of leaching decreases the irrigation efficiency. However, an alternative definition of irrigation efficiency includes not only ETaw but also the losses if they are beneficial such as deep percolation for leaching (Burt et al., 1997). Although beneficial deep percolation cannot immediately be quantified through IDC output values, IE would be higher for section 3.3.4 when the alternative definition of the irrigation efficiency is considered. As a rough estimate, it can be assumed that the difference between the annual deep percolation values from sections 3.3.3 and 3.3.4 is the beneficial deep percolation triggered by additional applied water. Then the IE expressed by Burt et al. (1997) can be computed as

$$\mathrm{IE} = \frac{\mathrm{ETaw} + \mathrm{D}_{\mathrm{beneficial}}}{\mathrm{AW}} = \frac{484 + 226 - 135}{822} \times 100 = 70\% \qquad (38)$$

5. Deficit irrigation is one way of increasing the irrigation efficiency (Kirda, 2002). Table 2 shows a 6% increase in the IE (see IE values for scenarios 3.3.5 and 3.3.6) when a deficit irrigation scenario is simulated.
6. IDC uses the ratio of the soil moisture due to irrigation to the total soil moisture storage in computing the ETaw (see equation (30)) and hence the IE. IDC allows the

user to input initial soil moisture content due to irrigation and precipitation. The ETaw values at the early stages of the simulation period are largely impacted by the user-defined initial proportioning of the moisture between precipitation and irrigation. Therefore, for a modeling study that addresses a short simulation period such as this example, IE values will be affected by the initial soil moisture estimates. Since the true portioning of the moisture between irrigation and precipitation is hard to estimate, it is advisable to include a "spin-up" period of a few years in IDC runs to achieve a more realistic mixture of stored moisture due to precipitation and applied water. This spin-up period will minimize the adverse effects of incorrect estimates of initial proportioning of the soil moisture storage on the IE calculations.

3.4 Example 2: A Real-World Application

For this example IDC was used to simulate the irrigation water requirements and root zone flow terms over a period of four water years (October 1, 1997 to September 30, 2001) at a section of California's Central Valley (Figure 9) using field data as input. The reason for the selection of this area was that another project, CalSim 3.0 hydrology development, also addressed the same area. CalSim is the CADWR's model used to simulate California State Water Project (SWP) and the Central Valley Project (CVP) operations. An earlier version of IDC was used during the CalSim 3.0 project so a large portion of the input data for this example was already developed. Furthermore, the modeled area intersected with seven Detailed Analysis Units (DAUs) (Figure 10). DAUs are the smallest study areas used by CADWR for analyses of water demand and supply, generally defined by hydrologic features or boundaries of organized water service agencies. CADWR has collected and developed

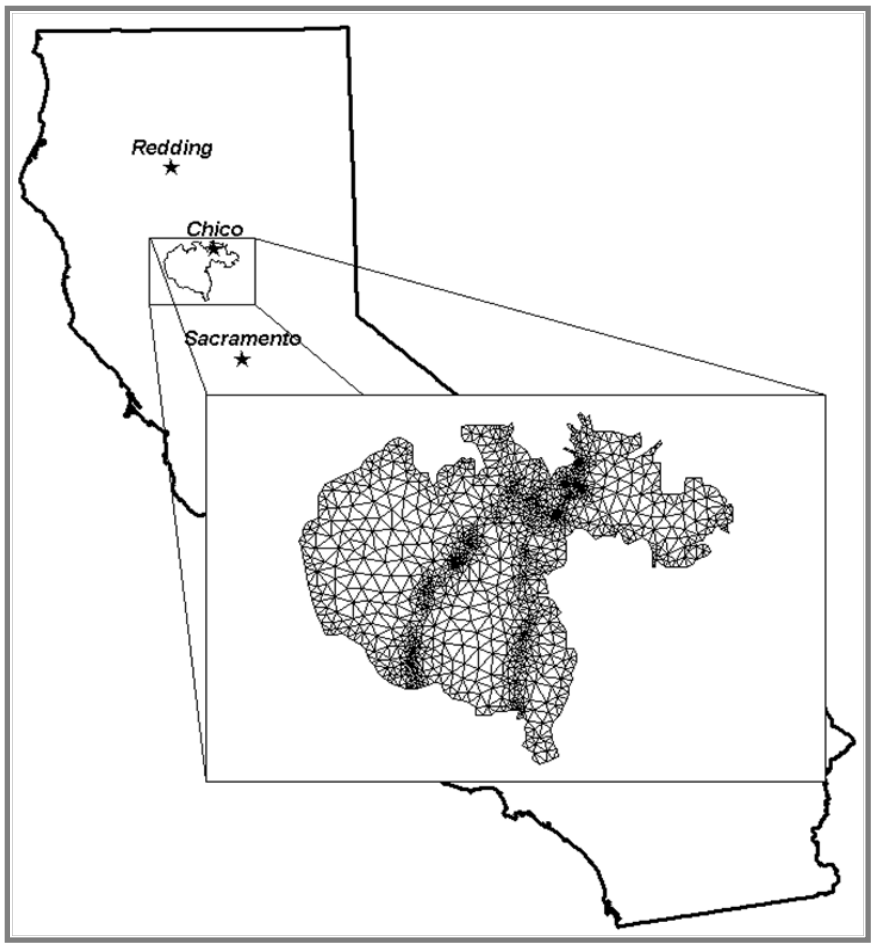


Figure 9. Model area and the simulation grid for Example 2

extensive data sets for these regions. To test their accuracy, IDC results were compared to data developed for the seven DAUs that the model area intersects.

The 2805 km^2 model area and the finite element grid for this example are shown in Figure 9. The simulation grid, which includes 2622 cells, was created using a mesh generator developed by CADWR as an add-on for ESRI's ArcGIS software. The part of each DAU that intersected with the model area was designated as an individual subregion (Figure 10) where subregions in IDC are used for aggregation and reporting of the simulation results.

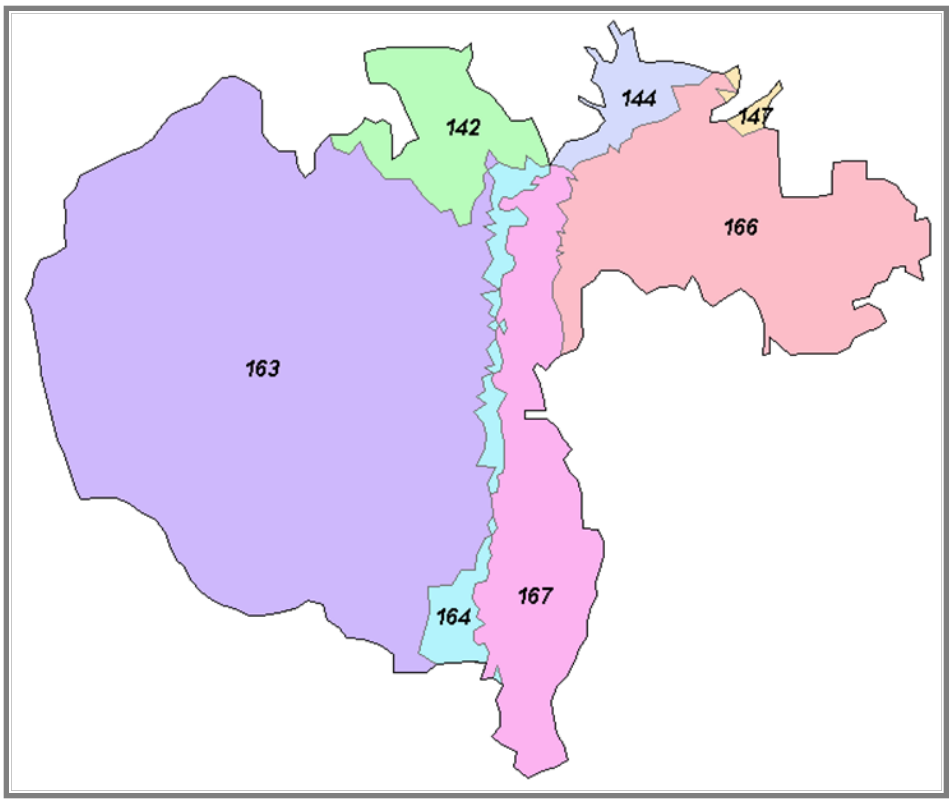


Figure 10. DAUs in modeled area in Example 2

The soil physical properties were compiled using the Natural Resources Conservation Service's (NRCS) Soil Survey Geographic Database (SSURGO). The soils map for the modeled area is shown in Figure 11 without the legend due to highly complex soil structure. Using the Soil Data Viewer software available from NRCS, the soil physical properties (field capacity, total porosity, saturated hydraulic conductivity and soil hydrologic group) were first averaged over soil horizons for each soil component. Properties defined for each component were then averaged for each soil map unit. Finally, properties defined for map units were intersected with simulation grid cells. Since each grid cell intersected with multiple map units, the physical soil properties were further area-averaged over grid cells to end up with a single value for each soil property for each element. The dominant surface soil texture for each grid cell was also identified and the arithmetic mean values for pore size distribution

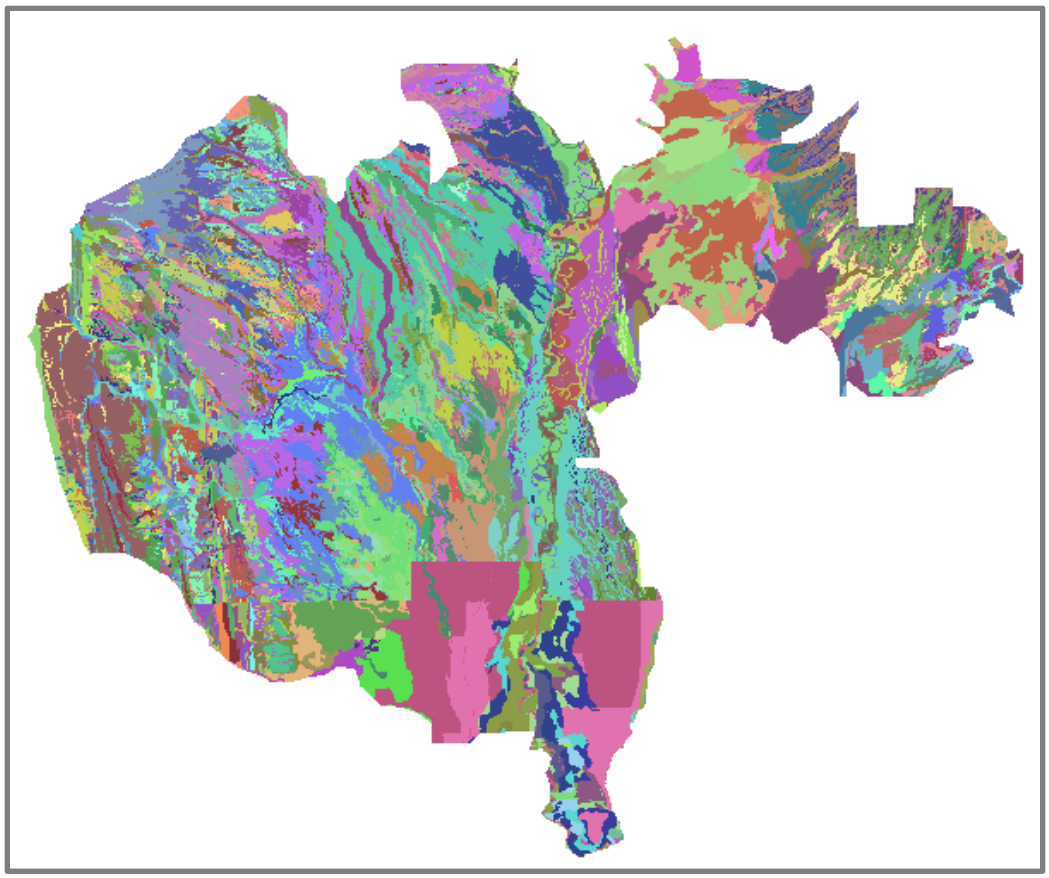


Figure 11. Soils map for the model area

index listed in Rawls et al. (1982) were assigned to matching soil textures. Wilting point for each cell was set to zero.

The land-use map for the model area was available as a Geographic Information System (GIS) layer (Figure 12). The agricultural crops were grouped into 20 non-ponded crop types including fallow or idle areas, and rice fields. The modeled area also included urban areas, wildlife refuges and native vegetation. Total area of water and non-irrigated agricultural lands were minor, 2% and 4% of the total modeled area, respectively. Therefore these land-use types were incorporated into the lands with native vegetation (Figure 12). The land-use map was intersected with the finite element grid and the area of each land-use type over every grid cell was computed.

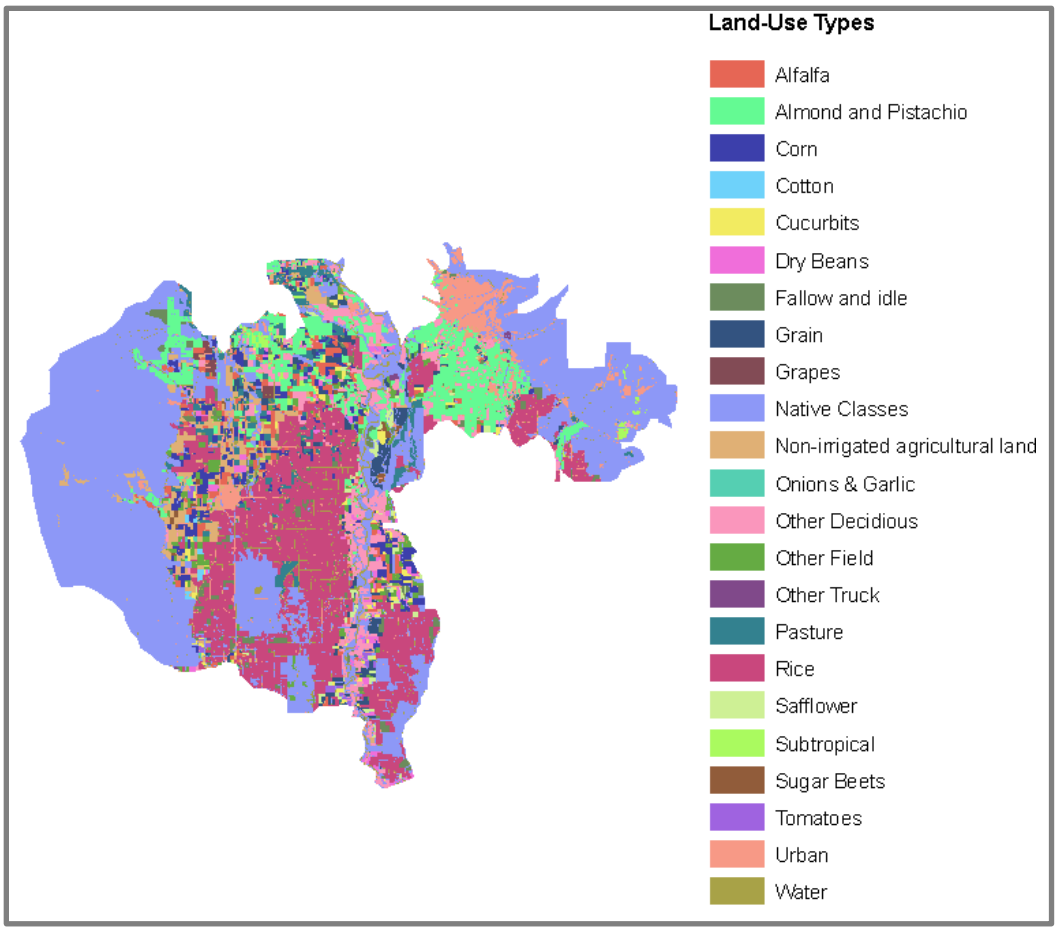


Figure 12. Land-use types in the modeled area

Precipitation data that was developed for Calsim 3.0 project using the PRISM climate data (PRISM, 2009) was utilized in this example.

ET data for each crop at each DAU obtained from DPLA changed from month to another and from year to year. However, it was zero for particular crops when they were not planted in certain years. On the other hand, the land-use areas used in this test was constant and did not change from year to year. Therefore, matching ET data from DPLA with constant land-use areas created a problem: in some years zero ET was assumed for land-use types whose area was not zero. To avoid this problem, ET data for each land use at each grid cell was obtained from the Calsim 3.0 project on a monthly basis. It changed from one

month to another but the same monthly values were used for each water year.

Rice operations data such as ponding depths and return flow depths were all taken from Calsim 3.0 study whose source was the Northern District of CADWR.

Even though the irrigation water demand data for modeled DAUs obtained from DPLA was for water years 1998 to 2001, IDC run was started from October 1, 1990; i.e. a spin-up period of eight years was used to ensure that the mixture of soil moisture storage due to irrigation and precipitation was realistic.

3.4.1 Results and Discussion

The data obtained from DPLA listed crop irrigation requirements for non-ponded agricultural crops and rice as well as ET_c for each DAU as unit rates in terms of acre-feet/acre. To be able to compare to DPLA values, IDC results were also converted to unit rates. Instead of comparing results for individual crops, the total irrigation requirements for each DAU for non-ponded crops computed by IDC were compared to total irrigation requirements for non-ponded crops obtained from DPLA. Irrigation requirement for rice from IDC and DPLA was compared individually since rice irrigation requires much more water than non-ponded crops.

Precipitation is one of the major drivers of the flow processes in IDC. Figure 13 shows the annual precipitation for each DAU.

The Soil Data Viewer from NRCS allows different ways of averaging of the soil physical properties. Also each soil physical property is assigned a lower and upper limit as well as a representative value. Combining the lower, upper and representative values with different averaging methods, one can obtain different values for each soil map unit. Figure 14 and Figure 15 show the simulated irrigation water requirements for non-ponded crops at

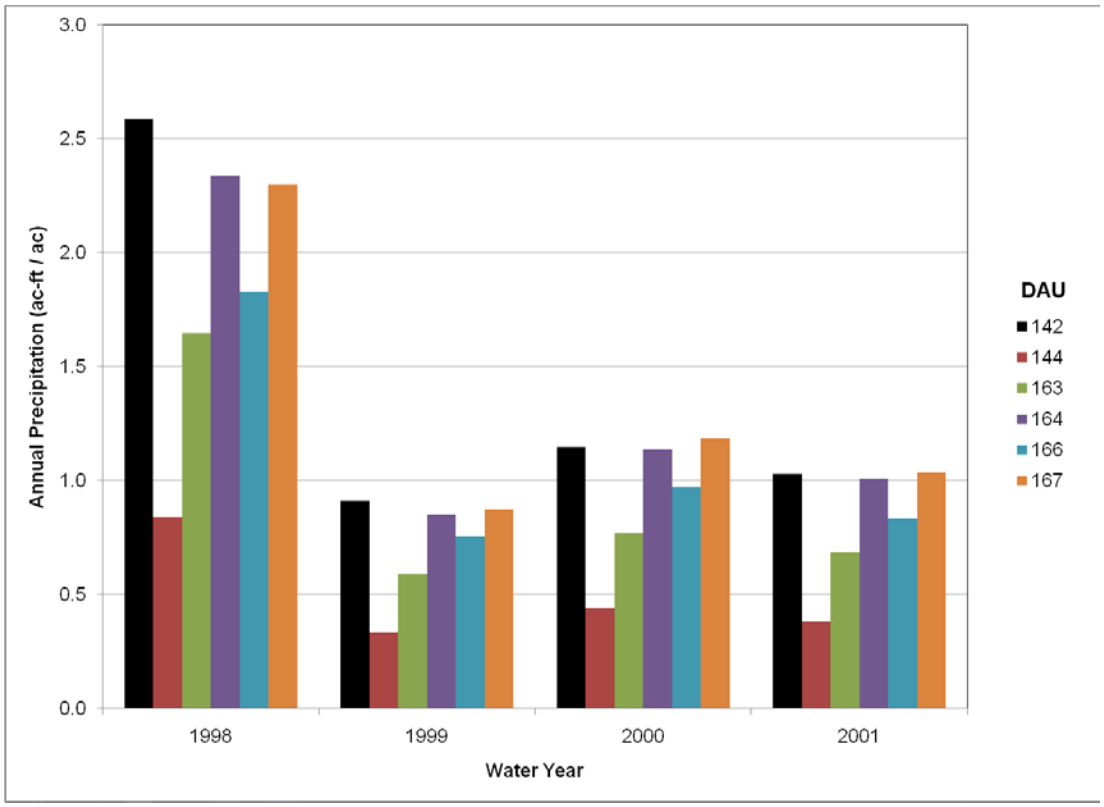


Figure 13. Annual precipitation for each DAU

DAU 142 and for rice in DAU 163, respectively, for varying average saturated hydraulic conductivities (K_{sat}). These DAUs were selected for analysis because DAU 142 had the largest percent non-ponded crop acreage (88% of the total modeled area of the DAU) and DAU 163 had the largest percent rice acreage (24% of the total modeled area of the DAU). Figure 14 shows results for four water years whereas Figure 15 shows those only for water year 2000 because there was no visible difference in the results from one year to another for rice irrigation requirements.

It can be seen that while irrigation water requirement for non-ponded crops is not extremely sensitive to K_{sat} (Figure 14), it is very sensitive in the case of rice (Figure 15). This is expected since rice is grown under saturated conditions. However, even though K_{sat} values shown in Figure 15 were computed using the NRCS data, larger K_{sat} values lead to

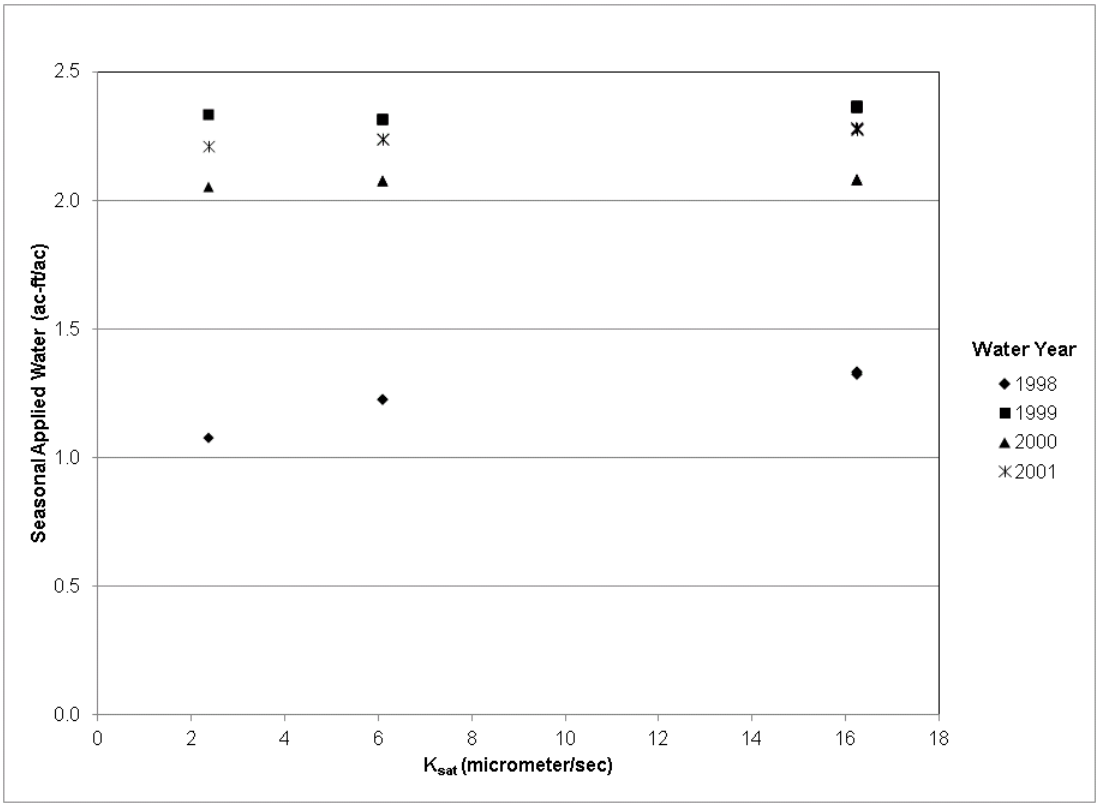


Figure 14. Seasonal irrigation water requirement versus saturated hydraulic conductivity for non-ponded crops at DAU 142

unreasonably high values of irrigation requirements for rice. In fact, using different averaging techniques featured in the NRCS Soil Data Viewer on upper, lower and representative K_{sat} values listed in the SSURGO database, the smallest average K_{sat} value obtained was 0.45 micrometers/sec. By contrast, DPLA assumes an average of 0.01 micrometer/sec (equivalent to 1 inch/month) percolation from rice fields in their analysis. This value is in line with other sources. For instance, Williams (2004) reports deep percolation at rice fields between 0.012 to 0.048 micrometers/sec (1.2 to 4.8 inches/month). Assuming that these rates represent the K_{sat} values, the smallest value obtained by averaging the data from SSURGO is one order of magnitude larger leading to large simulated irrigation requirements for rice. Although a visual inspection of SSURGO data showed that there were

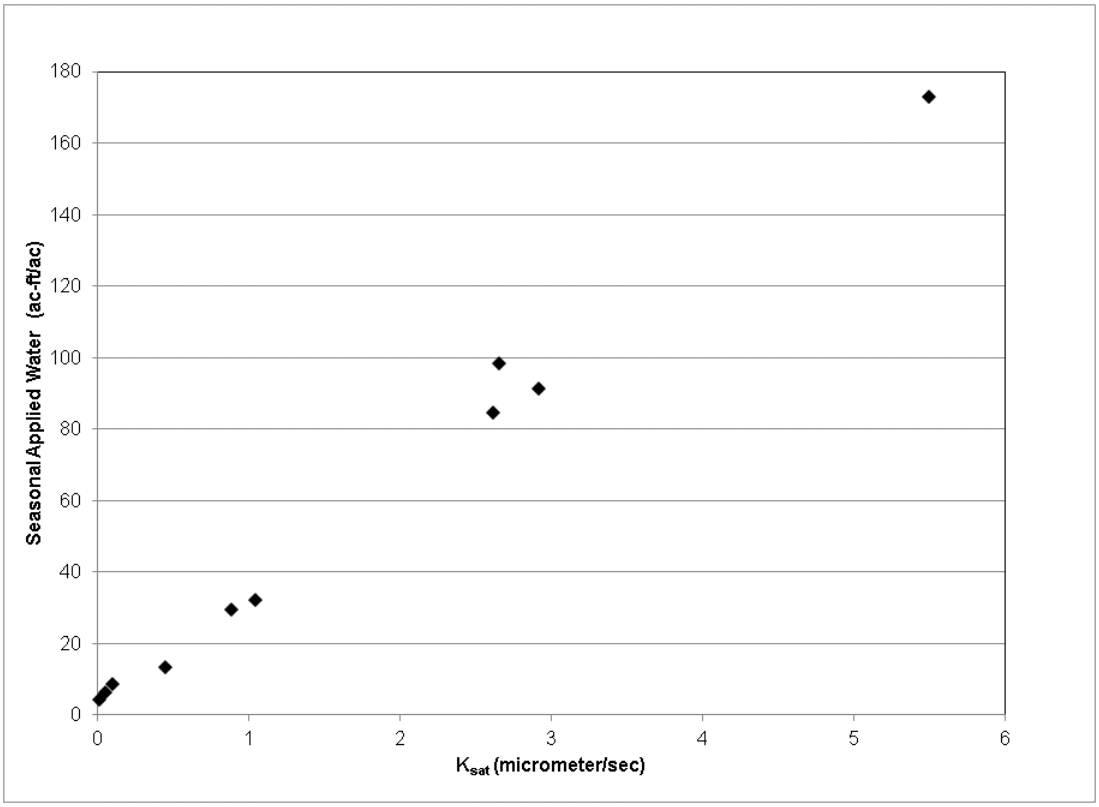


Figure 15. Seasonal irrigation water requirement versus saturated hydraulic conductivity for rice at DAU 163 for water year 2000

K_{sat} values as low as 0.001 micrometers/sec, this example shows that one needs to exercise caution when assigning K_{sat} values to grid elements where rice is grown.

To test how IDC performs for rice fields with soil properties suggested by other sources, grid cells that had rice fields were assigned K_{sat} values of 0.01, 0.05 and 0.1 micrometers/sec. The irrigation requirement for rice computed by IDC for water year 2000 was 4.6, 6.4 and 8.7 ac-ft/ac for K_{sat} values of 0.01, 0.05 and 0.1 micrometers/sec, respectively. For comparison purposes, DPLA reports 5.8 ac-ft/ac and Williams (2004) reports an average value of 6 to 6.5 ac-ft/ac which can vary from 4 to 8 ac-ft/ac or more. This comparison suggests that IDC is capable of producing reasonable values for irrigation requirements at rice fields when grid cell K_{sat} values are set properly. In contrast, the rice

irrigation requirement computed by IDC with the K_{sat} value at grid cells with rice set to the minimum values obtained by averaging the SSURGO data (0.45 micrometers/sec on average) was 13.6 ac-ft/ac.

As mentioned earlier, irrigation water requirement for non-ponded crops is not very sensitive to the changes in K_{sat} values (Figure 14). Figure 16 shows the seasonal irrigation water requirement (i.e. applied water) versus pore size distribution index, λ, for DAU 142 at different water years. For each soil texture, Rawls et al. (1982) list lower and upper limits as well as a representative value for λ. To generate Figure 16, IDC was run with the K_{sat} values computed by averaging representative values from SSURGO database combined with low, representative and high values of λ listed by Rawls et al. (1982). To gage the sensitivity of

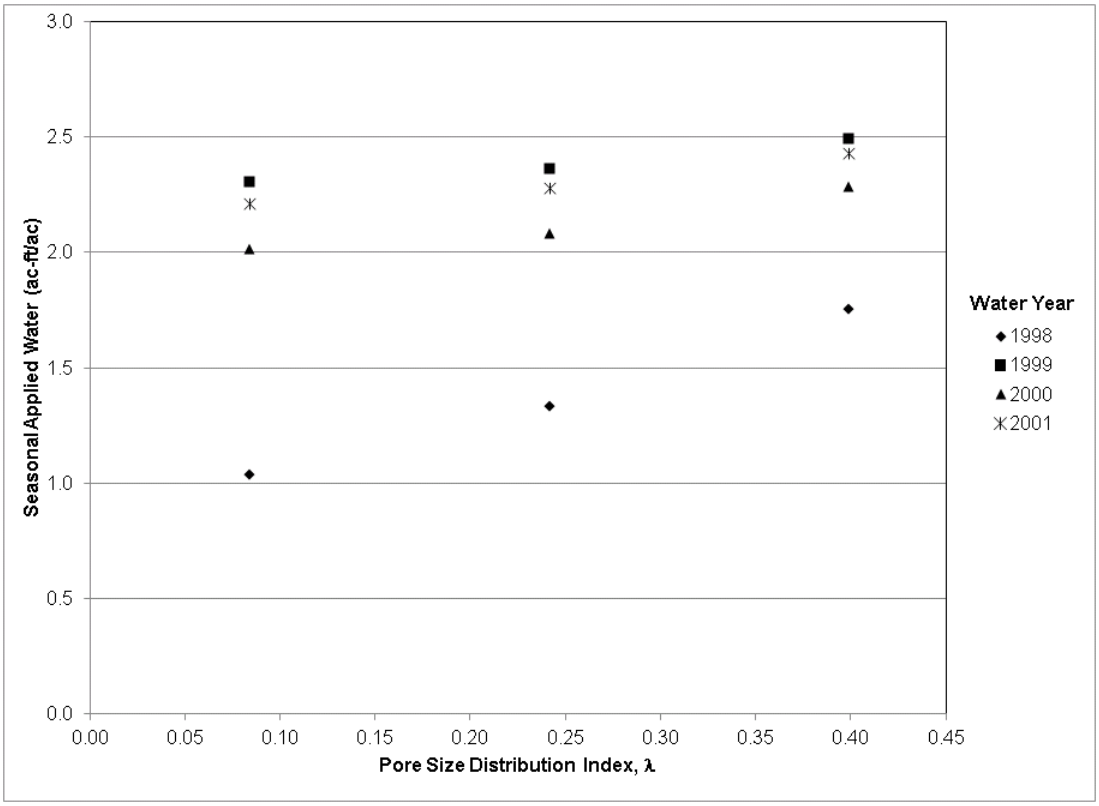


Figure 16. Seasonal irrigation water requirement versus pore size distribution index for non-ponded crops at DAU 142

irrigation requirement to K_{sat} and λ values, linear best-fit curves were computed for simulation results shown in Figure 14 and Figure 16, respectively; high gradient of the best-fit curve represented high sensitivity. The gradient of the best-fit line for K_{sat} versus irrigation requirement varied from 0.0007 for year 2000 to 0.014 for year 1998, whereas for λ versus irrigation requirement it varied from 0.505 for year 2001 to 2.169 for year 1998.

As a summary, one needs to choose K_{sat} values carefully for grid cells where rice is grown. K_{sat} values will not affect the irrigation requirements for non-ponded crops in these cells because they are insensitive to changes in K_{sat} values. On the other hand, to change the irrigation requirement for non-ponded crops one can modify λ with minimal effect on the values computed for rice.

Table 3 shows a general comparison of simulation results for non-ponded crops compared to DPLA values when K_{sat} at grid cells with rice was set to 0.01 micrometers/sec. Deep percolation from DPLA was not available so these values are shown as n/a (not applicable). One can see in Table 3 that the annual ET rates from DPLA change from one year to another, whereas IDC values are constant. This difference is likely to cause other values to be different as well. Furthermore, precipitation data used in DPLA analysis was not available. It was also observed that some crops that were present in some subregions in IDC had zero acreage in DPLA's data. The likelihood of precipitation data being different from IDC data along with different ET rates and different crop areas is responsible for some of the differences among other values such as applied water. Also, ETaw is constantly lower in IDC than in DPLA data, whereas ETp is higher. This means that DPLA values will lead to a higher irrigation efficiency than IDC values. This difference is likely due to different methods used for computing ETaw and ETp as well as different ET and precipitation input

Table 3. Comparison of IDC results for non-ponded crops to the values obtained from DPLA with K_{sat} values at cells with rice set to 0.01 micrometers/sec (all values are in ac-ft/ac; n/a = not applicable)

		ET		AW		ETaw		ETp		D	
Water Year	**DAU**	**IDC**	**DPLA**	**IDC**	**DPLA**	**IDC**	**DPLA**	**IDC**	**DPLA**	**IDC**	**DPLA**
1998	142	2.65	2.18	1.74	1.66	1.16	1.24	1.49	0.94	0.63	n/a
	144	2.71	2.68	2.10	1.91	1.23	1.50	1.48	1.17	1.09	n/a
	163	2.34	2.19	1.50	2.04	1.02	1.47	1.32	0.72	0.33	n/a
	164	2.51	2.38	1.20	2.05	0.85	1.52	1.66	0.87	0.40	n/a
	166	2.80	2.54	1.91	2.11	1.13	1.56	1.67	0.98	0.91	n/a
	167	2.01	1.98	1.28	1.47	0.75	1.09	1.26	0.89	0.62	n/a
1999	142	2.65	2.56	2.49	2.57	1.76	1.92	0.89	0.64	0.02	n/a
	144	2.71	2.65	2.78	2.56	1.79	2.01	0.92	0.65	0.12	n/a
	163	2.33	2.49	2.26	3.28	1.55	2.04	0.78	0.45	0.02	n/a
	164	2.50	2.74	2.26	3.47	1.50	2.19	1.00	0.55	0.01	n/a
	166	2.80	2.88	2.56	3.11	1.65	2.29	1.15	0.59	0.16	n/a
	167	2.01	2.17	1.89	2.32	1.15	1.56	0.86	0.60	0.06	n/a
2000	142	2.65	2.60	2.28	2.49	1.64	1.87	1.00	0.74	0.07	n/a
	144	2.71	3.22	2.52	2.86	1.65	2.26	1.07	0.96	0.27	n/a
	163	2.33	2.53	2.07	2.63	1.44	1.92	0.90	0.61	0.04	n/a
	164	2.51	2.77	1.93	2.71	1.36	2.00	1.14	0.76	0.02	n/a
	166	2.80	2.97	2.30	2.96	1.57	2.24	1.23	0.74	0.29	n/a
	167	2.01	2.33	1.63	2.13	1.04	1.57	0.97	0.76	0.11	n/a
2001	142	2.65	2.67	2.42	2.66	1.76	2.01	0.89	0.66	0.05	n/a
	144	2.71	3.32	2.68	3.23	1.75	2.53	0.96	0.79	0.20	n/a
	163	2.33	2.60	2.17	2.88	1.55	2.10	0.78	0.50	0.03	n/a
	164	2.51	2.88	2.09	2.95	1.50	2.20	1.01	0.68	0.01	n/a
	166	2.80	3.08	2.61	3.19	1.66	2.40	1.14	0.68	0.20	n/a
	167	2.01	2.37	1.84	2.29	1.14	1.70	0.87	0.67	0.08	n/a

data. It also appears that since applied water is generally lower in IDC (see Table 3), it is likely that the infiltration of precipitation in IDC is estimated higher compared with those in DPLA. By increasing the curve numbers in IDC, the infiltration of precipitation can be decreased which will lead to increased applied water with increased ETaw and decreased ETp. Overall, however, the values from IDC and DPLA are reasonably close given the fact that there was no effort to calibrate IDC to match values from DPLA.

Similarly, Table 4 shows the comparison of IDC and DPLA values for rice. As for Table 3, IDC results were obtained by setting the K_{sat} values for grid cells that include rice fields to 0.01 micrometers/sec. It can be seen that ET values are generally lower in IDC than DPLA, with the exception of 1998. For 1998, ET values are closer to each other. It appears that due to different ET rates, applied water and ETaw are also lower in IDC for years 1999 through 2001. Since ET rates are similar for 1998, these values are also close to each other for 1998. Overall, the results match relatively well compared to the results for non-ponded crops.

Table 4. Comparison of IDC results for rice to the values obtained from DPLA with K_{sat} values at cells with rice set to 0.01 micrometers/sec (all values are in ac-ft/ac; n/a = not applicable)

		ET		AW		ETaw		ETp		D	
Water Year	**DAU**	**IDC**	**DPLA**	**IDC**	**DPLA**	**IDC**	**DPLA**	**IDC**	**DPLA**	**IDC**	**DPLA**
1998	142	3.32	2.50	5.27	4.36	2.93	2.48	0.37	0.02	0.55	n/a
	144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	n/a
	163	2.78	2.50	4.49	4.22	2.47	2.40	0.29	0.10	0.51	n/a
	164	2.94	2.55	4.75	4.29	2.61	2.44	0.30	0.12	0.50	n/a
	166	3.49	2.53	5.87	4.25	3.16	2.42	0.30	0.12	0.66	n/a
	167	3.49	2.50	5.85	4.21	3.16	2.40	0.30	0.10	0.65	n/a
1999	142	3.32	3.30	5.40	7.73	3.02	3.19	0.27	0.12	0.53	n/a
	144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	n/a
	163	2.78	3.30	4.59	6.18	2.54	3.10	0.22	0.20	0.47	n/a
	164	2.94	3.26	4.85	5.98	2.68	3.06	0.23	0.20	0.49	n/a
	166	3.49	3.30	5.97	7.76	3.23	3.09	0.23	0.21	0.65	n/a
	167	3.49	3.30	5.94	6.18	3.22	3.10	0.23	0.20	0.65	n/a
2000	142	3.32	3.23	5.38	5.34	2.99	3.05	0.30	0.19	0.53	n/a
	144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	n/a
	163	2.78	3.39	4.58	5.78	2.53	3.29	0.23	0.10	0.47	n/a
	164	2.94	3.31	4.85	5.62	2.67	3.19	0.24	0.13	0.49	n/a
	166	3.49	3.37	5.96	5.73	3.21	3.26	0.25	0.11	0.65	n/a
	167	3.48	3.40	5.95	5.79	3.21	3.30	0.24	0.10	0.65	n/a
2001	142	3.32	3.45	5.43	5.71	3.03	3.25	0.26	0.20	0.53	n/a
	144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	n/a
	163	2.78	3.60	4.62	5.96	2.56	3.40	0.20	0.20	0.47	n/a
	164	2.94	3.54	4.89	5.90	2.70	3.34	0.21	0.20	0.49	n/a
	166	3.49	3.59	5.97	5.96	3.22	3.39	0.24	0.20	0.65	n/a
	167	3.49	3.60	5.99	5.96	3.24	3.40	0.21	0.20	0.65	n/a

4 Root Zone Component Version 4.1

This version is very similar to version 4.0 as described in the previous chapter. In addition to all the features of version 4.0, it includes two new capabilities, namely the riparian vegetation access to stream flow to meet the evapotranspirative demands and the root water uptake from groundwater. The root water uptake from groundwater requires depth-to-groundwater information which can be specified by the user as a time series data. However, IDC, when executed on its own, has no information about the stream flows. Therefore, riparian vegetation access to stream flow to meet the evapotranspirative demands is only effective when IDC is linked to an integrated hydrologic model such as IWFM that simulates both stream flows. When IDC is executed on its own, this feature will simply be ignored.

Since all the flow routing and demand calculations that are explained for version 4.0 are the same in version 4.1, these simulation methods will not be iterated here. Instead, only the new features will be detailed in the following sections.

4.1 Riparian Vegetation Access to Stream Flows

In version 4.0 of the root zone component, the only sources of moisture to meet the evapotranspirative demand of riparian vegetation are precipitation, any moisture that is already stored in the root zone and user-specified generic sources, if any. In the real-world, riparian vegetation grows near streams and part of the evapotranspirative demand is met by stream flow, either directly or by the moisture in the root zone that is due to stream flow seepage.

In IDC, the user specifies the stream node for each grid cell from which riparian vegetation in that cell will meet part or all of its evapotraspirative demand. Any grid cell that is away from streams with no riparian vegetation is assigned a stream node number of zero.

IDC uses the stream flow to meet the riparian water demand after considering the contribution of moisture that is already available in the root zone, precipitation, and any moisture from generic sources. First, equation (1) is solved to calculate the actual evapotranspiration at the end of the time step, ET^{t+1}, to check if it is less than the potential evapotranspiration specified by the user for riparian vegetation. The required amount of water from the stream to meet the unmet riparian demand is calculated as

$$ET_{strm,pot}^{t+1} = ET_{pot}^{t+1} - ET^{t+1} \geq 0 \tag{39}$$

where $ET_{strm,pot}^{t+1}$ is the potential rate of evapotranspiration to be taken out of the stream (L/T). The actual amount, ET_{strm}^{t+1}, depends on the actual stream flow that is available at the stream node that the grid cell is connected to and it is found only after the entire integrated hydrologic system is simulated (as mentioned earlier, riparian evapotranspiration from streams is only simulated when IDC is linked to an integrated hydrologic model):

$$ET_{strm}^{t+1} = \frac{\min\left(ET_{strm,pot}^{t+1} A_{rip}^{t+1}\ ,\ Q_{strm}^{t+1}\right)}{A_{rip}^{t+1}} \tag{40}$$

where ET_{strm}^{t+1} is the actual evapotranspiration from the stream (L/T), A_{rip}^{t+1} is the area of the riparian vegetation at the grid cell for which root zone flow processes are simulated (L^2),and Q_{strm}^{t+1} is the simulated stream flow (L^3/T). Once ET_{strm}^{t+1} is calculated, the total riparian vegetation evapotranspiration is calculated as

$$ET_{total}^{t+1} = ET_{strm}^{t+1} + ET^{t+1} \tag{41}$$

where ET_{total}^{t+1} is the total riparian vegetation evapotranspiration (L/T).

IDC assumes that all stream flow contribution to evapotranspiration of riparian vegetation is direct; i.e. the mechanism of the stream flow first seeping into the root zone before meeting the evapotranspiration is ignored. This is because of the conceptual set-up used in IDC where the flow exchange between the root zone and the stream system is not considered in order to minimize the computer run-times. On the other hand, the next section discusses the optional simulation of root water uptake from groundwater which can implicitly handle the case where the stream flow first seeps into the groundwater before potentially contributing to the riparian evapotranspiration through root water uptake.

4.2 Root Water Uptake from Groundwater

Shallow groundwater can meet part or all of the plant evapotranspirative demand. In IDC, groundwater contribution to evapotranspiration is considered as the first source of moisture that is available to the plants. As will be explained later, one of the information IDC requires to compute the root water uptake from groundwater is the depth-to-groundwater . When IDC is run as a stand-alone program the user can specify time series depth-to-groundwater data at each finite element cell. This data can be obtained either from field measurements or from separate groundwater models. If IDC is executed as a linked component of an integrated hydrologic model such as IWFM, depth-to-groundwater is calculated dynamically by the integrated hydrologic model and passed to IDC.

Figure 17 shows a schematic representation of the root zone and root water uptake from groundwater as simulated by IDC. At each grid cell the user specifies a capillary rise

above the saturated groundwater table. IDC assumes that the soil moisture content at the groundwater table is at total porosity (assumed equal to the specific yield of the aquifer material) and declines linearly to zero at a height equal to the capillary rise above the groundwater table. The maximum potential root water uptake from groundwater is calculated as the part of the capillary rise and the saturated groundwater that intersect with the root zone:

$$ET_{gw,pot}^{t+1} = \begin{cases} 0 & \text{if} \quad C_r + Z^{t+1} \le D_{gw}^{t} \\ \dfrac{S_y\left(Z^{t+1} - D_{gw}^{t} + C_r\right)^2}{2\Delta t C_r} & \text{if} \quad D_{gw}^{t} > C_r \;\; ; \;\; D_{gw}^{t} > Z^{t+1} \\ \dfrac{S_y Z^{t+1}}{\Delta t C_r}\left(\dfrac{Z^{t+1}}{2} + C_r - D_{gw}^{t}\right) & \text{if} \quad D_{gw}^{t} \le C_r \;\; ; \;\; D_{gw}^{t} > Z^{t+1} \\ \dfrac{S_y}{\Delta t}\left(Z^{t+1} - D_{gw}^{t}\right) & \text{if} \quad C_r = 0 \;\; ; \;\; D_{gw}^{t} \le Z^{t+1} \\ \dfrac{S_y C_r}{2\Delta t} + \dfrac{S_y}{\Delta t}\left(Z^{t+1} - D_{gw}^{t}\right) & \text{if} \quad C_r > 0 \;\; ; \;\; D_{gw}^{t} > C_r \;\; ; \;\; D_{gw}^{t} \le Z^{t+1} \\ \dfrac{S_y}{2\Delta t C_r}\left[2C_r Z^{t+1} - \left(D_{gw}^{t}\right)^2\right] & \text{if} \quad C_r > 0 \;\; ; \;\; D_{gw}^{t} \le C_r \;\; ; \;\; D_{gw}^{t} \le Z^{t+1} \end{cases} \tag{42}$$

where $ET_{gw,pot}^{t+1}$ is the maximum potential root water uptake from groundwater (L/T), S_y is the aquifer specific yield (dimensionless), D_{gw}^{t} is the depth-to-groundwater (computed as the ground surface elevation less the groundwater head) at the beginning of time step (L), C_r is the height of capillary rise above the groundwater table (L), and Δt is the simulation time step length (T). In equation (42), already known value of the depth-to-groundwater at the beginning of the time step is used to avoid additional iterations between IDC and the

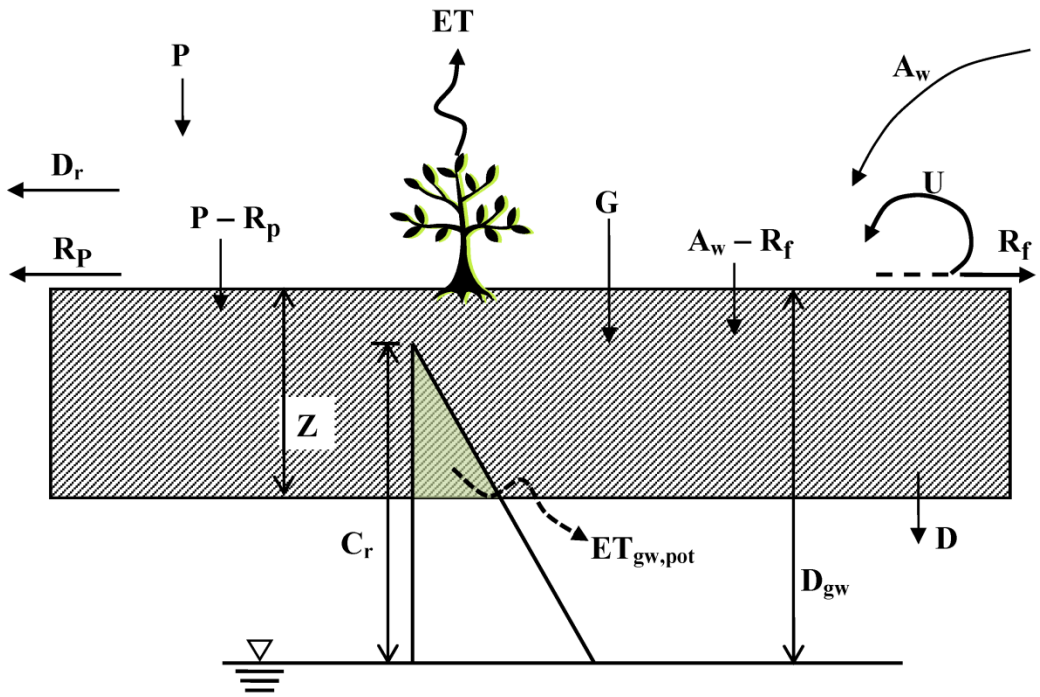


Figure 17. Schematic representation of the root zone and root water uptake from groundwater

groundwater simulation component of the integrated hydrologic model that would arise if the unknown head at the current time step were used.

The actual root water uptake from groundwater is calculated as

$$ET_{gw}^{t+1} = \min\left(ET_{pot}^{t+1}\ ,\ ET_{gw,pot}^{t+1}\right) \tag{43}$$

If IDC is linked to an integrated hydrologic model, then ET_{gw}^{t+1} in (43) becomes a sink term for the groundwater component of the model.

When simulated, root water uptake from groundwater also affects the demand for irrigation water for ponded and non-ponded crops. For non-ponded crops, IDC uses either equation (23) or equation (26) to calculate the irrigation water demand, depending on if IDC is asked to maintain a minimum deep percolation, whereas for ponded crops it uses equation (28). To calculate the effect of groundwater on irrigation water demand, IDC uses a modified

potential ET, $ET_{pot,mod}$, in equations (23), (26) or (28) by considering the ability of groundwater to meet part or all of the potential crop ET. Therefore, the irrigation water demand when root water uptake from groundwater is considered is calculated by using the modified potential ET instead of the original potential ET:

$$A_w^{t+1} = f\left(ET_{pot,mod}^{t+1}\right) \tag{44}$$

where

$$ET_{pot,mod}^{t+1} = \max\left(0\ ,\ ET_{pot}^{t+1} - ET_{gw,pot}^{t+1}\right) \tag{45}$$

5 Running IDC

IDC can be executed as a stand-alone model or it can be linked to other simulation models that operate on finite-element or finite-difference type computational grids. Both the source code and the compiled executables are available for download from the IDC web site at http://baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM/IDC/index_IDC.cfm. IDC, either executed as a stand-alone model or linked to other simulation models, requires a main control input file that lists the names of data files used for the simulation, the simulation period and length of time step, as well as the output options. Depending on the specifications listed in the input data files, one or more output files are generated. These files store simulated water budget information at each subregion and they are in HDF5 file format. Another program, Budget.exe, is required to process these files and generate water budget tables in ASCII text format. Budget.exe is also available for download from IWFM web site. Next, the IDC's time-tracking feature as well as input files that are used and output files that are generated by IDC are discussed.

5.1 Simulation Time Tracking

To better represent the temporal distribution of input and output data, IDC keeps track of the actual date and time of each time step in a simulation period. Each data entry in input time series data files is required to have a date and time stamp which allows IDC to retrieve time series data correctly. This, in return, allows the user to maintain a single set of time series input data files for applications where the starting and ending date and time of the simulation may change. For example, during the calibration stage of a project, the simulation is run for two periods: calibration period and the verification period. In a time tracking simulation, time series input data files can be prepared so that the data covers both the calibration and verification periods. Then the same time series data files can be used for both calibration and verification runs without the need for modification. Since a time tracking simulation keeps track of actual date and time of each of the simulation time steps, IDC can retrieve the correct data from the time series data files.

Time tracking simulations allow usage of HEC-DSS files as well as ASCII text files for time series data input and output. HEC-DSS is a database format designed by Hydrologic Engineering Center (HEC) of U.S. Army Corps of Engineers specifically for time-series data encountered in hydrologic applications. These files allow efficient storage and retrieval of hydrologic time series data, and HEC offers free utilities (HEC-DSSVue and DSS Excel add-in) for manipulation, visualization and analysis of data stored in DSS files. These utilities and instructions on how to use DSS files can be downloaded from HEC web site at www.hec.usace.army.mil.

Another advantage of time tracking simulations is that results that are printed to output files have date and time stamps associated with them. This allows easy comparison of

simulation results to observed values which generally come with the date and time of observation.

5.1.1 Length of Simulation Time Step

In order to be consistent with the standards of HEC-DSS database files, IDC restricts the length of simulation time step that can be used in an application. The allowable time step lengths are listed in Table 5.

5.1.2 Time Step Format

In IDC, start and end date and time of simulation period as well as the date and time of each data entry in time series data input files are required to be specified by using a time stamp. The format of the time stamp is as follows:

MM/DD/YYYY_hh:mm

where

MM = two digit month index;

DD = two digit day index;

YYYY = four digit year;

hh = two digit hour in terms of military time (e.g. 1:00pm is represented as 13:00);

mm = two digit minute.

The time is represented in military time and midnight is referred to as 24:00. For instance, 05/28/1973_24:00 represents the midnight on the night of May 28, 1973. Another example is the starting date and time of a simulation period: if the initial conditions for a daily simulation is given for the end of September 30, 1975, then the time stamp for the starting date and time of the simulation will be 09/30/1975_24:00. The first simulation result

Table 5. List of allowable time step lengths in IDC simulations

Time Step Length	IDC Notation
1 minute	1MIN
2 minutes	2MIN
3 minutes	3MIN
4 minutes	4MIN
5 minutes	5MIN
10 minutes	10MIN
15 minutes	15MIN
20 minutes	20MIN
30 minutes	30MIN
1 hour	1HOUR
2 hours	2HOUR
3 hours	3HOUR
4 hours	4HOUR
6 hours	6HOUR
8 hours	8HOUR
12 hours	12HOUR
1 day	1DAY
1 week	1WEEK
1 month	1MON
1 year	1YEAR

will be printed for October 1, 1975 at midnight with the time stamp 10/01/1975_24:00.

5.1.3 Preparation of Time Series Data Input Files

The user is allowed to use a mixture of ASCII text and DSS files for time series input data. In preparing these files, the rules listed below should be followed:

1. The data should have a regular interval. Gaps in the data are not allowed. For instance, if the data is monthly a value for every month should be entered.
2. The time stamp of the data represents the end of the interval for which the data is valid. For instance, in monthly time series evapotranspiration data, a data point time stamped with 08/31/1995_24:00 represents the evapotranspiration that occurred in August of 1995. As another example, if the starting date and time of the simulation period is 12/31/1970_24:00 (i.e. initial conditions are given at the midnight of December 31, 1970) in a daily simulation, then IDC will search for the time series data time-stamped as 01/01/1971_24:00 (data for January 1st in 1971) in the time series input files.
3. The smallest interval that can be used for time series data is 1 minute.
4. A time series input data can be constant throughout the simulation period. If an ASCII text file is used for data input, the time stamp for the constant value can be set to a date and time that is greater than the ending date and time of the simulation period. For instance, if the simulation period ends at 06/15/2003_18:00 (6:00pm on June 15, 2003), then the constant value can have a time stamp 12/31/2100_24:00 (midnight on the night of December 31, 2100). IDC reads the constant value for the midnight of December 31, 2100 and uses this value for all simulation times before this date and time. Generally, time series input files include conversion factors to

convert only the “spatial” component of the input data unit. The temporal unit is deduced from the time interval of the input data. In the case of constant time series data, IDC is not able to obtain the time interval and, hence, the temporal unit. If a constant value for time series data is used, the user should make sure that appropriate conversion factors are supplied so that the temporal and spatial units of the input data are consistent with those used internally during the simulation. Time series data that is constant can also be represented in DSS files but this is not suggested.

5. For rate-type time series data (e.g. evapotranspiration data), the time unit is assumed to be the interval of data. For instance, if the evapotranspiration data is entered monthly, IDC assumes that the time unit of the evapotranspiration rates is 1 month. When time series data is a constant value for the entire simulation period IDC has no way to figure out the time unit of the input data. In this case the user should make sure that the time unit of data is the same as the consistent time unit of simulation.
6. For recycled time series data (e.g. fraction of total urban water that is used indoors given for each month but do not change from one year to the other), the year of the time stamp can be set to 4000. Year 4000 is a special flag for IDC such that it replaces year 4000 with the simulation year to retrieve the appropriate data from the input file. As an example consider the time series data in Table 6 for the fraction of total urban water that is used indoors. This data set represents that for the initial third of each simulation year the urban water indoors usage fraction is 0.7, for the second third it is 0.5 and for the last third it is 0.35. Recycled time series data can be used in both ASCII text and DSS files. If a monthly time series data is to be recycled the user should enter the time stamp for the last day of February as 02/29/4000_24:00 to

address both the leap and non-leap years.

The interval of time series data is required to be synchronized with the simulation time step. Table 7 shows examples of accepted and unaccepted situations. It should be noted that IDC will continue to read data from the input files even if the data interval is not properly synchronized with the simulation time step. However, in such cases there is no guarantee that the correct data will be retrieved from the input file. Therefore, it is up to the user to ensure correct synchronization between the input data and the simulation time step.

5.2 Input and Output Data File Types

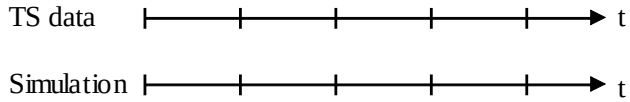
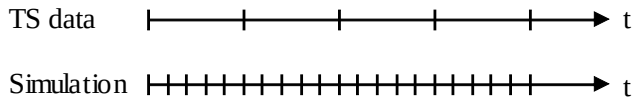
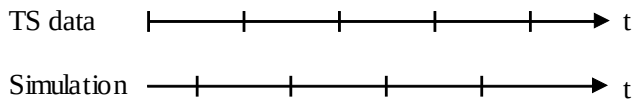
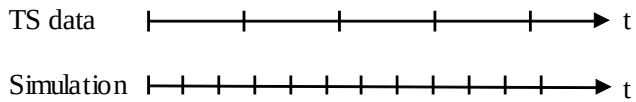
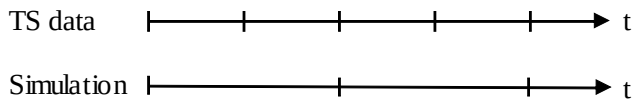
IDC can access multiple file formats: (i) ASCII text, (ii) HDF5, (iii) Fortran binary, and (iv) HEC-DSS files. The user can use several file formats in a single application. For instance, some of the input time series data can be read from HEC-DSS files whereas the rest can be read from ASCII text files. Some of the time series simulation results can be printed out to ASCII text files and the others can be printed out to HEC-DSS files.

Although IDC allows usage of several file formats in a single application, some of the input and output files are required to be in specific formats. For instance, all budget output files generated by IDC and read in by Budget post-processors are required to be in HDF5

Table 6. Example for the representation of recycled time series data

Time Stamp	Fraction of Urban Indoors Water
04/30/4000_24:00	0.70
08/31/4000_24:00	0.50
12/31/4000_24:00	0.35

Table 7. Examples of acceptable and unacceptable cases for the synchronization of time series data interval and the simulation time step

Situation	Graphical Representation	Accepted
Monthly time series data, monthly simulation		Yes
Monthly time series data, daily simulation		Yes
Monthly time series data, monthly simulation (TS data times don't match simulation times)		No
Monthly time series data, weekly simulation		No
Monthly time series data, yearly simulation		No

format. Another example is the main control input file for all IDC: this file is required to be in ASCII text file format.

IDC recognizes the file formats from the file name extensions. Table 8 lists the extensions that are recognized by IDC for each of the file formats.

5.3 Input Files

Input files in IDC include comment lines as well as the input data itself. A line with one of “C”, “c” or “*” at the first column is identified as a comment line. The inclusion of comment lines allows IDC files to be self-documenting; the purpose of each file along with the description of each input data are already included in IDC input file templates, and the user can include explanations for the data development directly in the input files using the comment lines.

A schematic representation of IDC input file structure is given in Figure 18. A Main Input File serves as the starting point for an IDC simulation. The IDC Main Input File lists

Table 8. File name extensions recognized by IDC

File Type	Recognized File Name Extensions
ASCII	.DAT .TXT .OUT .IN .IN1 .IN2 .BUD
HDF5	HDF HDF5 H5 HE5
Fortran binary	.BIN
HEC-DSS	.DSS

the names of the data files that include grid nodal x-y coordinates, element configuration data, precipitation and evaporation data, list of elements that are covered by lakes or reservoirs where root zone flow processes are not simulated, and the root zone parameters.

The IDC Main Input File also lists the beginning and ending date and time of the simulation as well as the simulation time step length. Factors to convert IDC simulation units into desired units of output are also listed in this file.

Root Zone Parameter File that is listed in the IDC Main Input File acts as a gateway to all the parameters and data files required for the simulation of the root zone flow processes and water demand computations. The first line of data entry in this file lists the version number of the root zone component (e.g. 4.0 or 4.1). Once IDC reads this version number it knows what additional parameters it should read and what flow processes it should simulate. The Root Zone Parameter File also includes names of gateway data files required for the simulation of non-ponded crops, ponded crops, urban lands, and lands with native and riparian vegetation. Additionally, it includes file names for simulation output, soil parameters at each cell and the destination for the surface runoff generated at each cell. Gateway files for non-ponded crops, ponded-crops, urban lands and lands with native and riparian vegetation act as containers for additional data file names and parameters that are necessary to simulate the flow processes and water demands (if applicable) for these land-use types. These gateway files provide a structure for the user to group related data files as well as turn on or off the simulation of particular land use types in an application. For instance, by leaving blank the name of the gateway file for non-ponded crops in the Root Zone Parameter File, the user can easily omit the simulation of flow processes for non-ponded

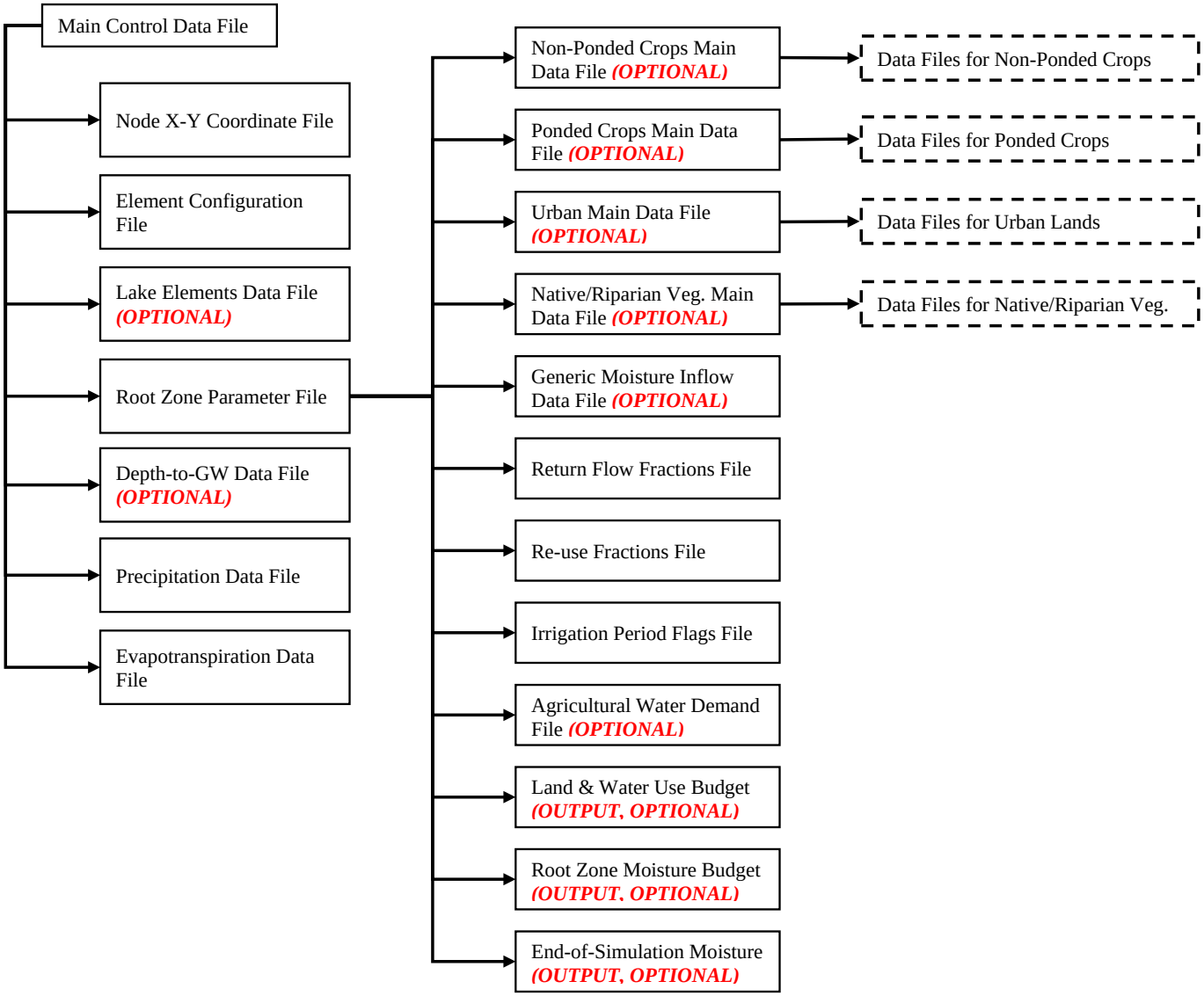


Figure 18. Schematic representation of the IDC input file structure

crops. This feature allows easy implementation of scenario studies where a particular land-use type is assumed to be non-existent with respect to a base-case scenario.

Each land-use type (non-ponded crops, ponded-crops, urban or native and riparian vegetation) include a data file that lists the area of each land-use type at a grid cell. These areas can be entered either as absolute areas or as fractions of the total cell area. In either case, IDC normalizes all areas (given as absolute areas or fractions) specified for a grid cell and converts all specified values into fractions of the cell area. However, whichever option is used to specify the land-use areas at a grid cell, it has to be consistent for all land-use types. For example, if the areas of non-ponded crops at a cell are specified as fractions, then areas for the ponded crops, urban lands and lands with native and riparian vegetation should also be specified as fractions. Otherwise, the total cell area will be incorrectly divided into the land-use types.

The following sections describe in detail the variables to be populated in each of the input file and display sample files.

5.3.1 IDC Main Input File

The IDC Main Input File serves as the starting point for an IDC simulation. The names of the data files for the IDC simulation are listed in this file as well as the beginning and ending date and time of the simulation, the simulation time step length and output control options.

The following is a list of the variables used in this data file:

BDT	Beginning simulation date and time; use MM/DD/YYYY_hh:mm format

EDT	Ending simulation date and time; use MM/DD/YYYY_hh:mm format
UNITT	Time step length and unit; choose one of the options listed in the IDC Main Input File which are time steps that are recognized by HEC-DSS database system
CACHE	This is the minimum number of simulation results for each time series output data that is stored in the computer memory before saved onto the hard disk; a large value (e.g. 50000 or more) that is permissible by the memory resources may have a substantial effect on decreasing the simulation run-times
KDEB	Switch for simulation progress monitoring (1 = print detailed messages on the screen; 0 = print only simulation timesteps on the screen; –1 = do not print any messages on the screen)

```
C*****************************************************************************
C
C                          IWFM DEMAND CALCULATOR (IDC)
C                              *** Version ### ***
C
C*****************************************************************************
C
C                            MAIN INPUT FILE
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: IDC_MAIN.in
C
C*****************************************************************************
C                               File Description
C
C    This file contains the control data for IDC that includes the names and
C    descriptions of all simulation files; simulation period and output control
C    options.
C
C****************************************************************************
C                            File Description
C
C  *Listed below are all input and output file names used when running the
C   utility.
C  *Each file name has a maximum length of 1000 characters
C  *If an optional file does not exist for a project, leave the filename blank
C
C-----------------------------------------------------------------------------
C    FILE NAME                                          DESCRIPTION
C-----------------------------------------------------------------------------------------
     Grid\Element.dat                                   / 1: ELEMENT CONFIGURATION FILE (INPUT, REQUIRED)
     Grid\NodeXY.dat                                    / 2: NODE X-Y COORDINATE FILE (INPUT, REQUIRED)
                                                        / 3: LAKE ELEMENTS DATA FILE (INPUT, OPTIONAL)
     RootZone\ROOTZONE_MAIN.dat                         / 4: ROOT ZONE PARAMETER DATA FILE (INPUT, REQUIRED)
     DepthToGW.dat                                      / 5: DEPTH-TO-GROUNDWATER DATA FILE (INPUT, OPTIONAL)
     Precip_ET\Precip.dat                               / 6: PRECIPITATION DATA FILE (INPUT, REQUIRED)
     Precip_ET\ET.dat                                   / 7: EVAPOTRANSPIRATION DATA FILE (INPUT, REQUIRED)
C****************************************************************************
C                          Model Simulation Period
C
C   The following lists the simulation beginning time, ending time and time step length.
C
C   BDT    ; Beginning simulation date and time. Use MM/DD/YYYY_hh:mm format.
C              * Midnight is 24:00
C   EDT   ; Ending simulation date and time.  Use MM/DD/YYYY_hh:mm format.
C              * Midnight is 24:00
C   UNITT  ; Time step length and unit. Choose one of the following:
C                  1MIN
C                  2MIN
C                  3MIN
C                  4MIN
C                  5MIN
C                  10MIN
C                  15MIN
C                  20MIN
C                  30MIN
C                  1HOUR
C                  2HOUR
C                  3HOUR
C                  4HOUR
C                  6HOUR
C                  8HOUR
C                  12HOUR
C                  1DAY
C                  1WEEK
C                  1MON
C                  1YEAR
C
C-----------------------------------------------------------------------------
C       VALUE                    DESCRIPTION
C-----------------------------------------------------------------------------
      09/30/1997_24:00           / BDT
      09/30/2001_24:00           / EDT
      1day                       / UNITT
C****************************************************************************
C                   Output Control Options
C
C    CACHE   ; Cache size in terms of number of values stored for time series data output
C    KDEB    ; Enter  1 - to print messages on the screen to monitor execution
C              Enter  0 - otherwise
C              Enter -1 - to supress printing of timesteps on the screen
C
C---------------------------------------------------------------------------
C       VALUE                    DESCRIPTION
C---------------------------------------------------------------------------
        5000000                  / CACHE
        0                        / KDEB
```

5.3.2 Element Configuration File

The Element Configuration File details the element configuration for each element represented in the finite element mesh, number of subregions that the model domain is divided into, the name of the subregions and the subregion number that each element belongs to. Each element is configured using three or four nodal points. All elements that represent the model domain are either triangular or quadrilateral. A zero value for IDE(4) indicates that the element is triangular. Nodes corresponding to each element are specified in a counterclockwise manner. IWFM Mesh Generator that is available for download from the IWFM web site can be used to quickly generate the finite element grid. The following variables are required as input in Element Configuration File:

NE	Number of elements within the model domain
NREGN	Number of subregions the model domain is divided into
RNAME	Name of each subregion (maximum 50 characters long)
IE	Element number
IDE	Nodes corresponding to each element number; 3 nodes are associated with each triangular element (4th node should be set to zero) and 4 nodes are associated with each quadrilateral element
IRGE	Subregion number that element IE belongs to

```
C*****************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*****************************************************************************
C
C                       ELEMENT CONFIGURATION FILE
C                        Discretization Component
C                          *** Version ### ***
C
C
C            Project:  IDC Version ### Release
C                      California Department of Water Resources
C            Filename: Element.dat
C
C*****************************************************************************
C                            File Description
C
C   This file  contains the element configuration for each element.
C   The nodes that make a finite element are listed for each element in
C   a counter-clock wise fashion starting with any node. For triangular elements,
C   the fourth node is specified as zero.
C
C
C   For example,
C
C                   13-------------14----------17
C                    I              I         I
C                    I      2       I   3   I
C                    I              I     I
C                    I              I   I
C                   15------------- 16
C
C
C   The configuration for elements 2 and 3 will be listed as,
C
C           element   node 1    node 2    node 3   node 4
C              2        13        15        16        14
C              3        14        16        17         0
C
C*****************************************************************************
C                     Element Configuration Data
C
C    NE    ;   Number of elements within the model domain
C    NREGN ;   Number of subregions
C
C-----------------------------------------------------------------------------
C   VALUE                          DESCRIPTION
C-----------------------------------------------------------------------------
    400                            / NE
    4                              / NREGN
C*****************************************************************************
C                         Sub-region Names
C
C   The following lists the names for each sub-region in a sequential order.
C
C-----------------------------------------------------------------------------
C
C   RNAME; Sub-region name (max. 50 characters)
C
C-----------------------------------------------------------------------------
C   VALUE                        DESCRIPTION
C-----------------------------------------------------------------------------
    Region1                      / RNAME1
    Region2                      / RNAME2
    Region3                      / RNAME3
    Region4                      / RNAME4
C*****************************************************************************
C
C   The data listed below represents all elements and corresponding nodes
C   within the model domain.
C
C   IE;      Element number
C   IDE;     Nodes corresponding to each element
C            *Note* IDE(4) is zero for all triangular elements
C   IRGE;    Subregion number to which element IE belongs to
C
C-----------------------------------------------------------------------------
C   Element     ------------Corresponding Nodes------------------      Subregion
C   IE          IDE(1)        IDE(2)       IDE(3)       IDE(4)           IRGE
C-----------------------------------------------------------------------------
     1           1             2            23           22               1
     2           2             3            24           23               1
     3           3             4            25           24               1
     4           4             5            26           25               1
     5           5             6            27           26               1
     .           .             .            .            .                .
     .           .             .            .            .                .
     .           .             .            .            .                ,
     397         416           417          438          437              4
     398         417           418          439          438              4
     399         418           419          440          439              4
     400         419           420          441          440              4
```

5.3.3 Nodal X-Y Coordinate File

The nodal coordinate file contains node numbers and corresponding x and y coordinates. Any coordinate units may be used as long as the appropriate conversion factor is given. This file sets up the spatial orientation of the finite element mesh nodes in the model domain. The finite element mesh is generated from the nodal coordinates, as well as relationship between elements and corresponding nodes (refer to the Element Configuration File).

ND	Number of nodes
FACT	Factor to convert nodal coordinates to simulation unit of length
ID	Node identification number
X	x-coordinate of node location
Y	y-coordinate of node location

```
C*******************************************************************************
C
C                    INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                        NODAL X-Y COORDINATE FILE
C                         Discretization Component
C                           *** Version ### ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: NodeXY.dat
C
C*******************************************************************************
C                            File Description
C
C   *This file includes all groundwater nodes that represent the model domain,
C    as well as the x and y coordinates that correspond with each node.
C
C   *The coordinates can be specified for any reference point and coordinate
C    system
C
C*******************************************************************************
C                    Groundwater Node Specifications
C
C   ND;    Number of groundwater nodes
C   FACT;  Conversion factor for nodal coordinates
C-------------------------------------------------------------------------------
C   VALUE                          DESCRIPTION
C-------------------------------------------------------------------------------
    441                            /ND
    1.0                            /FACT
C-------------------------------------------------------------------------------
C*******************************************************************************
C                      Groundwater Node Locations
C   The following lists the node number and x & y coordinate of each node
C
C   ID;   Groundwater node number
C   X,Y;  Coordinates of groundwater node location; [L]
C
C-------------------------------------------------------------------------------
C   Node     ----------Coordinates----------
C    ID            X                 Y
C-------------------------------------------------------------------------------
      1         0.0                0.0
      2         2000.0             0.0
      3         4000.0             0.0
      4         6000.0             0.0
      5         8000.0             0.0
      .         .                  .
      .         .                  .
      .         .                  .
    437         32000.0            40000.0
    438         34000.0            40000.0
    439         36000.0            40000.0
    440         38000.0            40000.0
    441         40000.0            40000.0
```

5.3.4 Lake Elements Data File

The Lake Elements Data File lists the grid cells that are lake elements and will be excluded from land surface and root zone flow computations. It should be noted that lakes in IDC are different then the ponded areas for rice and refuges. Rice and refuge ponding operations are explicitly simulated in IDC and the grid cells with such ponds should not be listed in the Lake Elements Data File.

The following variables are used in this data file:

NTELAKE	Total number of lake elements
IELAKE	List of lake elements

```
C*******************************************************************************
C
C                          IWFM DEMAND CALCULATOR (IDC)
C                              *** Version ### ***
C
C*******************************************************************************
C
C                      LAKE ELEMENTS DATA FILE
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: LakeElems.dat
C
C*******************************************************************************
C
C                              File Description:
C
C   This data file lists the lake elements that will be excluded from root zone
C   flow routing.
C
C*******************************************************************************
C                  Lake Elements Data
C
C   NTELAKE ;  Total number of lake elements
C   IELAKE  ;  Lake element number
C
C-------------------------------------------------------------------------------
C   VALUE                       DESCRIPTION
C-------------------------------------------------------------------------------
    7                           / NTELAKE
C-------------------------------------------------------------------------------
C   IELAKE
C-------------------------------------------------------------------------------
    12
    13
    56
    57
    58
    102
    103
```

5.3.5 Depth-to-Groundwater Data File

To simulate the contribution of groundwater to plant evapotranspiration, the Depth-to-Groundwater data file must be specified. This data file lists the specific yield for the underlying aquifer material and time series depth-to-groundwater at each finite element cell. This information can be obtained deduced from field measurements or from a groundwater model. When IDC is linked to an integrated hydrologic model such as IWFM, the depth-to-groundwater data is computed dynamically by the hydrologic model and passed to IDC. It should be noted that if the contribution of groundwater to evapotranspiration is to be simulated, then Root Zone Component Version 4.1 must be used.

The following variables are used in this file:

NDGW	Number of depth-to-groundwater time series data columns
FACTDGW	Conversion factor for depth-to-groundwater
NSPDGW	Number of time steps to update the depth-to-groundwater data; if time tracking simulation, enter any number
NFQDGW	Repetition frequency of the depth-to-groundwater data (enter zero if full time series data is supplied); if time tracking simulation, enter any number
DSSFL	If the time series data is stored in a DSS file, name of the file; leave blank if the data is listed in the Depth-to-Groundwater Data File

Aquifer Specific Yield and Cell-Data Connections

In this section, specific yield of the underlying aquifer material and the depth-to-groundwater data column pointer are listed for each finite element cell:

IE	Finite element identification number entered sequentially
SY	Specific yield of the underlying aquifer material at element IE; [L/L]
IDGW	Column number for the depth-to-groundwater time series data to be used at element IE

Data Input from Depth-to-Groundwater Data File

If the time series data is listed in the Depth-to-Groundwater Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

ITDGW	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
DGW	Depth-to-groundwater time series data, [L]

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                          IWFM DEMAND CALCULATOR (IDC)
C                              *** Version ### ***
C
C*******************************************************************************
C
C                     DEPTH-TO-GROUNDWATER DATA FILE
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: DepthToGW.dat
C
C*******************************************************************************
C
C                               File Description:
C
C   This data file lists the specific yield of underlying aquifer material and
C   time-series depth-to-groundwater data at each element to be used in water
C   demand calculations and root zone flow routing.
C
C*******************************************************************************
C              Depth-to-Groundwater Time Series Data Specifications
C
C   NDGW   ;  Number of data columns (or pathnames if DSS files are used)
C   FACTDGW;  Conversion factor for depth-to-groundwater data
C   NSPDGW ;  Number of time steps to update the depth-to-groundwater data
C              * Enter any number if time-tracking option is on
C   NFQDGW ;  Repetition frequency of the depth-to-groundwater data
C              * Enter 0 if full time series data is supplied
C              * Enter any number if time-tracking option is on
C   DSSFL  ;  The name of the DSS file for data input (maximum 50 characters);
C              * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-------------------------------------------------------------------------------
          1                                           / NDGW
          1.0                                         / FACTDGW
          1                                           / NSPDGW
          0                                           / NFQDGW
                                                      / DSSFL
C*******************************************************************************
C             Specific Yield and Element-Data-Column Connections
C
C   IE     ;  Element ID
C   SY     ;  Specific yield of the underlying aquifer material to be used in computing root
C               water uptake from groundwater; [L/L]
C   IDGW   ;  Depth-to-groundwater data column to be used for element IE
C
C-------------------------------------------------------------------------------
C   IE      SY     IDGW
C-------------------------------------------------------------------------------
   1        0.2     1
   2        0.2     1
   3        0.2     1
   .        .       .
   .        .       .
   .        .       .
   397      0.2     1
   398      0.2     1
   399      0.2     1
   400      0.2     1
C*******************************************************************************
C                        Depth-to-Groundwater Data
C                          (READ FROM THIS FILE)
C
C   List depth-to-groundwater data below, if it will
C   not be read from a DSS file (i.e. DSSFL is left blank above).
C
C   ITDGW ;   Time
C   DGW   ;   Depth-to-groundwater; [L]
C
C-------------------------------------------------------------------------------
C ITDGW               DGW[1]  DGW[2]  DGW[3] ... DGW[NDGW]
C-------------------------------------------------------------------------------
   12/31/2500_24:00   10.0
*
C-------------------------------------------------------------------------------
C                  Pathnames for Depth-to-Groundwater Data
C                         (READ FROM DSS FILE)
C
C   List the pathnames for the depth-to-groundwater data below, if it will be read
C   from a DSS file (i.e. DSSFL is specified above).
C
C   REC    ;  Time series record number
C   PATH   ;  Pathname for the time series record
C
C-------------------------------------------------------------------------------
C   REC        PATH
C-------------------------------------------------------------------------------
*
*
```

5.3.6 Precipitation File

The Precipitation File contains the time series rainfall values for each of the rainfall stations used in the simulation. Each element is associated with a rainfall station in the Root Zone Component Main File as described later in this document. The factors that convert the precipitation at rainfall stations to the precipitation over the elements are also listed in the Root Zone Component Main File. The rainfall data for a station associated with an element is multiplied by the corresponding factor to obtain the rainfall rate over an element.

In non-time tracking simulations a time-series precipitation data set of any frequency can be used as the precipitation data in IDC. NSPRN and NFQRN must be specified according to the frequency of the data entered. If the precipitation data is specified for the entire simulation period, NFQRN should be set to zero. In time tracking simulations the time series precipitation data can be either listed in this file or in a DSS file. If a DSS file is used for data input, then the name of the DSS file and the pathnames corresponding to each of the time series data are required.

The following variables are used:

NRAIN	Number of rainfall stations used in the model
FACTRN	Conversion factor for the spatial component of the unit for the rainfall rate
NSPRN	Number of time steps to update the precipitation data; if time tracking simulation, enter any number
NFQRN	Repetition frequency of the precipitation data (enter zero if full time series data is supplied); if time tracking simulation, enter any number

DSSFL	If the time series data is stored in a DSS file, name of the file; leave blank if the data is listed in the Precipitation File

Data Input from Precipitation File

If the time series data is listed in the Precipitation File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

ITRN	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
ARAIN	Rainfall rate at the corresponding rainfall station, [L/T]

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                         PRECIPITATION DATA FILE
C               Precipitation and Evapotranspiration Component
C                            *** Version ### ***
C
C
C             Project : IDC Version ### Release
C                       California Department of Water Resources
C             Filename: Precip.dat
C
C*******************************************************************************
C                              File Description:
C
C   This data file contains the time-series rainfall at each rainfall station used
C   in the model.
C
C*******************************************************************************
C                         Rainfall Data Specifications
C
C   NRAIN ;  Number of rainfall stations (or pathnames if DSS files are used)
C             used in the model
C   FACTRN;  Conversion factor for rainfall rate
C             It is used to convert only the spatial component of the unit;
C             DO NOT include the conversion factor for time component of the unit.
C             * e.g. Unit of rainfall rate listed in this file = INCHES/MONTH
C                    Consistent unit used in simulation        = FEET/DAY
C                    Enter FACTRN (INCHES/MONTH -> FEET/MONTH) = 8.33333E-02
C                      (conversion of MONTH -> DAY is performed automatically)
C   NSPRN ;  Number of time steps to update the precipitation data
C             * Enter any number if time-tracking option is on
C   NFQRN ;  Repetition frequency of the precipitation data
C             * Enter 0 if full time series data is supplied
C             * Enter any number if time-tracking option is on
C   DSSFL ;  The name of the DSS file for data input (maximum 50 characters);
C             * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-------------------------------------------------------------------------------
          2                                           / NRAIN
          8.33333E-2                                  / FACTRN   (in -> ft)
          1                                           / NSPRN
          0                                           / NFQRN
          TSDATA_IN.DSS                               / DSSFL
C-------------------------------------------------------------------------------
C                              Rainfall Data
C                         (READ FROM THIS FILE)
C
C   List the rainfall rates for each of the rainfall station below, if it will
C   not be read from a DSS file (i.e. DSSFL is left blank above).
C
C   ITRN ;   Time
C   ARAIN;   Rainfall rate at the corresponding rainfall station; [L/T]
C
C-------------------------------------------------------------------------------
C ITRN    ARAIN(1)  ARAIN(2)  ARAIN(3) ...
C-------------------------------------------------------------------------------
*
*
C-------------------------------------------------------------------------------
C                       Pathnames for Rainfall Data
C                         (READ FROM DSS FILE)
C
C   List the pathnames for the rainfall data below, if it will be read
C   from a DSS file (i.e. DSSFL is specified above).
C
C   REC    ;  Time series record number
C   PATH   ;  Pathname for the time series record
C
C-------------------------------------------------------------------------------
C   REC        PATH
C-------------------------------------------------------------------------------
     1         /SAMPLE_PROBLEM/GAGE1/PRECIP//1MON/PRECIPITATION/
     2         /SAMPLE_PROBLEM/GAGE2/PRECIP//1MON/PRECIPITATION/
```

5.3.7 Evapotranspiration File

The Evapotranspiration File contains time series ET data for all crop types and non-agricultural land use types. The ET rates listed in this file are associated with individual land-use types in each element using the related Root Zone Component files as described later in this document. The conversion factor for the ET rates is a required input, as well as the number of time steps to update the data and the repetition frequency of the data. In time tracking simulations the time series evapotranspiration data can be either listed in this file or in a DSS file. If a DSS file is used for data input, then the name of the DSS file and the pathnames corresponding to each of the time series data are required. The ET rates listed in this file are associated with individual land-use types in each element using the related root zone component files as described later in this document.

The example file given below shows how recycled time series data in a time tracking simulation can be specified using the special year 4000 flag. The following is a list of the variables that need to be specified:

NCOLET	Number of evapotranspiration data columns
FACTET	Conversion factor for the spatial component of the unit for the evapotranspiration rate
NSPET	Number of time steps to update the ET data; if time tracking simulation, enter any number
NFQET	Repetition frequency of the ET data (enter zero if full time series data is supplied); if time tracking simulation, enter any number
DSSFL	If the time series data is stored in a DSS file, name of the file; leave blank if the data is listed in the Evapotranspiration File

Data Input from Evapotranspiration File

If the time series data is listed in the Evapotranspiration File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

ITEV	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
AEVAP	Evapotranspiration rate, [L/T]

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                       EVAPOTRANSPIRATION DATA FILE
C               Precipitation and Evapotranspiration Component
C                           *** Version ### ***
C
C
C
C             Project : IDC Version ### Release
C                       California Department of Water Resources
C             Filename: ET.dat
C
C*******************************************************************************
C                          File Description:
C
C   This data file contains sets of evapotranspiration values that are used in
C   root zone, lake and small watershed components of Simulation.
C
C*******************************************************************************
C                     Evapotranspiration Data Specifications
C
C   NCOLET;  Number of ET columns (or pathnames if DSS files are used)
C   FACTET:  Conversion factor for evapotranspiration rate
C             It is used to convert only the spatial component of the unit;
C             DO NOT include the conversion factor for time component of the unit.
C             * e.g. Unit of ET rate listed in this file       = INCHES/MONTH
C                    Consistent unit used in simulation        = FEET/DAY
C                    Enter FACTET (INCHES/MONTH -> FEET/MONTH) = 8.33333E-02
C                     (conversion of MONTH -> DAY is performed automatically)
C   NSPET ;  Number of time steps to update the ET data
C             * Enter any number if time-tracking option is on
C   NFQET ;  Repetition frequency of the ET data
C             * Enter 0 if full time series data is supplied
C             * Enter any number if time-tracking option is on
C   DSSFL ;  The name of the DSS file for data input (maximum 50 characters);
C             * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                          DESCRIPTION
C-------------------------------------------------------------------------------
          5                                              / NCOLET
          0.083333                                       / FACTET  (in/month -> ft/month)
          1                                              / NSPET
          0                                              / NFQET
                                                         / DSSFL
C-------------------------------------------------------------------------------
C                             Evapotranspiration Data
C                              (READ FROM THIS FILE)
C
C   ITEV ;   Time
C   AEVAP;   Evapotranspiration rate; [L/T]
C
C-------------------------------------------------------------------------------
C ITEV  AEVAP[1]  AEVAP[2]  AEVAP[3] ...  AEVAP[NCOLET]
C-------------------------------------------------------------------------------
C                    Tomatoes  Alfalfa     Rice    Urban    Native
  10/31/4000_24:00     3.4       3.5       2.2      3.4       3.4
  11/30/4000_24:00     1.6       1.6       1.6      1.6       1.6
  12/31/4000_24:00     1.0       1.0       1.0      0.5       1.0
  01/31/4000_24:00     1.0       1.0       1.0      0.5       1.0
  02/29/4000_24:00     1.8       1.8       1.8      1.8       1.8
  03/31/4000_24:00     3.0       3.0       3.0      3.0       3.0
  04/30/4000_24:00     4.5       4.1       8.0      4.5       4.5
  05/31/4000_24:00     5.9       5.4       9.1      5.9       5.9
  06/30/4000_24:00     7.3       6.8      10.4      7.3       7.3
  07/31/4000_24:00     7.9       7.7       9.7      7.9       7.9
  08/31/4000_24:00     6.6       6.8       7.0      6.6       6.6
  09/30/4000_24:00     5.2       5.4       1.9      5.2       5.2
C-------------------------------------------------------------------------------
C                       Pathnames for Evapotranspiration Data
C                              (READ FROM DSS FILE)
C
C   List the pathnames for evapotranspiration  data below, if it will
C   be read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C-----------------------------------------------------------------------------------
C   REC       PATH
C-----------------------------------------------------------------------------------
*
*
```

5.3.8 Input Files for Root Zone Component Version 4.0

The root zone component is the main simulation part of IDC. Root Zone Component Main File is the gateway to additional data files that are used in simulating land surface and root zone flow processes at agricultural, urban, native vegetation and riparian vegetation lands. Agricultural and urban water demands are also computed in the root zone component. Root zone component version 4.0 files are described in detail in the following sections.

5.3.8.1 Root Zone Component Main File

The Root Zone Component Main File includes the convergence criteria for the iterative solution of the non-linear soil moisture mass balance equation, names of additional input files that are used to simulate land surface and root zone flow processes for agricultural, urban and natural lands, and agricultural and urban water demands. Subregional Land and Water Use as well as Subregional Root Zone Moisture Budget output filenames are also listed in this file. Soil properties at each grid cell and the destination for the surface flow generated at each cell are listed in the last section of the Root Zone Component Main File.

First data line of the Root Zone Component Main File lists the version number (i.e. 4.0) of the root zone component that will be used in simulating the land surface and root zone flow processes. IDC first reads this data line to figure out what other parameters will be read and what flow processes are to be simulated. This first line of data entry must not be modified.

The following sections and variables are defined in the rest of this file:

Root Zone Simulation Scheme Control and Filenames

In this section convergence criteria for the iterative solution methodology and names of additional input and output files are listed.

RZCONV	Convergence criteria for iterative soil moisture accounting as a fraction of total porosity; [L/L]
RZITERMX	Maximum number of iterations for iterative soil moisture accounting
FACTCN	Conversion factor to convert inches to the simulation unit of length
AGNPFL	Filename for the Non-Ponded Crops Main File (maximum 1000 characters); leave blank if non-ponded crops are not simulated
PFL	Filename for the Ponded Crops Main File (maximum 1000 characters); leave blank if rice and/or refuge lands are not simulated
URBFL	Filename for the Urban Lands Main File (maximum 1000 characters); leave blank if urban lands are not simulated
NVRVFL	Filename for the Natural Lands Main File (maximum 1000 characters); leave blank if native and/or riparian vegetation lands are not simulated
RFFL	File that lists the return flow fractions (maximum 1000 characters); leave blank if only native and/or riparian vegetation lands are simulated
RUFL	File that lists the irrigation water re-use factors (maximum 1000 characters); leave blank if only native and/or riparian vegetation lands are simulated

IPFL	File that lists the irrigation periods for each ponded and non-ponded crop (maximum 1000 characters); this is a required file even if ponded and non-ponded crops are not simulated
MSRCFL	File that lists generic source of moisture rates other than precipitation and irrigation (maximum 1000 characters); leave blank if there are no generic sources of moisture simulated
AGWDFL	File that lists agricultural water supply requirement (maximum 1000 characters); leave blank if agricultural water supply requirement for all crops will be computed dynamically
LWUBUDFL	HDF5 output file for subregional land and water use budget (maximum 1000 characters); leave blank if this output is not required
RZBUDFL	HDF5 output file for subregional root zone moisture (maximum 1000 characters); leave blank if this output is not required
FNSMFL	Output file for end-of-simulation soil moisture (maximum 1000 characters); leave blank if this output is not required

Soil Parameters and Surface Flow Destinations

In this section soil parameters, precipitation rates, generic soil moisture sources (if any) and surface runoff destinations are listed for each finite element.

FACTK	Conversion factor for the spatial component of the root zone hydraulic conductivity

TUNITK	Time unit of root zone hydraulic conductivity this should be one of the units recognized by HEC-DSS that are listed in the IDC Main Input File
IE	Element identification number
WP	Wilting point; [L/L]
FC	Field capacity; [L/L]
TN	Total porosity; [L/L]
LAMBDA	Pore size distribution index
K	Saturated hydraulic conductivity; [L/T]
RHC	Method to represent hydraulic conductivity versus moisture content curve (1 = Campbell's equation, 2 = van Genucten-Mualem equation)
IRNE	Precipitation rate; this number corresponds to the appropriate data column in the Precipitation File
FRNE	Factor to convert rainfall at the precipitation data column IRNE to rainfall at element IE
IMSRC	Generic source of moisture; this number corresponds to the appropriate data column in the Generic Moisture Source File that applies to element IE (enter any number if the Generic Moisture Source File, MSRCFL, is not defined)
TYPDEST	Destination type for the surface flow from element IE (0 = surface flow goes outside of model area, 1 = surface flow goes to a stream node, 2 = surface flow goes to another element, 3 = surface flow goes

	to a lake, 4 = surface flow goes to a subregion, 5 = surface flow recharges the groundwater)
DEST	Destination identification number for the surface flow from element IE; enter any number if surface flow from the element goes outside the model area (TYPDEST = 0) or recharges the groundwater (TYPDEST = 5)

```
#4.0
C***  DO NOT DELETE ABOVE LINE ***
C
C*****************************************************************************
C
C                    INTEGRATED WATER FLOW MODEL (IWFM)
C
C*****************************************************************************
C
C                      ROOT ZONE PARAMETERS DATA FILE
C                           Root Zone Component
C                           *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: ROOTZONE_MAIN.dat
C
C*****************************************************************************
C                           File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes.
C
C*****************************************************************************
C                Root Zone Simulation Scheme Control and File Names
C
C   RZCONV   ;  Convergence criteria for iterative soil moisture accounting as a
C                fraction of total porosity; [L/L]
C   RZITERMX ;  Maximum number of iterations for iterative soil moisture accounting
C   FACTCN   ;  Conversion factor to convert inches to the simulation unit of length
C   AGNPFL   ;  Non-ponded agricultural crop data file (max. 1000 characters)
C                * Leave blank if non-ponded crops are not simulated
C   PFL      ;  Rice/refuge data file (max. 1000 characters)
C                * Leave blank if rice and/or refuge lands are not simulated
C   URBFL    ;  Urban lands data file (max. 1000 characters)
C                * Leave blank if urban lands are not simulated
C   NVRVFL   ;  Native/riparian vegetation lands data file (max. 1000 characters)
C                * Leave blank if native and/or riparion veg. lands are not simulated
C   RFFL     ;  File that lists the return flow fractions (max. 1000 characters)
C                * Leave blank if only native/riparian vegetation lands are simulated
C   RUFL     ;  File that lists the irrigation water re-use factors (max. 1000 characters)
C                * Leave blank if only native/riparian vegetation lands are simulated
C   IPFL     ;  File that lists the irrigation periods for each ponded and
C                non-ponded crop (max. 1000 characters)
C                * Leave blank if both ponded and non-ponded crops are not simulated
C   MSRCFL   ;  File that lists generic source of moisture rates other than precipitation
C                and irrigation (max. 1000 characters)
C                * Leave blank if there are no generic sources of moisture simulated
C   AGWDFL   ;  File that lists agricultural water supply requirement (max. 1000 characters)
C                * Leave blank if agricultural water supply requirement will be computed
C                  dynamically
C   LWUBUDFL ;  HDF5 output file for land and water use budget at each
C                  subregion (max. 1000 characters)
C                * Leave blank if this output is not required
C   RZBUDFL  ;  HDF5 output file for root zone moisture budget at each
C                  subregion (max. 1000 characters)
C                * Leave blank if this output is not required
C   FNSMFL   ;  Output file for end-of-simulation soil moisture (max. 1000 characters)
C                * Leave blank if this output is not required
C
C-------------------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-------------------------------------------------------------------------------------
          0.0001                                      / RZCONV
          200                                         / RZITERMX
          0.08333                                     / FACTCN  (in -> ft)
          RootZone\NonPondedAg\NonPondedAg.dat        / AGNPFL
          RootZone\PondedAg\PondedAg.dat              / PFL
          RootZone\Urban\Urban.dat                    / URBFL
          RootZone\NVRV\NVRV.dat                      / NVRVFL
          RootZone\ReturnFlowFrac.dat                 / RFFL
          RootZone\ReuseFrac.dat                      / RUFL
          RootZone\IrrigPeriod.dat                    / IPFL
                                                      / MSRCFL
          RootZone\AgWaterDemand.dat                  / AGWDFL
          Budget\LWU.hdf                              / LWUBUDFL
          Budget\RZ.hdf                               / RZBUDFL
                                                      / FNSMFL
C*****************************************************************************
C             Parameters for Soil, Precipitation and Runoff Destination
C
C   Enter conversion factors.
C
C   FACTK  ;  Conversion factor for root zone hydraulic conductivity
C              It is used to convert only the spatial component of the unit;
C              DO NOT include the conversion factor for time component of the unit.
C              * e.g. Unit of hydraulic conductivity listed in this file = FT/MONTH
C                     Consistent unit used in simulation                 = IN/DAY
C                     Enter FACT (FT/MONTH -> IN/MONTH)                  = 8.33333E-02
C                     (conversion of MONTH -> DAY is performed automatically)
C   TUNITK ;  Time unit of root zone hydraulic conductivity.  This should be one of the
C             units recognized by HEC-DSS that are listed in the Main Control File.
C
C-------------------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-------------------------------------------------------------------------------------
          0.283464                                    / FACTK (micrometers/sec -> ft/day)
          1day                                        / TUNITK
C-------------------------------------------------------------------------------------
C
C   Enter soil parameters, precipitaion and surface flow destination data below for each
C   grid element.
C
C   IE     ;  Element ID
C   WP     ;  Wilting point; [L/L]
C   FC     ;  Field capacity; [L/L]
C   TN     ;  Total porosity; [L/L]
C   LAMBDA ;  Pore size distribution index; [dimensionless]
C   K      ;  Saturated hydraulic conductivity; [L/T]
C   RHC    ;  Method to represent hydraulic conductivity vs. moisture content curve
C               1 = Campbell's equation
```

```
C   WP     ;  Wilting point; [L/L]
C   FC     ;  Field capacity; [L/L]
C   TN     ;  Total porosity; [L/L]
C   LAMBDA ;  Pore size distribution index; [dimensionless]
C   K      ;  Saturated hydraulic conductivity; [L/T]
C   RHC    ;  Method to represent hydraulic conductivity vs. moisture content curve
C               1 = Campbell's equation
C               2 = van Genucten-Mualem equation
C   CSDTH  ;  Depth of groundwater below which root water uptake from groundwater ceases (i.e.
C               evapotranspiration from groundwater stops)
C               * Note: Set CSDTH to zero to use rooting depth as the depth below which
C                       root water uptake from groundwater ceases
C   IRNE   ;  Precipitation data column in the Precipitation file that applies to element IE
C   FRNE   ;  Factor to convert rainfall at the precipitation data column to
C               rainfall at element IE
C   IMSRC  ;  Generic source of moisture data column in the Generic Moisture Source file (MSRCFL
C               file listed above) that applies to element IE
C               * Note: Enter any number if MSRCFL above is left blank
C   TYPDEST;  Destination type for the surface flow from element IE
C               0 = Surface flow goes outside of model area
C               1 =   "       "    "  to a stream node
C               2 =   "       "    "   " another element
C               3 =   "       "    "   " a lake
C               4 =   "       "    "   " a subregion
C               5 =   "       "    "   " groundwater
C   DEST   ;  Destination for the surface flow from element IE
C               * Note: Enter any number if TYPDEST is set to 0 or 5
C
C-----------------------------------------------------------------------------------------------------------------
C  IE      WP        FC        TN        LAMBDA    K           RHC    CSDTH   IRNE   FRNE   IMSRC   TYPDEST   DEST
C-----------------------------------------------------------------------------------------------------------------
   1       0.0000    0.1370    0.4530    0.3780    5.000E-02   2      10.0    1      1.0      0       0         3
   2       0.0000    0.1571    0.4640    0.2420    5.100E+01   2      10.0    1      1.0      0       0         3
   3       0.0000    0.1053    0.4630    0.2520    5.000E-02   2      10.0    1      1.0      0       0         3
   .        .         .         .         .         .          .      .       .       .       .       .         .
   .        .         .         .         .         .          .      .       .       .       .       .         .
   .        .         .         .         .         .          .      .       .       .       .       .         .
   220     0.0000    0.1210    0.4300    0.2230    5.000E-02   2      10.0    3      1.0      0       0         3
   221     0.0000    0.0485    0.4530    0.3780    5.000E-02   2      10.0    3      1.0      0       0         0
   222     0.0000    0.2322    0.5010    0.2340    1.906E+01   2      10.0    3      1.0      0       0         0
   223     0.0000    0.1210    0.4300    0.2230    5.000E-02   2      10.0    3      1.0      0       0         3
```

5.3.8.2 Return Flow Fractions Data File

The Return Flow Fractions Data File lists return flows specified as time series fractions of applied water. Non-ponded crops, ponded crops and urban lands at each element are associated with data columns in this file through pointers specified in the Non-Ponded Crops Main File, Ponded Crops Main File and Urban Lands Main File, respectively.

The following variables are used in this file:

NCOLRT	Number of return flow fractions data columns
NSPRT	Number of time steps to update the return flow fractions; enter any number if time-tracking simulation
NFQRT	Repetition frequency of the return flow fractions data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Return Flow Fractions Data File

If the time series data is listed in the Return Flow Fractions Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
RTRNF	Return flows as a fraction of applied water

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                 RETURN FLOW FRACTIONS DATA FILE
C                       Root Zone Component
C                       *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: ReturnFlowFrac.dat
C
C*******************************************************************************
C                            File Description
C
C   This data file contains a set of return flows given as fractions of irrigation
C   water.
C
C*******************************************************************************
C               Return Flow Fractions Data Specifications
C
C   NCOLRT ; Number of return flow fractions data columns
C   NSPRT  ; Number of time steps to update the return flow fractions
C            * Enter any number if time-tracking option is on
C   NFQRT  ; Repetition frequency of the return flow fractions data
C            * Enter 0 if full time series data is supplied
C            * Enter any number if time-tracking option is on
C   DSSFL  ; The name of the DSS file for data input
C            * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                          DESCRIPTION
C-------------------------------------------------------------------------------
          2                                              / NCOLRT
          1                                              / NSPRT
          0                                              / NFQRT
                                                         / DSSFL
C-------------------------------------------------------------------------------
C                            Return Flow Fractions
C                            (READ FROM THIS FILE)
C
C   List the return flow fractions data below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   RTRNF;  Return flows as a fraction of applied water; [dimensionless]
C
C-------------------------------------------------------------------------------
C  TIME              RTRNF_AG    RTRNF_URB  RTRNF[3] ... RTRNF[NCOLRT]
C-------------------------------------------------------------------------------
   12/31/2500_24:00    0.2         0.2
*
C-------------------------------------------------------------------------------
C                    Pathnames for Return Flow Fractions Data
C                              (READ FROM DSS FILE)
C
C   List the pathnames for return flow fractions data below, if it
C   will be read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C-------------------------------------------------------------------------------
C   REC     PATH
C-------------------------------------------------------------------------------
*
*
```

5.3.8.3 Re-use Fractions Data File

The Re-use Fractions Data File lists re-used portion of the captured return flow from agricultural and urban lands. It is specified as time series fractions of applied water. The difference between the return flow and re-use is the net return flow from agricultural and urban lands. Non-ponded crops, ponded crops and urban lands at each element are associated with data columns in this file through pointers specified in the Non-Ponded Crops Main File, Ponded Crops Main File and Urban Lands Main File, respectively.

The following variables are used in this file:

NCOLRUF	Number of re-use fractions data columns
NSPRUF	Number of time steps to update the re-use fractions; enter any number if time-tracking simulation
NFQRUF	Repetition frequency of the re-use fractions data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Re-use Fractions Data File

If the time series data is listed in the Re-use Fractions Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
RUF	Re-use as a fraction of applied water

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                    RE-USE FRACTIONS DATA FILE
C                       Root Zone Component
C                       *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: ReuseFrac.dat
C
C*******************************************************************************
C                           File Description
C
C   This data file contains a set of re-use data given as fractions of irrigation
C   water.
C
C*******************************************************************************
C               Re-Use Fractions Data Specifications
C
C   NCOLRUF ; Number of re-use fractions data columns
C   NSPRUF  ; Number of time steps to update the re-use fractions
C              * Enter any number if time-tracking option is on
C   NFQRUF  ; Repetition frequency of the re-use fractions data
C              * Enter 0 if full time series data is supplied
C              * Enter any number if time-tracking option is on
C   DSSFL   ; The name of the DSS file for data input
C              * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                          DESCRIPTION
C-------------------------------------------------------------------------------
           2                                             / NCOLRUF
           1                                             / NSPRUF
           0                                             / NFQRUF
                                                         / DSSFL
C-------------------------------------------------------------------------------
C                              Re-Use Fractions
C                            (READ FROM THIS FILE)
C
C   List the re-use fractions data below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   RUF  ;  Re-use as a fraction of applied water; [dimensionless]
C
C-------------------------------------------------------------------------------
C  TIME                 RUF_AG  RUF_URB  RUF[3] ... RUF[NCOLRUF]
C-------------------------------------------------------------------------------
   12/31/2500_24:00    0.05     0.0
*
C-------------------------------------------------------------------------------
C                       Pathnames for Re-Use Fractions Data
C                             (READ FROM DSS FILE)
C
C   List the pathnames for re-use fractions data below, if it
C   will be read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C-------------------------------------------------------------------------------
C   REC     PATH
C-------------------------------------------------------------------------------
*
*
```

5.3.8.4 Irrigation Period Data File

The Irrigation Period Data File includes time series flags that represent cropping seasons for ponded and non-ponded crops. A value of 0 represents a non-cropping period so IDC does not compute agricultural water demand for that period; a value of 1 represents cropping period and IDC calculates water demand for that period. The ponded and non-ponded crops in each element are associated with data columns in this file through pointers specified in the Ponded Crops Main File and the Non-Ponded Crops Main File.

The following variables are used in this file:

NCOLIP	Number of data columns for irrigation period
NSPIP	Number of time steps to update the irrigation period data; enter any number if time-tracking option is on
NFQIP	Repetition frequency of the irrigation period data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Irrigation Period Data File

If the time series data is listed in the Irrigation Period Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
IP	Irrigation period indicator (0 = it is out of cropping season and IDC will not compute a water demand; 1 = cropping season and IDC will compute a water demand)

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                   IRRIGATION PERIOD DATA FILE
C                       Root Zone Component
C                       *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: IrrigPeriod.dat
C
C*******************************************************************************
C                           File Description
C
C   This data file contains a set of irrigation period indicators (1 for irrigation
C   season and 0 for non-irrigation season).  These values are correlated to
C   individual ponded and non-ponded crops through the Ponded Crops Main File and
C   the Non-Ponded Crops Main File.
C
C*******************************************************************************
C               Irrigation Period Data Specifications
C
C   NCOLIP  ; Number of irrigation period data columns
C   NSPIP   ; Number of time steps to update the irrigation period data
C             * Enter any number if time-tracking option is on
C   NFQIP   ; Repetition frequency of the irrigation period data
C             * Enter 0 if full time series data is supplied
C             * Enter any number if time-tracking option is on
C   DSSFL   ; The name of the DSS file for data input
C             * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-------------------------------------------------------------------------------
          22                                          / NCOLIP
          1                                           / NSPIP
          0                                           / NFQIP
          Example_Data.dss                            / DSSFL
C-----------------------------------------------------------------------------------------------
C                         Irrigation Period Indicators
C                            (READ FROM THIS FILE)
C
C   List the irrigtaion period data below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   IP   ;  Irrigation period indicator;
C             0 = non-irrigation period (i.e. agricultural water demand will not be computed)
C             1 = irrigation period (i.e. agricultural water demand will be computed)
C
C-----------------------------------------------------------------------------------------------
C  TIME  IP[1]  IP[2]  IP[3] ... IP[NCOLIP]
C-----------------------------------------------------------------------------------------------
*
*
C-------------------------------------------------------------------------------
C                        Pathnames for Irrigation Period Data
C                              (READ FROM DSS FILE)
C
C   List the pathnames for irrigation period indicators below, if it
C   will be read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C-----------------------------------------------------------------------------------------------
C   REC     PATH
C-----------------------------------------------------------------------------------------------
    1        /IWFM/GR_IP/FLAG//1MON/IRRIG_PERIOD/
    2        /IWFM/CO_IP/FLAG//1MON/IRRIG_PERIOD/
    3        /IWFM/SB_IP/FLAG//1MON/IRRIG_PERIOD/
    4        /IWFM/CR_IP/FLAG//1MON/IRRIG_PERIOD/
    5        /IWFM/DB_IP/FLAG//1MON/IRRIG_PERIOD/
    6        /IWFM/SF_IP/FLAG//1MON/IRRIG_PERIOD/
    7        /IWFM/FI_IP/FLAG//1MON/IRRIG_PERIOD/
    8        /IWFM/AL_IP/FLAG//1MON/IRRIG_PERIOD/
    9        /IWFM/PA_IP/FLAG//1MON/IRRIG_PERIOD/
    10       /IWFM/TM_IP/FLAG//1MON/IRRIG_PERIOD/
    11       /IWFM/CU_IP/FLAG//1MON/IRRIG_PERIOD/
    12       /IWFM/OG_IP/FLAG//1MON/IRRIG_PERIOD/
    13       /IWFM/TR_IP/FLAG//1MON/IRRIG_PERIOD/
    14       /IWFM/AP_IP/FLAG//1MON/IRRIG_PERIOD/
    15       /IWFM/OR_IP/FLAG//1MON/IRRIG_PERIOD/
    16       /IWFM/SO_IP/FLAG//1MON/IRRIG_PERIOD/
    17       /IWFM/FL_IP/FLAG//1MON/IRRIG_PERIOD/
    18       /IWFM/RICE_FL_IP/FLAG//1MON/IRRIG_PERIOD/
    19       /IWFM/RICE_NFL_IP/FLAG//1MON/IRRIG_PERIOD/
    20       /IWFM/RICE_NDC_IP/FLAG//1MON/IRRIG_PERIOD/
    21       /IWFM/RFG_SL_IP/FLAG//1MON/IRRIG_PERIOD/
    22       /IWFM/RFS_PR_IP/FLAG//1MON/IRRIG_PERIOD/
```

5.3.8.5 Generic Moisture Source File

The Generic Moisture Source File lists time series moisture inflow into the root zone from sources other than irrigation and precipitation. Possible sources of moisture are fog and lateral seepage through levees in places such as California's Sacramento-San Joaquin River Delta. The inflow rate is given in terms of unit rate per rooting depth of a land-use type. All land-use types can have access to generic sources of moisture. Each land-use type at each element is associated to a data column in this file through pointers in the respective main input file of a particular land-use.

The following variables are used in this file:

NCOLSRC	Number of generic moisture data columns
FACTSRC	Conversion factor for the spatial component of the generic moisture data
NSPSRC	Number of time steps to update the generic moisture data; enter any number if time-tracking simulation
NFQSRC	Repetition frequency of the generic moisture data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Generic Moisture Source File

If the time series data is listed in the Generic Moisture Source File, then the following variables need to be populated. Otherwise, these variables should be commented out using

“C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
MSRC	Generic moisture inflow rate; [(L/L)/T]

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C            GENERIC MOISTURE SOURCE DATA FILE
C                   Root Zone Component
C                   *** Version 4.0 ***
C
C
C            Project:  IDC Version ### Release
C                      California Department of Water Resources
C            Filename: GenericMoist.dat
C
C*******************************************************************************
C                            File Description:
C
C   This file contains a set of moisture time-series data to be used as generic
C   source of water for the root zone. This additional source of moisture can be
C   used to represent any source of water other then precipitation and irrigation.
C   The unit of the generic moisture is specified as [(L/L)/T], for instance
C   inches per foot per month. These values will be converted to unit rate of inflow
C   by the Root Zone Component by multiplying them with the rooting depth for each
C   land use. The generic moisture data are correlated to individual grid cells
C   through the Root Zone Parameter file.
C
C*******************************************************************************
C                  Generic Moisture Source Data Specifications
C
C   NCOLSRC; Number of generic moisture data columns (or pathnames if DSS files are used)
C   FACTSRC; Conversion factor for generic moisture data
C            It is used to convert only the spatial component of the unit;
C            DO NOT include the conversion factor for time component of the unit.
C            * e.g. Unit of generic moisture listed in this file          = INCHES/FOOT/MONTH
C                   Consistent unit used in simulation                    = FOOT/FOOT/DAY
C                   Enter FACTSRC (INCHES/FOOT//MONTH -> FOOT/FOOT/MONTH) = 8.33333E-02
C                     (conversion of MONTH -> DAY is performed automatically)
C   NSPSRC ; Number of time steps to update the generic moisture data
C            * Enter any number if time-tracking option is on
C   NFQSRC ; Repetition frequency of the generic moisture data
C            * Enter 0 if full time series data is supplied
C            * Enter any number if time-tracking option is on
C   DSSFL ;  The name of the DSS file for data input (maximum 50 characters);
C            * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-------------------------------------------------------------------------------
          3                                           / NCOLSRC
          0.083333                                    / FACTSRC   (in -> ft)
          1                                           / NSPSRC
          0                                           / NFQSRC
          INPUT_DATA.DSS                              / DSSFL
C-------------------------------------------------------------------------------
C                        Generic Moisture Data
C                        (READ FROM THIS FILE)
C
C   List the generic moisture rates below in units of L/L/T, if it will
C   not be read from a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;   Time
C   MSRC ;   Generic moisture rate; [L/L/T]
C
C-------------------------------------------------------------------------------
C  TIME      MSRC[1]  MSRC[2]  MSRC[3]  ...  MSRC[NCOLSRC] ...
C-------------------------------------------------------------------------------
*
*
C-------------------------------------------------------------------------------
C                    Pathnames for Generic Moisture Data
C                         (READ FROM DSS FILE)
C
C   List the pathnames for the generic moisture data below, if it will be read
C   from a DSS file (i.e. DSSFL is specified above).
C
C   REC    ;  Time series record number
C   PATH   ;  Pathname for the time series record
C
C-------------------------------------------------------------------------------------------
C   REC        PATH
C-------------------------------------------------------------------------------------------
    1          /DELTA/SOUTH_LEVEE/SEEP//1DAY/SEEPAGE/
    2          /DELTA/NORTH_LEVEE/SEEP//1DAY/SEEPAGE/
    3          /DELTA/EAST_LEVEE/SEEP//1DAY/SEEPAGE/
```

5.3.8.6 Agricultural Supply Requirement Data File

IDC allows time-series agricultural water demands to be specified for some or all of the crops rather than dynamically computing them. This feature is useful in planning studies when the water demand is dictated by the contractual limits rather than crop evapotranspirative requirements. This feature can also be used when the historical diversions are known and the part or all of the diversions are used for artificial recharge of the groundwater. The non-ponded and ponded crops in each element can optionally be associated with a data column in this file through the pointers in the Non-Ponded Crops Main File and the Ponded Crops Main File, respectively.

The following variables are used in this file:

NDMAG	Number of agricultural supply requirement data columns
FACTDMAG	Conversion factor for the spatial component of the agricultural supply requirement data
NSPDMAG	Number of time steps to update the agricultural supply requirement data; enter any number if time-tracking simulation
NFQDMAG	Repetition frequency of the agricultural supply requirement data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Agricultural Supply Requirement Data File

If the time series data is listed in the Agricultural Supply Requirement Data File, then

the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

ITDA	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
RDMAG	Agricultural water supply requirement; [L^3/T]

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

I	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*****************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*****************************************************************************
C
C          AGRICULTURAL WATER SUPPLY REQUIREMENT DATA FILE
C                        Root Zone Component
C                        *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: AgWaterDemand.dat
C
C*****************************************************************************
C                           File Description
C
C   This data file contains a set of agricultural water supply requirement data.
C   These data are correlated to individual crops through Non-Ponded and Ponded
C   Crop Data Files.
C
C*****************************************************************************
C             Agricultural Water Supply Requirement Data Specifications
C
C   NDMAG   ;  Number of agricultural water supply requirement data columns
C   FACTDMAG;  Conversion factor for the agricultural supply requirement
C               It is used to convert only the spatial component of the unit;
C               DO NOT include the conversion factor for time component of the unit.
C               * e.g. Unit of flow listed in this file           = AC-FT/MONTH
C                      Consistent unit used in simulation         = CU.FT/DAY
C                      Enter FACTDAGF (AC-FT/MONTH -> CU.FT/MONTH)= 2.29568E-05
C                     (conversion of MONTH -> DAY is performed automatically)
C   NSPDMAG ;  Number of time steps to update the agricultural supply requirement data
C               * Enter any number if time-tracking option is on
C   NFQDMAG ;  Repetition frequency of the agricultural supply requirement data
C               * Enter 0 if full time series data is supplied
C               * Enter any number if time-tracking option is on
C   DSSFL   ;  The name of the DSS file for data input
C               * Leave blank if DSS file is not used for data input
C
C-----------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-----------------------------------------------------------------------------
           31                                         / NDMAG
           43560.0                                    / FACTDMAG (ac.ft -> cu.ft)
           1                                          / NSPDMAG
           0                                          / NFQDMAG
                                                      / DSSFL
C-----------------------------------------------------------------------------
C              Agricultural Water Supply Requirement Data
C                        (READ FROM THIS FILE)
C
C   List the agricultural water supply requirement data below, if it will not
C   be read from a DSS file (i.e. DSSFL is left blank above).
C
C   ITDA;    Time
C   RDMAG;   Agricultural water supply requirement; [L^3/T]
C
C-----------------------------------------------------------------------------
C ITDA                    RDMAG(1)  RDMAG(2)
C-----------------------------------------------------------------------------
C                            1        2       3      ...    29        30      31
  10/31/4000_24:00        26.02    8.88    0.34    ...    4.06    6.71  213.58
  11/30/4000_24:00        18.24    6.22    0.24    ...    2.85    4.70  149.75
  12/31/4000_24:00        17.34    5.92    0.23    ...    2.71    4.47  142.39
  01/31/4000_24:00         9.87    3.37    0.13    ...    1.54    2.54   81.01
  02/29/4000_24:00         7.77    2.65    0.10    ...    1.21    2.00   63.83
  03/31/4000_24:00         2.69    0.92    0.04    ...    0.42    0.69   22.09
  04/30/4000_24:00         0.60    0.20    0.01    ...    0.09    0.15    4.91
  05/31/4000_24:00         2.69    0.92    0.04    ...    0.42    0.69   22.09
  06/30/4000_24:00         5.38    1.84    0.07    ...    0.84    1.39   44.19
  07/31/4000_24:00         9.27    3.16    0.12    ...    1.45    2.39   76.10
  08/31/4000_24:00        13.16    4.49    0.17    ...    2.05    3.39  108.02
  09/30/4000_24:00        18.24    6.22    0.24    ...    2.85    4.70  149.75
C-----------------------------------------------------------------------------
C                  Pathnames for Agricultural Water Supply Requirement Data
C                              (READ FROM DSS FILE)
C
C   List the pathnames for the agricultural water supply requirement data below,
C   if it will be read from a DSS file (i.e. DSSFL is specified above).
C
C   I    ;  Pathname number
C   PATH ;  Pathname for the time series record
C
C-----------------------------------------------------------------------------
C   I       PATH
C-----------------------------------------------------------------------------
*
*
```

5.3.8.7 Non-Ponded-Crops Component Files

5.3.8.7.1 Non-Ponded Crops Main File

The Non-Ponded Crops Main File is the gateway file for all data that is necessary to simulate non-ponded crops and generate non-ponded-crop related budget files.

The file is divided into several sections and uses the following variables:

General Data

Number of non-ponded crops simulated, crop codes and filename for the non-ponded crop acreage data are defined in this section:

NCROP	Number of agricultural crops excluding ponded crops (i.e. rice and refuge)
FLDMD	Flag for the root zone moisture to be used for the computation of agricultural water demand and the timing of irrigation (0 = use the soil moisture at the beginning of time step, 1 = use the soil moisture at the end of time step); setting FLDMD to 0 works well when the simulation time step is small (e.g. 1 day) while it should be set to 1 when the simulation time step is longer (e.g. 1 month)
CCODE	Crop codes; enter 2-character crop codes for each of the non-ponded crops modeled (following codes are reserved and should not be used: UR = Urban, RI = Rice, RF = Refuge, NV = Native vegetation, RV = Riparian vegetation)
LUFLNP	File that lists the crop areas (maximum 1000 characters)

Budget Output Files

To generate crop-specific land and water use and root zone budgets, the following variables must be specified:

NBCROP	Number of non-ponded crops for water budget output; enter 0 if crop specific budget output is not required
BCCODE	Crop codes (from above) for which water budget output is required
CLWUBUDFL	HDF5 output file for crop-specific land and water use budget at each subregion for selected crops (maximum 1000 characters); leave blank if this output is not required
CRZBUDFL	HDF5 output file for root zone moisture budget at each subregion for selected crops (maximum 1000 characters); leave blank if this output is not required

Rooting Depths

RZFRACFL	File that lists fraction of maximum root depths to represent root growth (maximum 1000 characters)
FACT	Conversion factor for maximum crop root zone depths
IC	Crop identification number; enter 1 through NCROP, sequentailly
ROOT	Maximum crop root zone depth; [L]
ICROOT	Root depth as a fraction of maximum root depth; this number corresponds to the appropriate data column in the Root Depth Fractions Data File

Curve Numbers for Rainfall Runoff Simulation

Curve numbers for each element and crop combination are entered in this section.

IE	Element identification number entered sequentially; enter 0 if curve numbers defined for each crop are to be used for all elements
CN	Curve number for each non-ponded agricultural crop

Crop Evapotranspiration

Crop evapotranspiration for each element and crop combination is listed here by specifying a column number in the Evapotranspiration File:

IE	Element identification number entered sequentially; enter 0 if following values are to be used for all elements
ICET	Crop ET; this number corresponds to the appropriate data column the Evapotranspiration File

Agricultural Water Supply Requirement

If, for any crop at an element, the agricultural water supply requirement is pre-specified instead of being computed dynamically, they are specified in this section:

IE	Element identification number; enter 0 if following values are to be used for all elements
ICAW	Agricultural water supply requirement; this number corresponds to the appropriate data column in the Agricultural Supply Requirement Data File (AGWDFL) listed in the Root Zone Component Main File (enter

0 if agricultural water supply requirement will be computed dynamically

Irrigation Periods

Time series irrigation period data is listed in this section for each crop and element combination:

IE	Element identification number; enter 0 if following values are to be used for all elements
ICIP	Irrigation period; this number corresponds to the appropriate data column in the Irrigation Period Data File (IPFL) listed in the Root Zone Parameters Data File.

Minimum Soil Moisture

The minimum soil moisture that is used to trigger an irrigation event for each crop and element combination is listed in this section:

MINSMFL	File that lists the minimum soil moisture for each crop (maximum 1000 characters)
IE	Element identification number; enter 0 if following values are to be used for all elements
ICMSM	Minimum soil moisture as a fraction of field capacity; this corresponds to the appropriate data column in the Minimum Soil Moisture Data File (MINSMFL)

Target Soil Moisture for Irrigation

The moisture level which is targeted to be achieved by the irrigation event is listed for each crop and element combination in this section:

TRGSMFL	File that lists the target soil moisture for each crop during irrigation (maximum 1000 characters); leave blank if target soil moisture is the field capacity
IE	Element identification number; enter 0 if following values are to be used for all elements
ICTRGSM	Target soil moisture as a fraction of field capacity; this number corresponds to the appropriate data column in the Target Soil Moisture Data File (TRGSMFL)

Return Flow Fractions

The return flow fractions for each crop and element combination are listed in this section:

IE	Element identification number; enter 0 if following values are to be used for all elements
ICRTRNF	Fraction of the applied water that becomes return flow; this number corresponds to the appropriate data column in the Return Flow Fractions Data File given in the Root Zone Component Main File

Re-use Fractions

The re-use fractions for each crop and element combination are listed in this section:

IE	Element identification number; enter 0 if following values are to be used for all elements
ICRUF	Fraction of the applied water that becomes re-used water; this number corresponds to the appropriate data column in the Re-use Fractions Data File given in the Root Zone Component Main File

Minimum Deep Percolation Fractions

If a minimum deep percolation amount needs to be specified, it is listed in this section for each crop and element combination:

DPFL	File that lists the minimum deep percolation fractions (maximum 1000 characters); leave blank if minimum deep percolation is not imposed
IE	Element identification number; enter 0 if following values are to be used for all elements
ICDPF	Fraction of the "infiltrated" applied water that is going to be deep percolation; this number corresponds to the appropriate data column in the Minimum Deep Percolation Fractions Data File (DPFL)

Initial Soil Moisture Conditions

IE	Element identification number; enter 0 if following values are to be used for all elements
FSOILMP	Fraction of initial soil moisture at element IE that is due to precipitation
SOILM	Initial root zone moisture content; [L/L]

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                NON-PONDED AGRICULTURAL CROPS DATA FILE
C                         Root Zone Component
C                         *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: NonPondedAg_MAIN.dat
C
C*******************************************************************************
C                          File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes and managament of non-ponded agricultural crops.
C
C*******************************************************************************
C            Number of Non-Ponded Agricultural Crops and Crop Codes
C
C   NCROP    ;  Number of agricultural crops excluding ponded crops (i.e. rice and refuge)
C   FLDMD    ;  Flag for the root zone moisture to be used for the computation of
C                agricultural water demand and the timing of irrigation
C                * 0: Use the soil moisture at the beginning of time step
C                * 1: Use the soil moisture at the end of time step
C   CCODE    ;  Crop codes (max. 2 characters)
C                (1 to NCROP)
C             * Note: The following codes are reserved and should not be used:
C                UR : Urban
C                RI : Rice
C                RF : Refuge
C                NV : Native vegetation
C                RV : Riparian vegetation
C   LUFLNP   ;  File that lists the crop areas (max. 1000 characters)
C
C-------------------------------------------------------------------------------
C   VALUE                 DESCRIPTION
C-------------------------------------------------------------------------------
    17                                                      / NCROP
    0                                                       / FLDMD
    GR                                                      / CCODE1    GRAIN
    CO                                                      / CCODE2    COTTON
    SB                                                      / CCODE3    SUGAR BEETS
    CR                                                      / CCODE4    CORN
    DB                                                      / CCODE5    DRY BEANS
    SF                                                      / CCODE6    SAFFLOWER
    FI                                                      / CCODE7    OTHER FIELD
    AL                                                      / CCODE8    ALFALFA
    PA                                                      / CCODE9    PASTURE
    TM                                                      / CCODE10   TOMATOES
    CU                                                      / CCODE11   CUCURBITS
    OG                                                      / CCODE12   ONIONS AND GARLIC
    TR                                                      / CCODE13   OTHER TRUCK
    AP                                                      / CCODE14   ALMONDS AND PISTACHIO
    OR                                                      / CCODE15   OTHER DECID.
    SO                                                      / CCODE16   SUBTROPICAL
    FL                                                      / CCODE17   FALLOW AND IDLE
    RootZone\NonPondedAg\NonPondedAgArea.dat                / LUFLNP
C*******************************************************************************
C                       Water Budget Output Files
C
C   NBCROP   ;  Number of non-ponded crops for water budget output
C                * Enter 0 if crop specific budget output is not required
C   BCCODE   ;  Crop codes (from above) for which water budget output is required
C                (1 to NBCROP)
C   CLWUBUDFL;  HDF5 output file for land and water use budget at each
C                  subregion for selected crops (max. 1000 characters)
C                * Leave blank if this output is not required
C   CRZBUDFL ;  HDF5 output file for root zone moisture budget at each
C                  subregion for selected crops (max. 1000 characters)
C                * Leave blank if this output is not required
C
C-------------------------------------------------------------------------------
C   VALUE                 DESCRIPTION
C-------------------------------------------------------------------------------
    17                                          / NBCROP
    GR                                          / BCCODE1    GRAIN
    CO                                          / BCCODE2    COTTON
    SB                                          / BCCODE3    SUGAR BEETS
    CR                                          / BCCODE4    CORN
    DB                                          / BCCODE5    DRY BEANS
    SF                                          / BCCODE6    SAFFLOWER
    FI                                          / BCCODE7    OTHER FIELD
    AL                                          / BCCODE8    ALFALFA
    PA                                          / BCCODE9    PASTURE
    TM                                          / BCCODE10   TOMATOES
    CU                                          / BCCODE11   CUCURBITS
    OG                                          / BCCODE12   ONIONS AND GARLIC
    TR                                          / BCCODE13   OTHER TRUCK
    AP                                          / BCCODE14   ALMONDS AND PISTACHIO
    OR                                          / BCCODE15   OTHER DECID.
    SO                                          / BCCODE16   SUBTROPICAL
    FL                                          / BCCODE17   FALLOW AND IDLE
    Budget\NonPondedAgLWU.hdf                   / CLWUBUDFL
    Budget\NonPondedAgRZ.hdf                    / CRZBUDFL
C*******************************************************************************
C                              Rooting Depths
C
C   RZFRACFL ;  File that lists fraction of maximum root depths to represent
C                root growth (max. 1000 characters)
C   FACT   ;    Conversion factor for maximum crop root zone depths
C   IC     ;    Crop type number (1 to NCROP);
C   ROOT   ;    Maximum crop root zone depth; [L]
C   ICROOT ;    Root depth as a fraction of maximum root depth - this number
C                corresponds to the appropriate data column in the root depth
C                fractions data file (RZFRACFL).
C
*   Crop/Land Use No.           Name
```

```
*   ----------------            ------
*       1                         GR  grain
*       2                         CO  cotton
*       3                         SB  sugar beets
*       4                         CR  corn
*       5                         DB  dry beans
*       6                         SF  safflower
*       7                         FI  other field
*       8                         AL  alfalfa
*       9                         PA  pasture
*       10                        TM  processed tomatoes
*       11                        CU  cucurbits
*       12                        OG  onions & garlic
*       13                        TR  other truck
*       14                        AP  almonds & pistachios
*       15                        OR  other deciduous
*       16                        SO  subtropical
*       17                        FL  fallow and idle
*
C-----------------------------------------------------------------------------
C   VALUE                                   DESCRIPTION
C-----------------------------------------------------------------------------
    RootZone\NonPondedAg\RootDepthFrac.dat   / RZFRACFL
    1.0                                      / FACT
C-----------------------------------------------------------------------------
C   IC    ROOT      ICROOT
C-----------------------------------------------------------------------------
    1     4.0       1
    2     6.0       2
    3     5.0       3
    4     4.0       4
    5     4.0       5
    6     4.0       6
    7     4.0       7
    8     6.0       8
    9     2.0       9
    10    5.0       10
    11    3.0       11
    12    3.0       12
    13    3.0       13
    14    6.0       14
    15    6.0       15
    16    4.0       16
    17    1.0       17
C*****************************************************************************
C                    Curve Numbers for Rainfall Runoff Simulation
C
C   Enter curve numbers for each grid element and crop combination.
C
C   IE     ;  Element ID (Enter 0 if following values are to be used for all element
C                and non-ponded agricultural crop combinations)
C   CN     ;  Curve number for each non-ponded agricultural crop (1 to NCROP)
C
C-----------------------------------------------------------------------------
C                                                                CN BY CROP
C IE  ---------------------------------------------------------------------------------------------------------------
C         GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C-----------------------------------------------------------------------------------------------------------------
    1     81    82    82    85    81    81    81    81    74    82    85    85    85    82    72    72    91
    2     81    82    82    85    81    81    81    81    74    82    85    85    85    82    72    72    91
    3     73    75    75    78    72    72    72    72    61    75    78    78    78    75    58    58    86
    .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .
    .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .
    .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .
    221   81    82    82    85    81    81    81    81    74    82    85    85    85    82    72    72    91
    222   73    75    75    78    72    72    72    72    61    75    78    78    78    75    58    58    86
    223   73    75    75    78    72    72    72    72    61    75    78    78    78    75    58    58    86
C*****************************************************************************
C                          Crop Evapotranspiration (ETc)
C
C   The following lists the ETc column pointers for each finite element and non-ponded
C   agricultural crop combination.
C
C   IE       ;  Element ID (Enter 0 if following values are to be used for all element
C                 and non-ponded agricultural crop combinations)
C   ICET     ;  Crop ET (ETc) - this number corresponds to the appropriate data column
C                 in the ET data file listed in the Main Input File.  List for each
C                 non-ponded agricultural crop (1 to NCROP).
C
C-----------------------------------------------------------------------------
C                                                                ICET BY CROP
C   IE  ---------------------------------------------------------------------------------------------------------------
C         GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C-----------------------------------------------------------------------------------------------------------------
    0     1     2     3     4     5     6     7     8     9     10    11    12    13    14    15    16    17
C*****************************************************************************
C                          Agricultural Water Supply Requirement
C
C   The following lists the agricultural water supply requirement column pointers
C   for each finite element and non-ponded agricultural crop combination.
C
C   IE       ;  Element ID (Enter 0 if following values are to be used for all element
C                 and non-ponded agricultural crop combinations)
C   ICAW     ;  Agricultural water supply requirement - this number corresponds to the
C                 appropriate data column in the agricultural water supply requirement data
C                 file (AGWDFL) listed in the Root Zone Parameters Data File.  List for each
C                 non-ponded agricultural crop (1 to NCROP).
C                 *** Note: Enter 0 if agricultural water supply requirement will be computed
C                           internally.
C
C-----------------------------------------------------------------------------
C                                                                ICAW BY CROP
C   IE  ---------------------------------------------------------------------------------------------------------------
C         GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C-----------------------------------------------------------------------------------------------------------------
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
C*****************************************************************************
C                          Irrigation Periods
C
C   The following lists the irrigation period column pointers for each
C   finite element and non-ponded agricultural crop combinations.
C
```

```
C   IE       ;  Element ID (Enter 0 if following values are to be used for all element
C                 and non-ponded agricultural crop combinations)
C   ICIP     ;  Irrigation period - this number corresponds to the appropriate data
C                 column in the irrigation period data file (IPFL) listed in the Root
C                 Zone Parameters Data File.  List for each non-ponded crop (1 to NCROP).
C
C-----------------------------------------------------------------------------
C                                                                ICIP BY CROP
C   IE  ---------------------------------------------------------------------------------------------------------------
C         GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C-----------------------------------------------------------------------------------------------------------------------
    0     1     2     3     4     5     6     7     8     9     10    11    12    13    14    15    16    17
C*****************************************************************************
C                      Minimum Soil Moisture
C
C   The following lists the minimum soil moisture column pointers for
C   each finite element and non-ponded agricultural crop combinations.
C
C   MINSMFL  ;  File that lists the minimum soil moisture for each crop
C                 (max. 1000 characters)
C   IE       ;  Element ID (Enter 0 if following values are to be used for all element
C                 and non-ponded agricultural crop combinations)
C   ICMSM    ;  Minimum soil moisture as a fraction of field capacity - this number
C                 corresponds to the appropriate data column in the minimum soil moisture
C                 data file (MINSMFL).  List for each non-ponded crop (1 to NCROP).
C
C-----------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-----------------------------------------------------------------------------
          RootZone\NonPondedAg\MinMoist.dat           / MINSMFL
C-----------------------------------------------------------------------------
C                                                                ICMSM BY CROP
C IE  ---------------------------------------------------------------------------------------------------------------
C         GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C-----------------------------------------------------------------------------------------------------------------------
   0      1     2     3     4     5     6     7     8     9     10    11    12    13    14    15    16    17
C*****************************************************************************
C                       Target Soil Moisture for Irrigation
C
C   The following lists the target soil moisture column pointers for
C   each finite element and non-ponded agricultural crop combinations.
C
C   TRGSMFL  ;  File that lists the target soil moisture for each crop during irrigation
C                 (max. 1000 characters)
C                 * Leave blank if target soil moisture is field capacity
C   IE       ;  Element ID (Enter 0 if following values are to be used for all element
C                 and non-ponded agricultural crop combinations)
C   ICTRGSM  ;  Target soil moisture as a fraction of field capacity - this number
C                 corresponds to the appropriate data column in the target soil moisture
C                 data file (TRGSMFL).  List for each non-ponded crop (1 to NCROP).
C
C-----------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-----------------------------------------------------------------------------
                                                      / TRGSMFL
C-----------------------------------------------------------------------------
C   IE    ICTRGSM[1]  ICTRGSM[2] ... ICTRGSM[NCROP]
C-----------------------------------------------------------------------------
*
*
C*****************************************************************************
C                        Irrigation Water Return Flow Fractions
C
C   The following lists the irrigation water return flow fraction column pointers
C   for each finite element and non-ponded agricultural crop combinations.
C
C   IE       ;  Element ID (Enter 0 if following values are to be used for all element
C                 and non-ponded agricultural crop combinations)
C   ICRTRNF  ;  Fraction of the applied water that becomes return flow - this number
C                 corresponds to the appropriate data column in irrigation water
C                 return flow factor data file (RFFL) given in the Root Zone
C                 Parameters Data File.  List for each non-ponded crop (1 to NCROP)
C
C-----------------------------------------------------------------------------
C                                                                ICRTRNF BY CROP
C IE  ---------------------------------------------------------------------------------------------------------------
C         GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C-----------------------------------------------------------------------------------------------------------------------
  0       1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1
C*****************************************************************************
C                        Irrigation Water Re-Use Fractions
C
C   The following lists the irrigation water re-use fraction column pointers
C   for each finite element and non-ponded agricultural crop combinations.
C
C   IE       ;  Element ID (Enter 0 if following values are to be used for all element
C                 and non-ponded agricultural crop combinations)
C   ICRUF    ;  Fraction of the applied water that is re-used - this number
C                 corresponds to the appropriate data column in irrigation water
C                 re-use factor data file (RUFL) given in the Root Zone
C                 Parameters Data File.  List for each non-ponded crop (1 to NCROP)
C
C-----------------------------------------------------------------------------
C                                                                ICRUF BY CROP
C IE  ---------------------------------------------------------------------------------------------------------------
C         GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C-----------------------------------------------------------------------------------------------------------------------
    0     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1
C*****************************************************************************
C                          Minimum Deep Percolation Fractions
C
C   The following lists the fractions for minimum deep percolation at each finite element.
C
C   DPFL     ;  File that lists the minimum deep percolation fractions (max. 1000 characters)
C                * Leave blank if minimum deep percolation is not imposed
C   IE       ;  Element ID (Enter 0 if following values are to be used for all element
C                and non-ponded agricultural crop combinations)
C   ICDPF    ;  Fraction of the "infiltrated" applied water that is going to be deep
C                percolation - this number corresponds to the appropriate data column in
C                minimum deep percolation factor data file (DPFL).  List for each non-ponded
C                crop (1 to NCROP).
C
```

```
C-------------------------------------------------------------------------------
C         VALUE                                        DESCRIPTION
C-------------------------------------------------------------------------------
                                                       / DPFL
C-------------------------------------------------------------------------------
C   IE    ICDPF[1]  ICDPF[2] ... ICDPF[NCROP]
C-------------------------------------------------------------------------------
*
*
C*******************************************************************************
C                           Initial Soil Moisture Condition
C                          For Non-Ponded Agricultural Lands
C
C   IE     ; Element ID (Enter 0 if following values are to be used for all element
C              and non-ponded agricultural crop combinations)
C   FSOILMP; Fraction of initial soil moisture at element IE that is due to precipitation
C   SOILM  ; Initial root zone moisture content; [L/L]
C              (1 to NCROP)
C
C-----------------------------------------------------------------------------------------------------------------------
C IE   FSOILMP   GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C-----------------------------------------------------------------------------------------------------------------------
  1      0.5     0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13
  2      0.5     0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15
  3      0.5     0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10
  .       .       .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .
  .       .       .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .
  .       .       .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .
  221    0.5     0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04
  222    0.5     0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23
  223    0.5     0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12
```

5.3.8.7.2 Non-Ponded Crops Area Data File

Areas of each non-ponded crop at every element are listed in this file:

FACTLNNP	Conversion factor for land use areas; enter 0.0 if land use distribution is given as a fraction of element area
NSPLNNP	Number of time steps to update the land use data; enter any number if time-tracking option is on
NFQLNNP	Repetition frequency of the crop area data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Non-Ponded Crops Area Data File

If the time series data is listed in the Non-Ponded Crops Area Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

ITLN	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
IE	Element identification number
ALAND	Area (or fraction of area) corresponding to non-ponded crops over an element; [L^2] or [L^2/L^2] based on FACTLNNP above

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

IE	Element identification number
LUTYPE	Crop identification number entered sequentially
PATH	Pathname corresponding to element and non-ponded crop type combination

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                       NON-PONDED CROP AREA FILE
C                          Root Zone Component
C                          *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: NonPondedCropArea.dat
C
C*******************************************************************************
C                           File Description
C
C   This data file contains the land use distribution of non-ponded crops for
C   each element for the simulation period.
C
C*******************************************************************************
C                            Land Use Data Specifications
C
C   FACTLNNP;   Conversion factor for land use area
C                * Enter 0.0 if land use distribution is given as a fraction of element area
C   NSPLNNP ;   Number of time steps to update the land use data
C                * Enter any number if time-tracking option is on
C   NFQLNNP ;   Repetition frequency of the land use data
C                * Enter 0 if full time series data is supplied
C                * Enter any number if time-tracking option is on
C   DSSFL   ;   The name of the DSS file for data input
C                * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-------------------------------------------------------------------------------------
          10.763910417                                / FACTLNNP  (sq.m. -> sq.ft.)
          1                                           / NSPLNNP
          0                                           / NFQLNNP
                                                      / DSSFL
C-------------------------------------------------------------------------------------
C                              Land Use Data
C                           (READ FROM THIS FILE)
C
C   List the land use data below, if it will not be read from a DSS file
C   (i.e. DSSFL is left blank above).
C
C   ITLN ;   Time
C   IE   ;   Element number
C   ALAND;   Area (or fraction of area) corresponding to non-ponded crops over an
C             element; [L^2] or [L^2/L^2] (based on FACTLNNP above)
C             (1 to NCROP)
C               1      : Non-ponded crop 1
C               2      : Non-ponded crop 2
C                              .
C                              .
C               NCROP  : Non-ponded crop NCROP
C            * Note: Crop areas over elements that are designated as lake elements
C                    will be ignored
C
C-----------------------------------------------------------------------------------------------------
C                                                                   ALAND
C                              ---------------------------------------------------------------------
C   ITLN              IE            GR           CO           SB    ...   OR           SO           FL
C-----------------------------------------------------------------------------------------------------
 12/31/2500_24:00     1            0.00         0.00         0.00   ...  0.00         0.00     52162.85
                      2            0.00         0.00         0.00   ...  0.00         0.00         0.00
                      3            0.00         0.00         0.00   ...  0.00         0.00         0.00
                      .             .            .            .     ...   .            .            .
                      .             .            .            .     ...   .            .            .
                      221          0.00    705478.12         0.00   ...  0.00         0.00       452.45
                      222          0.00         0.00         0.00   ...  0.00         0.00         0.00
                      223          0.00         0.00         0.00   ...  0.00         0.00         0.00
C-------------------------------------------------------------------------------------
C                              Pathnames for Land Use Data
C                                (READ FROM DSS FILE)
C
C   List the pathnames for the land use data below, if it will be read from a DSS file
C   (i.e. DSSFL is specified above).
C
C   The pathnames should be listed for each element and non-ponded crop combination.
C   They should be listed in an order such that, the crop type changes first.
C
C   * Example with 3 non-ponded agricultural crops (i.e. NCROP=3):
C
C       IE     LUTYPE      PATH
C        1        1       (pathname[1])
C        1        2       (pathname[2])
C        1        3       (pathname[3])
C        2        1       (pathname[4])
C        2        2       (pathname[5])
C        2        3       (pathname[6])
C        .        .            .
C        .        .            .
C       NE        1       (pathname[(NCROP)*NE - 2])
C       NE        2       (pathname[(NCROP)*NE - 1])
C       NE        3       (pathname[(NCROP)*NE])
C
C   IE     ;  Element number
C   LUTYPE ;  Land use type
C               1       = Non-ponded agricultural crop 1
C               2       = Non-ponded agricultural crop 2
C                              .
C                              .
C               NCROP   = Non-ponded agricultural crop NCROP
C   PATH   ;  Pathname corresponding to element and non-ponded crop type combination
C
C-------------------------------------------------------------------------------------
C   IE        LUTYPE        PATH
C-------------------------------------------------------------------------------------
*
```

5.3.8.7.3 Root Depth Fractions Data File

This file includes the time series rooting depths as a fraction of the maximum rooting depths listed in the Non-Ponded Crops Main File. The non-ponded crops are associated with data columns in this file through pointers specified in the Non-Ponded Crops Main File.

The following variables are listed in this file:

NCOLRDF	Number of data columns for the rooting depth fractions
NSPRDF	Number of time steps to update the rooting depth fractions; enter any number if time-tracking option is on
NFQRDF	Repetition frequency of the rooting depth fractions; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Root Depth Fractions Data File

If the time series data is listed in the Root Depth Fractions Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
RDFRC	Root depths as a fraction of the maximum rooting depth

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*************************************************************************
C
C                   ROOT DEPTH FRACTIONS DATA FILE
C                        Root Zone Component
C                        *** Version 4.0 ***
C
C
C            Project:  IDC Version ### Release
C                      California Department of Water Resources
C            Filename: RootDepthFrac.dat
C
C*************************************************************************
C                          File Description
C
C   This data file contains a set of rooting depths given as a fraction of the
C   maximum rooting depth to represent the root growth for non-ponded and ponded
C   crops.
C
C*************************************************************************
C               Root Depth Fractions Data Specifications
C
C   NCOLRDF ; Number of root depth fractions data columns
C   NSPRDF  ; Number of time steps to update the root depth fractions
C             * Enter any number if time-tracking option is on
C   NFQRDF  ; Repetition frequency of the root depth fractions data
C             * Enter 0 if full time series data is supplied
C             * Enter any number if time-tracking option is on
C   DSSFL  ; The name of the DSS file for data input
C             * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------
C         VALUE                                     DESCRIPTION
C-------------------------------------------------------------------------
          17                                        / NCOLRDF
          1                                         / NSPRDF
          0                                         / NFQRDF
                                                    / DSSFL
C-----------------------------------------------------------------------------------------
C                           Root Depth Fractions
C                           (READ FROM THIS FILE)
C
C   List the root depth fractions (between 0.0 and 1.0) data below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   RDFRC;  Root depths as a fraction of the maximum rooting depth; [dimensionless]
C
C-----------------------------------------------------------------------------------------
C  TIME               RDFRC[1]  RDFRC[2]  RDFRC[3] ... RTRNF[NCOLRDF]
C-----------------------------------------------------------------------------------------------------------------------
C                     GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C                     1     2     3     4     5     6     7     8     9     10    11    12    13    14    15    16    17
C-----------------------------------------------------------------------------------------------------------------------
   12/31/2500_24:00   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0
*
C-------------------------------------------------------------------------
C                     Pathnames for Root Depth Fractions Data
C                             (READ FROM DSS FILE)
C
C   List the pathnames for root depth fractions data below, if it
C   will be read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C-------------------------------------------------------------------------------------------------------------
C   REC     PATH
C-------------------------------------------------------------------------------------------------------------
*
*
```

5.3.8.7.4 Minimum Soil Moisture Data File

This file includes the time series minimum soil moisture data that is used by IDC as an irrigation event trigger. The data is specified as a fraction of the field capacity. In a given time step, if the root zone moisture falls below the minimum soil moisture IDC computes the agricultural supply requirement that is going to raise the moisture up to irrigation target moisture (field capacity, by default) after the losses due to deep percolation and return flow are taken into account. Each non-ponded crop at each grid cell is associated with a data column in this file through pointers listed in the Non-Ponded Crops Main File.

The following variables must be specified in this data file:

NCOLSM	Number of minimum soil moisture data columns
NSPSM	Number of time steps to update the minimum soil moisture data; enter any number if time-tracking option is on
NFQSM	Repetition frequency of the minimum soil moisture data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Minimum Soil Moisture Data File

If the time series data is listed in the Minimum Soil Moisture Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
SMMIN	Minimum soil moisture as a fraction of field capacity

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                  MINIMUM SOIL MOISTURE DATA FILE
C                       Root Zone Component
C                       *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: MinMoist.dat
C
C*******************************************************************************
C                           File Description
C
C   This data file contains a set of minimum soil moistures as a fraction of
C   field capacity that are used as trigger for irrigation events. The minimum
C   soil moisture value for a particular crop corresponds to the moisture content
C   at the Management Allowable Depletion (MAD) for that crop.  These values are
C   correlated to individual crops through the Non-Ponded Crop Data File.
C
C*******************************************************************************
C               Minimum Soil Moisture Data Specifications
C
C   NCOLSM ; Number of minimum soil moisture data columns
C   NSPSM  ; Number of time steps to update the minimum soil moisture data
C            * Enter any number if time-tracking option is on
C   NFQSM  ; Repetition frequency of the minimum soil moisture data
C            * Enter 0 if full time series data is supplied
C            * Enter any number if time-tracking option is on
C   DSSFL  ; The name of the DSS file for data input
C            * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                        DESCRIPTION
C-------------------------------------------------------------------------------
          17                                           / NCOLSM
          1                                            / NSPSM
          0                                            / NFQSM
                                                       / DSSFL
C-----------------------------------------------------------------------------------------------
C                         Minimum Soil Moisture Data
C                            (READ FROM THIS FILE)
C
C   List the minimum soil moisture data below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   SMMIN;  Minimum soil moisture as a fraction of field capacity; [L/L]
C
*   Crop/Land Use No.           Name
*   ----------------            ------
*       1                         GR  grain
*       2                         CO  cotton
*       3                         SB  sugar beets
*       4                         CR  corn
*       5                         DB  dry beans
*       6                         SF  safflower
*       7                         FI  other field
*       8                         AL  alfalfa
*       9                         PA  pasture
*       10                        TM  tomatoes
*       11                        CU  cucurbits
*       12                        OG  onions & garlic
*       13                        TR  other truck
*       14                        AP  almonds & pistachios
*       15                        OR  other deciduous
*       16                        SO  subtropical
*       17                        FL  fallow and bare soil
*
C-------------------------------------------------------------------------------------------------------------------------------
C TIME              GR     CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C-------------------------------------------------------------------------------------------------------------------------------
  12/31/2500_24:00  0.55   0.5   0.45  0.5   0.5   0.4   0.7   0.4   0.5   0.6   0.5   0.7   0.5   0.6   0.5   0.5   0.5
*
C-------------------------------------------------------------------------
C                     Pathnames for Minimum Soil Moisture Data
C                              (READ FROM DSS FILE)
C
C   List the pathnames for minimum soil moisture data below, if it
C   will be read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C-------------------------------------------------------------------------------------------------------------------
C   REC     PATH
C-------------------------------------------------------------------------------------------------------------------
*
*
```

5.3.8.7.5 Irrigation Target Moisture Data File

The Irrigation Target Moisture Data File is optional and lists the target moisture that IDC uses to compute the agricultural water supply requirement. This is the moisture level that will be achieved when the irrigation amount is equal to the IDC-computed water demand. The irrigation target moisture is specified as a fraction of the field capacity. A value that is less than 1.0 may represent deficit irrigation conditions (along with proper values of evapotranspiration rate and minimum soil moisture data) while a value that is larger than 1.0 may represent additional irrigation for leaching salts. If this file is omitted, then IDC uses field capacity as the irrigation target moisture. Each non-ponded crop at each element is associated with a data column in this file through pointers specified in the Non-Ponded Crops Data File.

The following variables are used in this file:

NCOLTSM	Number of irrigation target soil moisture data columns
NSPTSM	Number of time steps to update the irrigation target soil moisture data; enter any number if time-tracking option is on
NFQTSM	Repetition frequency of the irrigation target soil moisture data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Irrigation Target Moisture Data File

If the time series data is listed in the Irrigation Target Moisture Data File, then the

following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
SMTRG	Irrigation target soil moisture as a fraction of field capacity

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C               IRRIGATION TARGET SOIL MOISTURE DATA FILE
C                         Root Zone Component
C                         *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: TargetMoist.dat
C
C*******************************************************************************
C                           File Description
C
C   This data file contains a set of irrigation target soil moistures as a fraction of
C   field capacity that are used in computing irrigation water demand. During an
C   irrigation event the soil moisture is raised to the target soil moisture.  Target
C   soil mositure cannot be less than minimum soil moisture specified in the Minimum
C   Soil Moisture data file. These values are correlated to individual crops through
C   the Non-Ponded Crop Data File.
C
C*******************************************************************************
C               Irrigation Target Soil Moisture Data Specifications
C
C   NCOLTSM ; Number of irrigation target soil moisture data columns
C   NSPTSM  ; Number of time steps to update the irrigation target soil moisture data
C              * Enter any number if time-tracking option is on
C   NFQTSM  ; Repetition frequency of the irrigation target soil moisture data
C              * Enter 0 if full time series data is supplied
C              * Enter any number if time-tracking option is on
C   DSSFL   ; The name of the DSS file for data input
C              * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-------------------------------------------------------------------------------
          17                                          / NCOLTSM
          1                                           / NSPTSM
          0                                           / NFQTSM
                                                      / DSSFL
C-----------------------------------------------------------------------------------------------
C                       Irrigation Target Soil Moisture Data
C                             (READ FROM THIS FILE)
C
C   List the irrigation target soil moisture data below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   SMTRG;  Irrigation target soil moisture as a fraction of field capacity; [L/L]
C
*   Crop/Land Use No.           Name
*   ----------------            ------
*       1                         GR  grain
*       2                         CO  cotton
*       3                         SB  sugar beets
*       4                         CR  corn
*       5                         DB  dry beans
*       6                         SF  safflower
*       7                         FI  other field
*       8                         AL  alfalfa
*       9                         PA  pasture
*       10                        TM  tomatoes
*       11                        CU  cucurbits
*       12                        OG  onions & garlic
*       13                        TR  other truck
*       14                        AP  almonds & pistachios
*       15                        OR  other deciduous
*       16                        SO  subtropical
*       17                        FL  fallow and bare soil
*
C-------------------------------------------------------------------------------------------------------------------------------
C                                                          SMTRG
C                  ---------------------------------------------------------------------------------------------------------
C TIME              GR     CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C-------------------------------------------------------------------------------------------------------------------------------
  12/31/2500_24:00  1.0    1.0   0.7   1.1   1.0   1.0   1.1   1.0   1.0   1.0   1.0   0.7   1.0   1.0   1.0   1.0   0.0
*
C-------------------------------------------------------------------------------
C                Pathnames for Irrigation Target Soil Moisture Data
C                             (READ FROM DSS FILE)
C
C   List the pathnames for irrigation target soil moisture data below, if it
C   will be read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C-----------------------------------------------------------------------------------------------------------------------
C   REC     PATH
C-----------------------------------------------------------------------------------------------------------------------
*
*
```

5.3.8.7.6 Minimum Deep Percolation Fractions Data File

The Minimum Deep Percolation Fractions Data File is optional and lists the minimum deep percolation values that IDC uses to compute the agricultural water supply requirement. This is the deep percolation level that IDC will try to achieve with the applied water during an irrigation event. However, the deep percolation is limited with the saturated hydraulic conductivity of the root zone and IDC may not be able to achieve the user-specified minimum deep percolation if it is greater than the saturated hydraulic conductivity. The minimum deep percolation is specified as a fraction of the infiltrated applied water (i.e. total applied water less the net return flow). This minimum deep percolation data can be used to simulate the irrigation practices to facilitate the leaching of salts. If this file is omitted, then IDC will not try to increase the applied water to achieve a minimum deep percolation. Each non-ponded crop at each element is associated with a data column in this file through pointers specified in the Non-Ponded Crops Data File.

The following variables are used in this file:

NCOLDPF	Number of minimum deep percolation data columns
NSPDPF	Number of time steps to update the minimum deep percolation data; enter any number if time-tracking option is on
NFQDPF	Repetition frequency of the minimum deep percolation data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Minimum Deep Percolation Fractions Data File

If the time series data is listed in the Minimum Deep Percolation Fractions Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
LF	Minimum deep percolation as a fraction of the infiltrated applied water

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C              MINIMUM DEEP PERCOLATION FACTORS DATA FILE
C                         Root Zone Component
C                         *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: MinDeepPerc.dat
C
C*******************************************************************************
C                           File Description
C
C   This data file contains a set of minimum deep percolation factors given as
C   fractions of infiltrated irrigation water.  These values are correlated to
C   individual crops through the Non-Ponded Crop Data File.
C
C*******************************************************************************
C            Minimum Deep Percolation Factors Data Specifications
C
C   NCOLDPF ; Number of minimum deep percolation factors data columns
C   NSPDPF  ; Number of time steps to update the minimum deep percolation
C             * Enter any number if time-tracking option is on
C   NFQDPF  ; Repetition frequency of the minimum deep percolation factors data
C             * Enter 0 if full time series data is supplied
C             * Enter any number if time-tracking option is on
C   DSSFL   ; The name of the DSS file for data input
C             * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-------------------------------------------------------------------------------
          2                                           / NCOLDPF
          1                                           / NSPDPF
          0                                           / NFQDPF
                                                      / DSSFL
C-----------------------------------------------------------------------------------------------
C                         Minimum Deep Percolation Factors
C                            (READ FROM THIS FILE)
C
C   List the minimum deep percolation factors data below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   LF   ;  Minimum deep percolation factors as a fraction of infiltrated irrigation water; [dimensionless]
C
C-----------------------------------------------------------------------------------------------
C  TIME               DPF[1]  DPF[2]  DPF[3] ... DPF[NCOLLF]
C-----------------------------------------------------------------------------------------------
   12/31/2500_24:00   0.10    0.15
*
C-------------------------------------------------------------------------------
C                 Pathnames for Minimum Deep Percolation Factors Data
C                              (READ FROM DSS FILE)
C
C   List the pathnames for minimum deep percolation factors data below, if it
C   will be read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C-------------------------------------------------------------------------------------------------------
C   REC     PATH
C-------------------------------------------------------------------------------------------------------
*
*
```

5.3.8.8 Ponded-Crops Component Files

There are 5 pre-specified ponded crops simulated by IDC: i) rice with flooded decomposition, ii) rice with non-flooded decomposition, iii) rice with no decomposition, iv) seasonal refuges, and v) permanent refuges. Even though refuges are not agricultural lands, their ponding operations are very similar to those of rice fields. Therefore, they are grouped and simulated as ponded crops in IDC.

The following sections describe in detail the input data files that are used to simulated ponded crops.

5.3.8.8.1 Ponded Crops Main File

The Ponded Crops Main File is the gateway file for all data that is necessary to simulate ponded crops and generate ponded-crop related budget files.

The file is divided into several sections and uses the following variables:

Land-Use Areas

The filename for the ponded crop areas data file is listed in this section:

LUFLP	File that lists the ponded crop areas (maximum 1000 characters)

Budget Output Files

To generate crop-specific land and water use and root zone budgets, the following variables must be specified:

NBCROP	Number of ponded crops for water budget output; enter 0 if crop specific budget output is not required

BCCODE	Crop codes for which water budget output is required (RICE_FL = rice with flooded decomposition, RICE_NFL = rice with non-flooded decomposition, RICE_NDC = rice with no decomposition, REFUGE_SL = seasonal refuges, REFUGE_PR = permanent refuges)
CLWUBUDFL	HDF5 output file for crop-specific land and water use budget at each subregion for selected crops (maximum 1000 characters); leave blank if this output is not required
CRZBUDFL	HDF5 output file for root zone moisture budget at each subregion for selected crops (maximum 1000 characters); leave blank if this output is not required

Rooting Depths

FACT	Conversion factor for rice and refuge root zone depths
ROOTRI_FL	Root zone depth for rice with flooded decomposition; [L]
ROOTRI_NFL	Root zone depth for rice with non-flooded decomposition; [L]
ROOTRI_NDC	Root zone depth for rice with no decomposition; [L]
ROOTRF_SL	Root zone depth for seasonal refuges; [L]
ROOTRF_PR	Root zone depth for permanent refuges; [L]

Curve Numbers for Rainfall Runoff Simulation

Curve numbers for each element and ponded-crop combination are entered in this section. The curve numbers listed in this section are used only outside the ponding season; during ponding season a value of 100 is used.

IE	Element identification number entered sequentially; enter 0 if curve numbers defined for each ponded-crop are to be used for all elements
CNRI_FL	Curve number for rice lands with flooded decomposition
CNRI_NFL	Curve number for rice lands with non-flooded decomposition
CNRI_NDC	Curve number for rice lands with no decomposition
CNRF_SL	Curve number for seasonal refuge lands
CNRF_PR	Curve number for permanent refuge lands

Crop Evapotranspiration

Crop evapotranspiration for each element and ponded-crop combination is listed here by specifying a column number in the Evapotranspiration File:

IE	Element identification number entered sequentially; enter 0 if following values are to be used for all elements
ICETRI_FL	Evapotranspiration rate for rice with flooded decomposition; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the Root Zone Component Main File
ICETRI_NFL	Evapotranspiration rate for rice with non-flooded decomposition; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the Root Zone Component Main File
ICETRI_NDC	Evapotranspiration rate for rice with no decomposition; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the Root Zone Component Main File

ICETRI_SL	Evapotranspiration rate for seasonal refuges; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the Root Zone Component Main File
ICETRI_PR	Evapotranspiration rate for permanent refuges; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the Root Zone Component Main File

Agricultural Water Supply Requirement

If, for any ponded-crop at an element, the agricultural water supply requirement is pre-specified instead of being computed dynamically, they are specified in this section:

IE	Element identification number; enter 0 if following values are to be used for all elements
ICAWRI_FL	Agricultural water supply requirement for rice with flooded decomposition; this number corresponds to the appropriate data column in the Agricultural Supply Requirement Data File (AGWDFL) listed in the Root Zone Component Main File (enter 0 if agricultural water supply requirement will be computed dynamically
ICAWRI_NFL	Agricultural water supply requirement for rice with non-flooded decomposition; this number corresponds to the appropriate data column in the Agricultural Supply Requirement Data File (AGWDFL) listed in the Root Zone Component Main File (enter 0 if agricultural water supply requirement will be computed dynamically

ICAWRI_NDC	Agricultural water supply requirement for rice with no decomposition; this number corresponds to the appropriate data column in the Agricultural Supply Requirement Data File (AGWDFL) listed in the Root Zone Component Main File (enter 0 if agricultural water supply requirement will be computed dynamically
ICAWRF_SL	Water supply requirement for seasonal refuges; this number corresponds to the appropriate data column in the Agricultural Supply Requirement Data File (AGWDFL) listed in the Root Zone Component Main File (enter 0 if agricultural water supply requirement will be computed dynamically
ICAWRF_PR	Water supply requirement for permanent refuges; this number corresponds to the appropriate data column in the Agricultural Supply Requirement Data File (AGWDFL) listed in the Root Zone Component Main File (enter 0 if agricultural water supply requirement will be computed dynamically

Irrigation Periods

Time series irrigation period data is listed in this section for each ponded crop and element combination:

IE	Element identification number; enter 0 if following values are to be used for all elements

ICIP_FL Irrigation period for rice with flooded decomposition; this number corresponds to the appropriate data column in the Irrigation Period Data File (IPFL) listed in the Root Zone Parameters Data File.

ICIP_NFL Irrigation period for rice with non-flooded decomposition; this number corresponds to the appropriate data column in the Irrigation Period Data File (IPFL) listed in the Root Zone Parameters Data File.

ICIP_NDC Irrigation period for rice with no decomposition; this number corresponds to the appropriate data column in the Irrigation Period Data File (IPFL) listed in the Root Zone Parameters Data File.

ICIP_SL Irrigation period for seasonal refuges; this number corresponds to the appropriate data column in the Irrigation Period Data File (IPFL) listed in the Root Zone Parameters Data File.

ICIP_PR Irrigation period for permanent refuges; this number corresponds to the appropriate data column in the Irrigation Period Data File (IPFL) listed in the Root Zone Parameters Data File.

Rice and Refuge Operations Input Files

In this section filenames for input data files that list time series ponding depths and pond operation flows are listed:

PNDTHFL File that lists the ponding depths for rice and refuge operations (maximum 1000 characters)

FLOWFL File that lists rice and refuge pond operation flows that include water application depths for non-flooded decomposition of rice, re-use and

return flow depths (maximum 1000 characters)

Ponding Depths

Time series ponding depths for each element and ponded-crop combination are listed in this section.

IE	Element identification number; enter 0 if following values are to be used for all element and ponded-crop combinations
ICPDRI_FL	Ponding depth for rice with flooded decomposition including depths for decomposition operations; this number corresponds to the appropriate data column in the Ponding Depth Data File (PNDTHFL)
ICPDRI_NFL	Ponding depth for rice with non-flooded decomposition; this number corresponds to the appropriate data column in the Ponding Depth Data File (PNDTHFL)
ICPDRI_NDC	Ponding depth for rice with no decomposition; this number corresponds to the appropriate data column in the Ponding Depth Data File (PNDTHFL)
ICPDRF_SL	Ponding depth for seasonal refuge ponds; this number corresponds to the appropriate data column in the Ponding Depth Data File (PNDTHFL)
ICPDRF_PR	Ponding depth for permanent refuge ponds; this number corresponds to the appropriate data column in the Ponding Depth Data File (PNDTHFL)

Application Depths for Non-Flooded Decomposition of Rice

For rice with non-flooded decomposition, the water application rates for the decomposition of rice are listed here.

IE	Element identification number; enter 0 if following values are to be used for all element and ponded-crop combinations
ICDWRI_NFL	Water application depth for non-flooded decomposition of rice; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL).

Return Flow Depths

The return flow depths for each crop and element combination are listed in this section. The return flows for rice and refuges include circulation depths as well as lateral subsurface flows (i.e. seepage) into the return flow collection ditches.

IE	Element identification number; enter 0 if following values are to be used for all elements
ICRTRI_FL	Depth of return flow for rice with flooded decomposition; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)
ICRTRI_NFL	Depth of return flow for rice with non-flooded decomposition; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)
ICRTRI_NDC	Depth of return flow for rice with no decomposition; this number corresponds to the appropriate data column in the Pond Operation

	Flows Data File (FLOWFL)
ICRTRF_SL	Depth of return flow for seasonal refuges; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)
ICRTRF_PR	Depth of return flow for permanent refuges; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)

Re-use Flow Depth

The re-use flow depths for each crop and element combination are listed in this section:

IE	Element identification number; enter 0 if following values are to be used for all elements
ICRUFRI_FL	Depth of re-used water for rice with flooded decomposition; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)
ICRUFRI_NFL	Depth of re-used water for rice with non-flooded decomposition; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)
ICRUFRI_NDC	Depth of re-used water for rice with no decomposition; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)

ICRUFRF_SL	Depth of re-used water at seasonal refuges; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)
ICRUFRF_PR	Depth of re-used water at permanent refuges; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)

Initial Soil Moisture Conditions

The initial soil moisture content for each ponded crop and element combination is listed in this section. For ponded crops, soil moisture content can be greater 1.0; in this case the portion of the soil moisture above 1.0 represents the ponding depth.

IE	Element identification number; enter 0 if following values are to be used for all elements
FSOILMP	Fraction of initial soil moisture at element IE that is due to precipitation
SOILM_RI_FL	Initial root zone moisture content for rice with flooded decomposition; [L/L]
SOILM_RI_NFL	Initial root zone moisture content for rice with non-flooded decomposition; [L/L]
SOILM_RI_NDC	Initial root zone moisture content for rice with no decomposition; [L/L]
SOILM_RF_SL	Initial root zone moisture content for seasonal refuges; [L/L]
SOILM_RF_PR	Initial root zone moisture content for permanent refuges; [L/L]

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                    RICE AND REFUGE LANDS DATA FILE
C                         Root Zone Component
C                         *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: PondedAg_MAIN.dat
C
C*******************************************************************************
C                          File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes and managament of lands with rice and refuge.
C
C*******************************************************************************
C                         Land Use Areas
C
C   LUFLP   ;  File that lists the crop areas (max. 1000 characters)
C
C-------------------------------------------------------------------------------
    RootZone\PondedAg\PondedAgArea.dat                          / LUFLP
C*******************************************************************************
C                       Water Budget Output Files
C
C   NBCROP   ;  Number of ponded crops for water budget output
C                * Enter 0 if crop specific budget output is not required
C   BCCODE   ;  Crop codes for which water budget output is required
C                (1 to NBCROP)
C                * Use the following crop codes:
C                  RICE_FL  : Rice with flooded decomposition
C                  RICE_NFL : Rice with non-flooded decomposition
C                  RICE_NDC : Rice with no decomposition
C                  REFUGE_SL: Seasonal refuges
C                  REFUGE_PR: Permanent refuges
C   CLWUBUDFL;  HDF5 output file for land and water use budget at each
C                  subregion for selected crops (max. 1000 characters)
C                * Leave blank if this output is not required
C   CRZBUDFL ;  HDF5 output file for root zone moisture budget at each
C                  subregion for selected crops (max. 1000 characters)
C                * Leave blank if this output is not required
C
C-------------------------------------------------------------------------------
C   VALUE                 DESCRIPTION
C-------------------------------------------------------------------------------
      2                              / NBCROP
      RICE_FL                        / BCCODE[1]
      REFUGE_PR                      / BCCODE[2]
      Budget\PondedAgLWU.hdf         / CLWUBUDFL
      Budget\PondedAgRZ.hdf          / CRZBUDFL
C*******************************************************************************
C                              Rooting Depths
C
C   FACT      ;    Conversion factor for rice and refuge root zone depths
C   ROOTRI_FL ;    Root zone depth for rice with flooded decomposition; [L]
C   ROOTRI_NFL;    Root zone depth for rice with non-flooded decomposition; [L]
C   ROOTRI_NDC;    Root zone depth for rice with no decomposition; [L]
C   ROOTRF_SL ;    Root zone depth for seasonal refuges; [L]
C   ROOTRF_PR ;    Root zone depth for permament refuges; [L]
C
C-------------------------------------------------------------------------------
C   VALUE                 DESCRIPTION
C-------------------------------------------------------------------------------
    1.0                   / FACT
    2.0                   / ROOTRI_FL
    2.0                   / ROOTRI_NFL
    2.0                   / ROOTRI_NDC
    2.0                   / ROOTRF_SL
    2.0                   / ROOTRF_PR
C*******************************************************************************
C                    Curve Numbers for Rainfall Runoff Simulation
C
C   Enter curve numbers for each grid element and rice/refuge combination.
C
C   IE       ;  Element ID (Enter 0 if following values are to be used for all
C                element and ponded agricultural crop combinations)
C   CNRI_FL  ;  Curve number for rice lands with flooded decomposition
C   CNRI_NFL ;  Curve number for rice lands with non-flooded decomposition
C   CNRI_NDC ;  Curve number for rice lands with no decomposition
C   CNRF_SL  ;  Curve number for seasonal refuge lands
C   CNRF_PR  ;  Curve number for permanent refuge lands
C              * Note: CN for rice and refuge should be entered for the type of
C                      soil and land cover during non-ponding season. During the
C                      ponding season CN=100 will be used.
C
C-------------------------------------------------------------------------------
C  IE      CNRI_FL    CNRI_NFL    CNRI_NDC   CNRF_SL   CNRF_PR
C-------------------------------------------------------------------------------
    1          78          78          78        65        65
    2          78          78          78        65        65
    3          71          71          71        48        48
    .          .           .           .         .         .
    .          .           .           .         .         .
    .          .           .           .         .         .
    221        78          78          78        65        65
    222        71          71          71        48        48
    223        71          71          71        48        48
C*******************************************************************************
C                          Crop Evapotranspiration (ETc)
C
C   The following lists the ETc column pointers for each finite element, rice and
C   refuge combination.
C
C   IE         ;  Element ID (Enter 0 if following values are to be used for all element
C                   and ponded crop combinations)
C   ICETRI_FL  ;  ETc for rice with flooded decomposition - this number corresponds to the
```

```
C                   appropriate data column in the ET data file listed in the Main Control
C                   Data file.
C   ICETRI_NFL ;  ETc for rice with non-flooded decomposition - this number corresponds to
C                   the appropriate data column in the ET data file listed in the Main Control
C                   Data file.
C   ICETRI_NDC ;  ETc for rice with no decomposition - this number corresponds to
C                   the appropriate data column in the ET data file listed in the Main Control
C                   Data file.
C   ICETRF_SL  ;  ETc for seasonal refuge - this number corresponds to the appropriate data
C                   column in the ET data file listed in the Main Control Data file.
C   ICETRF_PR  ;  ETc for permanent refuge - this number corresponds to the appropriate data
C                   column in the ET data file listed in the Main Control Data file.
C
C-------------------------------------------------------------------------------
C   IE    ICETRI_FL    ICETRI_NFL    ICETRI_NDC    ICETRF_SL    ICETRF_PR
C-------------------------------------------------------------------------------
    1           18           18           18           19      19
    2           18           18           18           19      19
    3           18           18           18           19      19
    .           .            .            .            .       .
    .           .            .            .            .       .
    .           .            .            .            .       .
    221         18           18           18           19      19
    222         18           18           18           19      19
    223         18           18           18           19      19
C*******************************************************************************
C                         Water Supply Requirement
C
C   The following lists the water supply requirement column pointers for each finite
C   element and ponded crop combination.
C
C   IE         ;  Element ID (Enter 0 if following values are to be used for all element
C                   and ponded crop combinations)
C   ICAWRI_FL  ;  Water supply requirement for rice with flooded decomposition - this
C                   number corresponds to the appropriate data column in the agricultural
C                   water supply requirement data file (AGWDFL) listed in the Root Zone
C                   Parameters Data File.
C                   *** Note: Enter 0 if water supply requirement will be computed
C                             internally.
C   ICAWRI_NFL ;  Water supply requirement for rice with non-flooded decomposition - this
C                   number corresponds to the appropriate data column in the agricultural
C                   water supply requirement data file (AGWDFL) listed in the Root Zone
C                   Parameters Data File.
C                   *** Note: Enter 0 if water supply requirement will be computed
C                             internally.
C   ICAWRI_NDC ;  Water supply requirement for rice with no decomposition - this
C                   number corresponds to the appropriate data column in the agricultural
C                   water supply requirement data file (AGWDFL) listed in the Root Zone
C                   Parameters Data File.
C                   *** Note: Enter 0 if water supply requirement will be computed
C                             internally.
C   ICAWRF_SL  ;  Water supply requirement for seasonal refuge - this number corresponds
C                   to the appropriate data column in the agricultural water supply
C                   requirement data file (AGWDFL) listed in the Root Zone Parameters
C                   Data File.
C                   *** Note: Enter 0 if water supply requirement will be computed
C                             internally.
C   ICAWRF_PR  ;  Water supply requirement for permanentl refuge - this number corresponds
C                   to the appropriate data column in the agricultural water supply
C                   requirement data file (AGWDFL) listed in the Root Zone Parameters
C                   Data File.
C                   *** Note: Enter 0 if water supply requirement will be computed
C                             internally.
C
C-------------------------------------------------------------------------------
C   IE    ICAWRI_FL    ICAWRI_NFL    ICAWRI_NDC    ICAWRF_SL    ICAWRF_PR
C-------------------------------------------------------------------------------
    1           0            0            0            0       0
    2           0            0            0            0       0
    3           0            0            0            0       0
    .           .            .            .            .       .
    .           .            .            .            .       .
    .           .            .            .            .       .
    221         0            0            0            0       0
    222         0            0            0            0       31
    223         0            0            0            0       0
C*******************************************************************************
C                         Irrigation Periods
C
C   The following lists the irrigation period column pointers for each
C   finite element and ponded crop combinations.
C
C   IE       ;  Element ID (Enter 0 if following values are to be used for all element
C                 and ponded crop combinations)
C   ICIP_FL  ;  Irrigation period for rice with flooded decomposition - this number
C                 corresponds to the appropriate data column in the irrigation period
C                 data file (IPFL) listed in the Root Zone Parameters Data File.
C   ICIP_NFL ;  Irrigation period for rice with non-flooded decomposition - this number
C                 corresponds to the appropriate data column in the irrigation period
C                 data file (IPFL) listed in the Root Zone Parameters Data File.
C   ICIP_NDC ;  Irrigation period for rice with no decomposition - this number
C                 corresponds to the appropriate data column in the irrigation period
C                 data file (IPFL) listed in the Root Zone Parameters Data File.
C   ICIP_SL  ;  Irrigation period for seasonal refuge - this number corresponds to
C                 the appropriate data column in the irrigation period data file
C                 (IPFL) listed in the Root Zone Parameters Data File.
C   ICIP_PR  ;  Irrigation period for permanent refuge - this number corresponds to
C                 the appropriate data column in the irrigation period data file
C                 (IPFL) listed in the Root Zone Parameters Data File.
C
C-------------------------------------------------------------------------------
C   IE    ICIP_FL   ICIP_NFL   ICIP_NDC   ICIP_SL   ICIP_PR
C-------------------------------------------------------------------------------
    0       18        19         20         21        22
C*******************************************************************************
C                       Rice and Refuge Operations Input Files
C
C   The following lists the rice and refuge operations related data files.
C
C   PNDTHFL   ; File that lists the ponding depths for rice and refuge operations
C                 (max. 1000 characters)
C   FLOWFL    ; File that lists rice/refuge pond operation flows (water application
```

```
C                 depths for non-flooded decomposition of rice, re-use and return
C                 flow depths (max. 1000 characters)
C
C-----------------------------------------------------------------------------
C         VALUE                                        DESCRIPTION
C-----------------------------------------------------------------------------
    RootZone\PondedAg\PondDepth.dat                    / PNDTHFL
    RootZone\PondedAg\PondOperationFlows.dat           / FLOWFL
C*****************************************************************************
C                                   Ponding Depths
C
C   IE        ; Element ID (Enter 0 if following values are to be used for all element
C                 and ponded crop combinations)
C   ICPDRI_FL ; Ponding depth for rice with flooded decomposition including depths for
C                 decomposition operations - this number corresponds to the appropriate
C                 data column in the rice/refuge ponding depth data file (PNDTHFL).
C   ICPDRI_NFL; Ponding depth for rice with non-flooded decomposition - this number
C                 corresponds to the appropriate data column in the rice/refuge
C                 ponding depth data file (PNDTHFL).
C   ICPDRI_NDC; Ponding depth for rice with no decomposition - this number
C                 corresponds to the appropriate data column in the rice/refuge
C                 ponding depth data file (PNDTHFL).
C   ICPDRF_SL ; Ponding depth for seasonal refuge ponds - this number corresponds to the
C                 appropriate data column in the rice/refuge ponding depth data file (PNDTHFL).
C   ICPDRF_PR ; Ponding depth for permanent refuge ponds - this number corresponds to the
C                 appropriate data column in the rice/refuge ponding depth data file (PNDTHFL).
C
C-----------------------------------------------------------------------------
C   IE     ICPDRI_FL   ICPDRI_NFL   ICPDRI_NDC   ICPDRF_SL   ICPDRF_PR
C-----------------------------------------------------------------------------
     0       1           1            1            2           2
C*****************************************************************************
C                 Application Depths for Non-Flooded Rice Decomposition
C
C   IE        ; Element ID (Enter 0 if following values are to be used for all elements)
C   ICDWRI_NFL; Water application depth for non-flooded decomposition of rice - this number
C                 corresponds to the appropriate data column in the rice/refuge flows
C                 data file (FLOWFL).
C
C-----------------------------------------------------------------------------
C   IE     ICDWRI_NFL
C-----------------------------------------------------------------------------
    0       5
C*****************************************************************************
C                                 Return Flow Depths
C
C   IE        ;  Element ID (Enter 0 if following values are to be used for all element
C                  and ponded crop combinations)
C   ICRTRI_FL ;  Depth of return flow for rice with flooded decomposition - this number
C                  corresponds to the appropriate data column in the rice/refuge flows
C                  data file (FLOWFL).
C   ICRTRI_NFL;  Depth of return flow for rice with non-flooded decomposition - this number
C                  corresponds to the appropriate data column in the rice/refuge flows
C                  data file (FLOWFL).
C   ICRTRI_NDC;  Depth of return flow for rice with no decomposition - this number
C                  corresponds to the appropriate data column in the rice/refuge flows
C                  data file (FLOWFL).
C   ICRTRF_SL ;  Depth of return flow for seasonal refuges - this number corresponds to the
C                  appropriate data column in the rice/refuge flows data file (FLOWFL).
C   ICRTRF_PR ;  Depth of return flow for permanent refuges - this number corresponds to the
C                  appropriate data column in the rice/refuge flows data file (FLOWFL).
C                  *** Note: Return flow for rice and refuge includes circulation depths as well
C                            as lateral subsurface flow (i.e. seepage) to return flow collection
C                            ditches.
C
C-----------------------------------------------------------------------------
C   IE     ICRTRI_FL   ICRTRI_NFL   ICRTRI_NDC   ICRTRF_SL   ICRTRF_PR
C-----------------------------------------------------------------------------
    0       1           1            1            2           2
C*****************************************************************************
C                                 Re-use Flow Depths
C
C   IE        ;  Element ID (Enter 0 if following values are to be used for all element
C                  and ponded crop combinations)
C   ICRUFRI_FL ; Depth of re-used water at rice with flooded decomposition - this number
C                  corresponds to the appropriate data column in the rice/refuge
C                  flows data file (FLOWFL).
C   ICRUFRI_NFL; Depth of re-used water at rice with non-flooded decomposition - this number
C                  corresponds to the appropriate data column in the rice/refuge
C                  flows data file (FLOWFL).
C   ICRUFRI_NDC; Depth of re-used water at rice with no decomposition - this number
C                  corresponds to the appropriate data column in the rice/refuge
C                  flows data file (FLOWFL).
C   ICRUFRF_SL ; Depth of re-used water at seasonal refuges - this number corresponds to the
C                  appropriate data column in the rice/refuge flows data file (FLOWFL).
C   ICRUFRF_PR ; Depth of re-used water at permanent refuges - this number corresponds to the
C                  appropriate data column in the rice/refuge flows data file (FLOWFL).
C
C-----------------------------------------------------------------------------
C   IE     ICRUFRI_FL   ICRUFRI_NFL   ICRUFRI_NDC   ICRUFRF_SL   ICRUFRF_PR
C-----------------------------------------------------------------------------
    0       3            3            3             4            4
C*****************************************************************************
C                            Initial Soil Moisture Condition
C                                  For Ponded Lands
C
C   IE          ;   Element ID (0 if following values are to be used for all elements)
C   FSOILMP     ;   Fraction of initial soil moisture at element IE that is due to precipitation
C   SOILM_RI_FL ;   Initial root zone moisture content for rice with flooded decomposition; [L/L]
C   SOILM_RI_NFL;   Initial root zone moisture content for rice with non-flooded decomposition; [L/L]
C   SOILM_RI_NDC;   Initial root zone moisture content for rice with no decomposition; [L/L]
C   SOILM_RF_SL ;   Initial root zone moisture content for seasonal refuges; [L/L]
C   SOILM_RF_PR ;   Initial root zone moisture content for permanent refuges; [L/L]
C                   *** Note: SOILM can be greater than 1.0 to reflect
C                             ponding conditions for rice and refuge. When SOILM is
C                             greater than 1.0, the ponding depth will be computed as
C                             RootDepth x (SOILM-1)
C
C-----------------------------------------------------------------------------------------
C   IE    FSOILMP    SOILM_RI_FL   SOILM_RI_NFL   SOILM_RI_NDC   SOILM_RF_SL   SOILM_RF_PR
C-----------------------------------------------------------------------------------------
    1       0.5       0.1370        0.1370         0.1370         0.1370        0.1370
```

2	0.5	0.1571	0.1571	0.1571	0.1571	0.1571
3	0.5	0.1053	0.1053	0.1053	0.1053	0.1053
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
221	0.5	0.0485	0.0485	0.0485	0.0485	0.0485
222	0.5	0.2322	0.2322	0.2322	0.2322	0.2322
223	0.5	0.1210	0.1210	0.1210	0.1210	0.1210

5.3.8.8.2 Ponded Crops Area Data File

Areas of each ponded crop at every element are listed in this file:

FACTLNP	Conversion factor for land use areas; enter 0.0 if land use distribution is given as a fraction of element area
NSPLNP	Number of time steps to update the land use data; enter any number if time-tracking option is on
NFQLNP	Repetition frequency of the crop area data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Ponded Crops Area Data File

If the time series data is listed in the Ponded Crops Area Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

ITLN	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
IE	Element identification number
ALANDRI_FL	Area (or fraction of area) of rice with flooded decomposition over element IE; [L^2] or [L^2/L^2] based on FACTLNP above

ALANDRI_NFL	Area (or fraction of area) of rice with non-flooded decomposition over element IE; [L^2] or [L^2/L^2] based on FACTLNP above
ALANDRI_NDC	Area (or fraction of area) of rice with no decomposition over element IE; [L^2] or [L^2/L^2] based on FACTLNP above
ALANDRF_SL	Area (or fraction of area) of seasonal refuges over element IE; [L^2] or [L^2/L^2] based on FACTLNP above
ALANDRF_PR	Area (or fraction of area) of rice with permanent refuges over element IE; [L^2] or [L^2/L^2] based on FACTLNP above

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

IE	Element identification number
LUTYPE	Land-use identification number entered sequentially (1 = rice with flooded decomposition, 2 = rice with non-flooded decomposition, 3 = rice with no decomposition, 4 = seasonal refuges, 5 = permanent refuges)
PATH	Pathname corresponding to element and ponded crop type combination

```
C*****************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*****************************************************************************
C
C                        PONDED CROP AREA FILE
C                         Root Zone Component
C                         *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                      California Department of Water Resources
C             Filename: PondedAgArea.dat
C
C*****************************************************************************
C                          File Description
C
C   This data file contains the land use distribution of ponded crops for
C   each element for the simulation period.
C
C*****************************************************************************
C                           Land Use Data Specifications
C
C   FACTLNP;   Conversion factor for land use area
C                * Enter 0.0 if land use distribution is given as a fraction of element area
C   NSPLNP ;   Number of time steps to update the land use data
C                * Enter any number if time-tracking option is on
C   NFQLNP ;   Repetition frequency of the land use data
C                * Enter 0 if full time series data is supplied
C                * Enter any number if time-tracking option is on
C   DSSFL   ;   The name of the DSS file for data input
C                * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-------------------------------------------------------------------------------------
          10.763910417                                / FACTLNP  (sq.m. -> sq.ft.)
          1                                           / NSPLNP
          0                                           / NFQLNP
                                                      / DSSFL
C-------------------------------------------------------------------------------------
C                              Land Use Data
C                          (READ FROM THIS FILE)
C
C   List the land use data below, if it will not be read from a DSS file
C   (i.e. DSSFL is left blank above).
C
C   ITLN       ;  Time
C   IE         ;  Element number
C   ALANDRI_FL ;  Rice area (or fraction of area) over an element with flooded
C                   decomposition; [L^2] or [L^2/L^2] (based on FACTLNP above)
C   ALANDRI_NFL;  Rice area (or fraction of area) over an element with non-flooded
C                   decomposition; [L^2] or [L^2/L^2] (based on FACTLNP above)
C   ALANDRI_NDC;  Rice area (or fraction of area) over an element with no
C                   decomposition; [L^2] or [L^2/L^2] (based on FACTLNP above)
C   ALANDRF_SL ;  Seasonal refuge area (or fraction of area) over an
C                   element; [L^2] or [L^2/L^2] (based on FACTLNP above)
C   ALANDRF_PR ;  Permanent refuge area (or fraction of area) over an
C                   element; [L^2] or [L^2/L^2] (based on FACTLNP above)
C                 * Note: Crop areas over elements that are designated as lake elements
C                         will be ignored
C
C-------------------------------------------------------------------------------------------------------------------
C   ITLN      IE              ALANDRI_FL      ALANDRI_NFL     ALANDRI_NDC          ALANDRF_SL      ALANDRF_PR
C-------------------------------------------------------------------------------------------------------------------
 12/31/2500_24:00    1             311.19          0.0000          0.0000              0.0000          0.00
                     2               0.00          0.0000          0.0000              0.0000          0.00
                     3          409749.34          0.0000          0.0000              0.0000          0.00
                     4         1155717.27          0.0000          0.0000              0.0000          0.00
                     5               0.00          0.0000          0.0000              0.0000          0.00
                     .                 .             .               .                   .               .
                     .                 .             .               .                   .               .
                     .                 .             .               .                   .               .
                     219        505008.16          0.0000          0.0000              0.0000      27976.28
                     220       1607496.62          0.0000          0.0000              0.0000      46201.79
                     221         13063.29          0.0000          0.0000              0.0000          0.00
                     222             0.00          0.0000          0.0000              0.0000    1471081.66
                     223        958187.12          0.0000          0.0000              0.0000          0.00
C-------------------------------------------------------------------------------------
C                              Pathnames for Land Use Data
C                                (READ FROM DSS FILE)
C
C   List the pathnames for the land use data below, if it will be read from a DSS file
C   (i.e. DSSFL is specified above).
C
C   The pathnames should be listed for each element and ponded crop combination.
C   They should be listed in an order such that, the crop type changes first.
C
C   * Example:
C
C       IE     LUTYPE      PATH
C        1        1       (pathname[1])
C        1        2       (pathname[2])
C        1        3       (pathname[3])
C        1        4       (pathname[4])
C        1        5       (pathname[5])
C        2        1       (pathname[6])
C        2        2       (pathname[7])
C        2        3       (pathname[8])
C        2        4       (pathname[9])
C        2        5       (pathname[10])
C        .        .            .
C        .        .            .
C        .        .            .
C       NE        1       (pathname[5*NE - 4])
C       NE        2       (pathname[5*NE - 3])
C       NE        3       (pathname[5*NE - 2])
C       NE        4       (pathname[5*NE - 1])
C       NE        5       (pathname[5*NE    ])
C
C   IE     ;  Element number
```

```
C   LUTYPE ;  Land use type
C               1 = Rice with flooded decomposition
C               2 = Rice with non-flooded decomposition
C               3 = Rice with no decomposition
C               4 = Seasonal refuge
C               5 = Permanent refuge
C   PATH   ;  Pathname corresponding to element and ponded crop type combination
C
C-----------------------------------------------------------------------------------------
C   IE        LUTYPE        PATH
C-----------------------------------------------------------------------------------------
*
*
```

5.3.8.8.3 Ponding Depth Data File

This file includes the time series pond depths for rice and refuges. The ponded crops are associated with data columns in this file through pointers specified in the Ponded Crops Main File.

The following variables are listed in this file:

NCOLPND	Number of pond depth data columns
FACTPND	Conversion factor pond depths
NSPPND	Number of time steps to update the pond depths; enter any number if time-tracking option is on
NFQPND	Repetition frequency of the pond depths; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Ponding Depth Data File

If the time series data is listed in the Ponding Depth Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.

PND	Pond depth; [L]

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*****************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*****************************************************************************
C
C                 RICE/REFUGE POND DEPTH DATA FILE
C                       Root Zone Component
C                       *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: PondDepth.dat
C
C*****************************************************************************
C                           File Description
C
C   This data file contains a set of ponding depths for rice fields and refuges.
C   These values are correlated to individual grid elements through the Rice/Refuge
C   Data File.
C
C*****************************************************************************
C                 Rice/Refuge Pond Depth Data Specifications
C
C   NCOLPND  ; Number of pond depth data columns
C   FACTPND  ; Conversion factor for pond depths
C   NSPPND   ; Number of time steps to update the pond depths
C               * Enter any number if time-tracking option is on
C   NFQPND   ; Repetition frequency of the pond depth data
C               * Enter 0 if full time series data is supplied
C               * Enter any number if time-tracking option is on
C   DSSFL    ; The name of the DSS file for data input
C               * Leave blank if DSS file is not used for data input
C
C-----------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-----------------------------------------------------------------------------
          2                                           / NCOLPND
          0.08333                                     / FACTPND (in -> ft)
          1                                           / NSPPND
          0                                           / NFQPND
                                                      / DSSFL
C-------------------------------------------------------------------------------
C                         Rice/Refuge Pond Depth Data
C                            (READ FROM THIS FILE)
C
C   List the rice/refuge pond depths below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   PND  ;  Pond depths; [L]
C
*   Column 1: Growing season and decomp ponding depths for flooded-decomp rice
*   Column 2: Ponding depth for permanent refuges
C
C-------------------------------------------------------------------------------
C  TIME                 PND[1]   PND[2]    PND[3] ... PND[NCOLPND]
C-------------------------------------------------------------------------------
C                       1        2
   01/31/4000_24:00     0.0      2.5
   02/29/4000_24:00     0.0      2.5
   03/31/4000_24:00     0.0      2.5
   04/30/4000_24:00     0.0      2.5
   05/31/4000_24:00     3.0      2.5
   06/30/4000_24:00     5.0      2.5
   07/31/4000_24:00     8.0      2.5
   08/31/4000_24:00     0.0      2.5
   09/30/4000_24:00     0.0      2.5
   10/31/4000_24:00     3.0      2.5
   11/30/4000_24:00     6.0      2.5
   12/31/4000_24:00     0.0      2.5
C-----------------------------------------------------------------------------
C                           Pathnames for Pond Depths
C                             (READ FROM DSS FILE)
C
C   List the pathnames for pond depths below, if it will be
C   read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C-------------------------------------------------------------------------------
C   REC     PATH
C-------------------------------------------------------------------------------
*
*
```

5.3.8.8.4 Pond Operation Flows Data File

This file lists unit flow rates that represent the pond and decomposition operations such as return flows, amounts of re-used return flows and the application rates for the non-flooded rice decomposition. The data columns in this file are associated with specific ponded crops through pointers specified in the Ponded Crops Main File.

The following variables are used:

NCOLFLW	Number of data columns for pond operation flow rates
FACTFLW	Conversion factor for the spatial component of the pond operation flow rates
NSPFLW	Number of time steps to update the pond operation flow rates; enter any number if time-tracking option is on
NFQFLW	Repetition frequency of the pond operation flow rates; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Pond Operation Flows Data File

If the time series data is listed in the Pond Operation Flows Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
FLW	Pond operation flow rates; [L/T]

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*****************************************************************************
C
C                    INTEGRATED WATER FLOW MODEL (IWFM)
C
C*****************************************************************************
C
C              RICE/REFUGE OPERATION FLOW RATE DATA FILE
C                         Root Zone Component
C                         *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: PondOperationFlows.dat
C
C*****************************************************************************
C                           File Description
C
C   This data file contains a set of flow rates (in units of L/T) to be used for
C   simulating the rice and refuge return flows, re-use and water application rates
C   for non-flooded rice decomposition. These values are correlated to individual
C   grid elements through the Rice/Refuge Data File.
C
C*****************************************************************************
C                Rice/Refuge Operation Flow Rate Data Specifications
C
C   NCOLFLW  ; Number of data columns
C   FACTFLW  ; Conversion factor for operation flow rates
C                It is used to convert only the spatial component of the unit;
C                DO NOT include the conversion factor for time component of the unit.
C                * e.g. Unit of depth listed in this file        = INCHES/MONTH
C                       Consistent unit used in simulation       = FT/DAY
C                       Enter FACTOPS (INCHES/MONTH -> FT/MONTH) = 8.333333E-02
C                        (conversion of MONTH -> DAY is performed automatically)
C   NSPFLW   ; Number of time steps to update the operation flow rates
C                * Enter any number if time-tracking option is on
C   NFQFLW   ; Repetition frequency of the operation flow rate data
C                * Enter 0 if full time series data is supplied
C                * Enter any number if time-tracking option is on
C   DSSFL    ; The name of the DSS file for data input
C                * Leave blank if DSS file is not used for data input
C
C-----------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-----------------------------------------------------------------------------
          5                                           / NCOLFLW
          0.08333                                     / FACTFLW  (in/mon -> ft/mon)
          1                                           / NSPFLW
          0                                           / NFQFLW
                                                      / DSSFL
C-------------------------------------------------------------------------------------------
C                      Rice/Refuge Operation Flow Rate Data
C                            (READ FROM THIS FILE)
C
C   List the rice/refuge operation flow rates below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   FLW  ;  Operation flow rates; [L/T]
C
*   Column 1: Flow-thru (return flow) depth for entire year for flooded-decomp rice
*   Column 2: Return flow depth for permanent refuges
*   Column 3: Re-use depth for flooded decomp rice
*   Column 4: Re-use depth for refuges
*   Column 5: Application depth for non-ponded decomp rice
C
C-------------------------------------------------------------------------------------------
C  TIME    FLW[1]    FLW[2]    FLW[3] ... FLW[NCOLFLW]
C-------------------------------------------------------------------------------------------
C                     1       2       3       4       5
   01/31/4000_24:00   2.0     0.0     0.0     0.0     0.0
   02/29/4000_24:00   1.0     0.0     0.0     0.0     0.0
   03/31/4000_24:00   0.0     0.0     0.0     0.0     0.0
   04/30/4000_24:00   0.0     0.0     0.0     0.0     0.0
   05/31/4000_24:00   3.0     0.0     0.0     0.0     0.0
   06/30/4000_24:00   0.0     0.0     0.0     0.0     0.0
   07/31/4000_24:00   1.9     0.0     0.0     0.0     0.0
   08/31/4000_24:00   1.9     0.0     0.0     0.0     0.0
   09/30/4000_24:00   0.95    0.0     0.0     0.0     0.0
   10/31/4000_24:00   0.0     0.0     0.0     0.0     0.0
   11/30/4000_24:00   2.0     0.0     0.0     0.0     0.0
   12/31/4000_24:00   2.0     0.0     0.0     0.0     0.0
C-----------------------------------------------------------------------------
C                         Pathnames for Operation Flow Rates
C                             (READ FROM DSS FILE)
C
C   List the pathnames for operation flow rates below, if it will be
C   read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C-------------------------------------------------------------------------------------------
C   REC     PATH
C-------------------------------------------------------------------------------------------
*
*
```

5.3.8.9 Urban Component Files

5.3.8.9.1 Urban Lands Main File

The Urban Lands Main File is the gateway file for all data that is necessary to simulate land surface and root zone flow processes in urban lands.

The file is divided into several sections and uses the following variables:

Land-Use Areas

The filename for the urban areas data file is listed in this section:

LUFLU	File that lists the urban areas (maximum 1000 characters)

Rooting Depth

FACT	Conversion factor for urban outdoors root zone depth
ROOTURB	Root zone depth for urban outdoors; [L]

Urban Water Use, Management and Simulation Parameters

POPULFL	File that lists the time series urban population data (maximum 1000 characters)
WTRUSEFL	File that lists the rates of per capita water use (maximum 1000 characters)
URBSPECFL	File that lists the urban water use specifications (maximum 1000 characters)
IE	Element identification number
PERV	Fraction of pervious area to total urban areas

CNURB	Curve number for urban lands
ICPOPUL	Population; this number corresponds to the appropriate data column in the Population Data File (POPULFL)
ICWTRUSE	Per capita water use; this number corresponds to the appropriate data column in the Per Capita Water Use Data File (WTRUSEFL)
FRACDM	Relative proportion of the urban demand computed by multiplying population with per capita water use to be applied to element IE; enter -1.0 for all elements if relative proportion will be computed with respect to urban area at each element
ICETURB	Urban evapotranspiration; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the IDC Main Input File
ICRTFURB	Fraction of the urban applied water that becomes return flow; this number corresponds to the appropriate data column in the Return Flow Fractions Data File (RFFL) specified in the Root Zone Component Main File; for urban lands (return flow fraction applies only to pervious (lawns, parks, etc) urban areas; all water delivered to urban indoor areas becomes return flow)
ICRUFURB	Fraction of the urban applied water that is re-used; this number corresponds to the appropriate data column in the Re-use Fractions Data File (RUFL) specified in the Root Zone Component Main File
ICURBSPEC	Urban water use specification data as a fraction of total urban water that is used indoors; this number corresponds to the appropriate data

column in the Urban Water Use Specifications Data File (URBSPECFL)

Initial Soil Moisture Conditions

The initial soil moisture content for urban outdoors at each element is listed in this section.

IE	Element identification number; enter 0 if following values are to be used for all elements
FSOILMP	Fraction of initial soil moisture at element IE that is due to precipitation
SOILM	Initial root zone moisture content for urban outdoors; [L/L]

```
C*****************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C                          *** Version ### ***
C
C*****************************************************************************
C
C                        URBAN LANDS DATA FILE
C                         Root Zone Component
C                         for IWFM Simulation
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: Urban_MAIN.dat
C
C*****************************************************************************
C                          File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes and managament of urban lands.
C
C*****************************************************************************
C                         Land Use Areas
C
C   LUFLU   ;  File that lists the urban areas (max. 1000 characters)
C
C-----------------------------------------------------------------------------
    RootZone\Urban\UrbanArea.dat                        / LUFLU
C*****************************************************************************
C                              Rooting Depth
C
C   FACT   ;    Conversion factor for urban root zone depth
C   ROOTURB;    Urban root zone depth; [L]
C
C-----------------------------------------------------------------------------
C   VALUE                 DESCRIPTION
C-----------------------------------------------------------------------------
    1.0                   / FACT
    2.0                   / ROOTURB
C*****************************************************************************
C                  Urban Water Use, Management and Simulation Parameters
C
C   POPULFL  ;  File that lists the urban population (max. 1000 characters)
C   WTRUSEFL ;  File that lists the per capita water use (max. 1000 characters)
C   URBSPECFL;  File that lists the urban water use specifications (max. 1000 characters)
C   IE       ;  Element ID (Enter 0 if following values are to be used for all elements)
C   PERV     ;  Fraction of pervious area to total urban areas
C   CNURB    ;  Curve number for urban lands
C   ICPOPUL  ;  Population - this number corresponds to the appropriate data
C                 column in the Population file (POPULFL)
C   ICWTRUSE ;  Per capita water use - this number corresponds to the appropriate data
C                 column in the Per Capita Water Use file (WTRUSEFL)
C   FRACDM   ;  Relative proportion of the urban demand computed by multiplying population
C                 with per capita water use to be applied to element IE
C                 * Note: Enter -1.0 for all FRACDM if relative proportion will be computed
C                         with respect to urban area at each element
C   ICETURB  ;  Urban ETc - this number corresponds to the appropriate data column
C                 in the ET data file listed in the Main Control Data file.
C   ICRTFURB ;  Fraction of the urban applied water that becomes return flow - this
C                 number corresponds to the appropriate data column in irrigation
C                 water return flow factor data file (RFFL).
C                 * Note: For urban lands, return flow fraction applies only to
C                         pervious (lawns, parks, etc) urban areas. All water
C                         delivered to urban indoor areas becomes return flow.
C   ICRUFURB ;  Fraction of the applied water that is re-used - this number corresponds
C                 to the appropriate data column in irrigation water re-use factor data
C                  file (RUFL).
C   ICURBSPEC;  Urban water use specification data as a fraction of total urban water that
C                 is used indoors - this number corresponds to the appropriate data column
C                 in the urban water use specifications data file (URBSPECFL).
C
C-----------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-----------------------------------------------------------------------------
          RootZone\Urban\Population.dat               / POPULFL
          RootZone\Urban\WaterUse.dat                 / WTRUSEFL
          RootZone\Urban\UrbanSpecs.dat               / URBSPECFL
C-----------------------------------------------------------------------------------------------------------
C   IE      PERV   CNURB   ICPOPUL  ICWTRUSE     FRACDM     ICETURB   ICRTFURB   ICRUFURB    ICURBSPEC
C-----------------------------------------------------------------------------------------------------------
   1        0.62    79      1         4           -1.0        20        2          2           1
   2        0.62    79      1         4           -1.0        20        2          2           1
   3        0.62    69      1         4           -1.0        20        2          2           1
   .         .       .      .         .             .         .         .          .           .
   .         .       .      .         .             .         .         .          .           .
   .         .       .      .         .             .         .         .          .           .
   221      0.62    79      1         2           -1.0        20        2          2           1
   222      0.62    69      1         1           -1.0        20        2          2           1
   223      0.62    69      1         4           -1.0        20        2          2           1
C*****************************************************************************
C                            Initial Soil Moisture Condition
C                                   For Urban Lands
C
C   IE     ; Element ID (0 if following values are to be used for all elements)
C   FSOILMP; Fraction of initial soil moisture at element IE that is due to precipitation
C   SOILM  ; Initial root zone moisture content for urban land; [L/L]
C
C-----------------------------------------------------------------------------
C   IE    FSOILMP    SOILM
C-----------------------------------------------------------------------------
  1       0.5        0.1370
  2       0.5        0.1571
  3       0.5        0.1053
  .        .          .
  .        .          .
  .        .          .
  221     0.5        0.0485
  222     0.5        0.2322
  223     0.5        0.1210
```

5.3.8.9.2 Urban Area Data File

Area of urban lands at every element are listed in this file:

FACTLNU	Conversion factor for land use areas; enter 0.0 if land use distribution is given as a fraction of element area
NSPLNU	Number of time steps to update the land use data; enter any number if time-tracking option is on
NFQLNU	Repetition frequency of the land use data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Urban Area Data File

If the time series data is listed in the Urban Area Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

ITLN	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
IE	Element identification number
ALANDU	Urban area (or fraction of area) over element IE; [L^2] or [L^2/L^2] based on FACTLNU above

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

IE	Element identification number
PATH	Pathname corresponding to urban area at element IE

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                           URBAN AREA FILE
C                          Root Zone Component
C                          *** Version 4.0 ***
C
C
C            Project:  IDC Version ### Release
C                      California Department of Water Resources
C            Filename: UrbanArea.dat
C
C*******************************************************************************
C                          File Description
C
C   This data file contains the land use distribution of urban lands for
C   each element for the simulation period.
C
C*******************************************************************************
C                           Land Use Data Specifications
C
C   FACTLNU;   Conversion factor for land use area
C                * Enter 0.0 if land use distribution is given as a fraction of element area
C   NSPLNU ;   Number of time steps to update the land use data
C                * Enter any number if time-tracking option is on
C   NFQLNU ;   Repetition frequency of the land use data
C                * Enter 0 if full time series data is supplied
C                * Enter any number if time-tracking option is on
C   DSSFL   ;   The name of the DSS file for data input
C                * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-------------------------------------------------------------------------------------
          10.763910417                                / FACTLNU    (sq. m. -> sq. ft.)
          1                                           / NSPLNU
          0                                           / NFQLNU
                                                      / DSSFL
C-------------------------------------------------------------------------------------
C                             Land Use Data
C                          (READ FROM THIS FILE)
C
C   List the land use data below, if it will not be read from a DSS file
C   (i.e. DSSFL is left blank above).
C
C   ITLN   ;   Time
C   IE     ;   Element number
C   ALANDU ;   Urban area (or fraction of area) over an element; [L^2] or [L^2/L^2] (based on FACTLNU above)
C              * Note: Urban areas over elements that are designated as lake elements
C                      will be ignored
C
C-----------------------------------------------------------------------------------------------------------------
C   ITLN             IE              ALANDU
C-----------------------------------------------------------------------------------------------------------------
 12/31/2500_24:00    1                633.00
                     2                  0.00
                     3               8771.34
                     4              60486.76
                     5                  0.00
                     .                   .
                     .                   .
                     .                   .
                     219            99096.04
                     220           110491.22
                     221             2989.20
                     222                0.00
                     223            23114.89
C-------------------------------------------------------------------------------------
C                              Pathnames for Land Use Data
C                                (READ FROM DSS FILE)
C
C   List the pathnames for the land use data below, if it will be read from a DSS file
C   (i.e. DSSFL is specified above).
C
C   IE     ;  Element number
C   PATH   ;  Pathname corresponding to urban area at element IE
C
C-------------------------------------------------------------------------------------
C   IE        PATH
C-------------------------------------------------------------------------------------
*
*
```

5.3.8.9.3 Population Data File

This file lists urban population. Urban land in each element is associated with a data column in this file through pointers specified in the Urban Main File.

The following variables are listed in this file:

NCOLPOP	Number of population data columns
NSPPOP	Number of time steps to update the population data; enter any number if time-tracking option is on
NFQPOP	Repetition frequency of the population data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Population Data File

If the time series data is listed in the Population Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

ITPOP	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
POPUL	Population; [people]

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

I	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                     POPULATION DATA FILE
C                      Root Zone Component
C                      *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: Population.dat
C
C*******************************************************************************
C                              File Description
C
C   This data file contains a set of population data on a time-series basis
C
C*******************************************************************************
C                       Population Data Specifications
C
C   NCOLPOP;  Number of population data columns
C   NSPPOP ;  Number of time steps to update the population data
C              * Enter any number if time-tracking option is on
C   NFQPOP ;  Repetition frequency of the population data
C              * Enter 0 if full time series data is supplied
C              * Enter any number if time-tracking option is on
C   DSSFL  ;  The name of the DSS file for data input (maximum 50 characters);
C              * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                          DESCRIPTION
C-------------------------------------------------------------------------------
           1                                             / NCOLPOP
           1                                             / NSPPOP
           0                                             / NFQPOP
                                                         / DSSFL
C-------------------------------------------------------------------------------
C                           Population Data
C                         (READ FROM THIS FILE)
C
C   List the population data below, if it will not be read from a
C   DSS file (i.e. DSSFL is left blank above).
C
C   ITPOP;   Time
C   POPUL;   Population; [People]
C
C-------------------------------------------------------------------------------
C ITPOP                 POPUL(1)  POPUL(2)  POPUL(3) ...
C-------------------------------------------------------------------------------
   12/31/2500_24:00     100000
*
C-------------------------------------------------------------------------------
C                       Pathnames for Population Data
C                           (READ FROM DSS FILE)
C
C   List the pathnames for the population data below, if it will be read
C   from a DSS file (i.e. DSSFL is specified above).
C
C   I    ;  Pathname number
C   PATH ;  Pathname for the time series record
C
C-------------------------------------------------------------------------------
C   I       PATH
C-------------------------------------------------------------------------------
*
*
```

5.3.8.9.4 Per Capita Water Use Data File

Time series per-capita water use rates are listed in this file. The urban areas at each element are associated with a data column in this file through pointers specified in the Urban Lands Main File.

The following variables are used in this file:

NCOLWU	Number of per capita water use data columns
FACTWU	Conversion factor for the spatial component of the per capita water use data
NSPWU	Number of time steps to update the per capita water use data; enter any number if time-tracking option is on
NFQWU	Repetition frequency of the per capita water use data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Per Capita Water Use Data File

If the time series data is listed in the Per Capita Water Use Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

ITWU	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.

WU	Per capita water use; [(L^3/T)/person]

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                  PER CAPITA WATER USE DATA FILE
C                       Root Zone Component
C                       *** Version 4.0 ***
C
C
C            Project:  IDC Version ### Release
C                      California Department of Water Resources
C            Filename: WaterUse.dat
C
C*******************************************************************************
C                             File Description
C
C   This data file contains a set of per capita water use data on a time-series
C   basis.  Water use includes both indoors (M&I) and outdoors water.
C
C*******************************************************************************
C                      Per Capita Water Use Data Specifications
C
C   NCOLWU ;  Number of water use data columns
C   FACTWU ;  Conversion factor for the water use data
C               It is used to convert only the spatial component of the unit;
C               DO NOT include the conversion factor for time component of the unit.
C               * e.g. Unit of flow listed in this file           = AC-FT/MONTH
C                      Consistent unit used in simulation         = CU.FT/DAY
C                      Enter FACTWU (AC-FT/MONTH -> CU.FT/MONTH)= 2.29568E-05
C                     (conversion of MONTH -> DAY is performed automatically)
C   NSPWU  ;  Number of time steps to update the water use data
C              * Enter any number if time-tracking option is on
C   NFQWU  ;  Repetition frequency of the water use data
C              * Enter 0 if full time series data is supplied
C              * Enter any number if time-tracking option is on
C   DSSFL  ;  The name of the DSS file for data input (maximum 50 characters);
C              * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                        DESCRIPTION
C-------------------------------------------------------------------------------
           4                                           / NCOLWU
           43560.0                                     / FACTWU   (ac.ft. -> cu.ft.)
           1                                           / NSPWU
           0                                           / NFQWU
                                                       / DSSFL
C-------------------------------------------------------------------------------
C                       Per Capita Water Use Data
C                         (READ FROM THIS FILE)
C
C   List the per capita water use data below, if it will not be read from a
C   DSS file (i.e. DSSFL is left blank above).
C
C   ITWU;   Time
C   WU  ;   Per capita water use; [L^3/T/PERSON]
C
C-------------------------------------------------------------------------------
C ITWU    WU(1)  WU(2)  WU(3) ...
C-------------------------------------------------------------------------------
 01/31/4000_24:00   0.0014928   0.0013725       0.0000844       0.0059222
 02/29/4000_24:00   0.0014928   0.0013725       0.0000844       0.0059222
 03/31/4000_24:00   0.0018247   0.0016776       0.0001032       0.0072382
 04/30/4000_24:00   0.0028199   0.0025926       0.0001595       0.0111864
 05/31/4000_24:00   0.0036492   0.0033551       0.0002064       0.0144765
 06/30/4000_24:00   0.0041468   0.0038126       0.0002346       0.0164505
 07/31/4000_24:00   0.0046444   0.0042701       0.0002627       0.0184246
 08/31/4000_24:00   0.0043127   0.0039651       0.0002440       0.0171086
 09/30/4000_24:00   0.0034834   0.0032026       0.0001970       0.0138185
 10/31/4000_24:00   0.0021564   0.0019826       0.0001220       0.0085543
 11/30/4000_24:00   0.0016587   0.0015250       0.0000938       0.0065802
 12/31/4000_24:00   0.0014928   0.0013725       0.0000844       0.0059222
C-------------------------------------------------------------------------------
C                  Pathnames for Per Capita Water Use Data
C                          (READ FROM DSS FILE)
C
C   List the pathnames for the per capita water use data below, if it will be read
C   from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C-------------------------------------------------------------------------------
C   REC       PATH
C-------------------------------------------------------------------------------
*
*
```

5.3.8.9.5 Urban Water Use Specifications Data File

Time series urban water use specifications in terms of the fraction of indoor water use to total urban water use are listed in this file. The urban areas at each element are associated with a data column in this file through pointers specified in the Urban Lands Main File.

The following variables are used in this file:

NURBSP	Number of urban water use specifications data columns
NSPURBSP	Number of time steps to update the urban water use specifications data; enter any number if time-tracking option is on
NFQURBSP	Repetition frequency of the urban water use specifications data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Urban Water Use Specifications Data File

If the time series data is listed in the Urban Water Use Specifications Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

ITUSP	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
URINDR	Fraction of total urban water that is used indoors

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                  URBAN WATER USAGE SPECIFICATION DATA FILE
C                           Root Zone Component
C                           *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: UrbanSpecs.dat
C
C*******************************************************************************
C                              File Description
C
C   This data file contains a set of urban water usage specification data as the
C   fraction of total urban water that is used indoors.
C
C*******************************************************************************
C                           Urban Water Use Data Specifications
C
C   NURBSP   ;   Number of urban water use specifications data columns
C   NSPURBSP ;   Number of time steps to update the urban water use specification data
C                 * Enter any number if time-tracking option is on
C   NFQURBSP ;   Repitition frequency of the urban water use sepcification data
C                 * Enter 0 if full time series data is supplied
C                 * Enter any number if time-tracking option is on
C   DSSFL    ;   The name of the DSS file for data input (maximum 50 characters);
C                 * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                          DESCRIPTION
C-------------------------------------------------------------------------------
           1                                             / NURBSP
           1                                             / NSPURBSP
           0                                             / NFQURBSP
                                                         / DSSFL
C-----------------------------------------------------------------------------------
C                           Urban Water Use Data
C                           (READ FROM THIS FILE)
C
C   List the urban water use data below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   ITUSP ;  Time
C   URINDR;  Fraction of total urban water that is used indoors
C
C-----------------------------------------------------------------------------------
C   ITUSP         URINDR[1]  URINDR[2]  URINDR[3] ...
C-----------------------------------------------------------------------------------
10/31/4000_24:00     0.5
11/30/4000_24:00     0.7
12/31/4000_24:00     0.8
01/31/4000_24:00    1.00
02/29/4000_24:00    1.00
03/31/4000_24:00     0.6
04/30/4000_24:00     0.5
05/31/4000_24:00    0.45
06/30/4000_24:00     0.4
07/31/4000_24:00     0.4
08/31/4000_24:00     0.4
09/30/4000_24:00     0.4
C-------------------------------------------------------------------------------
C                       Pathnames for Urban Water Use Data
C                             (READ FROM DSS FILE)
C
C   List the pathnames for urban water use data below, if it will be read
C   from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C-----------------------------------------------------------------------------------
C   REC       PATH
C-----------------------------------------------------------------------------------
*
*
```

5.3.8.10 Native and Riparian Vegetation Component Files

5.3.8.10.1 Native and Riparian Vegetation Lands Main File

The Native and Riparian Vegetation Lands Main File is the gateway file for all data that is necessary to simulate land surface and root zone flow processes in areas that are covered with native and riparian vegetation.

The file is divided into several sections and uses the following variables:

Land-Use Areas

The filename for the native and riparian areas data file is listed in this section:

LUFLNVRV	File that lists the urban areas (maximum 1000 characters)

Rooting Depths

FACT	Conversion factor for native and riparian vegetation root zone depths
ROOTNV	Root zone depth for native vegetation; [L]
ROOTRV	Root zone depth for riparian vegetation; [L]

Native and Riparian Vegetation Simulation Parameters

IE	Element identification number entered sequentially; enter 0 if the following values are to be used for all elements
CNNV	Curve number for native vegetation lands
CNRV	Curve number for riparian vegetation lands

ICETNV	Native vegetation evapotranspiration rate; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the IDC Main Input File
ICETRV	Riparian vegetation evapotranspiration rate; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the IDC Main Input File

Initial Soil Moisture Conditions

The initial soil moisture contents for native and riparian vegetation at each element are listed in this section.

IE	Element identification number; enter 0 if following values are to be used for all elements
SOILM_NV	Initial root zone moisture content for native vegetation at element IE; [L/L]
SOILM_RV	Initial root zone moisture content for riparian vegetation at element IE; [L/L]

```
C*****************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*****************************************************************************
C
C                 NATIVE AND RIPARIAN VEGETATION DATA FILE
C                         Root Zone Component
C                         *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: NVRV_MAIN.dat
C
C*****************************************************************************
C                          File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes for native and riparian vegetation.
C
C*****************************************************************************
C                          Land Use Areas
C
C   LUFLNVRV   ;  File that lists the land use areas (max. 1000 characters)
C
C-----------------------------------------------------------------------------
    RootZone\NVRV\NVRVArea.dat                      / LUFLNVRV
C*****************************************************************************
C                              Rooting Depths
C
C   FACT  ;  Conversion factor for root zone depths
C   ROOTNV;  Native veg. root zone depth; [L]
C   ROOTRV;  Riparian veg. root zone depth; [L]
C
C-----------------------------------------------------------------------------
C   VALUE                  DESCRIPTION
C-----------------------------------------------------------------------------
    1.0                    / FACT
    3.0                    / ROOTNV
    3.0                    / ROOTNV
C*****************************************************************************
C         Native and Riparian Vegetation Root Zone Simulation Parameters
C
C   IE       ;  Element ID (0 if following values are to be used for all elements)
C   CNNV     ;  Curve number for native vegetation lands
C   CNRV     ;  Curve number for riparian vegetation lands
C   ICETNV   ;  Native vegetation ETc - this number corresponds to the appropriate
C                 data column in the ET data file listed in the Main Control Data file.
C   ICETRV   ;  Riparian vegetation ETc - this number corresponds to the appropriate
C                 data column in the ET data file listed in the Main Control Data file.
C
C-----------------------------------------------------------------------------
C   IE       CNNV   CNRV    ICETNV    ICETRV
C-----------------------------------------------------------------------------
    1        71     71      21        22
    2        71     71      21        22
    3        58     58      21        22
    .        .      .       .         .
    .        .      .       .         .
    .        .      .       .         .
    221      71     71      21        22
    222      58     58      21        22
    223      58     58      21        22
C*****************************************************************************
C                              Initial Soil Moisture Condition
C                        For Native and Riparian Vegetation Areas
C
C   IE      ;   Element ID (0 if following values are to be used for all elements)
C   SOILM_NV;   Initial root zone moisture content for native vegetation area; [L/L]
C   SOILM_RV;   Initial root zone moisture content for riparian vegetation area; [L/L]
C
C-----------------------------------------------------------------------------
C   IE      SOILM_NV    SOILM_RV
C-----------------------------------------------------------------------------
    1       0.1370      0.1370
    2       0.1571      0.1571
    3       0.1053      0.1053
    .        .           .
    .        .           .
    .        .           .
    221     0.0485      0.0485
    222     0.2322      0.2322
    223     0.1210      0.1210
```

5.3.8.10.2 Native and Riparian Vegetation Area Data File

Areas of native and riparian vegetation at every element are listed in this file:

FACTLNVRV	Conversion factor for land use areas; enter 0.0 if land use distribution is given as a fraction of element area
NSPLNVRV	Number of time steps to update the land use data; enter any number if time-tracking option is on
NFQLNVRV	Repetition frequency of the land use data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Native and Riparian Vegetation Area Data File

If the time series data is listed in the Native and Riparian Vegetation Area Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

ITLN	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
IE	Element identification number
ALANDNV	Native vegetation area (or fraction of area) over element IE; [L^2] or [L^2/L^2] based on FACTLNVRV above

ALANDRV	Riparian vegetation area (or fraction of area) over element IE; [L^2] or [L^2/L^2] based on FACTLNVRV above

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

IE	Element identification number
LUTYPE	Land-use type entered sequentially (1 = native vegetation, 2 = riparian vegetation)
PATH	Pathname corresponding to element and land-use type combination

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                  NATIVE AND RIPARIAN VEGETATION AREA FILE
C                            Root Zone Component
C                            *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: NVRVArea.dat
C
C*******************************************************************************
C                          File Description
C
C   This data file contains the land use distribution of native and riparian vegetation
C   for each element for the simulation period.
C
C*******************************************************************************
C                           Land Use Data Specifications
C
C   FACTLNVRV;   Conversion factor for land use area
C                  * Enter 0.0 if land use distribution is given as a fraction of element area
C   NSPLNVRV ;   Number of time steps to update the land use data
C                  * Enter any number if time-tracking option is on
C   NFQLNVRV ;   Repetition frequency of the land use data
C                  * Enter 0 if full time series data is supplied
C                  * Enter any number if time-tracking option is on
C   DSSFL    ;   The name of the DSS file for data input
C                  * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-------------------------------------------------------------------------------------
          10.763910417                                / FACTLNNRV    (sq. m. -> sq. ft.)
          1                                           / NSPLNVRV
          0                                           / NFQLNVRV
                                                      / DSSFL
C-------------------------------------------------------------------------------------
C                              Land Use Data
C                          (READ FROM THIS FILE)
C
C   List the land use data below, if it will not be read from a DSS file
C   (i.e. DSSFL is left blank above).
C
C   ITLN   ;   Time
C   IE     ;   Element number
C   ALANDNV;   Native vegetation area (or fraction of area) over an element;
C                 [L^2] or [L^2/L^2] (based on FACTLNVRV above)
C   ALANDRV;   Riparian vegetation area (or fraction of area) over an element;
C                 [L^2] or [L^2/L^2] (based on FACTLNVRV above)
C              * Note: Areas over elements that are designated as lake elements
C                      will be ignored
C
C-------------------------------------------------------------------------------------------------
C   ITLN            IE             ALANDNV                  ALANDRV
C-------------------------------------------------------------------------------------------------
 12/31/2500_24:00    1           964286.26                   0.0001
                     2          2414291.17                   0.0001
                     3           400223.27                   0.0001
                     4           380287.64                   0.0001
                     5          2113855.82                   0.0001
                     .                 .                      .
                     .                 .                      .
                     .                 .                      .
                     219        1391742.52                   0.0001
                     220         136979.26                   0.0001
                     221        1080191.08                   0.0001
                     222              0.00                   0.0001
                     223         190938.21                   0.0001
C-------------------------------------------------------------------------------------
C                             Pathnames for Land Use Data
C                               (READ FROM DSS FILE)
C
C   List the pathnames for the land use data below, if it will be read from a DSS file
C   (i.e. DSSFL is specified above).
C
C   The pathnames should be listed for each element and native and riparian vegetation combination.
C   They should be listed in an order such that, the land use type changes first.
C
C   * Example:
C
C       IE     LUTYPE      PATH
C        1        1       (pathname[1])
C        1        2       (pathname[2])
C        2        1       (pathname[3])
C        2        2       (pathname[4])
C        .        .            .
C        .        .            .
C        .        .            .
C       NE        1       (pathname[2*NE - 1])
C       NE        2       (pathname[2*NE])
C
C   IE     ;  Element number
C   LUTYPE ;  Land use type
C               1 = Native veg.
C               2 = Riparian veg.
C   PATH   ;  Pathname corresponding to element and land use type combination
C
C-------------------------------------------------------------------------------------
C   IE        LUTYPE        PATH
C-------------------------------------------------------------------------------------
*
*
```

5.3.9 Input Files for Root Zone Component Version 4.1

Most of the input data files required by the root zone component version 4.1 and the parameters required to be specified are the same as those for root zone component version 4.0. Therefore, only those input files that are different than the ones in version 4.0 will be explained in this section. For a detailed description of the other input files, please refer to section 5.3.8.

5.3.9.1 Root Zone Component Main File

Similar to the Root Zone Component Main File for version 4.0, this file includes the convergence criteria for the iterative solution of the non-linear soil moisture mass balance equation, names of additional input files that are used to simulate land surface and root zone flow processes for agricultural, urban and natural lands, and agricultural and urban water demands. Subregional Land and Water Use as well as Subregional Root Zone Moisture Budget output filenames are also listed in this file. Data to simulate root water uptake from groundwater and riparian vegetation access to stream flows are also listed in this file. Soil properties at each grid cell and the destination for the surface flow generated at each cell are listed in the last section of the Root Zone Component Main File.

First data line of the Root Zone Component Main File lists the version number (i.e. 4.1) of the root zone component that will be used in simulating the land surface and root zone flow processes. IDC first reads this data line to figure out what other parameters will be read and what flow processes are to be simulated. This first line of data entry must not be modified.

The following sections and variables are defined in the rest of this file:

Root Zone Simulation Scheme Control and Filenames

In this section convergence criteria for the iterative solution methodology and names of additional input and output files are listed.

RZCONV	Convergence criteria for iterative soil moisture accounting as a fraction of total porosity; [L/L]
RZITERMX	Maximum number of iterations for iterative soil moisture accounting
FACTCN	Conversion factor to convert inches to the simulation unit of length
GWUPTK	Flag to turn on or off the root water uptake from groundwater (0 = root water uptake from groundwater is NOT simulated; 1 = root water uptake from groundwater is simulated); this flag is effective only when IDC is executed when linked to an integrated hydrologic model such as IWFM
AGNPFL	Filename for the Non-Ponded Crops Main File (maximum 1000 characters); leave blank if non-ponded crops are not simulated
PFL	Filename for the Ponded Crops Main File (maximum 1000 characters); leave blank if rice and/or refuge lands are not simulated
URBFL	Filename for the Urban Lands Main File (maximum 1000 characters); leave blank if urban lands are not simulated
NVRVFL	Filename for the Natural Lands Main File (maximum 1000 characters); leave blank if native and/or riparian vegetation lands are not simulated

RFFL	File that lists the return flow fractions (maximum 1000 characters); leave blank if only native and/or riparian vegetation lands are simulated
RUFL	File that lists the irrigation water re-use factors (maximum 1000 characters); leave blank if only native and/or riparian vegetation lands are simulated
IPFL	File that lists the irrigation periods for each ponded and non-ponded crop (maximum 1000 characters); this is a required file even if ponded and non-ponded crops are not simulated
MSRCFL	File that lists generic source of moisture rates other than precipitation and irrigation (maximum 1000 characters); leave blank if there are no generic sources of moisture simulated
AGWDFL	File that lists agricultural water supply requirement (maximum 1000 characters); leave blank if agricultural water supply requirement for all crops will be computed dynamically
LWUBUDFL	HDF5 output file for subregional land and water use budget (maximum 1000 characters); leave blank if this output is not required
RZBUDFL	HDF5 output file for subregional root zone moisture (maximum 1000 characters); leave blank if this output is not required
FNSMFL	Output file for end-of-simulation soil moisture (maximum 1000 characters); leave blank if this output is not required

Soil Parameters and Surface Flow Destinations

In this section soil parameters, precipitation rates, generic soil moisture sources (if any) and surface runoff destinations are listed for each finite element.

FACTK	Conversion factor for the spatial component of the root zone hydraulic conductivity
FACTCPRISE	Conversion factor for capillary rise
TUNITK	Time unit of root zone hydraulic conductivity this should be one of the units recognized by HEC-DSS that are listed in the IDC Main Input File
IE	Element identification number
WP	Wilting point; [L/L]
FC	Field capacity; [L/L]
TN	Total porosity; [L/L]
LAMBDA	Pore size distribution index
K	Saturated hydraulic conductivity; [L/T]
RHC	Method to represent hydraulic conductivity versus moisture content curve (1 = Campbell's equation, 2 = van Genucten-Mualem equation)
CPRISE	Capillary rise; [L]
IRNE	Precipitation rate; this number corresponds to the appropriate data column in the Precipitation File
FRNE	Factor to convert rainfall at the precipitation data column IRNE to rainfall at element IE

IMSRC	Generic source of moisture; this number corresponds to the appropriate data column in the Generic Moisture Source File that applies to element IE (enter any number if the Generic Moisture Source File, MSRCFL, is not defined)
TYPDEST	Destination type for the surface flow from element IE (0 = surface flow goes outside of model area, 1 = surface flow goes to a stream node, 2 = surface flow goes to another element, 3 = surface flow goes to a lake, 4 = surface flow goes to a subregion, 5 = surface flow recharges the groundwater)
DEST	Destination identification number for the surface flow from element IE; enter any number if surface flow from the element goes outside the model area (TYPDEST = 0) or recharges the groundwater (TYPDEST = 5)

```
#4.1
C***  DO NOT DELETE ABOVE LINE ***
C
C*****************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*****************************************************************************
C
C                     ROOT ZONE PARAMETERS DATA FILE
C                          Root Zone Component
C                          *** Version 4.1 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: ROOTZONE_MAIN.dat
C
C*****************************************************************************
C                           File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes.
C
C*****************************************************************************
C                Root Zone Simulation Scheme Control and File Names
C
C   RZCONV   ;  Convergence criteria for iterative soil moisture accounting as a
C                fraction of total porosity; [L/L]
C   RZITERMX ;  Maximum number of iterations for iterative soil moisture accounting
C   FACTCN   ;  Conversion factor to convert inches to the simulation unit of length
C   GWUPTK   ;  Flag to turn on or off the root water uptake from groundwater
C                0 = DO NOT allow root water uptake from groundwater
C                1 = Allow root water uptake from groundwater
C   AGNPFL   ;  Non-ponded agricultural crop data file (max. 1000 characters)
C                * Leave blank if non-ponded crops are not simulated
C   PFL      ;  Rice/refuge data file (max. 1000 characters)
C                * Leave blank if rice and/or refuge lands are not simulated
C   URBFL    ;  Urban lands data file (max. 1000 characters)
C                * Leave blank if urban lands are not simulated
C   NVRVFL   ;  Native/riparian vegetation lands data file (max. 1000 characters)
C                * Leave blank if native and/or riparion veg. lands are not simulated
C   RFFL     ;  File that lists the return flow fractions (max. 1000 characters)
C                * Leave blank if only native/riparian vegetation lands are simulated
C   RUFL     ;  File that lists the irrigation water re-use factors (max. 1000 characters)
C                * Leave blank if only native/riparian vegetation lands are simulated
C   IPFL     ;  File that lists the irrigation periods for each ponded and
C                non-ponded crop (max. 1000 characters)
C                * Leave blank if both ponded and non-ponded crops are not simulated
C   MSRCFL   ;  File that lists generic source of moisture rates other than precipitation
C                and irrigation (max. 1000 characters)
C                * Leave blank if there are no generic sources of moisture simulated
C   AGWDFL   ;  File that lists agricultural water supply requirement (max. 1000 characters)
C                * Leave blank if agricultural water supply requirement will be computed
C                  dynamically
C   LWUBUDFL ;  HDF5 output file for land and water use budget at each
C                  subregion (max. 1000 characters)
C                * Leave blank if this output is not required
C   RZBUDFL  ;  HDF5 output file for root zone moisture budget at each
C                  subregion (max. 1000 characters)
C                * Leave blank if this output is not required
C   FNSMFL   ;  Output file for end-of-simulation soil moisture (max. 1000 characters)
C                * Leave blank if this output is not required
C
C-----------------------------------------------------------------------------------------
C         VALUE                                          DESCRIPTION
C-----------------------------------------------------------------------------------------
          0.0001                                         / RZCONV
          200                                            / RZITERMX
          0.08333                                        / FACTCN
          1                                              / GWUPTK
          RootZone\NonPondedAg\NonPondedAg.dat           / AGNPFL
          RootZone\PondedAg\PondedAg.dat                 / PFL
          RootZone\Urban\Urban.dat                       / URBFL
          RootZone\NVRV\NVRV.dat                         / NVRVFL
          RootZone\ReturnFlowFrac.dat                    / RFFL
          RootZone\ReuseFrac.dat                         / RUFL
          RootZone\IrrigPeriod.dat                       / IPFL
                                                         / MSRCFL
          RootZone\AgWaterDemand.dat                     / AGWDFL
          Budget\LWU.hdf                                 / LWUBUDFL
          Budget\RZ.hdf                                  / RZBUDFL
                                                         / FNSMFL
C*****************************************************************************
C             Parameters for Soil, Precipitation and Runoff Destination
C
C   Enter conversion factors.
C
C   FACTK     ;  Conversion factor for root zone hydraulic conductivity
C                 It is used to convert only the spatial component of the unit;
C                 DO NOT include the conversion factor for time component of the unit.
C                 * e.g. Unit of hydraulic conductivity listed in this file = FT/MONTH
C                        Consistent unit used in simulation                 = IN/DAY
C                        Enter FACT (FT/MONTH -> IN/MONTH)                  = 8.33333E-02
C                        (conversion of MONTH -> DAY is performed automatically)
C   FACTCPRISE;  Conversion factor for capillary rise
C   TUNITK    ;  Time unit of root zone hydraulic conductivity.  This should be one of the
C                 units recognized by HEC-DSS that are listed in the Main Control File.
C
C-----------------------------------------------------------------------------------------
C         VALUE                                          DESCRIPTION
C-----------------------------------------------------------------------------------------
          0.283464                                       / FACTK          (micrometers/sec -> ft/day)
          1.0                                            / FACTCPRISE
          1day                                           / TUNITK
C-----------------------------------------------------------------------------------------
C
C   Enter soil parameters, precipitaion and surface flow destination data below for each
C   grid element.
C
C   IE     ;  Element ID
C   WP     ;  Wilting point; [L/L]
```

```
C   FC     ;  Field capacity; [L/L]
C   TN     ;  Total porosity; [L/L]
C   LAMBDA ;  Pore size distribution index; [dimensionless]
C   K      ;  Saturated hydraulic conductivity; [L/T]
C   RHC    ;  Method to represent hydraulic conductivity vs. moisture content curve
C               1 = Campbell's equation
C               2 = van Genucten-Mualem equation
C   CPRISE ;  Capillary rise; [L]
C   IRNE   ;  Precipitation data column in the Precipitation file that applies to element IE
C   FRNE   ;  Factor to convert rainfall at the precipitation data column to
C               rainfall at element IE
C   IMSRC  ;  Generic source of moisture data column in the Generic Moisture Source file (MSRCFL
C               file listed above) that applies to element IE
C               * Note: Enter any number if MSRCFL above is left blank
C   TYPDEST;  Destination type for the surface flow from element IE
C               0 = Surface flow goes outside of model area
C               1 =   "       "    "  to a stream node
C               2 =   "       "    "   " another element
C               3 =   "       "    "   " a lake
C               4 =   "       "    "   " a subregion
C               5 =   "       "    "   " groundwater
C   DEST   ;  Destination for the surface flow from element IE
C               * Note: Enter any number if TYPDEST is set to 0 or 5
C
C-----------------------------------------------------------------------------------------------------------------
C  IE      WP        FC        TN        LAMBDA    K           RHC    CPRISE  IRNE   FRNE   IMSRC   TYPDEST   DEST
C-----------------------------------------------------------------------------------------------------------------
   1       0.0000    0.1370    0.4530    0.3780    5.000E-02   2      10.0    1      1.0      0       0         3
   2       0.0000    0.1571    0.4640    0.2420    5.100E+01   2      10.0    1      1.0      0       0         3
   3       0.0000    0.1053    0.4630    0.2520    5.000E-02   2      10.0    1      1.0      0       0         3
   .        .         .         .         .         .          .      .       .       .       .       .         .
   .        .         .         .         .         .          .      .       .       .       .       .         .
   .        .         .         .         .         .          .      .       .       .       .       .         .
   220     0.0000    0.1210    0.4300    0.2230    5.000E-02   2      10.0    3      1.0      0       0         3
   221     0.0000    0.0485    0.4530    0.3780    5.000E-02   2      10.0    3      1.0      0       0         0
   222     0.0000    0.2322    0.5010    0.2340    1.906E+01   2      10.0    3      1.0      0       0         0
   223     0.0000    0.1210    0.4300    0.2230    5.000E-02   2      10.0    3      1.0      0       0         3
```

5.3.9.2 Native and Riparian Vegetation Component Files

5.3.9.2.1 Native and Riparian Vegetation Lands Main File

The Native and Riparian Vegetation Lands Main File is the gateway file for all data that is necessary to simulate land surface and root zone flow processes in areas that are covered with native and riparian vegetation.

The file is divided into several sections and uses the following variables:

Land-Use Areas

The filename for the native and riparian areas data file is listed in this section:

LUFLNVRV	File that lists the urban areas (maximum 1000 characters)

Rooting Depths

FACT	Conversion factor for native and riparian vegetation root zone depths
ROOTNV	Root zone depth for native vegetation; [L]
ROOTRV	Root zone depth for riparian vegetation; [L]

Native and Riparian Vegetation Simulation Parameters

IE	Element identification number entered sequentially; enter 0 if the following values are to be used for all elements
CNNV	Curve number for native vegetation lands
CNRV	Curve number for riparian vegetation lands

ICETNV	Native vegetation evapotranspiration rate; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the IDC Main Input File
ICETRV	Riparian vegetation evapotranspiration rate; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the IDC Main Input File
ISTRMRV	Stream node at which water will be used to satisfy unmet riparian evapotranspirative demand in element IE; enter 0 if riparian vegetation in element IE has no access to a stream node

Initial Soil Moisture Conditions

The initial soil moisture contents for native and riparian vegetation at each element are listed in this section.

IE	Element identification number; enter 0 if following values are to be used for all elements
SOILM_NV	Initial root zone moisture content for native vegetation at element IE; [L/L]
SOILM_RV	Initial root zone moisture content for riparian vegetation at element IE; [L/L]

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                NATIVE AND RIPARIAN VEGETATION DATA FILE
C                        Root Zone Component
C                        *** Version 4.1 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: NVRV_MAIN.dat
C
C*******************************************************************************
C                          File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes for native and riparian vegetation.
C
C*******************************************************************************
C                         Land Use Areas
C
C   LUFLNVRV   ;  File that lists the land use areas (max. 1000 characters)
C
C-------------------------------------------------------------------------------
    RootZone\NVRV\NVRVArea.dat                          / LUFLNVRV
C*******************************************************************************
C                              Rooting Depths
C
C   FACT  ;  Conversion factor for root zone depths
C   ROOTNV;  Native veg. root zone depth; [L]
C   ROOTRV;  Riparian veg. root zone depth; [L]
C
C-------------------------------------------------------------------------------
C   VALUE                 DESCRIPTION
C-------------------------------------------------------------------------------
    1.0                   / FACT
    3.0                   / ROOTNV
    3.0                   / ROOTRV
C*******************************************************************************
C         Native and Riparian Vegetation Root Zone Simulation Parameters
C
C   IE       ;  Element ID (0 if following values are to be used for all elements)
C   CNNV     ;  Curve number for native vegetation lands
C   CNRV     ;  Curve number for riparian vegetation lands
C   ICETNV   ;  Native vegetation ETc - this number corresponds to the appropriate
C                 data column in the ET data file listed in the Main Control Data file.
C   ICETRV   ;  Riparian vegetation ETc - this number corresponds to the appropriate
C                 data column in the ET data file listed in the Main Control Data file.
C   ISTRMRV  ;  Stream node at which water will be used to satisfy unmet riparain ET
C                 requirement in element IE
C                 * Enter 0 if riparian vegetation in element IE has no access to a
C                   stream node
C
C-------------------------------------------------------------------------------
C   IE    CNNV    CNRV    ICETNV    ICETRV    ISTRMRV
C-------------------------------------------------------------------------------
    1        71      71      21        22        23
    2        71      71      21        22        23
    3        58      58      21        22        0
    .        .       .       .         .         .
    .        .       .       .         .         .
    .        .       .       .         .         .
    221      71      71      21        22        78
    222      58      58      21        22        0
    223      58      58      21        22        0
C*******************************************************************************
C                            Initial Soil Moisture Condition
C                         For Native and Riparian Vegetation Areas
C
C   IE      ;   Element ID (0 if following values are to be used for all elements)
C   SOILM_NV;   Initial root zone moisture content for native vegetation area; [L/L]
C   SOILM_RV;   Initial root zone moisture content for riparian vegetation area; [L/L]
C
C-----------------------------------------------------------------------------
C   IE     SOILM_NV     SOILM_RV
C-----------------------------------------------------------------------------
    1       0.1370      0.1370
    2       0.1571      0.1571
    3       0.1053      0.1053
    .        .           .
    .        .           .
    .        .           .
    221     0.0485      0.0485
    222     0.2322      0.2322
    223     0.1210      0.1210
```

5.4 Output Files

IDC produces several optional output files. In the Root Zone Component Main File, the user can specify file names to which soil moisture as well as land and water use budgets are printed for 4 main land-use types at each subregion. These files are created in HDF5 file format for run-time efficiency and to save computer storage space. A post-processing tool, Budget, which is available for download from the IDC web site and discussed later in this document is required to process these HDF5 files and create tables in ASCII text file format. Alternatively, *IWFM Tools Add-in for Excel 2007-2013* can be downloaded from IWFM Support Tools page (http://baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM/SupportTools/index_SupportTools.cfm). This add-in allows quick transfer of data stored in the IDC HDF5 output files into Excel for further analysis.

Optionally, IDC can generate an end-of-simulation moisture content output file that is already in ASCII text format. This file lists soil moisture for each land-use type at each element. The name for this file is specified in the Root Zone Parameter File. First, soil moisture content for non-ponded crops is printed, then those for ponded-crops and urban are printed. Finally, moisture contents for native and riparian vegetations are displayed.

The soil moisture and land and water use budget files specified in the Root Zone Parameter File stores information for 4 main land-use types at each subregion. Budget information for individual non-ponded or ponded crops are not stored in these files. Optionally, IDC can generate budget files for specific non-ponded and ponded crops at each subregion. This can be achieved by specifying crop codes and output file names in non-ponded and ponded parameter files. As mentioned earlier, the generated files will be in

HDF5 file format and the user will need either the Budget post-processor to process these files and generate tables in ASCII text format or the *IWFM Tools Add-in for Excel 2007-2013* to transfer the data stored in these files to MS Excel. The usage of Budget post-processor is explained later in this document. The user's manual for the *IWFM Tools Add-in for Excel 2007-2013* is included with the tool itself.

In the following sections, a detailed explanation of the budget tables that are produced by IDC and post-processed by the Budget post-processor is given.

5.4.1 Output Files for Root Zone Component Version 4.0

5.4.1.1 Subregional Land and Water Use Budget

The subregional land and water use budget HDF5 file is generated by specifying a proper filename in the Root Zone Component Main File. A budget table is produced for each subregion listed for the LPRNT variable in the Budget Main Input File. The title printed for each subregional land and water use budget includes IWFM version number, subregion name given by the user, the unit of data columns and the area of the subregion. All land and water use budget columns are in volumetric units except *Time*, *Agricultural Area* and *Urban Area*. The output units and conversion factors for area (UNITAROU and FACTAROU) and volume (UNITVLOU and FACTVLOU) are specified by the user in the Budget Main Input File.

The total agricultural and urban areas, as well as the agricultural potential consumptive use of applied water and the water supply requirements are reported in the output, followed by the components that the land and water use budget is comprised of. For agricultural lands, potential consumptive use is the amount of water needed to bring the soil moisture up to the irrigation target moisture (field capacity, by default) after the effects of

precipitation and generic moisture sources, excluding the net return flow, are taken into account. The agricultural supply requirement is the potential consumptive use of applied water plus the net return flow.

A positive or negative sign is given for each column that is a component of the subregional land and water use. The *Shortage* column is the resulting balance, based on water use components. A value of zero in this column indicates that the available water supply (surface water diversions, groundwater pumping andr surface runoff from upstream elements) meets the agricultural or urban supply requirements. A positive value indicates that the supply is not a large enough quantity to satisfy water requirements. Conversely, a negative value in the *Shortage* column signifies a water supply surplus. The last three columns for agricultural areas are informational and show the sources of water that are used in meeting the crop evapotranspirative requirement.

The following table defines each column in the subregional land and water use budget table printed out to a text file:

SUBREGIONAL LAND AND WATER USE BUDGET

COL. #	COLUMN NAME	DESCRIPTION
1	Time	Simulation date and time
Agricultural Area		
2	Area	Agricultural area
3	Potential CUAW	Applied water needed to increase the soil moisture to irrigation target moisture before taking into account the net return flow
4	Agricultural Supply Requirement	If agricultural water demands are computed internally, this is the total amount of applied water needed to increase the soil moisture to irrigation target moisture plus the net return flow. If agricultural water demands are specified, then this term equals the pre-specified water demand.
5	Pumping (–)	Portion of groundwater pumping that is used to meet the agricultural supply requirement

6	Diversion (–)	Portion of the stream diversions that is used to meet the agricultural supply requirement
7	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the agricultural supply requirement
8	Shortage (=)	Resulting water balance with respect to the agricultural supply requirements and actual water supply specified in preceding columns
9	ETAW	Amount of crop evapotranspiration that is met by applied water (summation of pumping, diversions and captured surface runoff from upstream elements) through current and previous irrigation events
10	Effective Precip	Amount of crop evapotranspiration that is met by current and previous precipitation events
11	ET from Other Sources	Amount of crop evapotranspiration that is met by generic water sources (e.g. lateral seepage, fog)
Urban Area		
12	Area	Urban area
13	Urban Supply Requirement	Sum of indoor and outdoor urban water demand
14	Pumping (–)	Portion of groundwater pumping that is used to meet the urban supply requirement
15	Diversion (–)	Portion of stream diversions that is used to meet the urban supply requirement
16	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the urban supply requirement
17	Shortage (=)	Resulting water balance with respect to the urban supply requirements and actual water supply specified in preceding columns

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_L&W_USE_BUD

Part B:

TTT (SR*XXX*) where *TTT* is the name of the subregion and *XXX* is the subregion number

Part C:

One of the following, depending on the output data:

i. *AREA*

ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the subregional land and water use budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AG_AREA* (corresponds to column 2 in text output file)

ii. *AG_POTNL_CUAW* (corresponds to column 3 in text output file)

iii. *AG_SUP_REQ* (corresponds to column 4 in text output file)

iv. *AG_PUMPING* (corresponds to column 5 in text output file)

v. *AG_DIVER* (corresponds to column 6 in text output file)

vi. *AG_SR_INFLOW* (corresponds to column 7 in text output file)

vii. *AG_SHORTAGE* (corresponds to column 8 in text output file)

viii. *AG_ETAW* (corresponds to column 19 in text output file)

ix. *AG_EFF_PRECIP* (corresponds to column 10 in text output file)

x. *AG_ET_OTH* (corresponds to column 11 in text output file)

xi. *URB_AREA* (corresponds to column 12 in text output file)

xii. *URB_SUP_REQ* (corresponds to column 13 in text output file)

xiii. *URB_PUMPING* (corresponds to column 14 in text output file)

xiv. *URB_DIVER* (corresponds to column 15 in text output file)

xv. *URB_SR_INFLOW* (corresponds to column 16 in text output file)

xvi. *URB_SHORTAGE* (corresponds to column 17 in text output file)

5.4.1.2 Crop-Specific Land and Water Use Budget

The crop-specific land and water use budget HDF5 files are generated by specifying the individual crops and proper filenames in the non-ponded and ponded crops section of the Root Zone Component Main File.

A budget table is produced for each subregion and crop combination listed for the LPRNT variable in the Budget Main Input File. The indices for subregion and crop combinations are arranged in the Root Zone Component such that crops are listed first and subregions second. For instance, if 5 non-ponded crops are specified for crop-specific land and water use budget output in a model with 2 subregions, indices 1 through 5 represent crops 1 through 5 in subregion 1, indices 6 through 10 represent crops 1 through 5 in subregion 2, and indices 11 through 15 represent crops 1 through 5 in the entire model domain. So, if LPRNT variable is set to {1, 7, 9}, budget tables for crop 1 in subregion 1 (index 1), crop 2 in subregion 2 (index 7) and crop 4 in subregion 2 (index 9) will be printed.

The generated budget table is similar to that generated for the subregional land and water use budget except that there is no information for urban lands. The title printed for each crop-specific land and water use budget includes IWFM version number, subregion name given by the user, the crop code, the unit of data columns and the area of the subregion. All land and water use budget columns are in volumetric units except *Time and Area*. The output units and conversion factors for area (UNITAROU and FACTAROU) and volume (UNITVLOU and FACTVLOU) are specified by the user in the Budget Main Input File.

The crop area, potential consumptive use of applied water and the supply requirement are reported in the output, followed by the components that the crop-specific land and water use budget is comprised of. A positive or negative sign is given for each column that is a component of the crop-specific land and water use. The *Shortage* column is the resulting balance, based on water use components. A value of zero in this column indicates that the available water supply (surface water diversions, groundwater pumping and surface runoff from upstream elements) meets the agricultural or urban supply requirements. A positive value indicates that the supply is not a large enough quantity to satisfy water requirements. Conversely, a negative value in the *Shortage* column signifies a water supply surplus. The last three columns are informational and show the sources of water that are used in meeting the crop evapotranspirative requirement. The following table defines each column in the crop-specific land and water use budget table printed out to a text file:

CROP-SPECIFIC LAND AND WATER USE BUDGET

COL. #	COLUMN NAME	DESCRIPTION
1	Time	Simulation date and time
2	Area	Crop area

3	Potential CUAW	Applied water needed to increase the soil moisture to irrigation target moisture before taking into account the net return flow
4	Agricultural Supply Requirement	If crop water demand is computed internally, this is the total amount of applied water needed to increase the soil moisture to irrigation target moisture plus the net return flow. If crop water demand is specified, then this term equals the pre-specified crop water demand.
5	Pumping (–)	Portion of groundwater pumping that is used to meet the crop water supply requirement
6	Diversion (–)	Portion of the stream diversions that is used to meet the crop water supply requirement
7	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the crop water supply requirement
8	Shortage (=)	Resulting water balance with respect to the crop water supply requirement and actual water supply specified in preceding columns
9	ETAW	Amount of crop evapotranspiration that is met by applied water (summation of pumping, diversions and captured surface runoff from upstream elements) through current and previous irrigation events
10	Effective Precip	Amount of crop evapotranspiration that is met by current and previous precipitation events
11	ET from Other Sources	Amount of crop evapotranspiration that is met by generic water sources (e.g. lateral seepage, fog)

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_L&W_USE_BUD

Part B:

TTT (SR*XXX*)_*YY* where *TTT* is the name of the subregion, *XXX* is the subregion number and *YY* is the user-specified crop code

Part C:

One of the following, depending on the output data:

i. *AREA*

i. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the crop-specific land and water use budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AREA* (corresponds to column 2 in text output file)

ii. *POTNL_CUAW* (corresponds to column 3 in text output file)

iii. *SUP_REQ* (corresponds to column 4 in text output file)

iv. *PUMPING* (corresponds to column 5 in text output file)

v. *DIVER* (corresponds to column 6 in text output file)

vi. *SR_INFLOW* (corresponds to column 7 in text output file)

vii. *SHORTAGE* (corresponds to column 8 in text output file)

viii. *ETAW* (corresponds to column 9 in text output file)

ix. *EFF_PRECIP* (corresponds to column 10 in text output file)

x. *ET_OTH* (corresponds to column 11 in text output file)

5.4.1.3 Subregional Root Zone Moisture Budget

The subregional root zone moisture budget is produced for each subregion listed for processing in the Budget Main Input File. The title printed for each subregional root zone moisture budget includes IWFM version number, subregion name given by the user, the unit of data columns and the area of the subregion. The output units are specified by the user in the Budget Main Input File.

The root zone moisture budget provides information on processes that are used to compute soil moisture in the root zone. Agricultural areas represent the areas where crops are located. Urban area includes indoor and outdoor urban areas and the native and riparian lands represent the undeveloped area in the subregion. For each area type (agricultural, urban, and native and riparian vegetation) precipitation and irrigation (except for native and riparian vegetation areas) along with direct runoff and return flows are listed. The *Infiltration* column is computed by adding the *Precipitation*, *Prime Applied Water* and *Inflow as Surface Runoff* columns and subtracting the *Runoff* and *Net Return Flow* columns. The following table describes the columns in the subregional root zone moisture budget when printed out to a text file:

SUBREGIONAL ROOT ZONE MOISTURE BUDGET

COL. #	COLUMN NAME	DESCRIPTION
1	Time	Simulation date and time
Agricultural Area		
2	Area	Agricultural area
3	Potential ET	Potential evapotranspiration for agricultural lands
4	Precipitation	Precipitation that falls on agricultural lands
5	Runoff	Direct runoff of precipitation that falls on agricultural lands

6	Prime Applied Water	Amount of water applied as a summation of diversions and pumping for irrigation purposes
7	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used for irrigation purposes
8	Reused Water	Amount of return flow that is captured and re-used for irrigation
9	Net Return Flow	Net return flow of irrigation on agricultural lands (after re-use)
10	Beginning Storage (+)	Root zone moisture in agricultural lands at the beginning of time step
11	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of agricultural lands increase (a negative value represents loss of moisture due to the decrease of agricultural area)
12	Infiltration (+)	Total infiltration on the agricultural lands; computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
13	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
14	Pond Drain (–)	Drainage of rice and refuge ponds
15	Actual ET (–)	Actual evapotranspiration in agricultural lands
16	Deep Percolation (–)	Deep percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in agricultural areas
17	Ending Storage (–)	Root zone moisture in agricultural lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
18	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of agricultural lands
Urban Area		
19	Area	Urban area
20	Potential ET	Potential evapotranspiration for urban lands
21	Precipitation	Precipitation that falls on urban lands

22	Runoff	Direct runoff of precipitation that falls on urban lands
23	Prime Applied Water	Total amount of pumping and diversions that is used to meet urban indoors and outdoors water demand
24	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used to meet urban water demand
25	Reused Water	The amount of return flow that is captured and re-used on urban lands
26	Net Return Flow	Net return flow of applied water used for urban indoors and outdoors usage (after re-use)
27	Beginning Storage (+)	Root zone moisture at the beginning of time step
28	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of urban lands increase (a negative value represents loss of moisture due to the decrease of urban area)
29	Infiltration (+)	Total infiltration on the urban lands computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
30	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
31	Actual ET (–)	Actual evapotranspiration in urban lands
32	Deep Percolation (–)	Deep percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in urban areas
33	Ending Storage (–)	Root zone moisture in urban lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
34	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of urban lands
Native & Riparian Vegetation Area		
35	Area	Native and riparian vegetation area
36	Potential ET	Potential evapotranspiration for native and riparian vegetation

37	Precipitation	Precipitation that falls on areas with native and riparian vegetation
38	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that flows into the lands with native and riparian vegetation
39	Runoff	Direct runoff of precipitation that falls on areas with native and riparian vegetation
40	Beginning Storage (+)	Root zone moisture in areas with native and riparian vegetation at the beginning of time step
41	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of native and riparian vegetation increase (a negative value represents loss of moisture due to the decrease of native and riparian vegetation area)
42	Infiltration (+)	Total infiltration on areas with native and riparian vegetation; computed as the sum of precipitation and inflow as surface runoff less runoff
43	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
44	Actual ET (–)	Actual evapotranspiration in areas with native and riparian vegetation
45	Deep Percolation (–)	Deep percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in areas with native and riparian vegetation
46	Ending Storage (+)	Root zone moisture in areas with native and riparian vegetation at the end of the time step; computed as the summation of the beginning storage and the net moisture inflow
47	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of lands with native and riparian vegetation

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_ROOTZN_BUD

Part B:

TTT (SR*XXX*) where *TTT* is the name of the subregion and *XXX* is the subregion number

Part C:

One of the following, depending on the output data:

i. *AREA*

ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the subregional root zone moisture budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AG_AREA* (corresponds to column 2 in text output file)

ii. *AG_POT_ET* (corresponds to column 3 in text output file)

iii. *AG_PRECIP* (corresponds to column 4 in text output file)

iv. *AG_RUNOFF* (corresponds to column 5 in text output file)

v. *AG_PRM_H2O* (corresponds to column 6 in text output file)

vi. *AG_SR_INFLOW* (corresponds to column 7 in text output file)

vii. *AG_RE-USE* (corresponds to column 8 in text output file)

viii. *AG_NT_RTRN_FLOW* (corresponds to column 9 in text output file)

ix. *AG_BEGIN_STOR* (corresponds to column 10 in text output file)

x. *AG_GAIN_EXP* (corresponds to column 11 in text output file)

xi. *AG_INFILTR* (corresponds to column 12 in text output file)

xii. *AG_OTHER_INFLOW* (corresponds to column 13 in text output file)

xiii. *AG_DRAIN* (corresponds to column 14 in text output file)

xiv. *AG_ET* (corresponds to column 15 in text output file)

xv. *AG_DEEP_PERC* (corresponds to column 16 in text output file)

xvi. *AG_END_STOR* (corresponds to column 17 in text output file)

xvii. *AG_DISCREPANCY* (corresponds to column 18 in text output file)

xviii. *URB_AREA* (corresponds to column 19 in text output file)

xix. *URB_POT_ET* (corresponds to column 20 in text output file)

xx. *URB_PRECIP* (corresponds to column 21 in text output file)

xxi. *URB_RUNOFF* (corresponds to column 22 in text output file)

xxii. *URB_PRM_H2O* (corresponds to column 23 in text output file)

xxiii. *URB_SR_INFLOW* (corresponds to column 24 in text output file)

xxiv. *URB_RE-USE* (corresponds to column 25 in text output file)

xxv. *URB_NT_RTRN_FLOW* (corresponds to column 26 in text output file)

xxvi. *URB_BEGIN_STOR* (corresponds to column 27 in text output file)

xxvii. *URB_GAIN_EXP* (corresponds to column 28 in text output file)

xxviii. *URB_INFILTR* (corresponds to column 29 in text output file)

xxix. *URB_OTHER_INFLOW* (corresponds to column 30 in text output file)

xxx. *URB_ET* (corresponds to column 31 in text output file)

xxxi. *URB_DEEP_PERC* (corresponds to column 32 in text output file)

xxxii. *URB_END_STOR* (corresponds to column 33 in text output file)

xxxiii. *URB_DISCREPANCY* (corresponds to column 34 in text output file)

xxxiv. *NRV_AREA* (corresponds to column 35 in text output file)

xxxv. *NRV_POT_ET* (corresponds to column 36 in text output file)

xxxvi. *NRV_PRECIP* (corresponds to column 37 in text output file)

xxxvii. *NRV_SR_INFLOW* (corresponds to column 38 in text output file)

xxxviii. *NRV_RUNOFF* (corresponds to column 39 in text output file)

xxxix. *NRV_BEGIN_STOR* (corresponds to column 40 in text output file)

xl. *NRV_GAIN_EXP* (corresponds to column 41 in text output file)

xli. *NRV_INFILTR* (corresponds to column 42 in text output file)

xlii. *NRV_OTHER_INFLOW* (corresponds to column 43 in text output file)

xliii. *NRV_ET* (corresponds to column 44 in text output file)

xliv. *NRV_DEEP_PERC* (corresponds to column 45 in text output file)

xlv. *NRV_END_STOR* (corresponds to column 46 in text output file)

xlvi. *NRV_DISCREPANCY* (corresponds to column 47 in text output file)

5.4.1.4 Crop-Specific Root Zone Moisture Budget

The crop-specific root zone moisture budget HDF5 files are generated by specifying the individual crops and proper filenames in the non-ponded and ponded crops section of the Root Zone Component Main File.

A budget table is produced for each subregion and crop combination listed for the LPRNT variable in the Budget Main Input File. The indices for subregion and crop combinations are arranged in the Root Zone Component such that crops are listed first and subregions second. For instance, if 5 non-ponded crops are specified for crop-specific root zone moisture budget HDF5 output in a model with 2 subregions, indices 1 through 5 represent crops 1 through 5 in subregion 1, indices 6 through 10 represent crops 1 through 5 in subregion 2, and indices 11 through 15 represent crops 1 through 5 in the entire model domain. So, if LPRNT variable is set to {1, 7, 9}, budget tables for crop 1 in subregion 1 (index 1), crop 2 in subregion 2 (index 7) and crop 4 in subregion 2 (index 9) will be printed.

The generated budget table is similar to that generated for the subregional root zone moisture budget except that there is no information for urban lands, and areas with native and riparian vegetation. The title printed for each crop-specific root zone moisture budget includes IWFM version number, subregion name given by the user, the crop code, the unit of data columns and the area of the subregion.

The following table describes the columns in the crop-specific root zone moisture budget when printed out to a text file:

CROP-SPECIFIC ROOT ZONE MOISTURE BUDGET

COL. #	COLUMN NAME	DESCRIPTION
1	Time	Simulation date and time

2	Area	Crop area
3	Potential ET	Potential evapotranspiration for the specified crop
4	Precipitation	Precipitation that falls on areas with the specified crop
5	Runoff	Direct runoff of precipitation that falls on areas with the specified crop
6	Prime Applied Water	Amount of water applied as a summation of diversions and pumping for irrigation purposes
7	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used for irrigation purposes
8	Reused Water	Amount of return flow that is captured and re-used for irrigation
9	Net Return Flow	Net return flow of irrigation on areas with the specified crop (after re-use)
10	Beginning Storage (+)	Root zone moisture in areas with the specified crop at the beginning of time step
11	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of the specified crop increases (a negative value represents loss of moisture due to the decrease of the crop area)
12	Infiltration (+)	Total infiltration on areas with the specified crop; computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
13	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
14	Pond Drain (–)	Drainage of rice and refuge ponds; this column is non-zero only if the specified crop is a ponded crop
15	Actual ET (–)	Actual evapotranspiration of the specified crop
16	Deep Percolation (–)	Deep percolation from the root zone which is the vertical moisture outflow from the bottom of the crop root zone
17	Ending Storage (–)	Root zone moisture in areas with the specified crop at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone

18	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of the specified crop

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_ROOTZN_BUD

Part B:

TTT (SR*XXX*)*_YY* where *TTT* is the name of the subregion, *XXX* is the subregion number and *YY* is the crop code specified by the user

Part C:

One of the following, depending on the output data:

i. *AREA*

ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the crop-specific root zone moisture budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AREA* (corresponds to column 2 in text output file)

ii. *POT_ET* (corresponds to column 3 in text output file)

iii. *PRECIP* (corresponds to column 4 in text output file)

iv. *RUNOFF* (corresponds to column 5 in text output file)

v. *PRM_H2O* (corresponds to column 6 in text output file)

vi. *SR_INFLOW* (corresponds to column 7 in text output file)

vii. *RE-USE* (corresponds to column 8 in text output file)

viii. *NET_RTRN_FLOW* (corresponds to column 9 in text output file)

ix. *BEGIN_STOR* (corresponds to column 10 in text output file)

x. *GAIN_EXP* (corresponds to column 11 in text output file)

xi. *INFILTR* (corresponds to column 12 in text output file)

xii. *OTHER_INFLOW* (corresponds to column 13 in text output file)

xiii. *DRAIN* (corresponds to column 14 in text output file)

xiv. *ET* (corresponds to column 15 in text output file)

xv. *DEEP_PERC* (corresponds to column 16 in text output file)

xvi. *END_STOR* (corresponds to column 17 in text output file)

xvii. *DISCREPANCY* (corresponds to column 18 in text output file)

5.4.2 Output Files for Root Zone Component Version 4.1

Since root zone component version 4.1 simulates root water uptake from groundwater and riparian vegetation access to stream flows in addition to other flow processes simulated in version 4.1, budget output files for version 4.1 have several additional data columns. Other data columns are the same as those in version 4.0 and are already explained in detail in section 5.4.1. Therefore, only the additional data columns that appear in version 4.1 will be explained in the following sections.

5.4.2.1 Subregional Land and Water Use Budget

In root zone component version 4.1, groundwater can meet all or a portion of the plant evapotranspirative demand. For agricultural areas, the portion of the total evapotranspiration that is met by groundwater is listed along with the other possible moisture sources; namely, irrigation, precipitation and generic moisture source.

The following table defines each column in the subregional land and water use budget table for root zone component version 4.1 when printed out to a text file:

SUBREGIONAL LAND AND WATER USE BUDGET

COL. #	COLUMN NAME	DESCRIPTION
1	Time	Simulation date and time
Agricultural Area		
2	Area	Agricultural area
3	Potential CUAW	Applied water needed to increase the soil moisture to irrigation target moisture before taking into account the net return flow
4	Agricultural Supply Requirement	If agricultural water demands are computed internally, this is the total amount of applied water needed to increase the soil moisture to irrigation target moisture plus the net return flow. If agricultural water demands are specified, then this term equals the pre-specified water demand.
5	Pumping (–)	Portion of groundwater pumping that is used to meet the agricultural supply requirement
6	Diversion (–)	Portion of the stream diversions that is used to meet the agricultural supply requirement
7	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the agricultural supply requirement
8	Shortage (=)	Resulting water balance with respect to the agricultural supply requirements and actual water supply specified in preceding columns

9	ETAW	Amount of crop evapotranspiration that is met by applied water (summation of pumping, diversions and captured surface runoff from upstream elements) through current and previous irrigation events
10	Effective Precip	Amount of crop evapotranspiration that is met by current and previous precipitation events
11	ET from Groundwater	Amount of crop evapotranspiration that is met by groundwater
12	ET from Other Sources	Amount of crop evapotranspiration that is met by generic water sources (e.g. lateral seepage, fog)
Urban Area		
13	Area	Urban area
14	Urban Supply Requirement	Sum of indoor and outdoor urban water demand
15	Pumping (–)	Portion of groundwater pumping that is used to meet the urban supply requirement
16	Diversion (–)	Portion of stream diversions that is used to meet the urban supply requirement
17	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the urban supply requirement
18	Shortage (=)	Resulting water balance with respect to the urban supply requirements and actual water supply specified in preceding columns

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_L&W_USE_BUD

Part B:

TTT (SR*XXX*) where *TTT* is the name of the subregion and *XXX* is the subregion number

Part C:

One of the following, depending on the output data:

i. *AREA*

ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the subregional land and water use budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AG_AREA* (corresponds to column 2 in text output file)

ii. *AG_POTNL_CUAW* (corresponds to column 3 in text output file)

iii. *AG_SUP_REQ* (corresponds to column 4 in text output file)

iv. *AG_PUMPING* (corresponds to column 5 in text output file)

v. *AG_DIVER* (corresponds to column 6 in text output file)

vi. *AG_SR_INFLOW* (corresponds to column 7 in text output file)

vii. *AG_SHORTAGE* (corresponds to column 8 in text output file)

viii. *AG_ETAW* (corresponds to column 19 in text output file)

ix. *AG_EFF_PRECIP* (corresponds to column 10 in text output file)

x. *AG_ET_GW* (corresponds to column 11 in text output file)

xi. *AG_ET_OTH* (corresponds to column 12 in text output file)

xii. *URB_AREA* (corresponds to column 13 in text output file)

xiii. *URB_SUP_REQ* (corresponds to column 14 in text output file)

xiv. *URB_PUMPING* (corresponds to column 15 in text output file)

xv. *URB_DIVER* (corresponds to column 16 in text output file)

xvi. *URB_SR_INFLOW* (corresponds to column 17 in text output file)

xvii. *URB_SHORTAGE* (corresponds to column 18 in text output file)

5.4.2.2 Crop-Specific Land and Water Use Budget

In addition to the output columns listed and explained for root zone component version 4.0 in section 5.4.1.2, the portion of plant evapotranspirative demand that is met by groundwater is listed for user-specified ponded and non-ponded crops. The following table defines each column in the crop-specific land and water use budget table printed out to a text file:

CROP-SPECIFIC LAND AND WATER USE BUDGET

COL. #	COLUMN NAME	DESCRIPTION
1	Time	Simulation date and time
2	Area	Crop area
3	Potential CUAW	Applied water needed to increase the soil moisture to irrigation target moisture before taking into account the net return flow
4	Agricultural Supply Requirement	If crop water demand is computed internally, this is the total amount of applied water needed to increase the soil moisture to irrigation target moisture plus the net return flow. If crop water demand is specified, then this term equals the pre-specified crop water demand.
5	Pumping (–)	Portion of groundwater pumping that is used to meet the crop water supply requirement
6	Diversion (–)	Portion of the stream diversions that is used to meet the crop water supply requirement

7	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the crop water supply requirement
8	Shortage (=)	Resulting water balance with respect to the crop water supply requirement and actual water supply specified in preceding columns
9	ETAW	Amount of crop evapotranspiration that is met by applied water (summation of pumping, diversions and captured surface runoff from upstream elements) through current and previous irrigation events
10	Effective Precip	Amount of crop evapotranspiration that is met by current and previous precipitation events
11	ET from Groundwater	Amount of crop evapotranspiration that is met by groundwater
12	ET from Other Sources	Amount of crop evapotranspiration that is met by generic water sources (e.g. lateral seepage, fog)

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_L&W_USE_BUD

Part B:

TTT (SR*XXX*)_*YY* where *TTT* is the name of the subregion, *XXX* is the subregion number and *YY* is the user-specified crop code

Part C:

One of the following, depending on the output data:

i. *AREA*

ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the crop-specific land and water use budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AREA* (corresponds to column 2 in text output file)

ii. *POTNL_CUAW* (corresponds to column 3 in text output file)

iii. *SUP_REQ* (corresponds to column 4 in text output file)

iv. *PUMPING* (corresponds to column 5 in text output file)

v. *DIVER* (corresponds to column 6 in text output file)

vi. *SR_INFLOW* (corresponds to column 7 in text output file)

vii. *SHORTAGE* (corresponds to column 8 in text output file)

viii. *ETAW* (corresponds to column 9 in text output file)

ix. *EFF_PRECIP* (corresponds to column 10 in text output file)

x. *ET_GW* (corresponds to column 11 in text output file)

xi. *ET_OTHER* (corresponds to column 12 in text output file)

5.4.2.3 Subregional Root Zone Moisture Budget

In addition to the output columns listed in section 5.4.1.3, several additional data columns appear in the budget output tables for root zone component version 4.1 to account for the effects of root water uptake from groundwater and riparian vegetation access to stream flow to meet part or all of the riparian evapotranspirative demand. The following

table describes the columns in the subregional root zone moisture budget when printed out to a text file:

SUBREGIONAL ROOT ZONE MOISTURE BUDGET

COL. #	COLUMN NAME	DESCRIPTION
1	Time	Simulation date and time
Agricultural Area		
2	Area	Agricultural area
3	Potential ET	Potential evapotranspiration for agricultural lands
4	Precipitation	Precipitation that falls on agricultural lands
5	Runoff	Direct runoff of precipitation that falls on agricultural lands
6	Prime Applied Water	Amount of water applied as a summation of diversions and pumping for irrigation purposes
7	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used for irrigation purposes
8	Reused Water	Amount of return flow that is captured and re-used for irrigation
9	Net Return Flow	Net return flow of irrigation on agricultural lands (after re-use)
10	Beginning Storage (+)	Root zone moisture in agricultural lands at the beginning of time step
11	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of agricultural lands increase (a negative value represents loss of moisture due to the decrease of agricultural area)
12	Infiltration (+)	Total infiltration on the agricultural lands; computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
13	Groundwater Inflow (+)	Portion of the actual agricultural evapotranspiration that is met by groundwater
14	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage

15	Pond Drain (–)	Drainage of rice and refuge ponds
16	Actual ET (–)	Actual evapotranspiration in agricultural lands
17	Deep Percolation (–)	Deep percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in agricultural areas
18	Ending Storage (–)	Root zone moisture in agricultural lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
19	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of agricultural lands
Urban Area		
20	Area	Urban area
21	Potential ET	Potential evapotranspiration for urban lands
22	Precipitation	Precipitation that falls on urban lands
23	Runoff	Direct runoff of precipitation that falls on urban lands
24	Prime Applied Water	Total amount of pumping and diversions that is used to meet urban indoors and outdoors water demand
25	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used to meet urban water demand
26	Reused Water	The amount of return flow that is captured and re-used on urban lands
27	Net Return Flow	Net return flow of applied water used for urban indoors and outdoors usage (after re-use)
28	Beginning Storage (+)	Root zone moisture at the beginning of time step
29	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of urban lands increase (a negative value represents loss of moisture due to the decrease of urban area)
30	Infiltration (+)	Total infiltration on the urban lands computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow

31	Groundwater Inflow (+)	Portion of the actual urban evapotranspiration that is met by groundwater
32	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
33	Actual ET (–)	Actual evapotranspiration in urban lands
34	Deep Percolation (–)	Deep percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in urban areas
35	Ending Storage (–)	Root zone moisture in urban lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
36	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of urban lands
Native & Riparian Vegetation Area		
37	Area	Native and riparian vegetation area
38	Potential ET	Total potential evapotranspiration for native and riparian vegetation
39	Precipitation	Precipitation that falls on areas with native and riparian vegetation
40	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that flows into the lands with native and riparian vegetation
41	Runoff	Direct runoff of precipitation that falls on areas with native and riparian vegetation
42	Beginning Storage (+)	Root zone moisture in areas with native and riparian vegetation at the beginning of time step
43	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of native and riparian vegetation increase (a negative value represents loss of moisture due to the decrease of native and riparian vegetation area)
44	Infiltration (+)	Total infiltration on areas with native and riparian vegetation; computed as the sum of precipitation and inflow as surface runoff less runoff
45	Groundwater Inflow (+)	Portion of the actual native and riparian vegetation evapotranspiration that is met by groundwater
46	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage

47	Stream Inflow for (ET)	Portion of the actual riparian vegetation evapotranspiration that is met by stream flows
48	Actual ET (–)	Actual evapotranspiration in areas with native and riparian vegetation
49	Deep Percolation (–)	Deep percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in areas with native and riparian vegetation
50	Ending Storage (+)	Root zone moisture in areas with native and riparian vegetation at the end of the time step; computed as the summation of the beginning storage and the net moisture inflow
51	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of lands with native and riparian vegetation

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_ROOTZN_BUD

Part B:

TTT (SR*XXX*) where *TTT* is the name of the subregion and *XXX* is the subregion number

Part C:

One of the following, depending on the output data:

i. *AREA*

ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the subregional root zone moisture budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AG_AREA* (corresponds to column 2 in text output file)

ii. *AG_POT_ET* (corresponds to column 3 in text output file)

iii. *AG_PRECIP* (corresponds to column 4 in text output file)

iv. *AG_RUNOFF* (corresponds to column 5 in text output file)

v. *AG_PRM_H2O* (corresponds to column 6 in text output file)

vi. *AG_SR_INFLOW* (corresponds to column 7 in text output file)

vii. *AG_RE-USE* (corresponds to column 8 in text output file)

viii. *AG_NT_RTRN_FLOW* (corresponds to column 9 in text output file)

ix. *AG_BEGIN_STOR* (corresponds to column 10 in text output file)

x. *AG_GAIN_EXP* (corresponds to column 11 in text output file)

xi. *AG_INFILTR* (corresponds to column 12 in text output file)

xii. *AG_GW_INFLOW* (corresponds to column 13 in text output file)

xiii. *AG_OTHER_INFLOW* (corresponds to column 14 in text output file)

xiv. *AG_DRAIN* (corresponds to column 15 in text output file)

xv. *AG_ET* (corresponds to column 16 in text output file)

xvi. *AG_DEEP_PERC* (corresponds to column 17 in text output file)

xvii. *AG_END_STOR* (corresponds to column 18 in text output file)

xviii. *AG_DISCREPANCY* (corresponds to column 19 in text output file)

xix. *URB_AREA* (corresponds to column 20 in text output file)

xx. *URB_POT_ET* (corresponds to column 21 in text output file)

xxi. *URB_PRECIP* (corresponds to column 22 in text output file)

xxii. *URB_RUNOFF* (corresponds to column 23 in text output file)

xxiii. *URB_PRM_H2O* (corresponds to column 24 in text output file)

xxiv. *URB_SR_INFLOW* (corresponds to column 25 in text output file)

xxv. *URB_RE-USE* (corresponds to column 26 in text output file)

xxvi. *URB_NT_RTRN_FLOW* (corresponds to column 27 in text output file)

xxvii. *URB_BEGIN_STOR* (corresponds to column 28 in text output file)

xxviii. *URB_GAIN_EXP* (corresponds to column 29 in text output file)

xxix. *URB_INFILTR* (corresponds to column 30 in text output file)

xxx. *URB_GW_INFLOW* (corresponds to column 31 in text output file)

xxxi. *URB_OTHER_INFLOW* (corresponds to column 32 in text output file)

xxxii. *URB_ET* (corresponds to column 33 in text output file)

xxxiii. *URB_DEEP_PERC* (corresponds to column 34 in text output file)

xxxiv. *URB_END_STOR* (corresponds to column 35 in text output file)

xxxv. *URB_DISCREPANCY* (corresponds to column 36 in text output file)

xxxvi. *NRV_AREA* (corresponds to column 37 in text output file)

xxxvii. *NRV_POT_ET* (corresponds to column 38 in text output file)

xxxviii. *NRV_PRECIP* (corresponds to column 39 in text output file)

xxxix. *NRV_SR_INFLOW* (corresponds to column 40 in text output file)

xl. *NRV_RUNOFF* (corresponds to column 41 in text output file)

xli. *NRV_BEGIN_STOR* (corresponds to column 42 in text output file)

xlii. *NRV_GAIN_EXP* (corresponds to column 43 in text output file)

xliii. *NRV_INFILTR* (corresponds to column 44 in text output file)

xliv. *NRV_GW_INFLOW* (corresponds to column 45 in text output file)

xlv. *NRV_OTHER_INFLOW* (corresponds to column 46 in text output file)

xlvi. *NRV_STRM_ET* (corresponds to column 47 in text output file)

xlvii. *NRV_ET* (corresponds to column 48 in text output file)

xlviii. *NRV_DEEP_PERC* (corresponds to column 49 in text output file)

xlix. *NRV_END_STOR* (corresponds to column 50 in text output file)

l. *NRV_DISCREPANCY* (corresponds to column 51 in text output file)

5.4.2.4 Crop-Specific Root Zone Moisture Budget

Contribution of groundwater to the evapotranspiration for user-specified ponded and non-ponded crops is listed in addition to the data columns listed for root zone component version 4.0 in section 5.4.1.4. The following table describes the columns in the crop-specific root zone moisture budget when printed out to a text file:

CROP-SPECIFIC ROOT ZONE MOISTURE BUDGET

COL. #	COLUMN NAME	DESCRIPTION
1	Time	Simulation date and time
2	Area	Crop area
3	Potential ET	Potential evapotranspiration for the specified crop
4	Precipitation	Precipitation that falls on areas with the specified crop
5	Runoff	Direct runoff of precipitation that falls on areas with the specified crop
6	Prime Applied Water	Amount of water applied as a summation of diversions and pumping for irrigation purposes
7	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used for irrigation purposes
8	Reused Water	Amount of return flow that is captured and re-used for irrigation
9	Net Return Flow	Net return flow of irrigation on areas with the specified crop (after re-use)
10	Beginning Storage (+)	Root zone moisture in areas with the specified crop at the beginning of time step
11	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of the specified crop increases (a negative value represents loss of moisture due to the decrease of the crop area)
12	Groundwater Inflow (+)	Portion of the actual evapotranspiration for the user-specified crop that is met by groundwater
13	Infiltration (+)	Total infiltration on areas with the specified crop; computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
14	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
15	Pond Drain (–)	Drainage of rice and refuge ponds; this column is non-zero only if the specified crop is a ponded crop
16	Actual ET (–)	Actual evapotranspiration of the specified crop

17	Deep Percolation (–)	Deep percolation from the root zone which is the vertical moisture outflow from the bottom of the crop root zone
18	Ending Storage (–)	Root zone moisture in areas with the specified crop at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
19	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of the specified crop

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_ROOTZN_BUD

Part B:

TTT (SR*XXX*)_*YY* where *TTT* is the name of the subregion, *XXX* is the subregion number and *YY* is the crop code specified by the user

Part C:

One of the following, depending on the output data:

i. *AREA*

ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the crop-specific root zone moisture budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for

further details):

i. *AREA* (corresponds to column 2 in text output file)

ii. *POT_ET* (corresponds to column 3 in text output file)

iii. *PRECIP* (corresponds to column 4 in text output file)

iv. *RUNOFF* (corresponds to column 5 in text output file)

v. *PRM_H2O* (corresponds to column 6 in text output file)

vi. *SR_INFLOW* (corresponds to column 7 in text output file)

vii. *RE-USE* (corresponds to column 8 in text output file)

viii. *NET_RTRN_FLOW* (corresponds to column 9 in text output file)

ix. *BEGIN_STOR* (corresponds to column 10 in text output file)

x. *GAIN_EXP* (corresponds to column 11 in text output file)

xi. *INFILTR* (corresponds to column 12 in text output file)

xii. *GW_INFLOW* (corresponds to column 13 in text output file)

xiii. *OTHER_INFLOW* (corresponds to column 14 in text output file)

xiv. *DRAIN* (corresponds to column 15 in text output file)

xv. *ET* (corresponds to column 16 in text output file)

xvi. *DEEP_PERC* (corresponds to column 17 in text output file)

xvii. *END_STOR* (corresponds to column 18 in text output file)

xviii. *DISCREPANCY* (corresponds to column 19 in text output file)

5.5 Budget Post-Processor

IDC prints out its results into HDF5 files to decrease the computer run times as well as the size of the output files. The information in these HDF5 files need to be processed to generate understandable information in a table format. The Budget post-processor is created

for this purpose and it is available for download from the IDC's web site at http://baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM/IDC/index_IDC.cfm.

Budget post-processor can process multiple HDF5 files at the same time. The user specifies the number of HDF5 files to be processed, the names of these files and the output files where the processed results will be printed out.

For each HDF5 file to be processed the user can choose the "locations" for which the IDC results will be listed in a tabulated form. A location can either be a subregion or a set of specified land-uses at a subregion. For instance, the user can specify names for root zone moisture, and land and water use budget files in the Root Zone Parameter File. For these files, a location is a subregion. If the model has 20 subregions, then the user can choose in the Budget post-processor to process these two HDF5 files and generate tabulated data for all or some of the subregions.

Similar output file names can also be specified for non-ponded and ponded crops as well as urban, native vegetation and riparian vegetation lands. In this case, a location will be a land-use and subregion combination. For instance, if the user chooses to generate HDF5 soil moisture budget file for 4 crops (e.g. grain, alfalfa, corn and sugar beets), the first location for the processed and tabulated data will be grain in the first subregion, second location will be alfalfa in the first subregion, third location will be corn in the first subregion, etc. Fifth location will be grain in the second subregion.

By using the output features of IDC and Budget post-processor the user can obtain detailed land and water use as well as soil moisture budgets for total agriculture, urban, and native and riparian vegetation lands as well as for specific crops in each subregion.

When executed, Budget post-processor asks for the name of the Budget Main Input

File which is described below.

5.5.1 Budget Main Input File

The Budget Main Input File contains output unit controls, beginning and ending simulation times for the budget print-out, names of the HDF5 files to be processed, budget print-out locations and the print-out interval of the budget data.

The values stored in the HDF5 files have units used in the IDC run. The output unit control information allows the user to print out the budget data in a different set of units. The user is required to enter the beginning date and time, BDT, and the ending date and time, EDT for the budget outputs. The user can process as many budget files as needed. A single HDF5 file can be processed multiple times with different output intervals. For each HDF5 file to be processed, the user is required to enter the name of the HDF5 file, the name of the output file, output interval, number of *locations* for budget print-out and a list of the location indices. If the output interval is greater than the simulation time step, the budget flow terms will be accumulated over the output interval.

The meaning of *location* depends on the type of the budget file being processed. For instance, for subregional root zone budget, *location* represents a subregion. For crop specific root zone budget a *location* represents agricultural lands occupied by a specific crop at a subregion. When location is specified as −1, Budget post-processor prints out budget tables for all locations in that particular budget class. If a value of 0 is specified for the location, then Budget suppresses the processing of the budget tables.

The following is a list of variables that need to be defined in this file:

FACTLTOU	Factor to convert simulation unit of length to output unit of length
UNITLTOU	Output unit of length (maximum of 8 characters)

FACTAROU	Factor to convert simulation unit of area to output unit of area
UNITAROU	Output unit of area (maximum of 8 characters)
FACTVLOU	Factor to convert simulation unit of volume to output unit of volume
UNITVLOU	Output unit of volume (maximum of 8 characters)
CACHE	Cache size in terms of number of output values stored in the memory before being printed to the output file; a large CACHE value (e.g. 50000 or more depending on the memory resources of the computer where Budget runs are taking place) can drastically decrease the program run-time especially when the budget tables are printed out to a DSS file.
TBEGIN	Beginning time step for the budget tables; used only for non-time-tracking simulations (note that IDC only performs time-tracking simulations)
TLAST	Ending time step for the budget tables; used only for non-time-tracking simulations (note that IDC only performs time-tracking simulations)
BDT	Beginning date and time for the budget tables; used only for time-tracking simulations
EDT	Ending date and time for the budget tables; used only for time-tracking simulations
NBUDGET	Number of budget files to be processed

NBUDGET, described above, informs the Budget post-processor about the number of budget files that will be processed. For each of the budget files to be processed the following variables need to be set:

HDFFILE	Name of the HDF5 budget file (maximum 1000 characters)
OUTFILE	Name of the budget output file (maximum 1000 characters); the filename extension dictates if the output file will be text file or a DSS file (see section 5.2 for file types and corresponding filename extensions)
INTPRNT	Interval for budget print-out (budget flow terms will be accumulated over the output interval); this should be one of the units recognized by HEC-DSS that are listed in the IDC Main Input File. If left blank, the print-out interval will be the same as the simulation time step.
NLPRNT	Number of *locations* for budget table print-out; a *location* corresponds to different spatial attributes depending on the type of the budget table being processed (e.g. a subregion for subregional root zone budgets, lands that are occupied by a specific crop in a subregion for crop specific root zone budget, etc.)
LPRNT	Index for locations for which a budget table will be generated; for budget tables at subregions, the index for the entire domain is the number of subregions plus 1 (–1 = print budget tables for all locations, 0 = suppress printing of all budget tables)

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C                         *** Version ### ***
C
C*******************************************************************************
C
C                            BUDGET INPUT FILE
C                        for IWFM Post-Processing
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: Budget.in
C
C*******************************************************************************
c
C                             File Description
C
C    This file contains the names of all HDF5 input files,
C    conversion factors and output control options for running the post-processor.
C
C*******************************************************************************
C                    Output Unit Control
C
C    FACTLTOU; Factor to convert simulation unit of length to output unit of length
C    UNITLTOU; Output unit of length (8 characters max.)
C    FACTAROU; Factor to convert simulation unit of area to output unit of area
C    UNITAROU; Output unit of area (8 characters max.)
C    FACTVLOU; Factor to convert simulation unit of volume to output unit of volume
C    UNITVLOU; Output unit of volume (8 characters max.)
C
C-------------------------------------------------------------------------------
C   VALUE                          DESCRIPTION
C-------------------------------------------------------------------------------
    1.0                            / FACTLTOU
    FT.                            / UNITLTOU
    2.295684114e-5                 / FACTAROU  (sq.ft. -> ac)
    AC.                            / UNITAROU
    2.295684114e-5                 / FACTVLOU  (cu.ft. -> ac.ft.)
    AC.FT.                         / UNITVLOU
C*******************************************************************************
C                    Output Cache Size
C
C    CACHE;   Cache size in terms of number of values stored for time series
C             data output
C
C-------------------------------------------------------------------------------------
C   VALUE                          DESCRIPTION
C-------------------------------------------------------------------------------------
    500000                         / CACHE
C*******************************************************************************
C                        Budget Output Control Options
C                    (Simulation Date and Time NOT Tracked)
C
C    If the actual simulation date and time is NOT tracked enter the following
C    variables. Otherwise, comment out the following variables and use the
C    "Simulation Date and Time NOT Tracked" option below.
C
C    TBEGIN ; Beginning time for the budget tables
C             * Use ##.# format
C    TLAST  ; Ending time for the budget tables
C             * Use ##.# format
C
C-------------------------------------------------------------------------------
C   VALUE                        DESCRIPTION
C-------------------------------------------------------------------------------
*                                / TBEGIN
*                                / TLAST
C-------------------------------------------------------------------------------
C                        Budget Output Control Options
C                     (Simulation Date and Time Tracked)
C
C    If the actual simulation date and time is tracked enter the following
C    variables. Otherwise, comment out the following variables and use the
C    "Simulation Date and Time NOT Tracked" option above.
C
C    BDT    ; Begining date and time for the budget output
C             * Use MM/DD/YYYY_HH:MM format
C             * Midnight is 24:00
C    EDT    ; Ending date and time for the budget output
C             * Use MM/DD/YYYY_HH:MM format
C             * Midnight is 24:00
C
C-------------------------------------------------------------------------------
C   VALUE                        DESCRIPTION
C-------------------------------------------------------------------------------
    09/30/1980_24:00             / BDT
    09/30/2006_24:00             / EDT
C*******************************************************************************
C                           Budget Output Data
C
C   List below the number of budget classes (i.e. groundwater budget, stream
C   budget, small watershed budget, etc.), and for each budget class list the
C   input file, output file and the locations for which a budget table will
C   be generated.
C
C   NBUDGET ;  Number of budget classes to be printed
C   HDFFILE ;  Name of the input budget file (max. 1000 characters)
C   OUTFILE ;  Name of the budget output file (max. 1000 characters)
C   INTPRNT ;  Interval for budget print out (e.g. 1DAY, 1MONTH, etc.). The interval
C                must be a one of those listed in the Main Input File for the
C                executable that generated the HDF5 input files.
C                * Leave blank to use the same interval as the data.
C                * This interval will only be used for simulation with
C                  date and time tracked
C   NLPRNT  ;  Number of location indices for budget table print-out
C   LPRNT   ;  Index for locations (i.e. subregions, lakes, stream reaches, etc.
C                depending on the budget class) for which a budget table will be
C                generated.  For budget tables at subregions, the index for the
C                entire domain is the number of subregions plus 1.
C                * Enter -1: to print budget tables for all locations
```

```
C                        0: to suppress printing of any budget tables
C
C-------------------------------------------------------------------------------
C   VALUE                       DESCRIPTION
C-------------------------------------------------------------------------------
     4                          / NBUDGET
C*******************************************************************************
C                          Data for Budget Class 1
C
C-------------------------------------------------------------------------------
C   VALUE                       DESCRIPTION
C-------------------------------------------------------------------------------
   LWU.HDF                      / HDFFILE
   LWU.BUD                      / OUTFILE
   1mon                         / INTPRNT
   1                            / NLPRNT
   -1                           / LPRNT[1]
C*******************************************************************************
C                          Data for Budget Class 2
C
C-------------------------------------------------------------------------------
C   VALUE                       DESCRIPTION
C-------------------------------------------------------------------------------
   RZ.HDF                       / HDFFILE
   RZ.BUD                       / OUTFILE
                                / INTPRNT
   1                            / NLPRNT
   -1                           / LPRNT[1]
C*******************************************************************************
C                          Data for Budget Class 3
C
C-------------------------------------------------------------------------------
C   VALUE                       DESCRIPTION
C-------------------------------------------------------------------------------
    NonPondedAgLWU.hdf          / HDFFILE
    NonPondedAgLWU.bud          / OUTFILE
                                / INTPRNT
    3                           / NLPRNT
    1                           / LPRNT[1]
    7                           / LPRNT[2]
    14                          / LPRNT[3]
C*******************************************************************************
C                          Data for Budget Class 4
C
C-------------------------------------------------------------------------------
C   VALUE                       DESCRIPTION
C-------------------------------------------------------------------------------
    NonPondedAgLWU.hdf          / HDFFILE
    NonPondedAgLWU_ANNUAL.bud   / OUTFILE
    1year                       / INTPRNT
    1                           / NLPRNT
    -1                          / LPRNT[1]
```

5.6 Linking IDC to Other Models

The source code of IDC has been compiled into a dynamic link library (DLL) and the procedures necessary to link IDC to other models have been exported. The models that are using IDC need to be linked to the IDC DLL.

When IDC is linked to other models it still requires the same input data files that are utilized when IDC is used as a stand-alone model. This means that some information that is used by the linking model may need to be re-structured in a format that IDC expects. For instance, the linking model may already be using precipitation data for other processes it simulates. Since IDC also requires precipitation as input the same or additional precipitation data needs to be re-structured into the format that IDC expects. Another information that needs to be redefined in a format that IDC requires is the configuration of the computational grid. If the linking model utilizes a finite-element grid, it is likely that the format of the grid configuration data for the linking model is in a different format than IDC requires. In this case, the grid configuration needs to be redefined in the format that IDC expects to read. Similarly, if the linking model utilizes a finite-difference grid, the grid configuration should be redefined as if it is a finite-element grid in the format that IDC expects.

To successfully link IDC to other models, the modeler needs to know the interfaces to the exported procedures in the IDC DLL. Next, the exported procedures and their interfaces are given.

5.6.1 Procedure Interfaces

5.6.1.1 IDC_GetMainControlData

Given the name of the Main Control Data File, this procedure reads information stored in this file and initializes the simulation time period.

```
FUNCTION IDC_GetMainControlData(LenFileName,MainFileName) RESULT(iStat)
   INTEGER,INTENT(IN)                          :: LenFileName
   CHARACTER(LEN=LenFileName),INTENT(IN) :: MainFileName
   INTEGER                                     :: iStat
END FUNCTION IDC_GetMainControlData
```

LenFileName : Length of the name for the Main Control Data file.

MainFileName : Name of the Main Control Data File

5.6.1.2 IDC_InitApp

Using the information included in the data files that are listed in the Main Control Data File, this procedure instantiates the simulation grid, precipitation, evapotranspiration and root zone components for the simulation.

```
FUNCTION IDC_InitApp() RESULT(iStat)
   INTEGER :: iStat
END FUNCTION IDC_InitApp
```

iStat : Error code that is returned by the procedure; 0 represents successful execuation of the procedure.

5.6.1.3 IDC_CheckTSDataPointers

This procedure makes sure that input time-series data is consistent such that a time-series data column that does not exist is not being referred to by IDC.

```
SUBROUTINE IDC_CheckTSDataPointers()
END SUBROUTINE IDC_CheckTSDataPointers
```

5.6.1.4 IDC_ConvertTimeUnit

This subroutine converts the time units initially defined for IDC parameters to the simulation time unit.

```
SUBROUTINE IDC_ConvertTimeUnit(LenNewUnit,NewUnit)
   INTEGER,INTENT(IN)                          :: LenNewUnit
   CHARACTER(LEN=LenNewUnit),INTENT(IN) :: NewUnit
END SUBROUTINE IDC_ConvertTimeUnit
```

LenNewUnit : Length of the name of the simulation time unit; for instance, if simulation time unit is ‘1DAY’, then LenNewUnit is 4 (i.e. number of characters in ‘1DAY’)

NewUnit : Simulation time unit into which time units of IDC parameters will be converted.

5.6.1.5 IDC_AdvanceTime

This procedure advances the time step for IDC and generates the new time stamp using the length of time step specified in the Main Control Data File. The new time stamp is used to read locate and read data from the time-series input data files.

```
FUNCTION IDC_AdvanceTime() RESULT(iStat)
   INTEGER :: iStat
END FUNCTION IDC_AdvanceTime
```

iStat : Error code that is returned by the procedure; 0 represents successful execuation of the procedure.

5.6.1.6 IDC_ReadTSData

This procedure reads data from time-series input files for the corresponding time step in the simulation.

```
FUNCTION IDC_ReadTSData() RESULT(iStat)
   INTEGER :: iStat
END FUNCTION IDC_ReadTSData
```

iStat : Error code that is returned by the procedure; 0 represents successful execution of the procedure.

5.6.1.7 IDC_ComputeGWInflow

Given depth-to-groundwater and specific yield of the aquifer material, this procedure calculates the potential amount of groundwater that can contribute to the plant evapotranspiration.

```
SUBROUTINE IDC_ComputeGWInflow(NElements,DepthToGW,Sy)
   INTEGER,INTENT(IN) :: NElements
   REAL(8),INTENT(IN)   :: DepthToGW(NElements),Sy(NElements)
SUBROUTINE IDC_ComputeGWInflow
```

NElements : Number of cells in the computational grid.

DepthToGW : Depth-to-groundwater at each cell as measured from ground surface.

Sy : Aquifer specific yield at each cell.

5.6.1.8 IDC_GetRatio_DestSupplyToRegionSupply_Ag

This procedure returns the ratio of the agricultural water demand at each demand location to the total agricultural water demand at the subregion that each demand location belongs to. These ratios can then be used to distribute subregional water supplies to specific demand locations within those subregions.

```
SUBROUTINE IDC_GetRatio_DestSupplyToRegionSupply_Ag(NLocations,Ratio)
   INTEGER,INTENT(IN)  :: NLocations
   REAL(8),INTENT(OUT) :: Ratio(NLocations)
END SUBROUTINE IDC_GetRatio_DestSupplyToRegionSupply_Ag
```

NLocations : Number of demand locations.

Ratio : Ratio of agricultural water demand at each demand location to the total agricultural water demand at the subregion that the demand location belongs to.

5.6.1.9 IDC_GetRatio_DestSupplyToRegionSupply_Urb

This procedure returns the ratio of the urban water demand at each demand location to the total urban water demand at the subregion that each demand location belongs to. These ratios can then be used to distribute subregional water supplies to specific demand locations within those subregions.

```
SUBROUTINE IDC_GetRatio_DestSupplyToRegionSupply_Urb(NLocations,Ratio)
    INTEGER,INTENT(IN)  :: NLocations
    REAL(8),INTENT(OUT) :: Ratio(NLocations)
END SUBROUTINE IDC_GetRatio_DestSupplyToRegionSupply_Urb
```

NLocations : Number of demand locations.

Ratio : Ratio of urban water demand at each demand location to the total urban water demand at the subregion that the demand location belongs to.

5.6.1.10 IDC_ComputeWaterDemand

This procedure computes applied water demand for ponded and non-ponded agricultural crops as well as for urban areas.

```
FUNCTION IDC_ComputeWaterDemand() RESULT(iStat)
    INTEGER :: iStat
END FUNCTION IDC_ComputeWaterDemand
```

iStat : Error code that is returned by the procedure; 0 represents successful execuation of the procedure.

5.6.1.11 IDC_GetFlowsToStreams

This procedure returns the surface flows into each stream node in terms of return flows and rainfall runoff as well as the required outflow (actual amount is limited by the amount of actual flow in the stream) from each stream node due to riparian evapotranspiration at each stream node.

```
SUBROUTINE IDC_GetFlowsToStreams(NStrmNodes,DirectRunoff,ReturnFlow,RiparianET)
   INTEGER,INTENT(IN)  :: NStrmNodes
   REAL(8),INTENT(OUT) :: DirectRunoff(NStrmNodes),ReturnFlow(NStrmNodes),     &
                          RiparianET(NStrmNodes)
END SUBROUTINE IDC_GetFlowsToStreams
```

NStrmNodes : Number of stream nodes simulated in the system.

DirectRunoff : Rainfall runoff into each stream node as calculated by IDC.

ReturnFlow : Agricultural and urban return flow into each stream node as calculated by IDC.

RiparianET : Required outflow from each stream node to meet the riparian evapotranspirative demand.

5.6.1.12 IDC_ZeroSupply

This procedure resets the water supply to each element to zero.

```
FUNCTION IDC_ZeroSupply() RESULT(iStat)
   INTEGER :: iStat
END FUNCTION IDC_ZeroSupply
```

iStat : Error code that is returned by the procedure; 0 represents successful execuation of the procedure.

5.6.1.13 IDC_SetSupply

This procedure sets the water supply to each demand location (element or subregion). The source of water supply can be either stream diversions or groundwater pumping. Water

supply can be assigned to each element or to each subregion. If the supply is assigned to each subregion than IDC distributes the subregional water supply to individual elements in proportion to the water demand at each element in the subregion. This procedure can be called multiple times to represent a mixture of pumping and diversions to elements or subregions. When the procedure is called multiple times, IDC accumulates supplies to elements.

```
FUNCTION IDC_SetSupply (NLocations,Supply,SupplyType) RESULT(iStat)
    INTEGER,INTENT(IN)  :: NLocations,SupplyType
    REAL(8),INTENT(IN)  :: Supply(NLocations)
    INTEGER             :: iStat
END FUNCTION IDC_SetSupply
```

NLocations : Number of demand calculation locations.

Supply : Water supply amounts to each element or subregion.

SupplyType : Enter 1 if source of water supply is diversions; enter 2 if the source is groundwater pumping.

5.6.1.14 IDC_SetActualRiparianET_AtStrmNodes

This procedure specifies the actual outflow from each stream node to meet riparian evapotranspirative demand after stream flows are simulated.

```
SUBROUTINE IDC_SetActualRiparianET_AtStrmNodes(NStrmNodes,RiparianETFrac)
    INTEGER,INTENT(IN)  :: NStrmNodes
    REAL(8),INTENT(IN)  :: RiparianETFrac(NStrmNodes)
END SUBROUTINE IDC_SetActualRiparianET_AtStrmNodes
```

NStrmNodes : Number of stream nodes simulated in the system.

RiparianETFrac : Ratio of the actual riparian evapotranspiration from each stream node to the required riparian evapotranspiration.

5.6.1.15 IDC_Simulate

This procedure computes the root zone and land surface flow processes.

```
FUNCTION IDC_Simulate() RESULT(iStat)
   INTEGER :: iStat
END FUNCTION IDC_Simulate
```

iStat : Error code that is returned by the procedure; 0 represents successful execuation of the procedure.

5.6.1.16 IDC_GetDeepPercAll

This procedure is used to get the deep percolation computed at all elements of the computational grid computed by IDC. These values can be used by the calling simulation model as the recharge to the groundwater.

```
SUBROUTINE IDC_GetDeepPercAll(NElements,DeepPerc)
   INTEGER,INTENT(IN)  :: NElements
   REAL(8),INTENT(OUT) :: DeepPerc(NElements)
END SUBROUTINE IDC_GetDeepPercAll
```

NElements : Number of cells in the computational grid.

DeepPerc : Deep percolation at every cell computed by IDC.

5.6.1.17 IDC_GetDeepPercElement

This procedure is used to get deep percolation at a specific cell of the computational grid computed by IDC.

```
FUNCTION IDC_GetDeepPercElement(iElem) RESULT(DeepPerc)
   INTEGER,INTENT(IN)  :: iElem
   REAL(8)             :: DeepPerc
END FUNCTION IDC_GetDeepPercElement
```

iElem : Identification number of the grid cell for which the deep percolation computed by IDC is required.

DeepPerc : Deep percolation at grid cell iElem computed by IDC.

5.6.1.18 IDC_GetElementGWInflows

This procedure returns the actual amount of groundwater that is used to meet the plant evapotranspirative demand at each grid cell. These values can be used as sink terms in the simulation of the groundwater.

```
SUBROUTINE IDC_GetElementGWInflows(NElements,GWInflows)
   INTEGER,INTENT(IN) :: NElements
   REAL(8),INTENT(OUT):: GWInflows(NElements)
END SUBROUTINE IDC_GetElementGWInflows
```

NElements : Number of cells in the computational grid.

GWInflows : Actual amount of groundwater that is used to meet the plant evapotranspirative need at each cell.

5.6.1.19 IDC_RegionalDeepPerc

This procedure returns the total deep percolation at each subregion including the deep percolation at the entire model domain.

```
SUBROUTINE IDC_RegionalDeepPerc(NSubregions,RPERC)
   INTEGER,INTENT(IN) :: NSubregions
   REAL(8),INTENT(OUT):: RPERC(NSubregions+1)
END SUBROUTINE IDC_RegionalDeepPerc
```

NSubregions : Number of subregions that the model domain is divided into.

RPERC : Total deep percolation at each subregion; The very last component of array RPERC returns the total deep percolation at the entire model domain.

5.6.1.20 IDC_PrintResults

This procedure prints out the results to the ouput files specified by the user. To speed up the computer run-times, IDC stores the values to be printed in cache whose size is defined

by the user in thye Main Control Data File. When cache is full, the values are flushed to the output files. To trigger the flushing of the values to the output files at the end of the simulation even when the cache is not full, this procedure requires the user to specify if it is the end of simulation or not.

```
FUNCTION IDC_PrintResults(iEndOfSimulation) RESULT(iStat)
    INTEGER,INTENT(IN) :: iEndOfSimulation
    INTEGER            :: iStat
END FUNCTION IDC_PrintResults
```

iEndOfSimulation : If it is the last time step of the simulation, enter 1. Otherwise enter 0.

iStat : Error code that is returned by the procedure; 0 represents successful execuation of the procedure.

5.6.1.21 IDC_AdvanceState

This procedure advances the state of the root zone in time. The flow rates that are computed at the end of the time step are labeled as flow rates at the beginning of the next time step.

```
FUNCTION IDC_AdvanceState() RESULT(iStat)
    INTEGER :: iStat
END FUNCTION IDC_AdvanceState
```

iStat : Error code that is returned by the procedure; 0 represents successful execuation of the procedure.

5.6.1.1 IDC_GetNDemandLocations

This function returns the number of computational locations where demand is calculated. This procedure will currently return the number of finite element cells used in the model.

```
FUNCTION IDC_GetNDemandLocations() RESULT(NLoc)
   INTEGER  :: NLoc
END FUNCTION IDC_GetNDemandLocations
```

NLoc : Number of locations (currently, number of cells) where water demand is computed .

5.6.1.2 IDC_GetWaterDemand_Ag

This subroutine obtains the agricultural water demand at each demand location computed by IDC. These demands can be used by the linking model to adjust the diversions and groundwater pumping.

```
SUBROUTINE IDC_GetWaterDemand_Ag(NLocations,WaterDemand)
   INTEGER,INTENT(IN)  :: NLocations
   REAL(8),INTENT(OUT) :: WaterDemand(NLocations)
END SUBROUTINE IDC_GetWaterDemand_Ag
```

NLocations : Number of water demand calculation locations.

ElemDemand : Agricultural water demand at each demand location computed by IDC.

5.6.1.3 IDC_GetWaterDemand_Urb

This subroutine obtains the urban water demand at demand calculation location computed by IDC. These demands can be used by the linking model to adjust the diversions and groundwater pumping.

```
SUBROUTINE IDC_GetWaterDemand_Urb(NLocations,WaterDemand)
   INTEGER,INTENT(IN)  :: NLocations
   REAL(8),INTENT(OUT) :: WaterDemand(NLocations)
END SUBROUTINE IDC_GetWaterDemand_Urb
```

NElements : Number of cells in the computational grid.

ElemDemand : Urban water demand at each grid cell computed by IDC.

5.6.1.4 IDC_GetElementAgAreas

This subroutine obtains the agricultural areas at each grid cell.

```
SUBROUTINE IDC_GetElementAgAreas(NElements,Areas)
   INTEGER,INTENT(IN)  :: NElements
   REAL(8),INTENT(OUT) :: Areas(NElements)
END SUBROUTINE IDC_GetElementAgAreas
```

NElements : Number of cells in the computational grid.

Areas : Agricultural areas at each grid cell.

5.6.1.5 IDC_GetElementUrbanAreas

This subroutine obtains the urban areas at each grid cell.

```
SUBROUTINE IDC_GetElementUrbanAreas(NElements,Areas)
   INTEGER,INTENT(IN)  :: NElements
   REAL(8),INTENT(OUT) :: Areas(NElements)
END SUBROUTINE IDC_GetElementUrbanAreas
```

NElements : Number of cells in the computational grid.

Areas : Urban areas at each grid cell.

5.6.1.6 IDC_GetWaterSupply_Ag

This procedure returns the total water supplies to each demand location to meet agricultural water demand.

```
SUBROUTINE IDC_GetwaterSupply_Ag(NLocations,Supply)
   INTEGER,INTENT(IN)  :: NLocations
   REAL(8),INTENT(OUT) :: Supply(NElements)
END SUBROUTINE IDC_GetWaterSupply_Ag
```

NLocations : Number of demand locations.

Supply : Agricultural water supply to each demand location.

5.6.1.7 IDC_GetWaterSupply_Urb

This procedure returns the total water supplies to each demand location to meet urban

water demand.

```
SUBROUTINE IDC_GetWaterSupply_Urb(NLocations,Supply)
   INTEGER,INTENT(IN)  :: NLocations
   REAL(8),INTENT(OUT) :: Supply(NElements)
END SUBROUTINE IDC_GetWaterSupply_Urb
```

NLocations : Number of demand locations.

Supply : Urban water supply to each demand location.

5.6.1.8 IDC_GetSurfaceFlowDestinations

This procedure returns the identification numbers for the destination of surface flows generated at each grid cell. This information must be used in conjunction with the destination type identification numbers (see section 5.6.1.9 for retrieving destination type identification numbers).

```
SUBROUTINE IDC_GetSurfaceFlowDestinations(NElements,Dest)
   INTEGER,INTENT(IN)     :: NElements
   INTEGER,INTENT(OUT) :: Dest(NElements)
END SUBROUTINE IDC_GetSurfaceFlowDestinations
```

NElements : Number of cells in the computational grid.

Dest : Surface flow destination identification number for each grid cell.

5.6.1.9 IDC_GetSurfaceFlowDestinationTypes

This procedure returns the destination type identification number for the surface flow from each grid cell. This information must be used in conjunction with the destination identification numbers (see section 5.6.1.8 for retrieving destination identification numbers).

```
SUBROUTINE IDC_GetSurfaceFlowDestinationTypes(NElements,DestTypes)
   INTEGER,INTENT(IN)     :: NElements
   INTEGER,INTENT(OUT) :: DestTypes(NElements)
END SUBROUTINE IDC_GetSurfaceFlowDestinationTypes
```

NElements : Number of grid cells.

DestTypes : Surface flow destination type identification number for each cell. 0 = surface flow from cell goes outside model domain; 1 = surface flow from cell flows into a stream node; 2 = surface flow from cell goes to a downstream cell; 3 = surface flow from cell flows into a lake; 4 = surface flow from cell goes to a subregion; 5 = surface flow from cell becomes recharge to the groundwater at the same cell.

5.6.1.10 IDC_GetActualRiparianET_AtStrmNodes

This procedure retrieves the actual outflow at each stream node due to riparian evapotranspiration.

```
SUBROUTINE IDC_GetActualRiparianET_AtStrmNodes(NStrmNodes,QRVET)
    INTEGER,INTENT(IN)  :: NStrmNodes
    REAL(8),INTENT(OUT) :: QRVET(NStrmNodes)
END SUBROUTINE IDC_GetActualRiparianET_AtStrmNodes
```

NStrmNodes : Number of stream nodes simulated in the system.

QEVET : Actual outflow at each stream node due to riparian evapotranspiration.

5.6.1.11 IDC_GetVersion

This subroutine returns the version number of IDC as well as the version numbers all components it is linked to.

```
SUBROUTINE IDC_GetVersion(LenVersion,cVersion)
    INTEGER,INTENT(IN)          :: LenVersion
    CHARACTER,INTENT(OUT) :: cVersion*LenVersion
END SUBROUTINE IDC_ GetVersion
```

LenVersion : Maximum length of the version number in terms of characters. The version number is at least 9 characters long.

cVersion : Version number of IDC.

5.6.1.12 IDC_GetActiveRootZoneVersion

This function returns the version number of the active root zone component that is being used in the simulation as an integer (e.g. it returns 40 if root zone component version 4.0 is being used).

```
FUNCTION IDC_GetActiveRootZoneVersion() RESULT(iVersion)
   INTEGER :: iVersion
END FUNCTION IDC_GetActiveRootZoneVersion
```

iVersion : Version number of the active root zone component being used for the simulation

5.6.1.13 IDC_IsLandUseUpdated

This function checks if the land-use areas have already been read from the input data file and updated.

```
FUNCTION IDC_IsLandUseUpdated() RESULT(iUpdated)
   INTEGER :: iUpdated
END FUNCTION IDC_IsLandUseUpdated
```

iUpdated : 1 if the land-use areas are already updated; 0 if they are not yet updated.

5.6.1.14 IDC_IsRootZoneDefined

This function checks if the root zone component has been instantiated.

```
FUNCTION IDC_IsRootZoneDefined() RESULT(iDefined)
   INTEGER  :: iDefined
END FUNCTION IDC_IsRootZoneDefined
```

iDefined : Flag to check if the root zone has been instantiated; a value of 0 means it has not been instantiated and a value of 1 means it has been instantiated.

5.6.1.15 IDC_Kill

This subroutine clears the memory associated with IDC and resets all IDC-related

parameters.

```
SUBROUTINE IDC_Kill()
END SUBROUTINE IDC_Kill
```

5.6.2 Example Code That Links to IDC

For IDC to execute properly when linked to other models, it is necessary to invoke the procedures in the IDC DLL in a specific order. Figure 19 is an example code that demonstrates how another model can be linked to IDC. The code is incomplete because particular procedures to execute the linking model are not shown. The example assumes that the computational grid has 1000 cells with 100 stream nodes modeled. The linked IDC and model combination runs for 3000 time steps.

The example given in Figure 19 assumes that the aquifer and stream systems simulated by the linked model have enough storage to meet the water demand computed by IDC at all times. In certain cases, the aquifer and stream storage may be limited and the demand may not be met. In this case, iterations between the linked model and IDC may be necessary. This is a complex situation and is not considered in Figure 19.

```
PROGRAM Test_IDC_DLL
 IMPLICIT NONE

 !Local variables
 CHARACTER(LEN=11)    :: cFile = 'IDC_Main.in'
 INTEGER,PARAMETER :: nTimeSteps= 3000  , &
                      nElems    = 1000  , &
                      nStrms    = 100
 INTEGER              :: iStat,indx,iEndOfSimulation,nLocs
 INTEGER,EXTERNAL     :: IDC_GetMainControlData,IDC_InitApp,IDC_AdvanceTime,  &
                      IDC_ReadTSData,IDC_ComputeWaterDemand,       &
                      IDC_ZeroSupply,IDC_SetSupply,IDC_Simulate,       &
                      IDC_PrintResults,IDC_AdvanceState,IDC_GetNDemandLocations
 REAL(8)              :: DeepPerc(nElems),DirectRunoff(nStrms),RetFlow(nStrms)
 REAL(8),ALLOCATABLE  :: Demand_Ag(:),Demand_Urb(:),Demand(:),Supply_Div(:),Supply_GW(:)

 !Initialize the model
 iStat            = IDC_GetMainControlData(11,cFile)     !Read the Main Control Data
 iStat            = IDC_InitApp()                        !Instantaite model
 nLocs            = IDC_GetNDemandLocations()            !Numner of demand locations
 iEndOfSimulation = 0                                    !It is NOT end-of-simulation yet
 ALLOCATE (Demand_Ag(nLocs),Demand_Urb(nLocs),Demand(nLocs),  &
           Supply_Div(NLocs),Supply_GW(nLocs))

 !Run the model
 DO indx=1,nTimeSteps
  iStat = IDC_AdvanceTime()                          !Advance time step to read proper data from input files
  iStat = IDC_ReadTSData()                           !Read the time-series data at the simulation time step
  iStat = IDC_ComputeWaterDemand()                   !Compute water demand at each element
  iStat = IDC_ZeroSupply()                           !Zero out all water supply to all elements
  CALL IDC_GetWaterDemand_Ag(nLocs,Demand_Ag)        !Obtain the ag water demand
  CALL IDC_GetWaterDemand_Urb(nLocs,Demand_Urb)      !Obtain the urban water demand
  Demand = Demand_Ag + Demand_Urb

  !Here, linked model computes groundwater pumping and diversions
  !  to meet water demand
  Supply_Div  = ...
  Supply_GW  = ...

  iStat = IDC_SetSupply(nLocs,Supply_Div,1)                  !Water supply as diversions
  iStat = IDC_SetSupply(nLocs,Supply_GW,2)                   !Water supply as pumping
  iStat = IDC_Simulate()                                     !Compute root zone/land surface flows
  IF (indx .EQ. nTimeSteps) iEndOfSimulation = 1             !Is it the last time step?
  iStat = IDC_PrintResults(iEndOfSimulation)                 !Print results from IDC
  CALL IDC_GetDeepPercAll(nElems,DeepPerc)                   !Obtain computed deep perc at all elements
  CALL IDC_GetFlowsToStreams(NStrms,DirectRunoff,RetFlow)    !Obtain the surface runoff into streams

  !Here, the linked model simulates stream and groundwater
  !  dynamics with IDC-computed deep percolation and flows
  !  into stream
   CALL LinkedModel_Simulate(DeepPerc,DirectRunoff,RetFlow,...)

  iStat = IDC_AdvanceState()                                 !Advance the state of the root zone in time
 END DO
```

Figure 19. Example code demonstrating the linkage of IDC to another model

6 References

Allen, R.G., Pereira, L.S., Raes, D., and Smith, M., 1998. Crop evapotranspiration - Guidelines for computing crop water requirements: Food and Agriculture Organization of the United Nations, Irrigation and Drainage Paper 56, 300 p.

Ayers, R. S., and D. W. Westcot. 1985. Water quality for agriculture: Food and Agriculture Organization of the United Nations, Irrigation and Drainage Paper 29.

Burt, C. M., A. J. Clemmens, T. S. Strelkoff, K. H. Solomon, R. D. Bliesner, L. A. Hardy, T. A. Howell, and D. E. Eisenhauer. 1997. Irrigation performance measures: Efficiency and uniformity. Journal of Irrigation and Drainage Engineering 123, (6) (Nov-Dec): 423-442

CADWR 2005. California Water Plan Update 2005, A Framework for Action. Regional Reports, Volume 3. Bulletin 160-05. California Department of Water Resources. Sacramento, CA.

CADWR 2009. IWFM: Integrated Water Flow Model. http://baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM/index.cfm (accessed September 29, 2009)

Camp, C. R., G. D. Christenbury, and C. W. Doty. 1988. Scheduling irrigation for corn and soybeans in the southern coastal plains. *Trans. ASAE* 31, 513-518.

Campbell, G. S. 1974. A simple method for determining unsaturated hydraulic conductivity from moisture retention data. *Soil Sci.*, 117(6), 311-314.

Corwin, D. L., J. D. Rhoades, and J. Simunek. 2007. Leaching requirement for soil salinity control: Steady-state versus transient models. *Agricultural Water Management* 90(3), 165-180.

DHI (Danish Hydraulic Institute). 1999. MIKE SHE Pre- and Post-Processing User Manual. DHI Software, Hørsholm, Denmark.

Dogrul, E. C. 2007. Integrated Water Flow Model (IWFM v3.0): Theoretical documentation. Sacramento (CA): Integrated Hydrological Models Development Unit, Modeling Support Branch, Bay-Delta Office, California Department of Water Resources, variously paged.

Dudley, L. M., A. Ben-Gal, and U. Shani. 2008. Influence of plant, soil, and water on the leaching fraction. *Vadose Zone Journal* 7(2), 420-425.

Fereres, E. and M. A. Soriano. 2007. Deficit irrigation for reducing agricultural water use. *J. Experimental Botany* 58(2), 147-159.

George, B. A., S. A. Shende, and N. S. Raghuwanshi. 2000. Development and testing of an irrigation scheduling model. *Agricultural Water Management* 46 (2), 121-136.

Gerald, C., and P. O. Wheatley. 1994. *Applied numerical analysis. Fifth edition.* Addison-Wesley Publishing Co.748 p.

Goodall, J. L., B. F. Robinson, F. M. Shatnawi, and A. M. Castronova. 2007. *Linking hydrologic models and data: The OpenMI approach*. 2007 American Geophysical Union Fall Meeting, San Francisco, CA (USA), 10-14 Dec 2007.

Gregersen, J.P., P.J.A. Gijsbers, and S.J.P. Westen. 2007. OpenMI: Open modelling Interface. Journal of Hydroinformatics, 9(3), 175-191.

Heng, L. K., T. Hsiao, S. Evett, T. Howell, and P. Steduto. 2009. Validating the FAO AquaCrop model for irrigated and water deficient field maize. *Agronomy Journal* 101(3), 488-498.

Kavvas, M. L., Z. Q. Chen, C. Dogrul, J. Y. Yoon, N. Ohara, L. Liang, H. Aksoy, M. L. Anderson, J. Yoshitani, K. Fukami, and T. Matsuura. 2004. Watershed Environmental Hydrology (WEHY) model based on upscaled conservation equations: Hydrologic Module. J. Hydrol. Eng. 9:450-464.

Kincaid, D. C., and D. F. Heerman. 1974. Scheduling irrigations using a programmable calculator. ARS-NC-12, USDA Agric. Res. Service, Lincoln, Nebraska.

Kirda, C. 2002. Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. In *Deficit irrigation practices: Water reports 22*, Food and Agriculture Organization of the United Nations, Rome.

Leavesley, G. H., R. W. Lichty, B. M. Troutman, and L. G. Saindon. 1983. Precipitation-Runoff Modeling System: User's Manual: U.S. Geological Survey Water-Resources Investigations 83-4238.

Markstrom, S. L., R. G. Niswonger, R. S. Regan, D. E. Prudic, and P. M. Barlow. 2008. GSFLOW--Coupled Ground-water and Surface-water FLOW model based on the integration of the Precipitation-Runoff Modeling System (PRMS) and the Modular Ground-Water Flow Model (MODFLOW-2005): U.S. Geological Survey Techniques and Methods 6-D1.

Mualem, Y. 1976. A new model for predicting the hydraulic conductivity of unsaturated porous media. Water Resour. Res., 12, 513-522.

Orang, M. N., J. S. Matyac, and R. L. Synder. 2004. Consumptive Use Program (CUP) model. In *IV International symposium on irrigation of horticultural crops*, ed. R. L. Synder. Acta Hort., 664, 461-468, ISHS.

PRISM [PRISM Climate Group]. 2009. Oregon State University, http://www.prismclimate.org (accessed September 10, 2009).

Raes, D., P. Steduto, T. C. Hsiao, and E. Fereres. 2009. AquaCrop – The FAO crop model to simulate yield response to water. FAO Land and Water Division, FAO, Rome.

Rawls, W. J., D. L. Brakensiek, and K. E. Saxton. 1982. Estimation of soil water properties. T. ASAE, 25(5), 1316-1320.

Ritchie, J. T. 1981. Soil water availability. Plant and Soil, 58, 327-333.

Schmid, W., R. T. Hanson, T. Maddock III, and S. A. Leake. 2006. User guide for the farm process (FMP1) for the US Geological Survey's modular three-dimensional finite-difference groundwater flow model, MODFLOW-2000. (Book 6). Reston (VA): US Geological Survey. 127 p. Techniques and Methods 6-A17. Available at: http://pubs.usgs.gov/tm/2006/tm6A17/

Schroeder, P. R., T. S. Dozier, P. A. Zappi, B. M. McEnroe, J. W. Sjostrom and R. L. Peton. 1994. The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation for Version 3, EPA/600/R-94/168b. U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Smith, M. 1991. CROPWAT: A computer program for irrigation planning and management. FAO Land and Water Development Division, FAO, Rome.

Snyder, R. L., M. N. Orang, J. S. Matyac, S. Geng, and S. Sarreshteh. 2004. A simulation model for ET of applied water. In *IV International symposium on irrigation of horticultural crops*, ed. R. L. Synder. Acta Hort., 664, 623-629, ISHS.

Sophocleous, M. A., J. K. Koelliker, R. S. Govindaraju, T. Birdie, S. R. Ramireddygari, and S. P. Perkins. 1999. Integrated numerical modeling for basin-wide water management: The case of the rattlesnake creek basin in south-central Kansas. *Journal of Hydrology* 214, (1-4) (Jan): 179-196.

Tayfur, G., K. K. Tanji, B. House, F. Robinson, L. Teuber, and G. Kruse. 1995. Modeling deficit irrigation in alfalfa production. *Journal of Irrigation and Drainage Engineering* 121(6), 442-451.

Therrien, R., R. G. McLaren, E. A. Sudicky, and S. M. Panday. 2009. HydroGeoSphere – a three-dimensional numerical model describing fully-integrated subsurface and surface flow and solute transport (Draft ed.). Groundwater Simulations Group, University of Waterloo, Waterloo, Canada.

USDA, Natural Resources Conservation Service. 1997. National engineering handbook. Washington (DC): US Department of Agriculture. Part 652, Irrigation guide.

USDA, Natural Resources Conservation Service. 2004. National engineering handbook. Washington (DC): US Department of Agriculture. Part 630, Hydrology, Chapters 9 and 10.

van Genuchten, M. T. 1985. A closed-form solution for predicting the conductivity of unsaturated soils. Soil Sci. Soc. Am. J., 44, 892-898.

Williams, J. 2004. Water management. California Rice Production Workshop, 2004. University of California Cooperative Extension. http://ucce.ucdavis.edu/files/filelibrary/6318/36235.pdf (accessed August 5, 2009).

Williamson, A. K., D. P. Prudic, and L. W. Swain. 1989. Ground-water flow in the Central Valley, California. U. S. Geologic Survey Professional Paper, 1401-D.