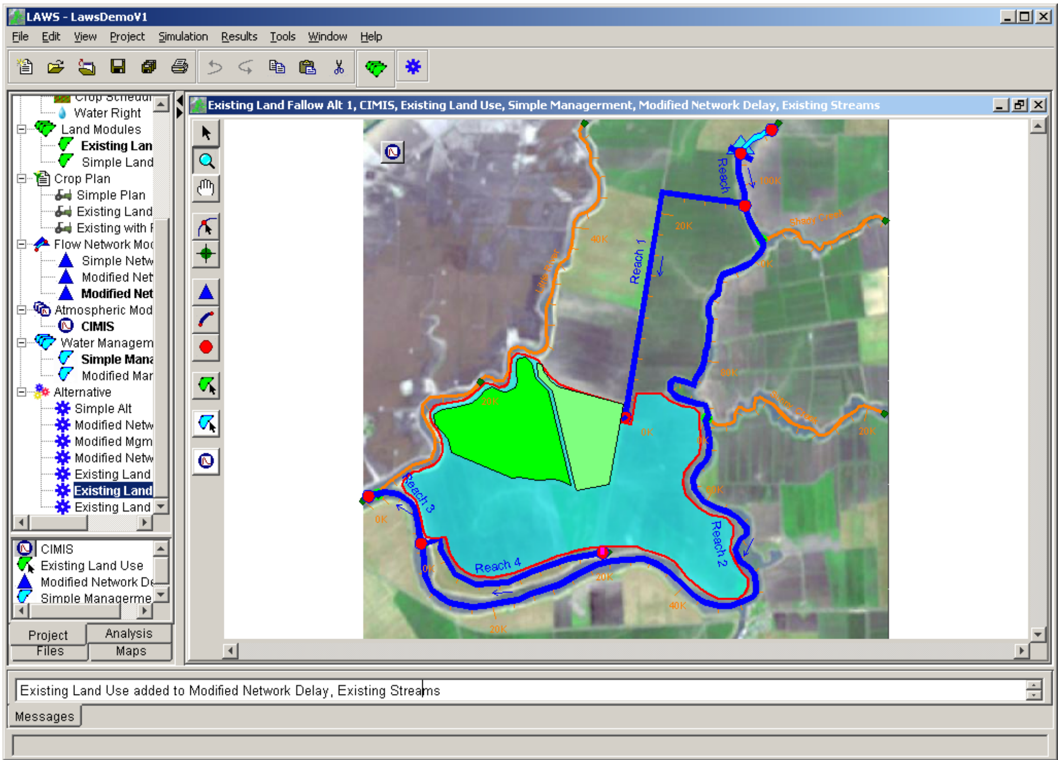
Land Atmosphere Water Simulator



LAWS 1.5

RECLAMATION
Managing Water in the West

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

February 2007 – Revised August 2011

Land Atmosphere Water Simulator (LAWS)

Version 1.5

Report Prepared by:

Bureau of Reclamation Mid Pacific Region, Division of Planning

Stockholm Environment Institute, Sacramento, CA

Resource Management Associates, Suisun, CA

Project Team Members:

Michael K. Tansey, Ph.D, Hydrologist, Soil Scientist, Reclamation

Charles Young, Ph.D, Water Resource Engineer,SEI

John F. DeGeorge, Ph.D. P.E. Civil Engineer, RMA

Shannon Larson, BS. Software Engineer, RMA

February 2007 – Revised August 2011

Table of Contents

Section 1 – LAWS Overview…….......................… 4

Section 2 – Training Exercises……………………… 20

NOTE TO USERS: This version of LAWS has been superseded by LAWS V2. Updated documentation and workshop exercises for LAWS V2 are available at the Reclamation website.

Section 1

LAWS Overview

Introduction

The Land Atmosphere Water Simulator (LAWS) is a tool designed for the management of large-scale, multi-organizational water supply systems. LAWS differs from other water management models in several significant ways.

First, LAWS simulates daily, field-scale land, crop, and water management practices. It provides users with tools to simulate alternative methods for managing soil moisture on a daily basis during the irrigation season based on soil properties, crop type and growth stage. This approach permits LAWS to compute evapotranspiration, soil water content, surface water ponding, runoff, canal and drain losses, return flows to rivers, and deep percolation to groundwater at level of spatial and temporal resolution not present in existing planning and operations models. Although LAWS performs these calculations at the field scale, LAWS also provides users with ability to aggregate these results within larger user definable areas so that water budgets can be readily computed for arbitrary organizational regions.

Second, LAWS does not solve any governing flow equations except continuity nor is it an optimization model. This approach allows LAWS to be very computationally efficient but it requires the LAWS user to provide key input data from other sources of information such field studies, remote sensing, GIS databases, physical process models, and expert judgment. Although LAWS provides users with multiple methods for allocating water supplies and making priority based delivery decisions, LAWS does not employ any mathematical methods to determine what is the "best" allocation of water. In contrast, LAWS provides users with a powerful graphical user interface (GUI) that allows users to readily change water allocation and delivery priorities, land and crop management practices, and infrastructure characteristics to compare the effects of alternative system configurations on reservoir water supplies.

Third, LAWS has a native GIS capability built directly into the GUI. This GIS capability allows users to setup and analyze spatially accurate LAWS simulations across a span of scales ranging from large regional watersheds to sub-regions contained with individual fields. LAWS also provides users with the capability to import imagery, maps, and GIS information developed with commercially available software packages. Furthermore, LAWS has been developed from the Corp of Engineers Water Management System (CWMS) software from which it has inherited a powerful suite of tools to examine model outputs including side by side comparisons of outputs from multiple alternative simulations and animations of spatial and temporal time series results.

System Manager

LAWS captures both the spatial and hierarchical organization of a water supply system. In LAWS, the supply system is conceptualized as a series of nested spatial units that range in size from multi-regional watersheds to individual land units as small as fields. The largest scale land area is associated with a System Manger (SM). In a LAWS simulation, there may be one or more SMs. At the next smaller spatial scale, each Area Manager (AM) manages a particular region within the system. Within these regions, there are one or more Delivery Managers (DM). These DMs represent sub-regions within the AM region where water management is performed differently based on some unique characteristics of the land or the water supply associated with the sub-region. At the smallest scale, an individual land unit is represented by a Land Manager (LM). Each LM is located within a single DM sub-region. In LAWS, the geospatial locations of major reservoirs, rivers, canals and drains are explicitly located through its GIS capability down to the AM-scale. Although simulated mathematically, smaller scale conveyance infrastructure at the DM- and LM-scales is not explicitly geospatially referenced. The LAWS spatial organization is shown in Figure 1 below.

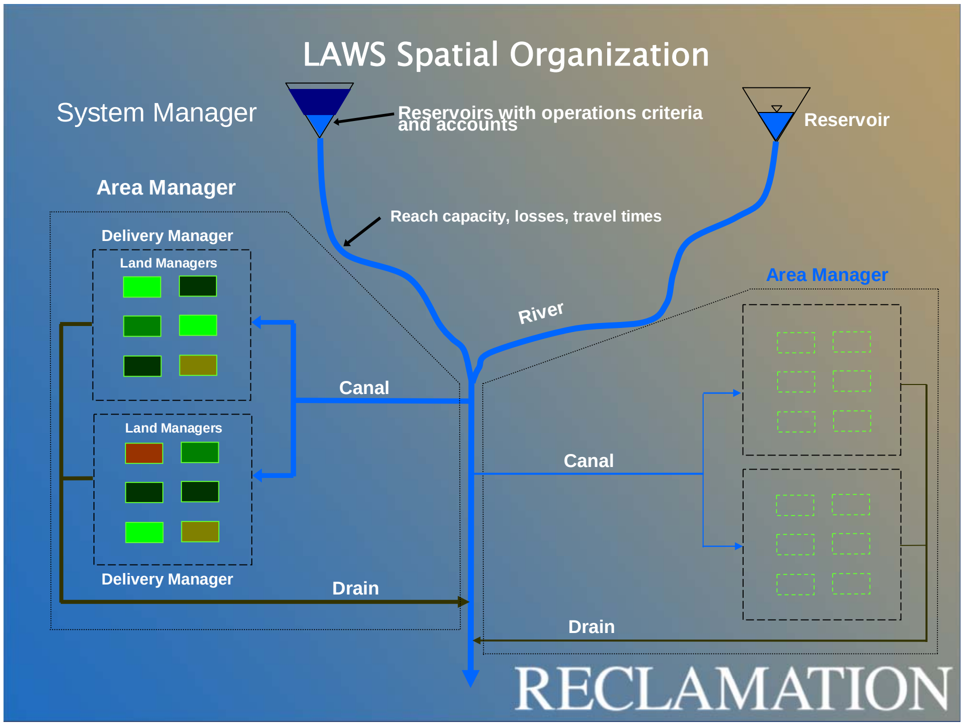


Figure 1. LAWS Spatial Organization

The LAWS hierarchical organization represents the basic structure for managing requests for water supplies and making management decisions necessary for determining the amounts of water to be released from reservoirs as well as the amounts of supply to be provided by groundwater pumping and drain water reuse by individual Land Managers. The LAWS hierarchical organization is presented on Figure 2 below.

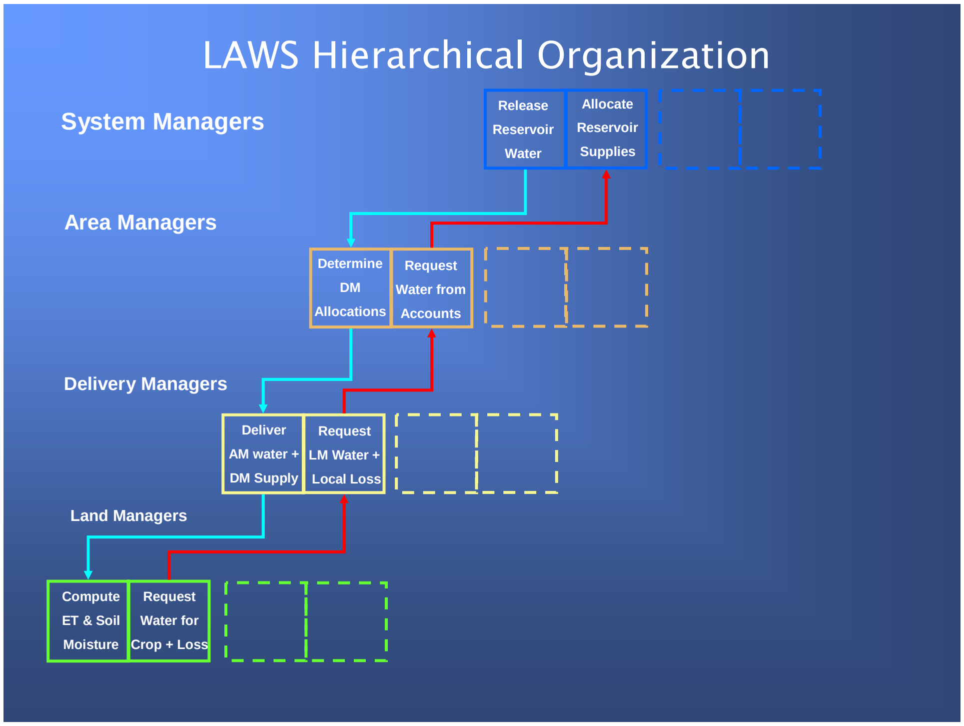


Figure 2. LAWS Hierarchical Organization

Each SM operates one of more reservoirs which may be located on different rivers systems within a regional watershed. Each reservoir consists of one or more accounts each of which is associated with a specific AM. The volume of water in each AM account is determined by a user specified percentage of the conservation pool. The amount of water in the conservation pool is reset on annual basis during the course of a multi-year simulation. The LAWS user has the option to allow an AM account to receive additional supply during a simulation in order to determine how much additional supply would be necessary to meet their water requirements over the simulation period.

At each daily time step, the SM can use either a sequential or balanced allocation method to determine how much water to release from each of the reservoirs it manages. In a sequential allocation the highest ranking account associated with a particular AM is fully depleted before the next highest ranking account is utilized. In a balanced allocation, water from each reservoir account associated with a particular AM is utilized simultaneously in a user specified proportion. If an account is completely utilized before the simulation is complete, the balance allocation ratios are recomputed to reflect the relative weighting of the accounts that still have remaining water supplies.

The total amount of the SM deliveries must be constrained by the available release capacity of the reservoir and the capacity of the downstream river channels to convey releases without causing flood damage. Since LAWS is intended to work in conjunction with other water management models, the reservoir release capacity can be specified at every time step. This approach permits LAWS reservoir releases to be constrained by other in-stream flow requirements that are not explicitly modeled in a LAWS simulation. This capability is accomplished by specifying a LAWS reservoir release capacity as the maximum physical release capacity minus the non-consumptive use flows that are released for other in-stream flow or water quality requirements. Typically, these regulatory releases would be simulated with another model and a daily time series of maximum reservoir release capacities would be computed for a LAWS simulation.

In LAWS, SM reservoir releases are delivered to AMs through an explicitly modeled network of rivers, canals, and drains. The hydraulic properties of these conveyance system features are represented explicitly at user defined reaches along the channels. The LAWS user specifies a maximum flow capacity for each reach and can simulate accretions and depletions in these reaches with simple gain/loss factors. The transit time for water flowing through reaches is also specified by the user.

It is important to recognize that LAWS does not solve the governing equations of flow in open channels. LAWS simulates flow hydraulics and surface-groundwater interactions by using user specified factors. Consequently, the LAWS user must develop this information from field studies, simulations using hydrodynamic and groundwater models, or expert judgment. This simplistic approach used throughout LAWS avoids the computational overhead and complex data requirements of numerical models. However, since LAWS is a mass conservative model, it can be used to determine water budgets from the regional-scale all the way down to the field-scale. Further, the simplicity of the approach permits the LAWS user to efficiently compare alternative land and water management practices, infrastructure characteristics and configurations as well as water delivery priorities explicitly established at each level of the multi-organizational hierarchy.

Area Manager

A LAWS Area Manger is one of the four levels in the LAWS hierarchical organization. An AM represents an organizational unit that manages of water supplies for a particular spatial region within the water supply system. In the LAWS hierarchy, an AM is the intermediary between a System Manager (SM) and the Delivery Managers (DM) which supplies water to individual Land Managers (LM).

The AM manages one or more water accounts. Each of these accounts is associated with a particular SM and has a specified maximum volume. An AM may have accounts with multiple SMs and more than one account with the same SM. The AM is responsible for managing the use of its accounts during a simulation. There are two account utilization mechanisms in LAWS. In a sequential utilization operation, the highest priority account is used completely before water from the next highest priority account is delivered from reservoir storage. In a balanced utilization operation, water from each account is utilized simultaneously in a user specified proportion. If an account is completely utilized before the simulation is complete, the balanced utilization ratios are recomputed to reflect the relative weighting of the accounts that still have remaining water supplies.

Although the SM determines the actual daily amounts of water released from an AM reservoir account, the AM is responsible for establishing the amounts of the groundwater pumping and drain water reuse to be used to meet consumptive use requirements within its DM sub-regions. In LAWS, the total volume of ground water use is not absolutely constrained to a specified amount. However, the amount of drain water recycling is limited to a user specified fraction of the total drain water inflow during each time step. These user specified factors represent the percentage of the total consumptive use requirement that is to be met from these sources of supply. The groundwater pumping and drain water reuse factors are set by the user for each DM in the AM region at each time step. In the event that the amount of drain water available for recycling is not sufficient to meet the AM target, groundwater pumping is automatically increased to make up for the deficit. Since the groundwater pumping and recycling factors may be set to zero by the user, alternative simulations using only reservoir supplies may be readily performed for comparison with various pumping and drain water recycling alternatives.

The AM is responsible for establishing the water delivery priorities that are to be implemented within its region. LAWS employs a user specified hierarchical system to determine how water is delivered to individual LM within a DM sub-region. The application delivery logic is designed to be user extensible so that multiple factors such as seniority of water rights, types of crop, growth stage, moisture stress or other user defined criteria could be employed in the delivery decision logic in future versions of the model.

The AM is responsible for managing the DMs within its region. At each time step, the AM must determine how much water to supply to each of its DMs. After receiving deliveries for each of its accounts from one or more SMs, the AM may use one of three different delivery priority mechanisms. In a sequential delivery operation, each DM is given a fixed priority relative to the others in the AM region and the highest priority DM's consumptive use requirement is completely satisfied before water from the next highest priority DM is delivered. In a balanced delivery operation, delivery is made to each DM in a user specified proportion. In hierarchical delivery operation, deliveries are to each DM based on the priority of individual LMs within the DM. This mechanism essentially treats all DMs with equal priority but insures that LMs meeting the highest ranking in the highest hierarchical level are completely satisfied before lower priority water deliveries are made. If a ranking is reached for which the remaining water supply is inadequate, a shortage delivery is made to the LMs in this ranking group.

At each daily time step, the AM is responsible for receiving and accumulating the requests for water supplies from each of its DMs. Using this request information, the AM employs its account utilization methods to determine how much water to request from its various accounts. The amounts of requests are adjusted to account for conveyance depletions/accretions and forwarded to the SMs associated with each of its accounts.

Delivery Manager

Within the overall structure of LAWS, the Deliver Manager serves as an intermediary between the Land Manager (LM) whose function is to apply water to an individual land unit and the Area Manager (AM) that requests and distributes water received from the System Manager (SM). Each DM is associated with a single AM and operates to meet requests for water from multiple LMs.

At each time step, the DM is responsible for accumulating the amounts of water requested by each of its LMs. After all the LMs' application requests have been received, the DM has the responsibility for determining an appropriate amount of water to request from its AM to meet the needs of all the land units within its sub-region.

In order to determine the amount to request, the DM takes into account a number of physical and management factors impacting water use within its sub-region. The physical factors include conveyance losses from canals, inflows and outflows associated with adjacent DM sub-regions, deep percolation to groundwater, as well as various inflows and outflows from drains. Management factors include the desired amount of groundwater pumping and drain water reuse within the DM's sub-region. The water budget components of the DM system are shown on the Figure 3 below.

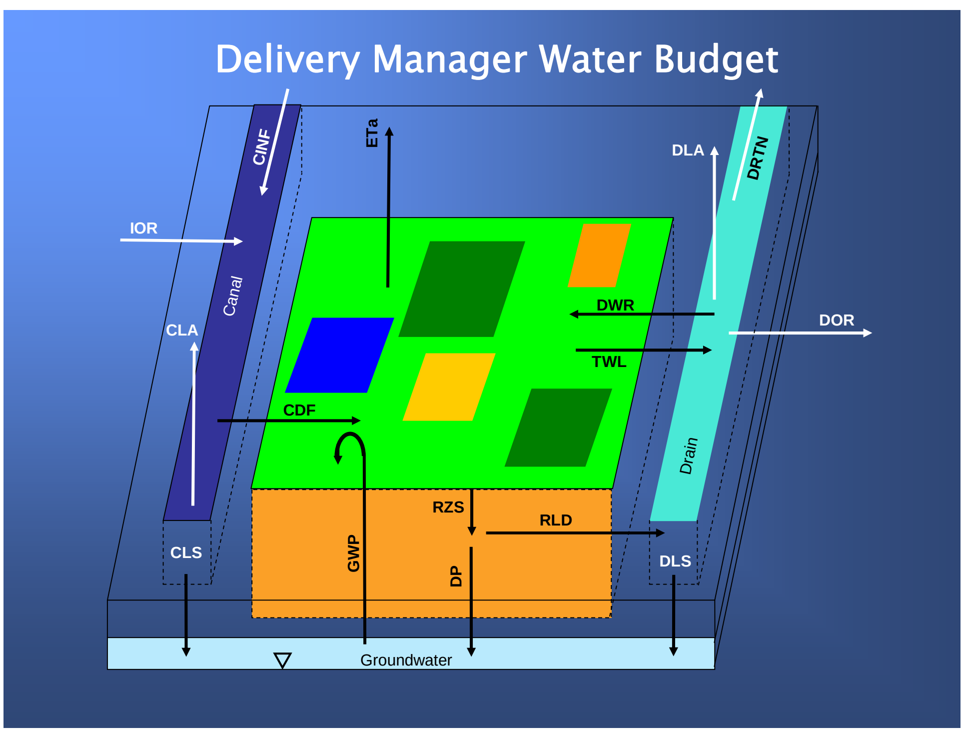


Figure 3 Delivery Manager Water Budget Components

It is important to recognize that the canals and drains within a DM sub-region are not explicitly represented as physical features within a LAWS model. The DM canals and drains represent the affect of field scale canals and drains on the overall water budget within the sub-region. This approach allows simulation of a sub-region's water balance without the difficult and time consuming task of explicitly accounting for all field-scale infrastructure typically found in a water delivery system. At the same time, this approach allows users ample flexibility to investigate the important effects these features exert on the amount the water needed to meet consumptive use requirements.

During each time step, the three major functions of a DM are to deliver to the LMs the water received from the AM, receive water application requests from LMs and determine an appropriate amount of water to request from the AM in the next time step. It is important to recognize that the actual amounts of water received from the AM for delivery to the LMs may be less than the amount requested.

At each time step, the AM establishes the deliver priorities within its region and notifies each DM of the supply available for delivery. The total amount consists of reservoir releases, groundwater pumping, and recycled drain water. Using the delivery priorities established by the AM, the DM delivers water to all the LMs for which sufficient supply is available.

As the DM delivers water, LMs inform the DM of any unmet water needs by making an application request for whatever amount is still required for consumptive use based on the final soil water content after delivery to the land unit. Once all the possible deliveries have been made, the DM queries the remaining LMs to determine their application requests. This process insures that every land unit is queried and results in the soil water content and other water budget components of every land unit being updated at every time step.

After the DM has completed the delivery process, the total amount of all LM application requests is known. The DM must now determine the total amount of water to request (DIV) for the entire sub-region. This process involves accounting for gains, losses and reuse of water within the sub-region. In addition to water supplied by the AM, other sources of supply to the DM sub-region include inflows into canals from adjacent sub-regions (IOR) and groundwater pumping (GWP). Other than consumptive use of applied water (CUAW), losses from the sub-region include canal seepage (CLS), drain seepage (DLS), and deep percolation (DP) to groundwater, evaporation from canals (CLA) and drains (DLA) to the atmosphere, outflows from drains to adjacent sub-regions (DOR) and return flow from DM drains to AM drains (DRTN). Tail water losses (TWL) and drain water reuse (DWR) within the DM's sub-region are other user defined management factors that affect the amount of water the DM requests from the AM.

Land Manager

The purpose of this design document is to outline the procedure and functions involved in the application of water to land units. These land units are the fundamental spatial units included in the LAWS model. In general, it is anticipated that these land units are agricultural fields, wetlands, or urban areas on which water is used consumptively.

Within the overall structure of LAWS, the role of the Land Manager (LM) is to apply water received from the Delivery Manager (DM) to the land, determine the soil moisture content after application and request an appropriate amount of water from the DM depending on the status of the soil water content relative to particular management targets in effect at various times during the year.

In order to provide flexibility for managing vegetation, the annual cycle is divided into 5 vegetation stages. These stages include: pre-germination (pg), rapid growth (rg), maturation (m), harvest (h), and post-harvest (ph). The starting and ending dates for each of these periods can be specified by starting and ending dates during the calendar year. The evapotranspiration of the crop (ETC) is computed using user specified reference evapotranspiration and a crop coefficient as shown on Figure 4 below during each of the crop growth stages.

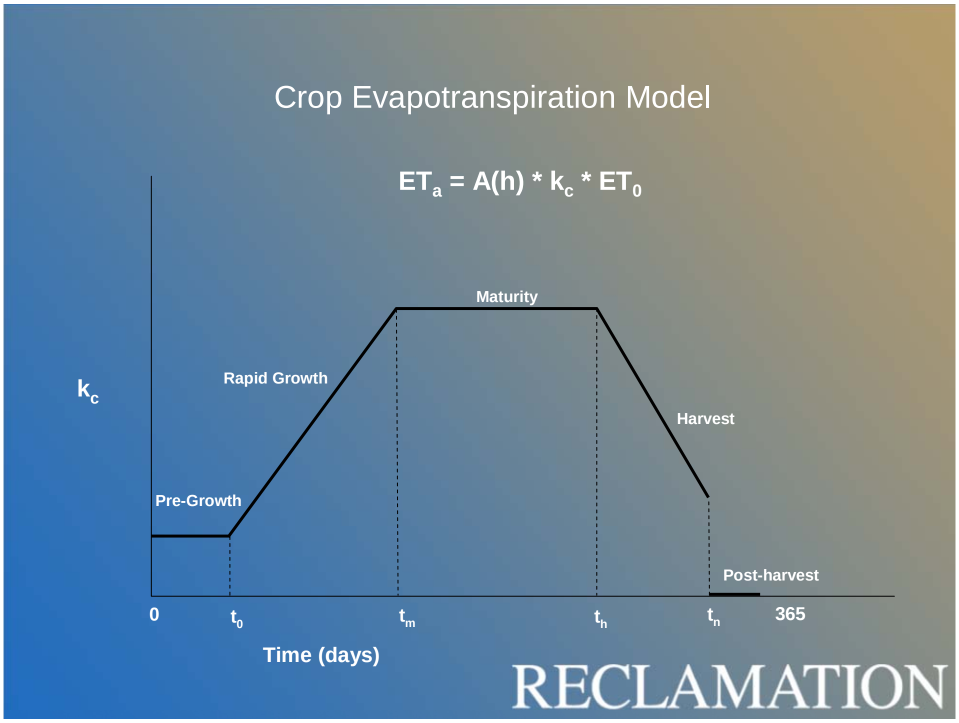


Figure 4 LAWS Evapotranspiration Model

A(h) is a water stress function and is shown in Figure 5.

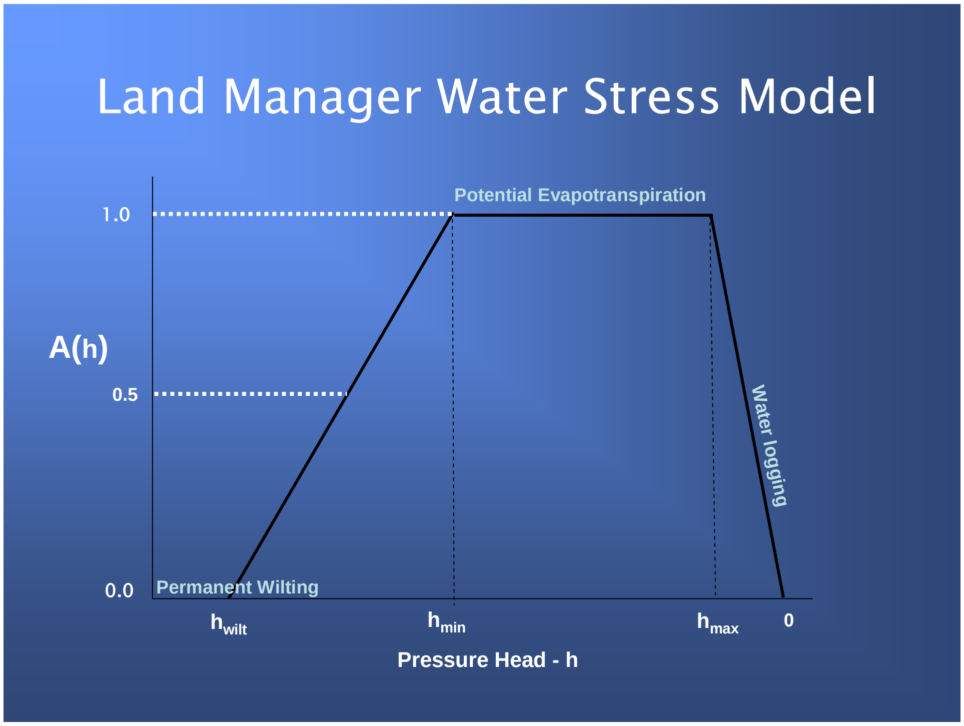


Figure 5 Water stress function.

The root zone depth model employed in LAWS is shown on Figure 6.

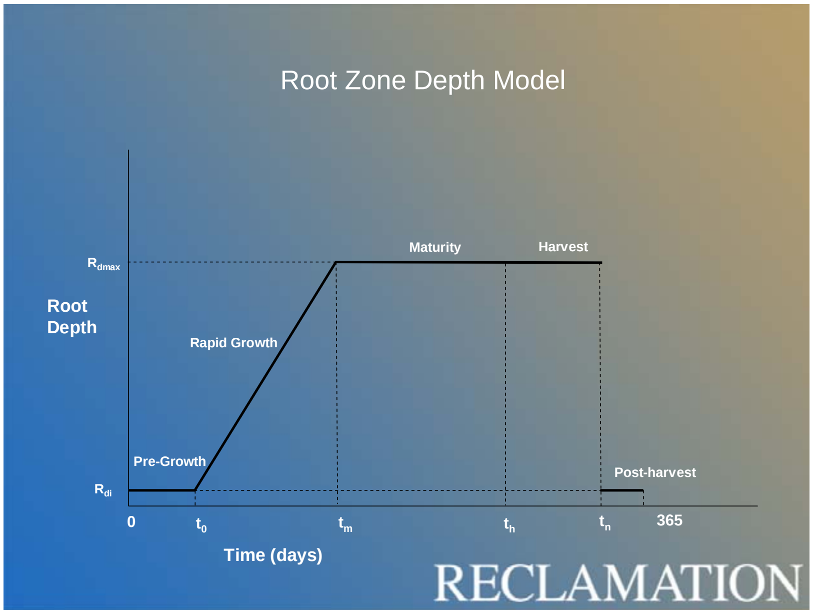


Figure 6 LAWS root zone depth model

A user specified soil water content that triggers a water application request is associated with each of the management periods. A request for water is generated when the root zone soil water content falls below the management Allowable Depletion (MAD). The soil moisture management model is shown on Figure 7.

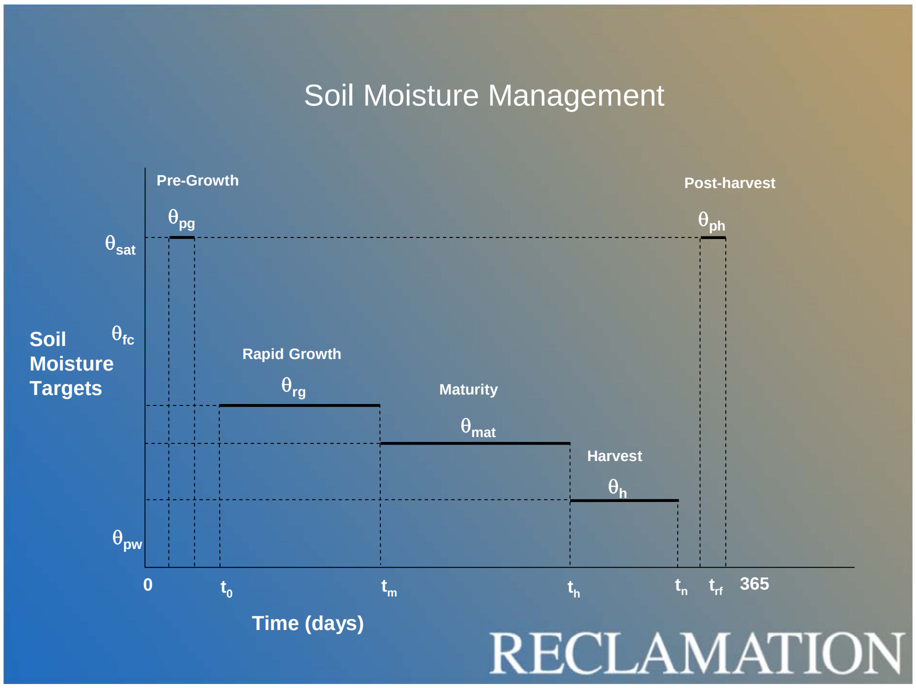


Figure 7 LAWS Soil moisture management model.

The amount of water requested is determined by the root zone storage capacity at the time the request is made and the application efficiency of the system used to apply the water to the land unit. The soil water capacity and hydraulic properties used by LAWS are presented on Figure 8.

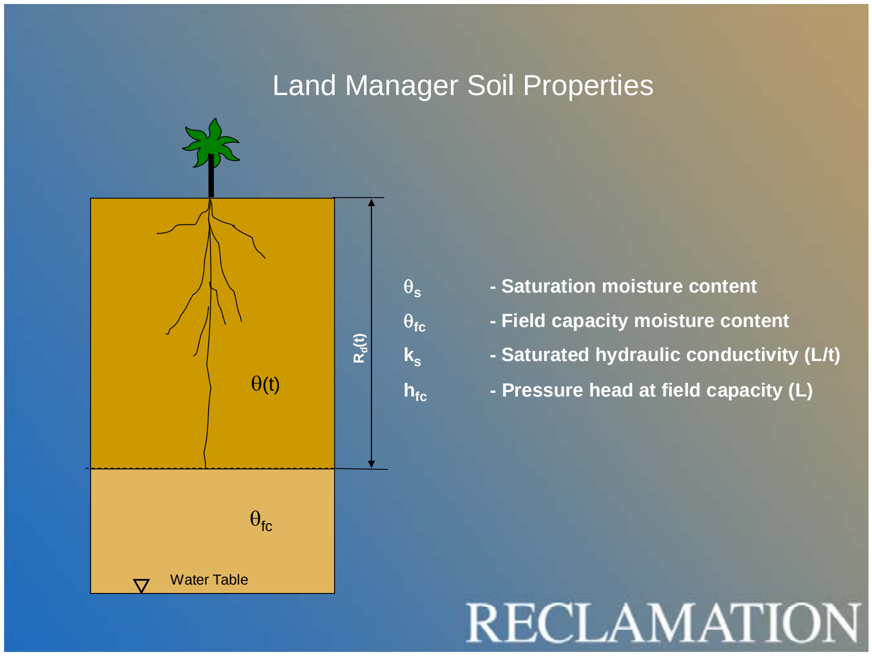


Figure 8 LAWS soil water capacity and hydraulic properties.

Since certain crops and management practices require ponding of water on the soil surface, a provision is made to manage water under both ponded and unponded conditions. Components of the LAWS water budget with and without ponding are shown on Figure 9 and 10 respectively.

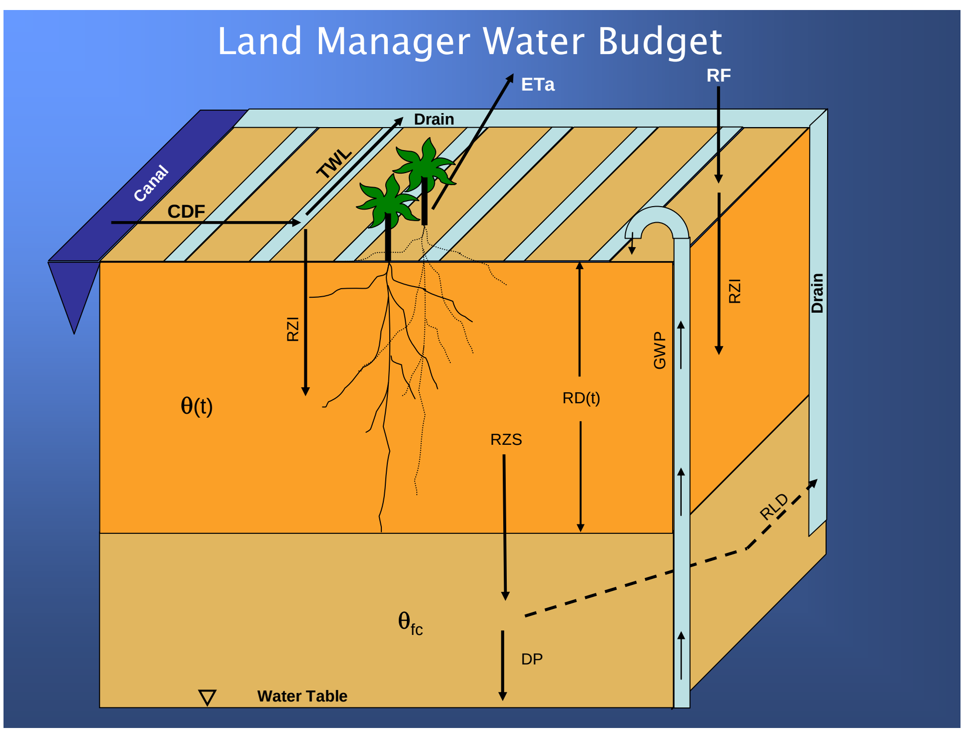


Figure 9 LAWS water budget components under ponding

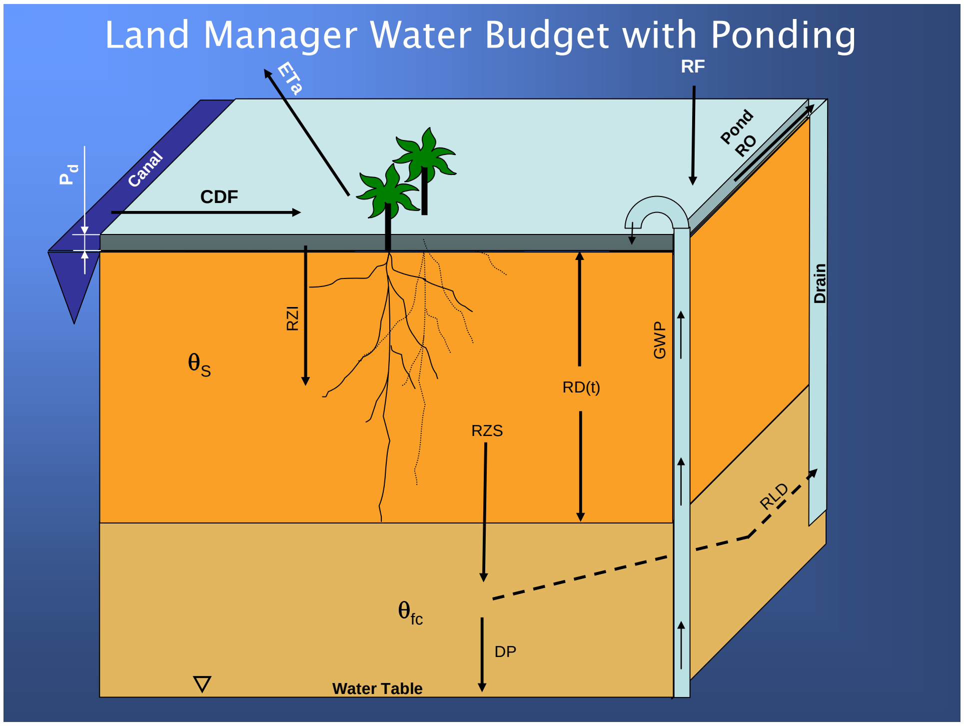


Figure 10 LAWS water budget components without ponding.

The following outline lays out the main calculations performed by the Land Manager.

Non-ponded conditions

The root zone mass balance is calculated using the following equation:

$$\theta(t) = \theta(t-1) + \{(CDF + GWP + RF) - (ETa + TWL + RZS)\} / RD(t)$$

where:

θ(t)	= water content of root zone at time t;
CDF	= canal delivery (L);
GWP	= applied groundwater (L);
RF	= rainfall (L);
ETa	= crop evapotranspiration (L);
TWL	= tail water loss (L);
RZS	= root zone seepage (L);
RD(t)	= root zone depth(L).

The canal delivery is determined during previous time steps by considering the difference between the Soil Water Delivery Target set in the Irrigation System Type Editor and the Management Allowable Depletion (MAD) set in the Crop Type Editor. This volume is then increased by taking into account the application efficiency set in the Irrigation

System Type Editor. This volume is then adjusted by the Demand Manager to account for the availability of groundwater and drain water recycling.

During the current timestep, the total application of canal delivery water and groundwater is multiplied by the tailwater loss factor set in the Irrigation Systems Type Editor to calculate the tailwater water loss. Rainfall generates no runoff. ETa is calculated as described above. Root zone seepage is calculated at the end of the timestep as the difference between the soil moisture content in the root zone and field capacity.

Ponded conditions

A land manager can become ponded if the sum of canal deliveries, groundwater pumping, and rainfall is in excess of the available soil moisture storage (ASMS) which is calculated as:

$$ASMS = (\theta s - \theta(t-1))RD(t)$$

where:

θs = soil moisture content at saturation.

This situation will occur if there is a rainfall event that is in excess of the ASMS or if the ponding depth set in the Crop Type Editor is non-zero. In this case, the ponded water depth (Pd) is calculated as:

$$Pd(t) = Pd(t-1) + (CDL+GWP+RF) - (ETa + SWRO + PWI)$$

where:

Pd(t) = depth of surface ponding at time t (L);
SWRO = surface water runoff from ponding (L);
PWI = pond water infiltration (L).

SWRO is calculated as the product of the ponded water depth (DSP) and the Surface Water Runoff Factor located in the Land Manager Editor. Root zone infiltration (RZI) is calculated using the Darcy Equation assuming that the soil beneath the root zone is at field capacity:

$$RZI = Ks\frac{Pd(t) + RD(t) - PH\_FC}{RD(t)}\ (1\text{ day})$$

where:

Ks = saturated hydraulic conductivity (L/T);
PH_FC = pressure head at field capacity (L);

Since the root zone is considered to be saturated it is assumed that all RZI becomes root zone seepage (RZS).

Drainage and Deep Percolation

Subsurface drainage is calculated as the product of the root zone seepage and the Drain Inflow Factor specified in the Land Manager Editor. Deep percolation is the remainder of the root zone seepage.

Section 2

Training Exercises

Exercise 1 – Creating a New Project and Stream Alignment

Introduction

Exercise 1 will start you on the process of becoming familiar with using the LAWS application. This exercise demonstrates the initial setup of a LAWS project by familiarizing you with the process of adding maps and creating stream alignments.

In this exercise, you will gain experience by using a simple fictitious area named Deltaville.

Figure 1.1 - Deltaville Agricultural Region

Task Description

The goal of this first exercise is to create a LAWS Project that contains a map and a simple stream alignment with one tributary. Although subsequent exercises will contain a more detailed stream alignment, this exercise will only have a simple two segmented stream alignment. This will help get you used to the stream tools and become comfortable when creating more detailed streams in the future. The stream alignment will represent the main stem of a river (Sandy River) and one tributary, Farmer Creek. A watershed background map of the Deltaville region is provided on the LAWS install directory, under the following subdirectory Wokshops/Exercise1/maps.

Getting Started

The first step in starting the process of using LAWS is to create a new Project.

- Launch LAWS by double-clicking on the LAWS icon on your PC's desktop.
- Select **New…** from the **File** menu.
- In the **New…** dialog select **Project** from the list and click **Next**.

The **New Project** dialog will display as the one pictured below.

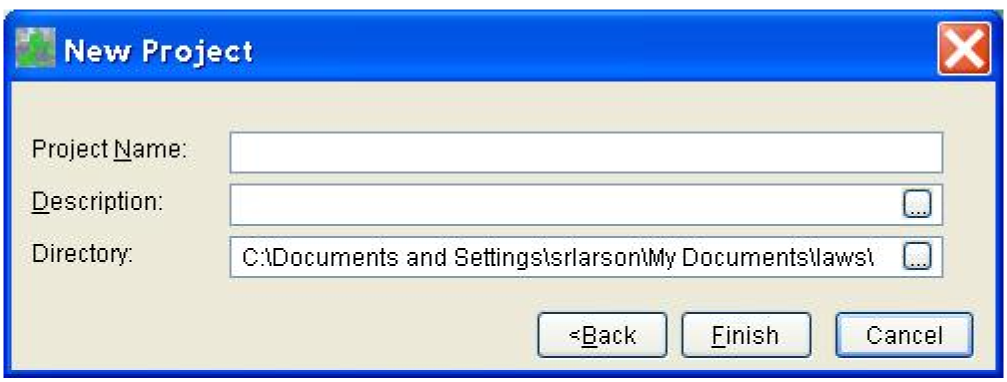


Figure 1.2 - New Project Dialog

- Give the project the **Name** "Project1" and a **Description**.
- Select a directory you would like the project to reside in by clicking the ellipse button within the **Directory** text field.
- Last, click the **Finish** button.

A Project directory is created using the given name. All Project related files and directories reside under this main Project directory.

The Project's node will appear at the top of a Project Tree in the Project Tree Pane. The tree will also fill with data nodes and open an empty Map Schematic window.

Note: You may need to move the **Content Pane** down in order to see the full Project Tree in the **Project Tree Pane**. To reposition the **Content Pane**, move the mouse pointer onto the border between the two panes. The pointer will display as a double arrow (↔). Then click and hold down the left mouse key. Drag the edge down.

Adding A Map Layer

Maps are imported into the Project by adding them via the **Map** context menu.

- Right-click on the **Map** node in the Project Tree and select **Add Map**.

- Using the File Browser, browse to the LAWS install directory subfolder LAWS/Workshop/Exercise1/maps and select the **basemap.img** file.

- Select the **Create Copy** check box located on the right side of the dialog to copy the map files to the Project's directory and click **OK**.

TIP: Selecting **Create Copy** in the Map Browser will create a Map directory in the Project's directory and copy the map file(s) to the directory. If the option is not checked, the map's path will be hard coded to the directory where they reside. If you move the Project to another location, the project may not be able to find the maps.

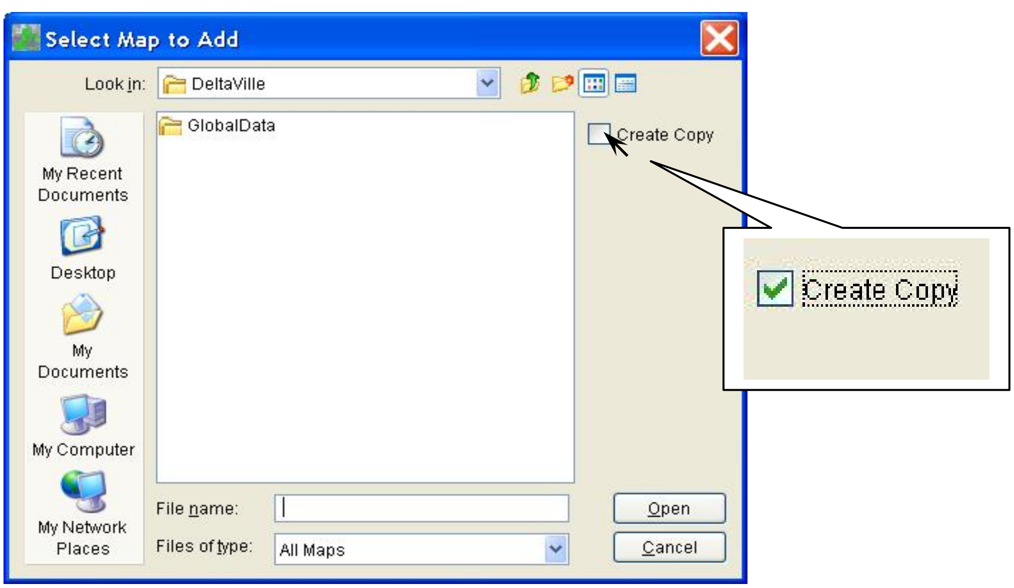


Figure 1.3 - Map Browser Dialog

The Map Schematic window will expand by default to show the total map extent. However, the map extent can be changed manually through the **Default Map Properties** editor, which is accessed under the **Projects -> Default Map Properties** menu. For more detailed information on this editor, use the LAWS online Help system. To view the Help System, select the **Help -> Help** menu. Look under the **Interface** , **Additional Tools** section.

The following is a list of supported map types:

DLG (USGS Digital Line Graphs)
SHP (ArcView shapefiles)
DXF (AutoCAD Digital Exchange Format)
DEM (USGS Digital Elevation Models)
IMG (Raster Image)
ASC (ArcInfo ASCII grid)
NET (ASCII NetTIN)

Creating a Stream Alignment

The Stream Alignment is a visual representation of the modeled stream system. With or without a map, a Stream Alignment will need to be created or imported.

- Right-click the Stream Alignment node in the Project Tree and select **New...** from the popup menu.

- In the **New Stream Alignment** dialog, enter the **Name** "Deltaville SA" and a **Description** then click **OK**.

- Stream Alignment Tools will be added to the current Map Schematic. A new Stream Alignment node  with the label "Deltaville SA" will appear under the main **Stream Alignment** node.

Figure 1.4 - Deltaville Sandy River

TIP: If a Map Schematic is not opened, the creation of the stream alignment will open one automatically.

Note: The newly created Stream Alignment name is displayed in the Project Tree in **bold** type. This indicates that the stream alignment is currently displayed in the active Map Schematic window. Also notice there is an asterisk (*) next to the new Stream Alignment node. This asterisk is there to indicate that the new node's data has not yet been saved to disk. The asterisk also appears if any changes where made to the nodes data. It is good practice to save the project after adding new items or if any significant changes have been made to the project. To save the project, simply click the Save All icon on the menu bar.

Drawing the Stream Alignment

- Select the **Stream Alignment Tool** from the tool bar along the left side of the Map Schematic.

Figure 1.5 - Sandy River Stream

- Using **Figure 1.5** as a guide, draw the Sandy River stream alignment. The stream alignment must be drawn from upstream to downstream. In our exercise, the upstream area is at the top right-hand corner of the map.

- Hold down the **Ctrl** key and click with the left mouse button to place the first point of the main stream. This will "drop" the first point (vertex) of the stream alignment and the cursor will change to a crosshair.

- ***Continue to hold down the CTRL key*** and, using the mouse/cursor, progress from *upstream* to *downstream* and clicking at each succeeding point to draw the alignment.

TIP: Don't worry about following the stream image exactly. We'll show you how to edit the stream alignment drawing in section 6 of this exercise.

- To terminate the stream element, release the **Ctrl** key and click to place the last point of the stream. A dialog will appear asking for the **Name** and **Description**.

- **Name** the Stream Alignment "Sandy River", then click **OK**. The name will display along the stream alignment in the map schematic.

Adding a Tributary

Now let's add the Farmer Creek tributary to our Sandy River stream alignment.

- Using Figure 1.6 as a guide, start adding the Farmer Creek tributary by holding down the **Ctrl** key and clicking the upstream location.

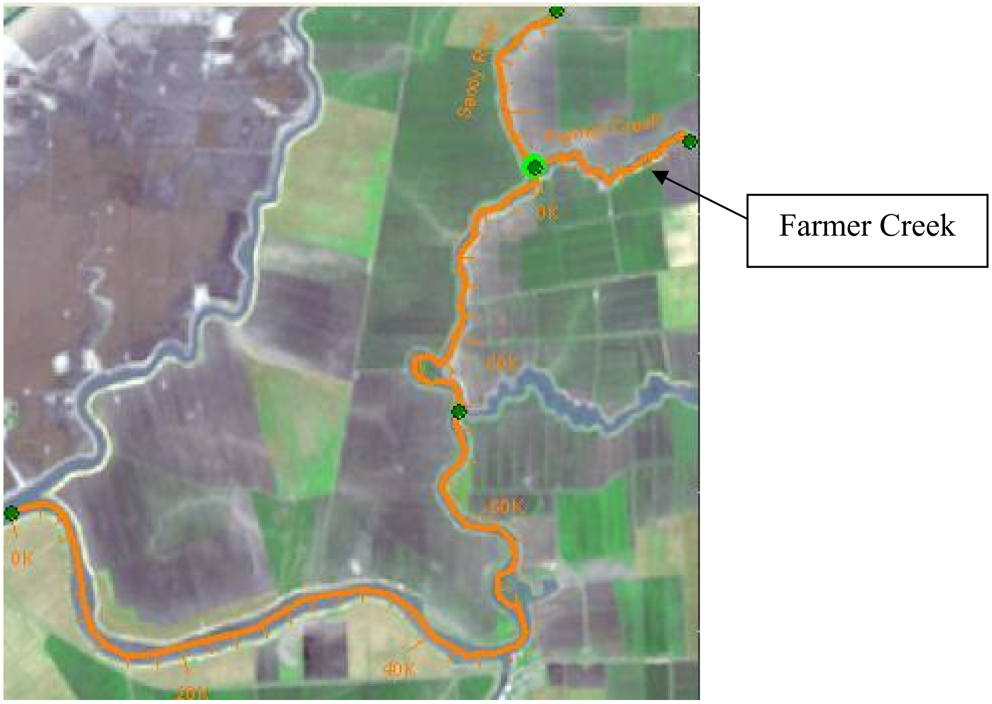


Figure 1.6 - Farmer Creek Before Creating Stream Alignment

- Continue to hold down the **Ctrl** key and, using the mouse/cursor, progress from *upstream* to *downstream* and clicking at each succeeding point to draw the alignment.

- To terminate the stream element, release the **Ctrl** key and click to place the last point of the stream.

- The name request dialog will appear. Name the stream "Farmer Creek" and click **OK**.

- Next, a dialog will appear asking if you would like to connect the tributary to the stream alignment Sandy River. Click **Yes**. The stream will turn orange on the Map Schematic.

Editing the Stream Alignment

Practice editing the stream alignment. Refine your first stream so that it more closely follows the BaseMap image.

First, use the **Zoom Tool** to get a closer view of the stream.

- In the Map Schematic, select the **Zoom Tool** . Click and hold down the left mouse button. Drag the mouse cursor down and to the right. You will see the outline of a rectangle appear. Enclose the area you would like to enlarge inside this rectangle. To zoom out, right-click inside the Map Schematic.

- Once you have the desired area of the stream within the rectangle, let go of the mouse key. The mage within the rectangle will enlarged.

- To start editing the stream, first select the **Stream Alignment Tool** . Then double-click on the stream. The stream will turn red with blue points along it.

Figure 1.7 - Selected Stream Alignment

- To move the blue points, select one with the mouse and hold down the left mouse key. Move the point to a new location and then release the mouse key to place the point. The stream will redraw to the new point location.

- To add points, hold down both the **Ctrl** and **Alt** keys and left-click on the red stream alignment. A blue point will appear.

- To delete extra points on the stream alignment left-click on the point while holding down the **Ctrl** and **Shift** keys.

Figure 1.8 - Configured Stream Alignment

- Zoom out by selecting the Zoom Tool and Right-clicking in the Map Schematic.
- Practice editing in a few other locations until you are comfortable with the process.

Save the Project and Exit LAWS

- **Save** the Project by selecting **Save Project** in the **File** menu.
- **Exit** LAWS from the **File** menu.

Exercise 2 – Global Data

Introduction

Exercise 2 introduces the Global Data portion of a LAWS project. Global Data represents the base data that will be used later to create LAWS simulations. These data are divided into four categories.

- Crop Types
- Irrigation System Types
- Soil Types
- Crop Schedules

A LAWS project is provided in the LAWS install directory under the subdirectory LAWS/Workshop/Exercise2. In this exercise, you will gain experience by using a simple fictitious area named Deltaville.

Figure 2.1 - Deltaville Agricultural Region

Task Description

The goal of this exercise is to create four Global Data sets for the Deltaville LAWS Project using the information provided on irrigation systems, soil types, crop types, and crop schedules. This information will be used in later exercises to create other parts of the LAWS project. Although subsequent exercises will contain more Global Data, Exercise 2 will only have a few simple examples to get you familiar with the software.

Getting Started

- Launch LAWS
- Select **Open Project** from the **File** menu.
- Browse to the location of this exercise's project using the File Browser. The project is located in the LAWS install directory under the following: LAWS/Workshop/Exercise2/Exercise2.prj file.
- Then click **Open**.

The Exercise 2 project will load into LAWS.

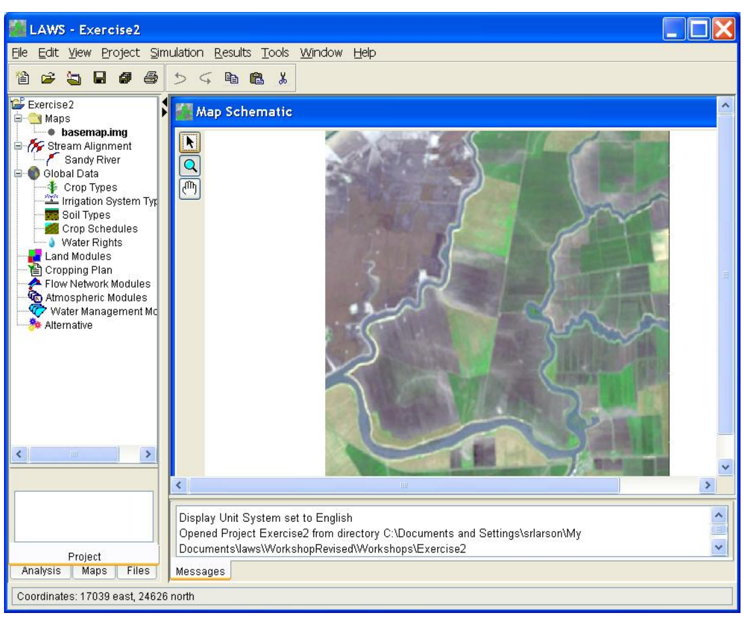


Figure 2.2 - Deltaville Exercise 2

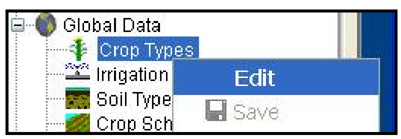
- Open the Sandy River Stream Alignment in the current Map Schematic by right-clicking on the **Sandy River** node label in the Project Tree and select **Open** from the popup menu.

The Sandy River stream alignment will draw in the current Map Schematic.

Adding Crop Types

Crop Types indicate the choices of agricultural crops that will be available for modeling in the Project. Each Crop Type contains information on the plant's type, life cycle, growth stage, and planting dates. Two Crop Types have already been created, Wheat and Corn. In this exercise, we will be adding Tomatoes.

- Open the **Crop Type Editor** by right-clicking on the **Crop Type** node in the Project Tree and selecting **Edit**.



TIP: You can also activate the editor by double-clicking on the Crop Type node in the Project Tree.

NOTE: To view existing Crop Types, use the navigation buttons to the right of the current Crop Type name. The Navigation buttons include: First Record, Previous Record, Next Record, and Last Record. The Crop Types can also be selected using the **Name** combo box list. All editors in LAWS use this navigation to view previously created items.

- The **Crop Type Editor** will open.

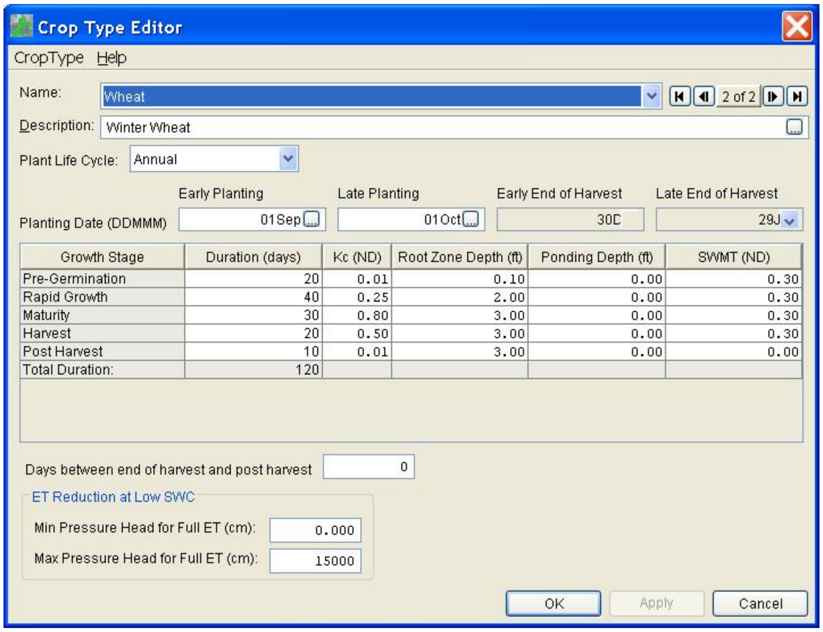


Figure 2.3 - Crop Type Editor

TIP: Use the **Help** menu in the editor to learn more about the **Crop Type Editor**

- To create the new Crop Type, select **CropType** -> **New** from the menu bar in the editor.
- The **New Crop Type** dialog will appear. Give the Crop Type the **Name** "Tomatoes" and a **Description**.
- Using the values displayed below in Figure 2.4, fill in the information on Alfalfa.

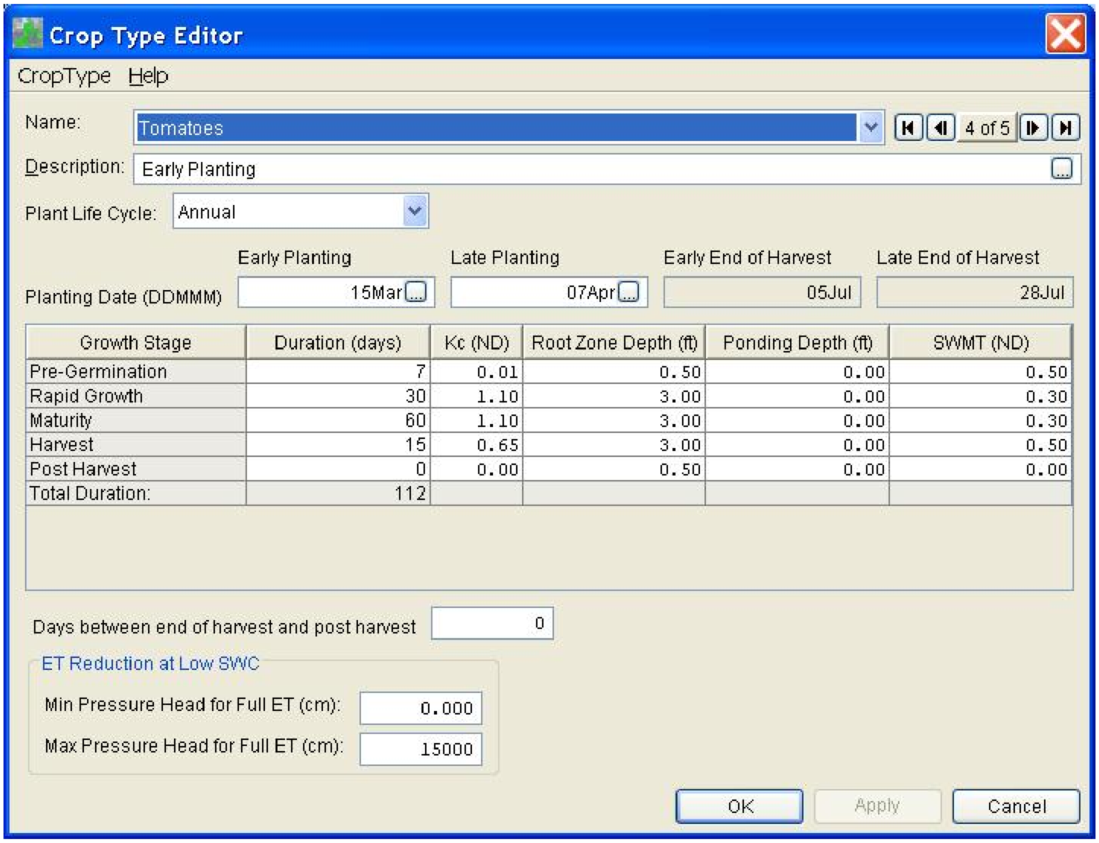


Figure 2.4 - Crop Type Editor

NOTE: SWMT is the Soil Water Management Target. Please use the online Help to understand the values used in the Editor.

- When you are finished entering information into the editor, click **OK** to save the new Crop Type and close the editor.
- Save the new Crop Type to the Project files. Right-click on the Crop Type node in the Project Tree and select Save form the popup menu.

NOTE: Additional information on Crop coefficient data can be obtained from the following references:

- On the Web at http://biomet.ucdavis.edu/evapotranspiration/CropCoef/crop_coefficients.htm
- Reference Book
  Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage
  By Richard G Allen, Luis S. Pereira, Dirk Raes, Martin Smith

FAO - Food and Agriculture Organization of the United Nations
Rome, 1998
Available on the Web at:
http://www.fao.org/docrep/X0490E/X0490E00.htm

Adding Irrigation System Types

Irrigation System Types represent the different irrigation methods used to provide water to the crops. Examples of Irrigation System Types include Drip Line, Sprinkler, etc.

- Double-click the **Irrigation System Types** node in the Project Tree.

TIP: You can also activate the editor by right-clicking the **Irrigation System Types** node and selecting **Edit** from the popup menu.

- The **Irrigation System Types Editor** will display as below.

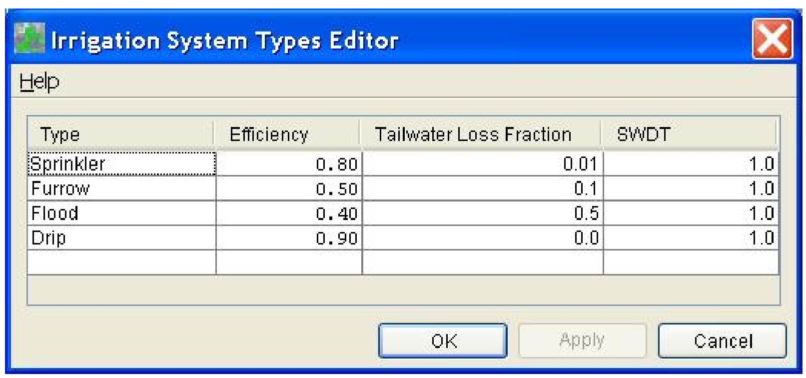


Figure 2.5 - Irrigation System Type Editor

TIP: Use the **Help** menu in the editor to learn more about the **Irrigation System Types Editor.**

- There are four default Irrigation types already populating the editor. We need a more specific type of sprinkler, a center pivot, added to our project.
- Each row in the table represents a different system. To add the Center Pivot, click on the bottom row's first cell in the table and type "Center Pivot".
- The **Efficiency** value for the Center Pivot is ".90". The **Tailwater Loss Fraction** is "0.0". And the **SWDT** (Soil Water Delivery Target) is "1.0".
- Click **OK** to save the changes and close the editor.

TIP: Notice there is an asterisk (*) next to the Crop Type and Irrigation System Type nodes. This asterisk is there to indicate that changes have been made to the nodes data and that these changes have not been saved to disk. In our case, new data has been created. It is good practice to save the project after significant changes have been made to the project.

- Save the project by clicking on the Save All icon on the main toolbar.

Adding Soil Types

Soil Types represent the various soils that can be modeled.

- Double-click on the **Soil Type** node in the Project Tree.
- The **Soil Type Editor** dialog will appear as the one pictured below.

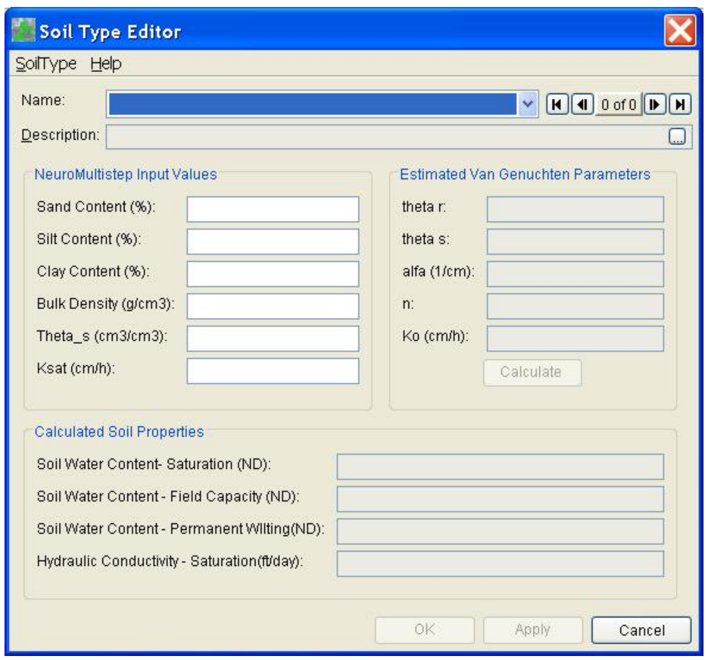


Figure 2.6 - Soil Type Editor

TIP: Use the **Help** menu in the editor to learn more about the **Soil Types Editor.**

- In the **Soil Types Editor**, create a new **Soil Type** by selecting **Soil Type -> New...**
- Give the new Soil Type the **Name** "DeltavilleClay" and a **Description**, then click **OK**.
- In the editor, enter the following values:
    - **Sand Content** 20%

- **Silt Content** 20%
- **Clay Content** 60%

NOTE: The total percent must equal 100 before the calculation can be preformed.

- Once the percentages for the Sand, Silt, and Clay in are filled in, click on the **Calculate** button.

Notice that the **Van Genuchten Parameters** now appear on the right-side of the editor. These values are used in modeling unsaturated flow in LAWS. Also note that values for the **Soil Water Content** at various moisture levels and hydraulic conductivity at saturation are calculated.

NOTE: For additional information on Soil Types see the following references:

- Soil Texture Triangle on the Web: http://www.uwsp.edu/geo/faculty/ritter/glossary/s_u/soil_texture_triangle.html

- When you are done adding the Soil Type, click **OK** to close the editor and save the information.

- Save the project by clicking on the Save All icon  on the main toolbar.

Adding Crop Schedules

Crop Schedules indicate the agricultural rotations for the crops. They include the year and date in which a particular Crop Type will be planted. During a simulation, if the year indicated by the Crop Schedule is not included in the time range of the computations, then the Crop Schedule will automatically determine the appropriate initial crop and proceed to rotate the crops throughout the simulation. However, the user should to determine whether the Crop Schedule is appropriate for their purposes.

- Double-click the **Crop Schedule** Node in the Project Tree.

- The **Crop Schedule Editor** dialog will appear as pictured below.

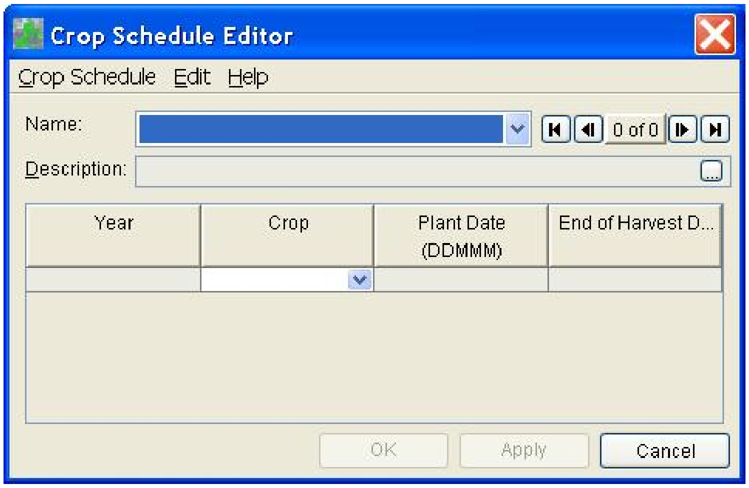


Figure 2.7 - Crop Schedule Editor

TIP: Use the **Help** menu in the editor to learn more about the **Crop Schedule Editor.**

- To create a new Crop Schedule select **Crop Schedule** -> **New....**
- On the **New Crop Schedule** dialog, enter the **Name** "Rotation1" and the **Description** "Corn, wheat, and tomato rotation." then click **OK**.
- In the **Crop Schedule Editor** fill in the table with the following planting events, choosing from the Crop Types created earlier.
    - 1980 Corn
    - 1981 Wheat
    - 1982 Tomatoes

NOTE: If the simulation were to continue into 1983, corn would be planted again, then Wheat in 1984 and Tomatoes in 1985.

TIP: Crop Types editor is available through the Crop Schedule editor's menu **Edit -> Crop Types.**

- The **Plant Date** and **End of Harvest** areas will fill automatically with the Early Planting and Harvest date for each event once the **Year** and **Crop** are entered. These dates were determined when the Crop Type was created. For more information on this topic, see the section on Crop Schedules in the online Help.
- When you are done, click the **OK** button.

NOTE: The **Content Pane**, located just below the **Project Tree Pane**, displays the selected tree node's content. For example, if the **Crop Type** node is selected in the Project Tree, each previously created Crop Type will be listed in the Content Pane.

Save the Project and Exit LAWS

- **Save** the Project by selecting **Save Project** in the **File** menu.
- **Exit** LAWS from the **File** menu.

Exercise 3 – Land Modules and Cropping Plans

Introduction

Exercise 3 introduces Land Modules and Cropping Plans.

Land Modules can be added to the project by importing them from a shape file or manually creating them using the Land Manager Tool. A Land Module represents a collection of Land Managers. Land Managers represent individual parcels of land within the modeled area. Land Managers display as polygons on the Map Schematic.

Cropping Plans link the Land Managers to the Crop Types and Crop Schedules created in the Global Data.

A LAWS project is provided in the LAWS install directory under the subdirectory LAWS/Workshop/Exercise3. In this exercise, you will gain experience by using a simple fictitious area named Deltaville.

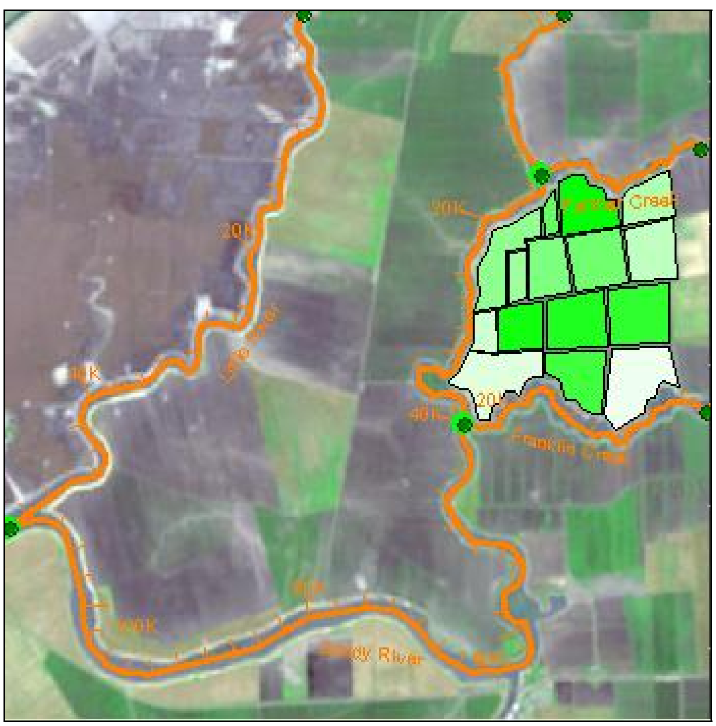


Figure 3.1 -Deltaville Agricultural Region

Task Description

The goal of this exercise is to create multiple Land Managers for the Deltaville LAWS Project using the information provided. You will become familiar with using the Land Manager Tool to create new Land Managers. Although subsequent exercises will contain more Land Managers, Exercise 3 will only have a few simple examples to get you familiar with the software.

Getting Started

- Launch LAWS by double-clicking on the LAWS icon on your PC's desktop.
- Select **Open Project** from the **File** menu.
- Browse to the location of the LAWS install directory using the File Browser. The project file will be under the following subfolder:

  LAWS/Workshop/Exercise3/Exercise3.prj file.

- Then click **Open**.

The Exercise3 project will load into LAWS.

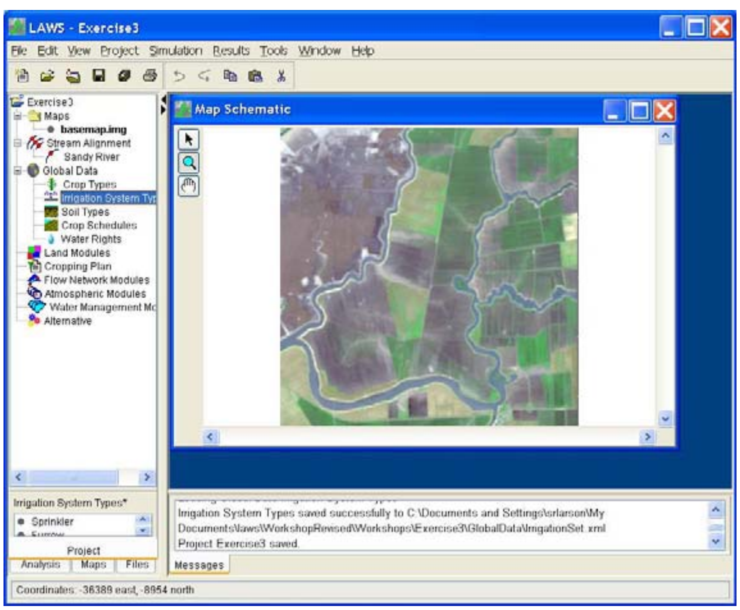


Figure 3.2 - Main Screen

- Open the Sandy River Stream Alignment in the current Map Schematic by right-click on the **Sandy River** node label in the Project Tree and select **Open** from the popup menu.

The Sandy River stream alignment will draw in the current Map Schematic.

Importing a Land Module

Land Modules are collections of Land Managers. In our example, a Land Manager represents an individual agricultural field. Most Land Modules will contain a large number of Land Managers. Initially each Land Manager must be created manually. The Land Manager information is saved to an Arc Shape file, <*Land Module Name*>.shp, which is automatically created. You can also create such a file using GIS. In our example, we will be using a previously created Land Module Arc Shape file to create our Land Module. We will then manually add a Land Manager to it.

- Right-click on the **Land Module** node and select **Create Land Module from Shape File** from the popup menu.

- An **Import Land Manager Wizard** dialog will appear as the one pictured in Figure 3.2 below.

Figure 3.3 - Import Land Managers Wizard Step 1

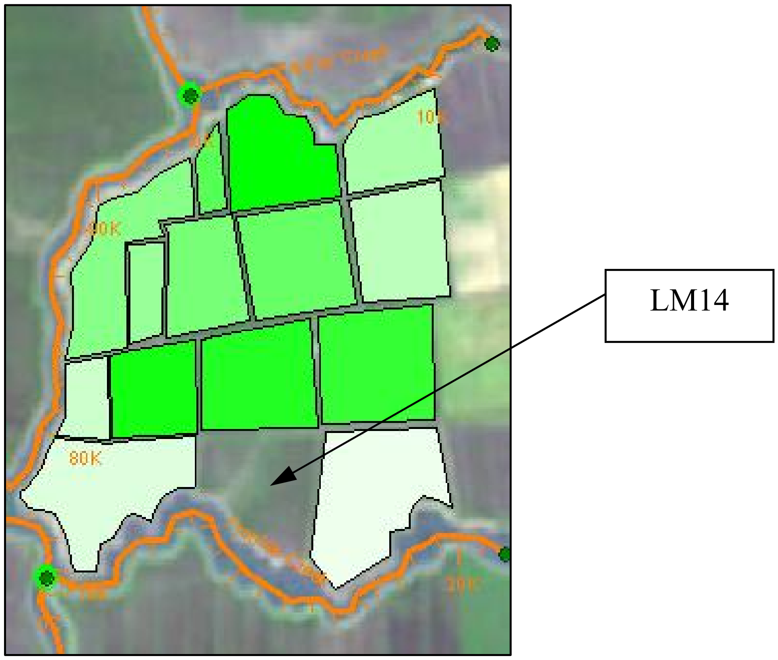
- Enter the **Name** "Base" and fill out the **Description** field.
- Select the ellipse button in the **Shape File** field and locate to the Base.shp file on the LAWS install directory under LAWS/Workshop/Exercise3/DataSheets.
- Click **Next**
- Step 2 of the wizard will display, pictured in Figure 3.3 below.

Figure 3.4 - Import Land Managers Wizard Step 2

- Select the only option available in the **Land Manager Name Attribute** dropdown list.
- Click **Next**
- Step 3 appears. We would like to draw one of the fields by hand, so uncheck LM14 from the listed fields (ID_NAME). Then select **Next**.
- After looking over the summary of the import in Step 4, select **Finish**.
- A new Land Module node will appear under the **Land Modules** node in the Project Tree. The **Land Manager Tool**  will be added to the toolbar on the current Map Schematic.
- We will use this tool to create a Land Manager on the map in the next step.

Manually Creating a Land Manager

- First select the **Land Manager Tool**  in the Map Schematic.



- Use the **Zoom Tool** to zoom in on the location of the missing Land Manager, LM14.
- Select the **Land Manager Tool** again. While holding down the **Ctrl** key, left-click in the Map Schematic window were you would like to place the first point.
- While *continuing to hold down* the **Ctrl** key, outline of the field shape by left-clicking points on the map.

TIP: Be sure to create an enclosed area and not overlap the outline on itself.

- For the final point, release the **Ctrl** key and click.
- The outlined area will fill in with yellow, indicating it is selected, otherwise it will appear green.
- To Zoom out, select the **Zoom Tool**. Then, inside the Map Schematic window, click the right mouse button.
- Save the changes you made by selecting **Save Project** in the **File** menu.

Editing the Land Managers

The Land Managers now need to be assigned Soil and Irrigation System Types.

- Select the **Land Manager Tool**.
- Right click on a Land Manager in the Map Schematic and select **Edit Land Manager** from its popup menu.
- The **Land Manager Editor** will appear with the selected field information displayed.

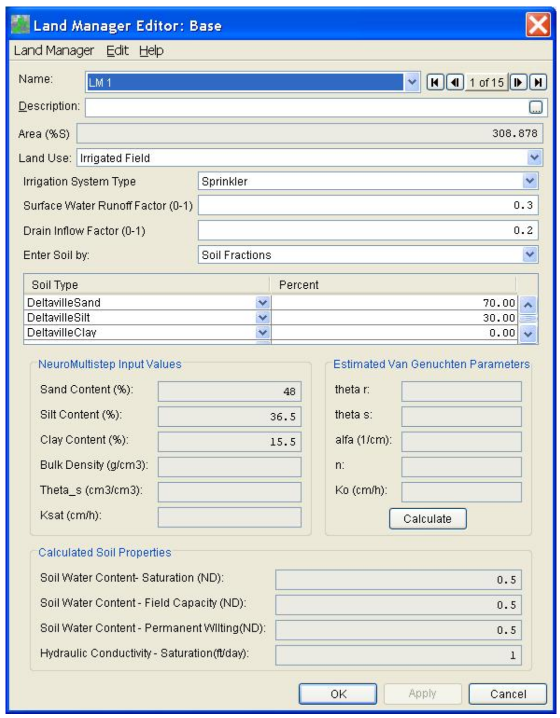


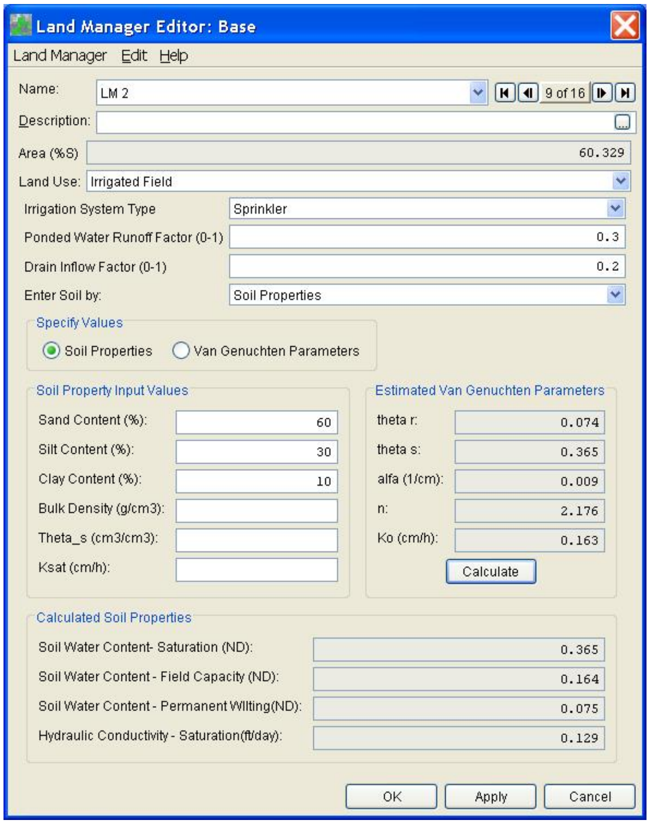
Figure 3.5 - Land Manager Editor

TIP: Use the **Help** menu in the editor to learn more about the **Land Manager Editor**

- Using the data below, fill out the information for LM1 and LM2 in the **Land Manager Editor**.
    - **Land Manager** LM1:
        - **Land Use**: Irrigated Field
        - **Irrigation System Type**: Portable
        - **Ponding Water Runoff Factor**: 0.1
        - **Drain Inflow Factor**: 0.2
        - **Enter Soil By**: Soil Type
        - **Soil Type**:
            - 70% DeltavilleSand

- 30% DeltavilleSilt
- 0% DeltavilleClay

- Once you are done enter data for LM1, click the **Compute** button.



  - **Land Manager** LM2:
    - **Land Use**: Irrigated Field
    - **Irrigation System Type**: Furrow
    - **Ponding Water Runoff Factor**: 0.3
    - **Drain Inflow Factor**: 0.2
    - **Enter Soil By**: Soil Properties
    - **Specify Values, NeuroMultiStep Values**
    - **Soil Property Input Values**:
      - **Sand Content** 60%
      - **Silt Content** 30%
      - **Clay Content** 10%

- Again, when you are done enter data for LM2, click the **Compute** button.

- Click **OK** to close and save the editor.

Editing Multiple Land Managers Simultaneously

Multiple Land Mangers can be edited all at once. Instead of entering this information repeatedly for each Land Manager at a time, you can enter it once for all of them. In our example, we will enter data for Land Manager LM5 through LM16.

- First be sure the **Land Manager Tool**  is selected.
- To edit multiple Land Managers, hold down the **Shift** key and left-click on Land Managers LM5 through LM16.

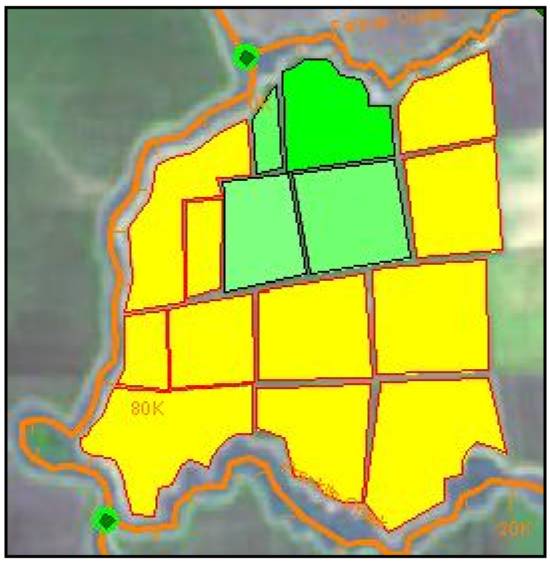


Figure 3.6 - Multiple Land Managers Selected

HINT: Multiple Land Managers can also be selected by circling them with the Land Manager tool. Hold the mouse key down and draw a circle around the Land Managers you would like to edit, see below.

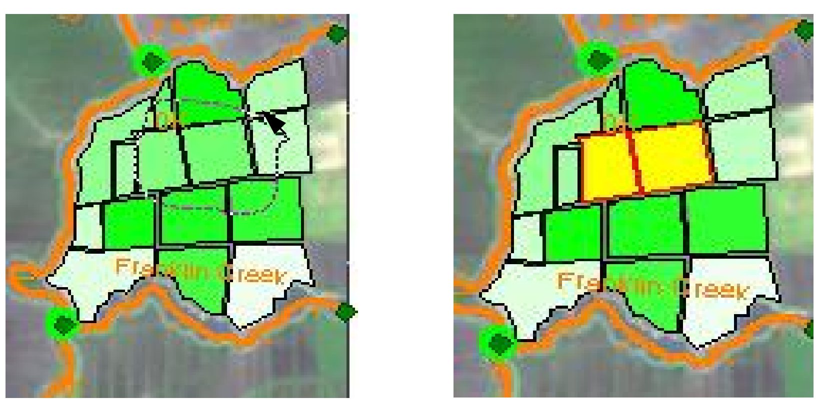


Figure 3.7- Selecting Multiple Land Managers by Circling Them

TIP: To see the name of the Land Manager, hover the cursor over the Land Manager until the name tooltip appears.

- The Land Managers will turn yellow, indicating they are selected.

- Once all the desired Land Managers are selected, right-click one to trigger the popup menu and select **Edit Land Manager**.

- The **Land Manager Editor** will appear.

- All selected Land Managers' names will be shown in the Land Manager **Name** text field. Information entered in the editor will be applied to all selected Land Managers.

- Use the values below to fill out the Land Managers' information.
    - **Land Managers**:
        - **Land Use**: Irrigated Field
        - **Irrigation System Type**: Drip
        - **Ponding Water Runoff Factor**: 0.0
        - **Drain Inflow Factor**: 0.1
        - **Enter Soil By**: Soil Type
        - **Soil Type**:
            - 60% DeltavilleSand
            - 20% DeltavilleSilt
            - 20% DeltavilleClay

- When you are done enter the data, click the Calculate button.

- Click **OK** to save and close the dialog.

Creating a Cropping Plan

A Cropping Plan links the Land Managers to Crop Schedules.

- Right-click on the **Cropping Plan** node and select **New…** from the popup menu.
- The **New Cropping Plan** dialog appears.
- Give the new Cropping Plan the **Name** "Simple Plan" and a **Description**, then click **OK**.
- A Cropping Plan node will appear labeled with the new name.
- Right-click on the new **Simple Plan** node and select **Edit** from the popup menu. The **Cropping Plan Editor** will appear.
- Select a Crop Schedule for each Land Manager listed in the **Cropping Plan Editor** using Figure 3.7 below as a guide.

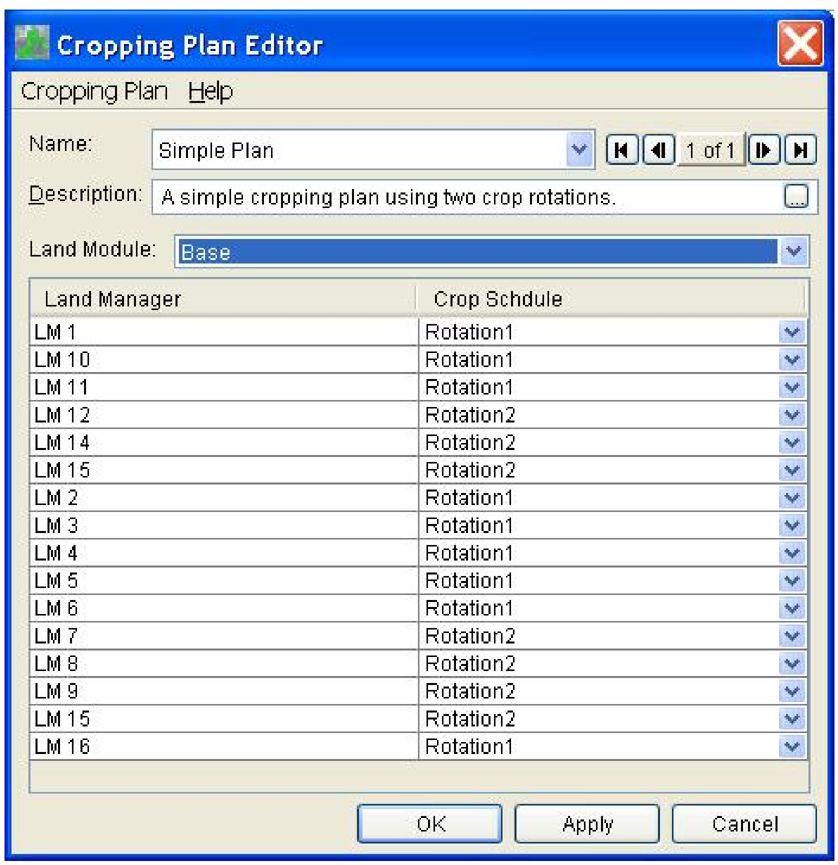


Figure 3.1 - Cropping Plan Editor

TIP: Use the **Help** menu in the editor to learn more about the **Land Manager Editor**

NOTE: The Crop Schedule "Rotation 1" was created in the previous exercise, Exercise 2.

- When you are finished, click **OK** to close and save the dialog.

Save the Project and Exit LAWS

- **Save** the Project by selecting **Save Project** in the **File** menu.
- **Exit** LAWS from the **File** menu.

Exercise 4 – Flow Network and Atmospheric Modules

Introduction

Exercise 4 introduces the creation of Flow Networks and Atmospheric Modules. Flow Networks represent the water storage and conveyance system simulated by the model. These resources include the following:

- Reservoirs
- Reaches
- Junctions

Using the data provided, you will learn how to create visual representations of reaches, a reservoir, and Met Stations.

Atmospheric Modules hold collections of Met Stations. A Met Station is used to indicate the location and area of influence of a meteorological station. The Met Station's default display is a simple Icon on the Map Schematic. The area of influence of a Met Station is specified by a radius or polygon.

A LAWS project is provided in the LAWS install directory under the subdirectory LAWS/Workshop/Exercise4. In this exercise, you will gain experience by using a simple fictitious area named Deltaville.

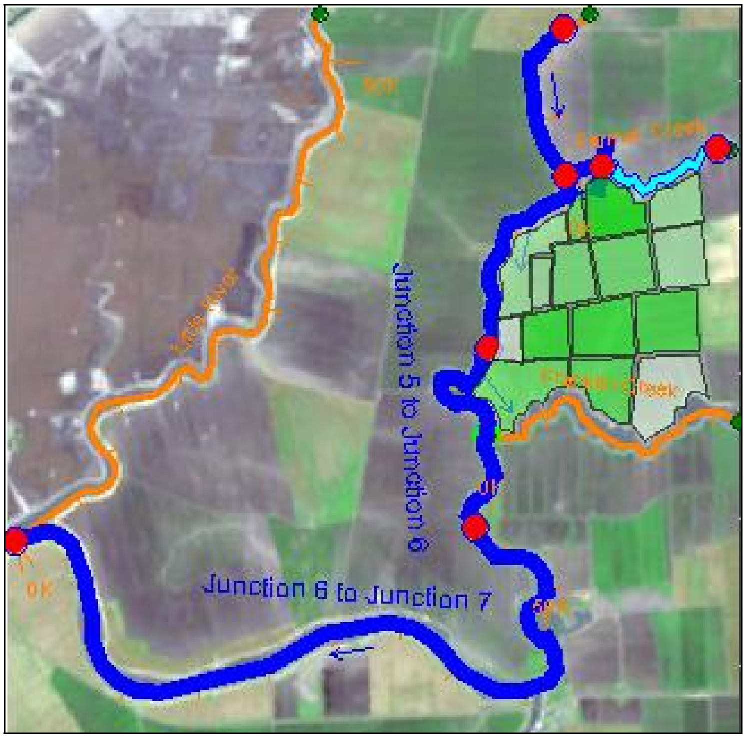


Figure 4.1 - Deltaville Agricultural Region

Task Description

The goal of this exercise is to become familiar with creating and editing Flow Networks and Met Stations. You will become familiar with using the Reach, Reservoir, and Met Station tools to create new Flow Networks and Atmospheric Modules.

Getting Started

- Launch LAWS by double-clicking on the LAWS icon on your PC's desktop.
- Select **Open Project** from the **File** menu.
- Browse to the location of the Exercise 3 project using the File Browser. The project file will be under the LAWS install directory in the following subfolder: LAWS/Workshop/Exercise4/Exercise4.prj file.
- Then click **Open**.

The Exercise 4 project will load into LAWS.

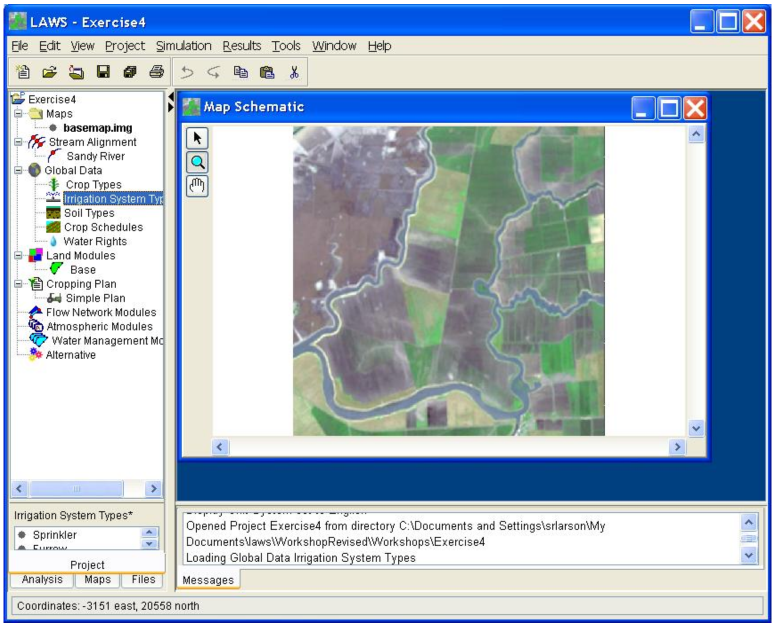


Figure 4. 2 - Project Exercise 4

- Open the Sandy River Stream Alignment by right-clicking on the **Sandy River** node label in the Project Tree and selecting **Open** from the popup menu.

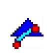
The Sandy River stream alignment will draw in the current Map Schematic.

- Open and load the Base Land Module by right-clicking on the **Base** node and selecting **Open** from the popup menu.

The Land Managers will appear on the Map Schematic like those pictured above in Figure 4.2.

Creating a Flow Network

Flow Networks represent the rivers and conveyance infrastructure used to provide water to the fields. They are represented visually on the Map Schematic as Reaches, Reservoirs, and Junctions.

- Right-click the **Flow Network Module** node  in the Project Tree and select **New...** from the popup menu.

- In the **New** dialog, enter a **Name** and **Description** for the new Flow Network.

- Select the Sandy River **Stream Alignment** for the Flow Network and click **OK**.

- A new Flow Network Node  will be created under the Flow Network Module Node. Flow Network tools will be added to the toolbar in the current Map Schematic.

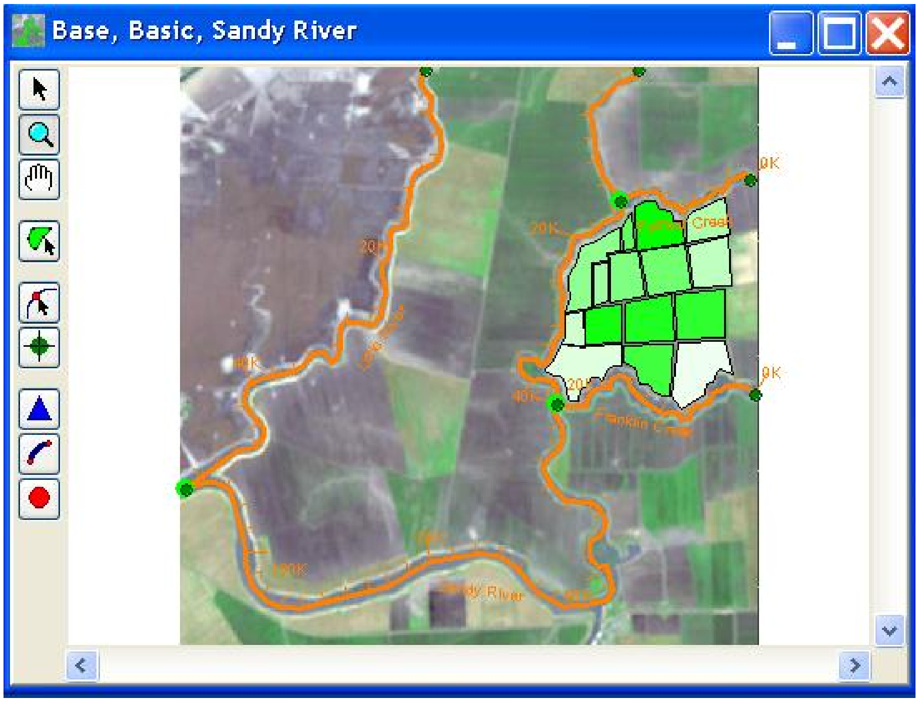


Figure 4.3 - Land Managers

Creating a Reservoir

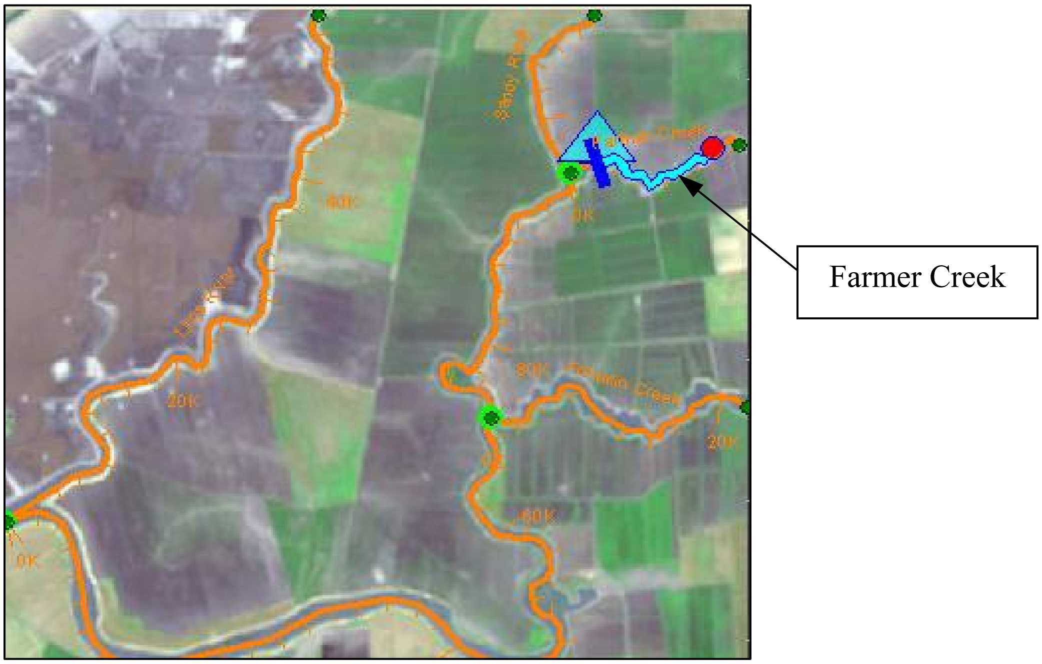


Figure 4.4 - Flow Network

Reservoirs must be drawn on the stream alignments within the Map Schematic. Using the Reservoir Tool, a reservoir can be created on top of the stream. Use Figure 4.4, above as a reference for placing the reservoir. Do not worry about matching the picture exactly. This exercise is to get you used to using the tools and not to mimic the picture.

- Select the **Reservoir Tool** in the Map Schematic.
- While holding down the **Ctrl** key, left-click the Stream Alignment to select the *upstream* location of the reservoir on Farmer Creek.
- Release the **Ctrl** key just before the confluence with Sandy River and left-click on the Stream Alignment to select the *downstream/end* location of the reservoir.

HINT: Before left-clicking you will see a line connecting the point arrow to the last click placement. This line is to indicate where the reservoir begins and is intended to help with its placement.

- The **Name New Reservoir** dialog will appear. Give the new reservoir the **Name** "Farmers Reservoir" and click **OK**.
- The reservoir's reach will fill in and a triangle will appear at the downstream location.

TIP: This triangle is the Reservoir's pool. This pool shape can be changed to reflect the actual shape of the reservoir's pool.

Creating Reaches

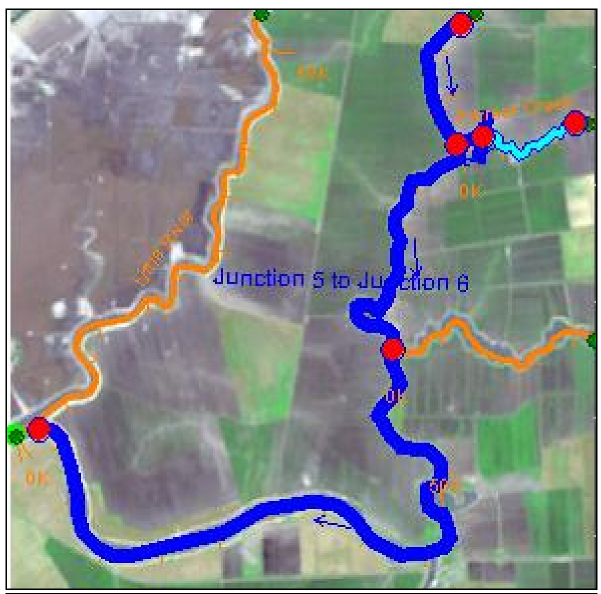


Figure 4.5 Reaches

Reaches represent the rivers, streams, canals, and channels within the flow network used by the model. Like the reservoir, they must be drawn on the stream alignment by the user. Use Figure 4.5 above as a reference for creating reaches for the Deltaville project. Do not worry about matching the project perfectly.

- Use the Zoom Tool to zoom in on the location just below Farmer Reservoir.

- Select the Reach Tool  in the Map Schematic.

- While holding down the **Ctrl** key, click the downstream location of Farmer Reservoir, where the Reach will begin on the Stream Alignment.

- Release the **Ctrl** key and click on the Stream Alignment where Farmer Creek meets Sandy River.

- The **Name New Junction** dialog will appear. Accept the default name by clicking **OK**.

- The **Name New Reach** dialog will appear. Again, use the default name and click **OK**.

TIP: Similar to the Reservoir placement, you will see a line connecting the point arrow to the last clicked spot on the stream.

- The end points will become red Junctions , unless the Reach was ended or started at a Junction. In that case, the Reach will use the existing Junctions. The area between the points, along the stream alignment, will fill with the new Reach.

- Create another reach that goes from the top of Sandy River to the new Farmer Creek junction.

- You can continue to create more reaches down the river.

Editing a Reservoir

Reservoirs have physical data that need to be filled out through the editor.

- Be sure the **Reservoir Tool** is selected, then right-click on the Reservoir in the current Map Schematic and select **Edit Reservoir** from the popup menu.

HINT: You can also access the editor by right-clicking on the Flow Network's node and selecting **Edit -> Reservoir** from the popup menu.

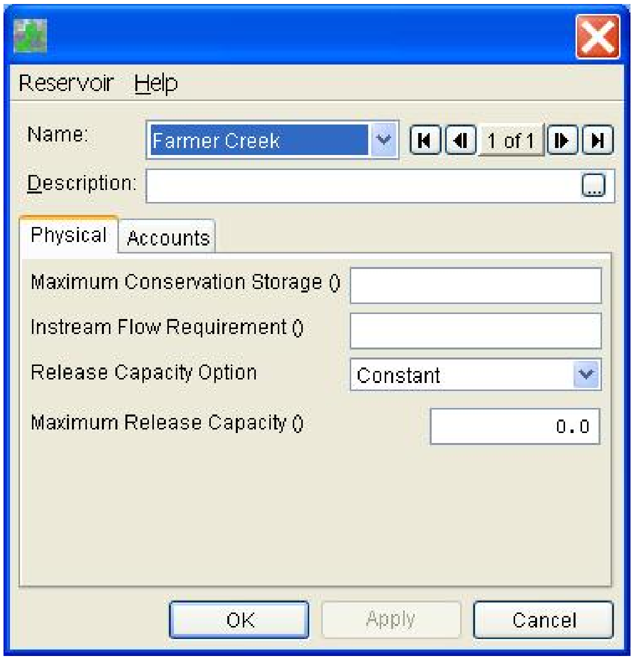


Figure 4.6 - Reservoir Editor

TIP: Use the **Help** menu in the editor to learn more about the **Reservoir Editor**

- In the **Reservoir Editor,** enter 23,000 ac-ft for **Maximum Conservation Storage** and 0 cfs for the **Instream Flow Requirement**.

- Choose **Constant** for the **Release Capacity Option** from the option's dropdown list.

- Enter the 3,000 for the **Maximum Release Capacity**.

- Click **OK** to save the changes and close the dialog.

Editing the Reaches

Similar to reservoirs, reaches need to have physical data filled out through the editor. In this exercise, we will only be filling in Reach data for one reach.

- Be sure the **Reach Tool**  is selected, then right-click on the Reach in the current Map Schematic and select **Edit Reach** from the popup menu.

HINT: You can also access the editor by right-clicking on the Flow Network's node and selecting **Edit -> Reach** from the popup menu.

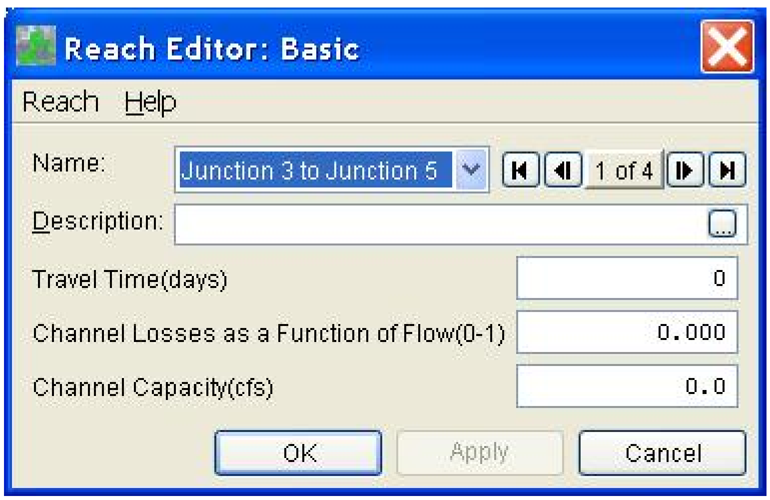


Figure 4.5 - Reach Editor

TIP: Use the **Help** menu in the editor to learn more about the **Reservoir Editor**

- The **Reach Editor** will appear. Within this editor fill in 2 days for the **Travel Time**, 0.1 for the **Channel Losses**, and 3,000 cfs for the **Channel Capacity**.
- When you are done, click **OK** to save and close the editor.
- Save the project changes so far by clicking on the Save All icon  on the main toolbar.

Creating an Atmospheric Module

Atmospheric Modules hold collections of Met Stations. Met Stations represent meteorological stations for a specified area. This data includes reference ET and precipitation data.

- Right-click on the **Atmospheric Modules node** in the Project Tree and select **New...** from the popup menu.
- The **New Atmospheric Module** dialog appears.
- Give the Module the **Name** "Simple" and a **Description**.
- Click **OK**.
- The new Atmospheric Module node , with the given name, will appear under the Module's node.
- A **Met Station Tool** will be added to the current Map Schematic's Toolbar.

Adding Met Stations to the Map Schematic

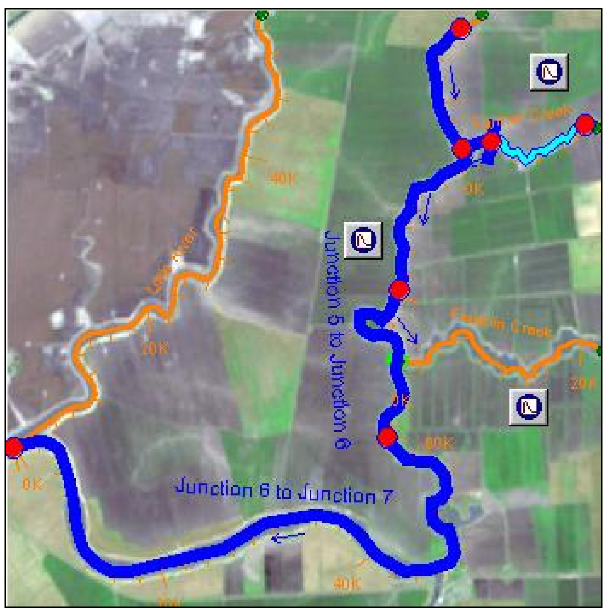


Figure 4.6 - Met Stations

A Met Station is placed at the location where meteorological data is collected. The Met Station's default display is a simple icon in the Map Schematic. The Met Station has an area associated with it. The area, by default, is not drawn on the Map Schematic. It can be displayed to encircle the Met Station icon by a given radius or with a polygon shape. These shapes represent the area where the meteorological station data is used in the model.

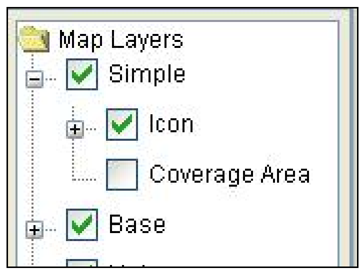
- Select the Met Station Tool in the Map Schematic.

- Hold the Ctrl key down and click on the area you would like to place a Met Station. Use Figure 4.7 above as a reference.

- To display the actual area of influence for the Met Station you must select it on the Maps tab.

- Select the Maps tab at the bottom left-hand side of the LAWS screen.
- In the Map Layers tree, find the Atmospheric Modules name, Simple, and expand its tree node by selecting the plus + sign next to it.

- You should be able to see two more tree nodes, Coverage Area and Icon. Click the box next to the word Coverage Area.

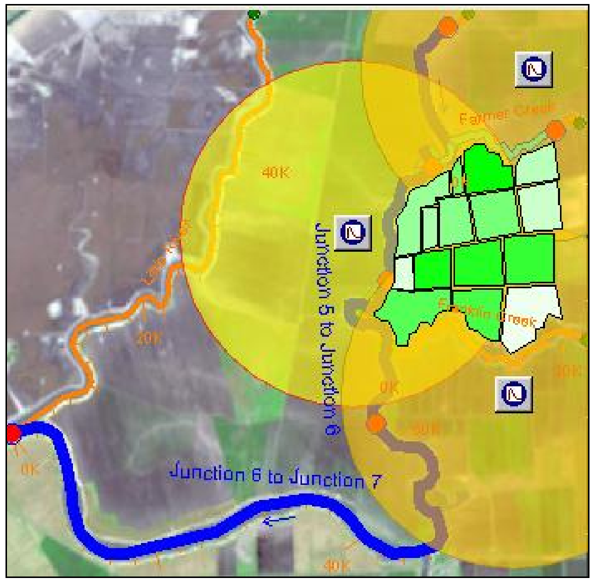


- A yellow circle will appear around the Met Stations in the Map Schematic. The circle represents the area covered by the Met Station's data.

- You can increase the area of the Met Stations by right clicking in the Map Schematic and selecting **Edit Met Station** from the popup menu.

TIP: At least one Met Station needs to cover every Land Manager.

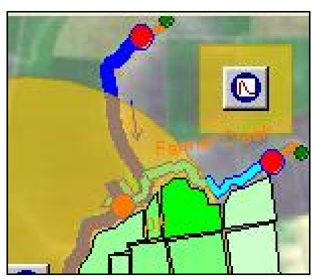
- In the **Met Station Editor**, increase the value of the **Radius (ft)** and click **Apply**.



Change one of the area's shape to a **Polygon**.

- Select the **Met Station Tool**.
- Right-click on a Met Station and select **Edit Met Station** from the popup menu.
- In the editor, select **Polygon** from **Region Type** dropdown list.
- Click **OK** to save and close the editor.

Now change the shape of the polygon.



- Use the **Zoom Tool** to zoom in on the polygon in the Map Schematic.
- Double-click on the polygon shape to set it active. Notice that yellow points appear on the edges of the polygon shape.
- To move a point, left-click on the point and hold down the mouse button. Move the point to a new location and release the mouse button.
- To add points, left click while holding down the **Ctrl** key.

- To remove a point, left-click on the point while holding down the **Ctrl** and **Shift** keys.

Saving the Project and Exiting LAWS

- **Save** the Project by selecting **Save Project** in the **File** menu.

- **Exit** LAWS from the **File** menu.

Exercise 5 – Water Management Modules

Introduction

Exercise 5 introduces the creation of a Water Management Module. This module is made up of the following three managers:

- System Manager
- Area Manager
- Delivery Manager

A System Manager manages reservoir releases that are requested for delivery into the area modeled. An Area Manager determines the allocation of available water resources to meet the requests for water from the Delivery Managers. Last, the Delivery Manager distributes the water to individual Land Managers.

Using the data provided, you will learn how to create visual representations of Delivery Managers. You will also become familiar with each Managers' editor and their information requirements.

A LAWS project is provided in the LAWS install directory under the subdirectory LAWS/Workshop/Exercise 5. In this exercise, you will gain experience by using a simple fictitious area named Deltaville.

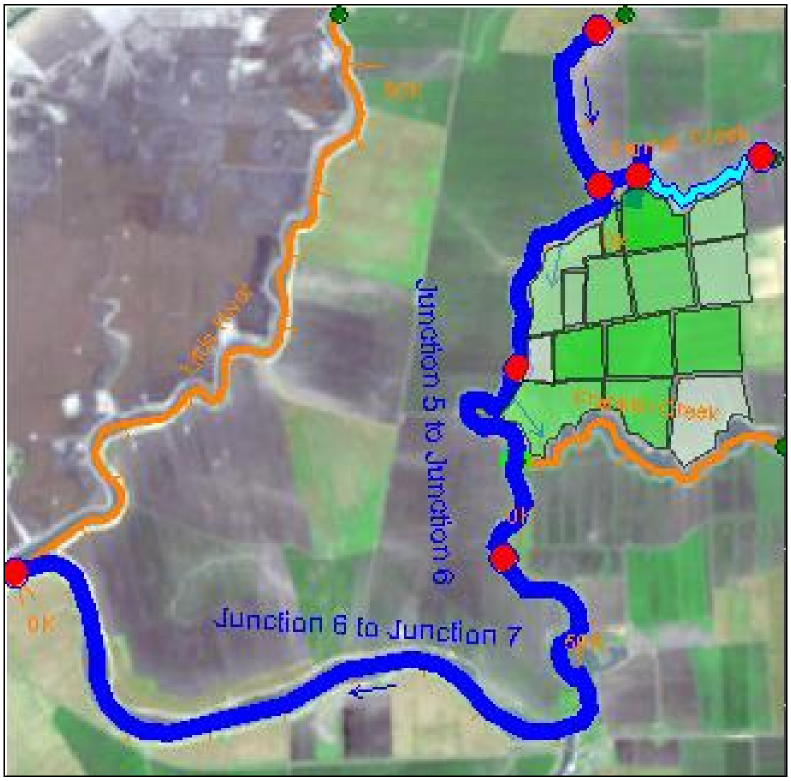


Figure 5.1 - Deltaville Agricultural Region

Task Description

The goal of this exercise is to become familiar with creating and editing System, Area, and Delivery Managers. You will become familiar with using the Delivery Manager Tool to create new Delivery Managers within the Map Schematic.

Getting Started

- Launch LAWS by double-clicking on the LAWS icon on your PC's desktop.
- Select **Open Project** from the **File** menu.
- Browse to the LAWS install directory using the File Browser and select the LAWS/Workshop/Exercise5/Exercise5.prj file.
- Then click **Open**.

The Exercise 5 project will load into LAWS.

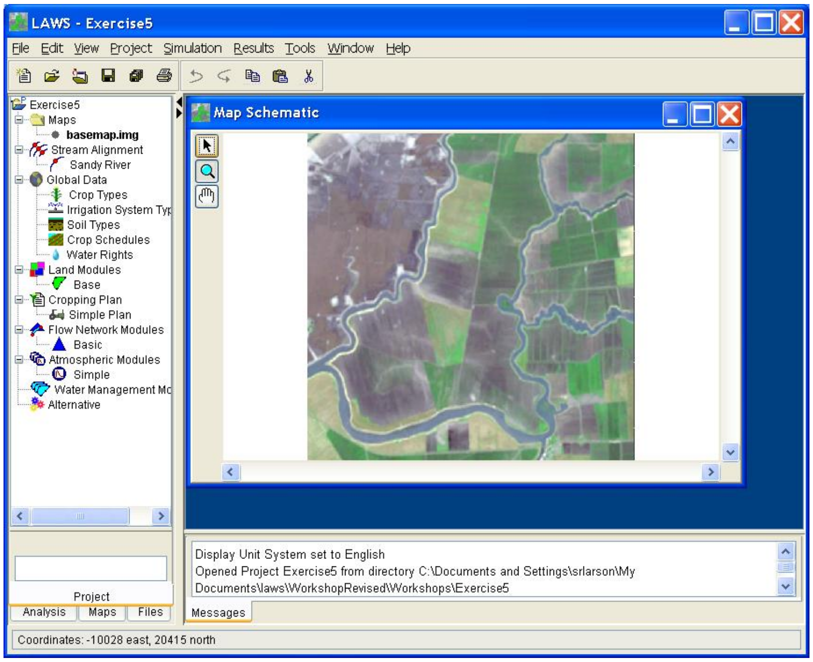


Figure 5.2 - Project Exercise 5

- Open the Sandy River Stream Alignment by right-clicking on the **Sandy River** node label in the Project Tree and selecting **Open** from the popup menu.

The Sandy River stream alignment will draw in the current Map Schematic.

- Open and load the "Base" Land Module by right-clicking on the **Base** node and selecting **Open** from the popup menu.

The Land Managers will appear on the Map Schematic like those pictured below in Figure 5.3.

- Open and load the "Basic" Flow Network Module by right-clicking on the Basic node and selecting **Open** from the popup menu.

Creating a Water Management Module

The Water Management Module holds the three managers that represent the water resource management area.

- Right-click the **Water Management** node  in the Project Tree and select **New...** from the popup menu.
- The **New Water Management** dialog appears. Give the Module the **Name** "Main" and a **Description**.
- Click **OK**.
- A new node  with the label "**Main**" will appear under the **Water Management Module** node. The **Delivery Manager Tool** , will also be added to the current Map Schematic. However, it will not be available for use until the System and Area Mangers are created.

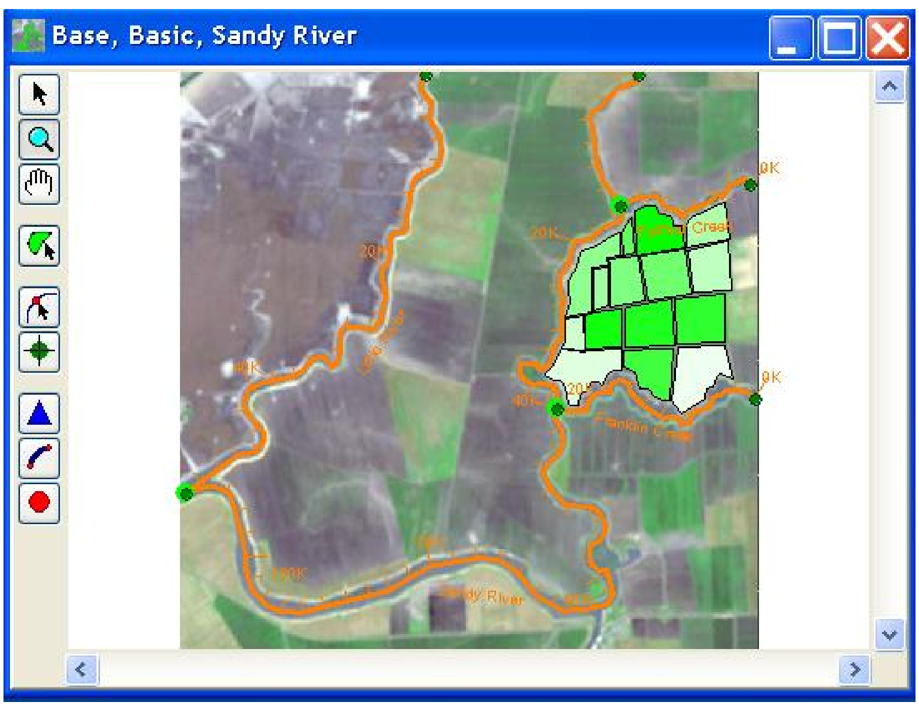


Figure 5.3 - Land Managers

Creating a System Manager

- Right-click on a **Main** Water Management node and select **Edit** -> **System Manger** from the context menu.
- The **System Manager Editor** will appear. In the **System Manager** menu select **New....**
- A **New System Manger** dialog will appear.
- Give the new System Manager the **Name** "Base System" and a **Description** then click **OK**.
- The editor will fill with the new System Manager's information.

Editing the System Manager

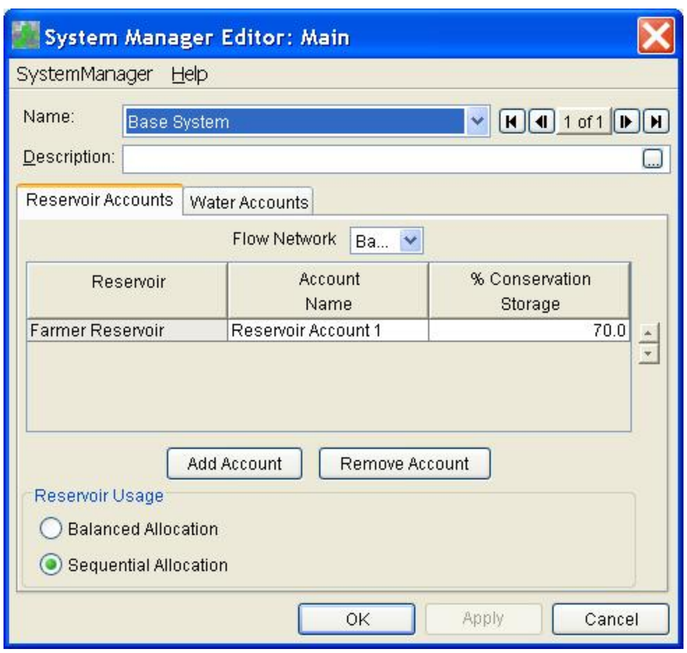


Figure 5.4 - System Manager Editor

TIP: Use the **Help** menu in the editor to learn more about the **System Manager Editor**

Create a Reservoir Account for the System Manager.

- Select the **Add Account** button on the **Reservoir Accounts** tab of the **System Manager Editor** dialog.
- The New **Reservoir Account** dialog will appear.
- **Name** the Reservoir Account "Reservoir Account 1".
- Select Farmer Reservoir in the **Reservoir** dropdown list and click **OK**.
- Set the **% Conservation Storage** for the Reservoir1 to 70% and then click **OK**.
- Save the project changes so far by clicking on the Save All icon  on the main toolbar.

Creating an Area Manager

- Right-click on a **Main** Water Management Node and select **Edit** -> **Area Manager** from the context menu.
- The **Area Manager Editor** will appear. In the **Area Manager** menu select **New....**
- A **New Area Manger** dialog will appear.
- Give the new Area Manager the **Name** "Base Area" and a **Description** then click **OK**.

Editing the Area Manager

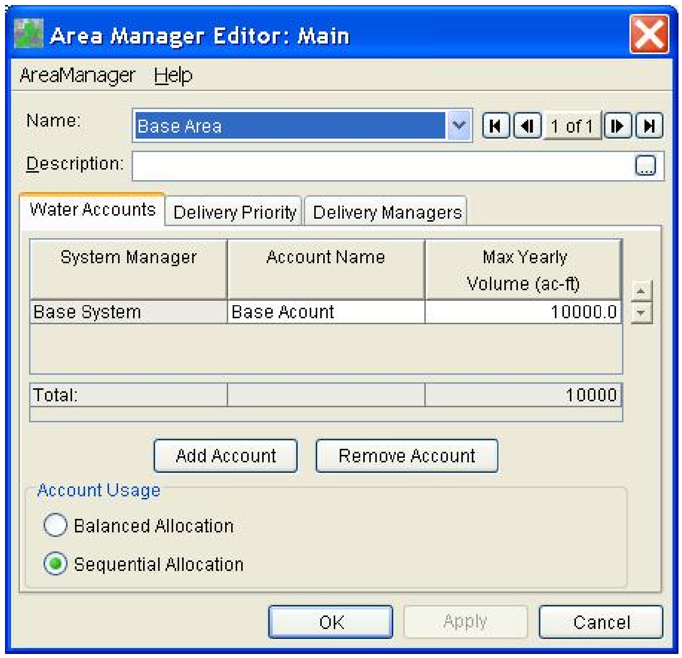
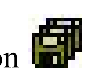


Figure 5.5 - Area Manager Editor

TIP: Use the **Help** menu in the editor to learn more about the **Area Manager Editor**

Link the Area Manager to the System Manager.

- Select the **Add Account** button on the **Water Accounts** tab of the **Area Manager Editor** dialog.
- The **New Water Account** dialog will appear.
- Give the new Water Account the **Name** "Base Account" and a **Description**.
- Select your previously created System Manager in the **System Manager** dropdown list and click **OK**.
- Set the **Max Yearly Volume** to 10000 ac-ft.
- Once you are done, click **OK** to save and close the editor.
- Save the project changes so far by clicking on the Save All icon  on the main toolbar.

Creating Delivery Managers

Delivery Managers are the one piece of the Water Management Module that is created in the Map Schematic. Delivery Managers are drawn over the Land Managers. The Delivery Managers link the actual Land Managers to the Area Managers. In our example, we will create two.

The idea is to enclose Land Managers in the Delivery Managers. In our example we are enclosing the top 8 Land Managers in one Delivery Manager and the bottom 7 in another Delivery Manager. In Figure 5.7 below, the left screen shot shows the Delivery Mangers without displaying the Land Managers. The right-side shows the Land Managers displaying on top of the Delivery Managers.

This exercise is only to get you used to using the tools. Use Figure 5.7 below as a reference on placement, but do not worry about copying it perfectly.

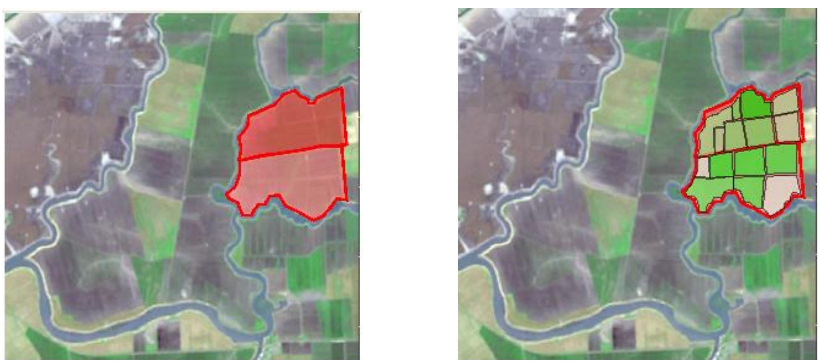


Figure 5.6- Delivery Managers

- Select the **Delivery Manager Tool**  on the Map Schematic.

TIP: The **Delivery Manager Tool** is used exactly like the **Land Manager Tool**.

- While holding down the **Ctrl** key, click in the Map Schematic were you would like to place the first point.
- Continue creating the outline of the manager's shape by clicking points on the map.
- Be sure to encompass each Land Mangers in only one Delivery Manager Area.
- For the final point, release the **Ctrl** key and click near or on the first point.
- Be sure to create an enclosed area and not overlap the outline on itself.
- A dialog will appear prompting you to give the Manager a **Name**, **Description**, and assign it the previously created **Area Manager**.

- Click **OK**.

- The outlined area will be filled in with a transparent color, so you can see the Land Managers it encompasses. Otherwise, it will appear blue. Create as many Delivery Managers as you would like.

- Each Delivery Manager will fill with the color associated with the Area Manger assigned to it. In our case, there is only one Area Manger, so both Delivery Managers will fill with the same color, red.

Editing the Delivery Managers

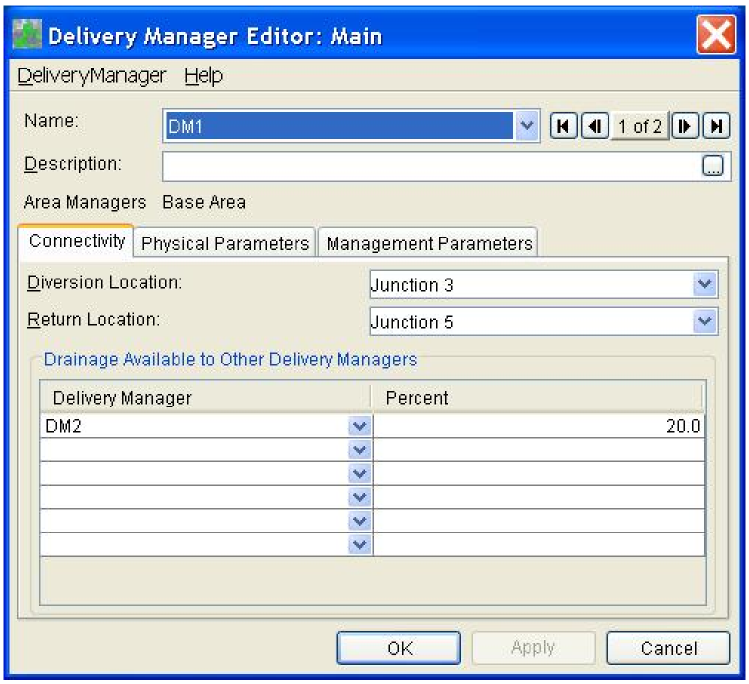


Figure 5.7 - Delivery Manager Editor

TIP: Use the **Help** menu in the editor to learn more about the **Delivery Manager Editor**

- Be sure to select the **Selection Tool** and then double-click on a Delivery Manger in the Map Schematic.

- The **Delivery Manager Editor** dialog will appear.

- On the **Connectivity** tab set the **Diversion Location** to Junction 3 and the **Return Location** to Junction 5.

- Select the other Delivery Manager you created in the **Drainage Available to Other Delivery Managers** and enter the value 20% in the **Percent** column.

- On the **Physical Parameters** tab enter the following values:

    - **Delivery Canal**
        - **Losses to Atmosphere** - 5%
        - **Losses to Groundwater** - 10%

    - **Drain**
        - **Losses to Atmosphere** - 10%
        - **Losses to Groundwater** - 5%

- On the **Management Parameters** tab enter the following information:

    - **Groundwater Min Use** - 0%
    - **Groundwater Max Use** - 80%
    - **Drain Water Re-use** - 10%

- Do not worry about filling the information for the next Delivery Manager. The information will be filled out for you in the next exercise.

- Once you are done filling in the information, click **OK** to save and close the dialog.

Saving the Project and Exiting LAWS

- **Save** the Project by selecting **Save Project** in the **File** menu.

- **Exit** LAWS from the **File** menu.

Exercise 6 – Alternatives, Computing, and Viewing Results

Introduction

In Exercise 6 all the previous exercises come together to create a computable Alternative. Each Module created provides the choices and alternatives for modeling the system. After creating and computing the alternative, results can be viewed. There are four different ways to view results in LAWS:

- Plots
- Summaries
- Reports
- Animation

A LAWS project is provided in the LAWS install directory under the subdirectory LAWS/Workshop/Exercise6. In this exercise, you will gain experience by using a simple fictitious area named Deltaville.

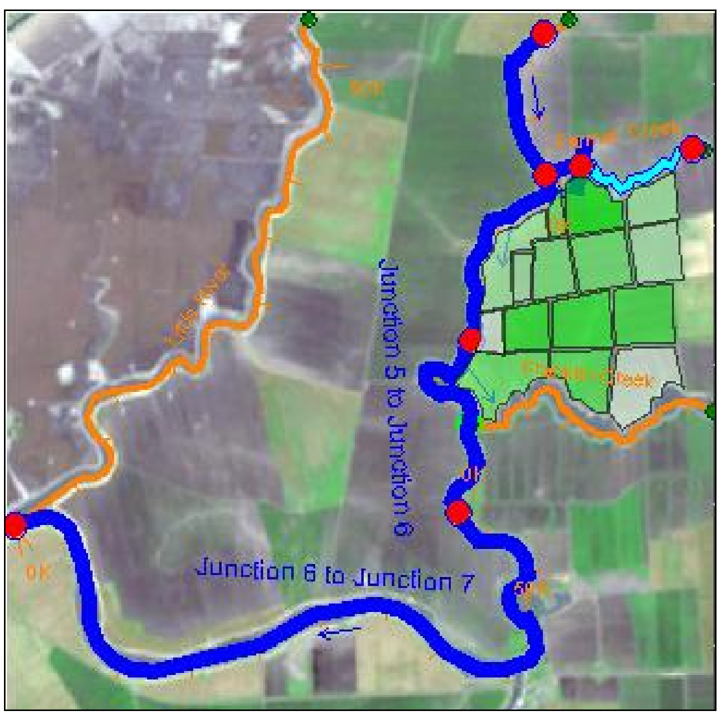


Figure 6.1 - Deltaville Agricultural Region

Task Description

The goal of this exercise is to become familiar with creating, editing, and computing an Alternative. You will also become familiar with interacting with the four types of results: plots, reports, summaries, and animation.

Getting Started

- Launch LAWS by double-clicking on the LAWS Icon on your PC's desktop.
- Select **Open Project** from the **File** menu.
- Browse to the LAWS install directory using the File Browser and select LAWS/Workshop/Exercise6/Exercise6.prj file.
- Then click **Open**.

The Exercise 6 project will load into LAWS.

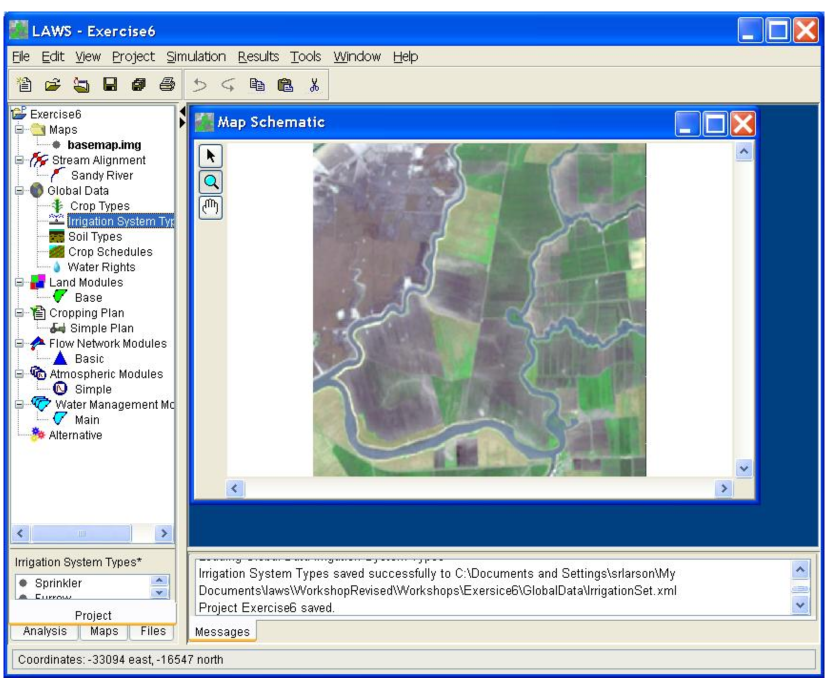


Figure 6.2 - Project Exercise 6

Creating and Editing an Alternative

- Right-click the **Alternative** node in the Project Tree and select **New...** from the popup menu. The **New Alternative** dialog will appear.

- Give the Alternative the **Name** "BaseAlt" and **a Description**. Then click **OK**.

- The **Alternative Editor** dialog will appear with the new Alternative selected for editing.

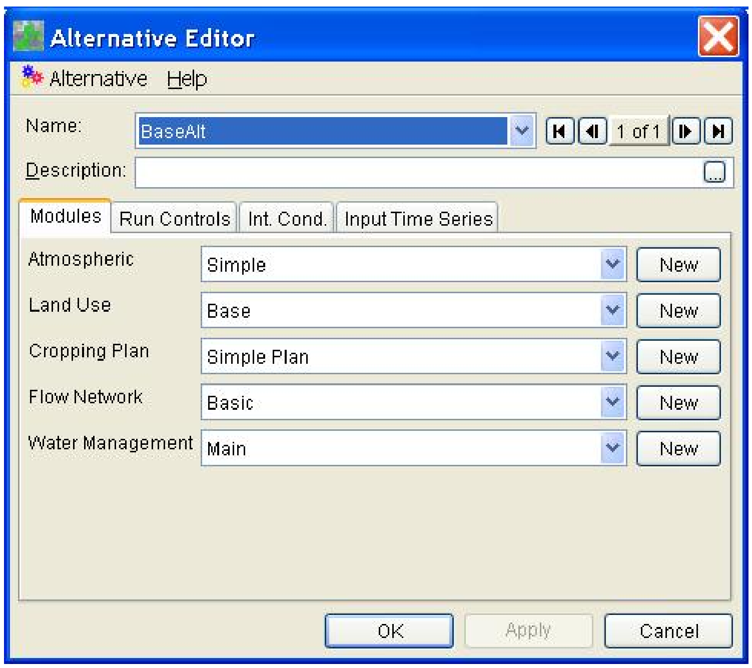


Figure 6.3 - Alternative Editor

Selecting Modules:

- On the **Module** tab of the **Alternative Editor,** select the Modules you would like the Alternative to use. In this example of LAWS, each module has only one choice in their dropdown lists. Select each choice for the corresponding module. If you have any droughts, see **Error! Reference source not found.** above.

Run Controls tab:

- The computation period is specified on this tab. For the **Start Date** enter "31Oct2000". For the **End Date** enter "31Oct2002".

- Click the box next to **Write Land Manager ASCII Output File**.

Input Time Series tab:

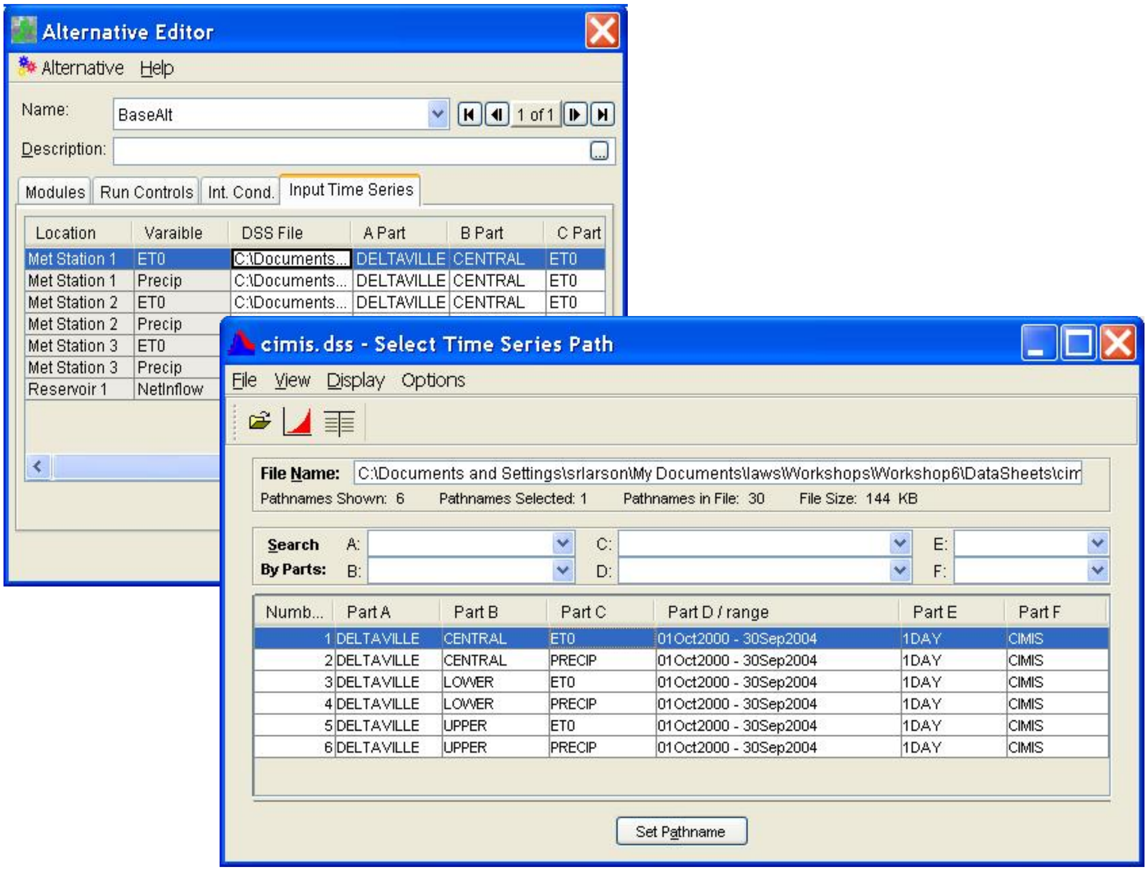


Figure 6.4 - DSS Pathname Selection

On the **Input Time Series** tab, DSS files are assigned to the Met Stations and the Reservoir. Using the following table, assign the corresponding Time Series data to the Met Stations and Reservoir.

Location	Variable	Dss File	Pathname
Met Station 1	ETO	cimis.dss	DELTAVILLE/CENTRAL/ETO
Met Station 1	Precip	cimis.dss	DELTAVILLE/CENTRAL/PRECIP
Met Station 2	ETO	cimis.dss	DELTAVILLE/LOWER/ETO
Met Station 2	Precip	cimis.dss	DELTAVILLE/LOWER/ PRECIP
Met Station 3	ETO	cimis.dss	DELTAVILLE/UPPER/ETO
Met Station 3	Precip	cimis.dss	DELTAVILLE/UPPER/ PRECIP
Reservoir 1	NetInflow	cdec.dss	ORO/RESERVOIR INFLOW

- Click on and highlight a row in the **Input Time Series** table. This will be the first row you will set a DSS pathname for.

- Select the **Browse DSS Paths** button.

- A **Select Time Series Path** dialog displays*.

- In the browser, select **File** -> **Open**. Use the file browser to find the location of the DSS files on the provided in the Workshop directory. The two files you will use are in the LAWS install directory under the following subdirectory: LAWS/Workshop/Exercise6/DataSheets

- Click **OK**.

- The DSS file will fill the **Select Time Series Path** dialog with its available dss paths.

- In the **Select Time Series Path** dialog, click and highlight the path you would like to assign to the highlighted row back on the **Alternative Editor**.

- Click the **Set Pathname** button. This will assign the DSS pathname to the selected row back on the **Alternative Editor**. Once a path is chosen, it will display in the **Alternative Editor's Time Series** table in the row it was assigned to.

- Now assign a pathname to the next row on the **Alternative Editor**. Click on and highlight the next row on the table. Go back to the **Select Time Series Path** dialog and choose the dss pathname. Repeat the process for the remaining rows.
- When you are done, close the **Select Time Series Path** dialog using the button in the upper right-hand side of the dialog.

- Click **OK** to save the changes and close the **Alternative Editor**.

- To display all the map elements for the new Alternative, click on the Alternative's node. Then, while holding down the mouse key, drag the Alternative node to the empty Map Schematic.

- Save the Alternative's data to the project files. Click on the **Save All** icon on the main menu bar.

A full version of* ***HecDssVue* *is available through the* ***Tools*** *menu on the main menu bar. For more information on* ***HecDssVue,*** *see the online help section* ***Interface****,* ***Additional Tools****.*

Computing the Alternative

There are two ways to start the compute running for an Alternative.

- Select **Simulation** -> **Compute Alternative** from the main menu bar or...

- Right-click the Alternative's node and select **Compute** from the popup menu.

Once the Alternative starts computing, a compute progress bar will display. A compute message tab, labeled with the Alternative's name, will be added to the **Messages** Pane area on the bottom of the LAWS screen.

Viewing Plot Results

Once the Alternative has successfully computed, you can access the resulting plots. If you are having trouble with the compute, you can go ahead and open the first completed Exercise6 project provided under the LAWS/Workshop/Completed directory, named Complete.prj.

Plots are accessed through right-click context menus on specific graphics on the Map Schematic.

- Select the **Pointer Tool**  in the Map Schematic.

- Right-click on Reservoir1 and select **Plot Flow and Storage** from the popup menu.

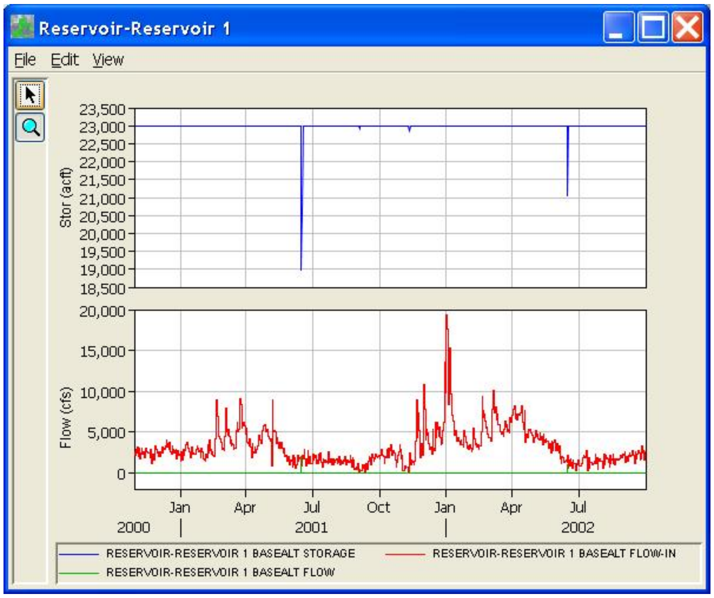
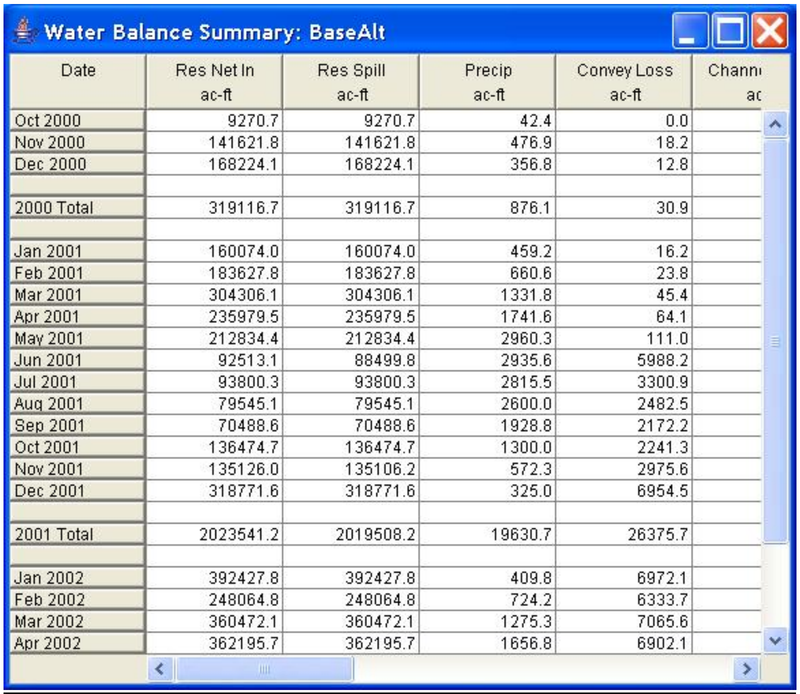


Figure 6. 5 - Plot Dialog

- The **Reservoir Flow and Storage Plot** dialog will appear. Play around with the plot. Use the **Zoom Tool** to get a closer look at the data. Place the mouse over the plot line. Explore the menu options. When you're done, close the Plot window.

- Right-click on other graphics in the map and locate more plots.

Viewing Summary Results


Water Balance Summary: BaseAlt

Date	Res Net In ac-ft	Res Spill ac-ft	Precip ac-ft	Convey Loss ac-ft	Chann ac
Oct 2000	9270.7	9270.7	42.4	0.0	
Nov 2000	141621.8	141621.8	476.9	18.2	
Dec 2000	168224.1	168224.1	356.8	12.8	
2000 Total	319116.7	319116.7	876.1	30.9	
Jan 2001	160074.0	160074.0	459.2	16.2	
Feb 2001	183627.8	183627.8	660.6	23.8	
Mar 2001	304306.1	304306.1	1331.8	45.4	
Apr 2001	235979.5	235979.5	1741.6	64.1	
May 2001	212834.4	212834.4	2960.3	111.0	
Jun 2001	92513.1	88499.8	2935.6	5988.2	
Jul 2001	93800.3	93800.3	2815.5	3300.9	
Aug 2001	79545.1	79545.1	2600.0	2482.5	
Sep 2001	70488.6	70488.6	1928.8	2172.2	
Oct 2001	136474.7	136474.7	1300.0	2241.3	
Nov 2001	135126.0	135106.2	572.3	2975.6	
Dec 2001	318771.6	318771.6	325.0	6954.5	
2001 Total	2023541.2	2019508.2	19630.7	26375.7	
Jan 2002	392427.8	392427.8	409.8	6972.1	
Feb 2002	248064.8	248064.8	724.2	6333.7	
Mar 2002	360472.1	360472.1	1275.3	7065.6	
Apr 2002	362195.7	362195.7	1656.8	6902.1	

Figure 6.6 - Summary Dialog

Summaries are available through the Alternative node's right-click popup menu. The summaries display the total monthly values for a variety of variables computed for the time period.

- View a summary by selecting **View Water Balance Summary** from the Alternative node's popup menu.

TIP: You can also use the **Results** menu to access the summaries.

TIP: Use the scrollbars located on the right-side and bottom of the summary dialog to view more data.

Create a Second Alternative

Before viewing the animation results of the Alternative, let's create a new Alternative to compare the results with. We will use the Alternative we just created, but change some of its data.

Make a new Crop Schedule to use in the new Alternative.

- Double-click on the **Crop Schedule** node. The **Crop Schedule Editor** will appear.
- Select **Crop Schedule** -> **New** from the menu in the editor.
- In the **New** dialog **Name** the new Crop Schedule "Rotation 3".
- Set the new schedule to only plant Wheat with the starting year of 1999.
- When you are done entering the information on Wheat, click **OK** to save and close the editor.

Now create a new Cropping Plan from the original, "Simple Plan", and assign your new Crop Schedule to a few Land Managers.

- Right-click on the "Simple Plan" Cropping Plan and select **Save As** from the popup menu.
- In the **Save Cropping Plan As** dialog, **Name** the new Cropping Plan, "Simple Plan2" and then click **OK**.

The new Cropping Plan will appear as a node under the Cropping Plan section of the Project Tree.

- Open the "Simple Plan2" editor by double-clicking on the node.
- In the **Cropping Plan Editor**, change a few of the Land Managers to use the new "Rotation 3" Crop Schedule. Then click **OK** to save and close the editor.

Create the new Alternative and assign it the new Cropping Plan.

- Right-click on BaseAlt and select **Save As** from the popup menu.
- In the **Save Alternative As** dialog, **Name** the new Alternative "BaseAlt2", then click **OK**.

The new Alternative will appear as a "BaseAlt2" node under the **Alternative** node in the Project Tree.

- Right-click on the BaseAlt2 Alternative's node and select **Edit** from the popup menu. The **Alternative Editor** will appear filled with the BaseAlt2's information.

- On the **Modules** tab of the **Alternative Editor**, select the new "Simple Plan2" Cropping Plan from the **Cropping Plan** dropdown list. Then click **OK** to save and close the editor.

- Save all the changes you made to the project file. Click on the **Save All** icon on the main menu bar.

Viewing Animation Results

Once the second Alternative is computed successfully, its results can be animated along with the original Alternative's results. The animations are defined by color variations of the Land Modules, which change with each time step.

If you are having trouble with computing BaseAlt2, you can open the next completed Exercise6 project containing both Alternatives. The project is provided under the LAWS install directory under the following subdirectory:
LAWS/Workshop/Completed2/Complete2.prj.

Open both Alternatives in separate Map Schematic windows. The first Alternative, BaseAlt, should already be displayed in a Map Schematic window. However, if it is not, double-click on the alternative's node in the Project Tree.

- Double-click on the BaseAlt2 node.

A **Select Map** dialog should appear.

- In the **Select Map** dialog, click the **New Map Window** radio button and then click **OK**.

- The BaseAlt2 Alternative will appear in a new Map Schematic window.

Display the two alternatives side-by-side.

- Select **Window** -> **Tile** in the main LAWS menu bar.

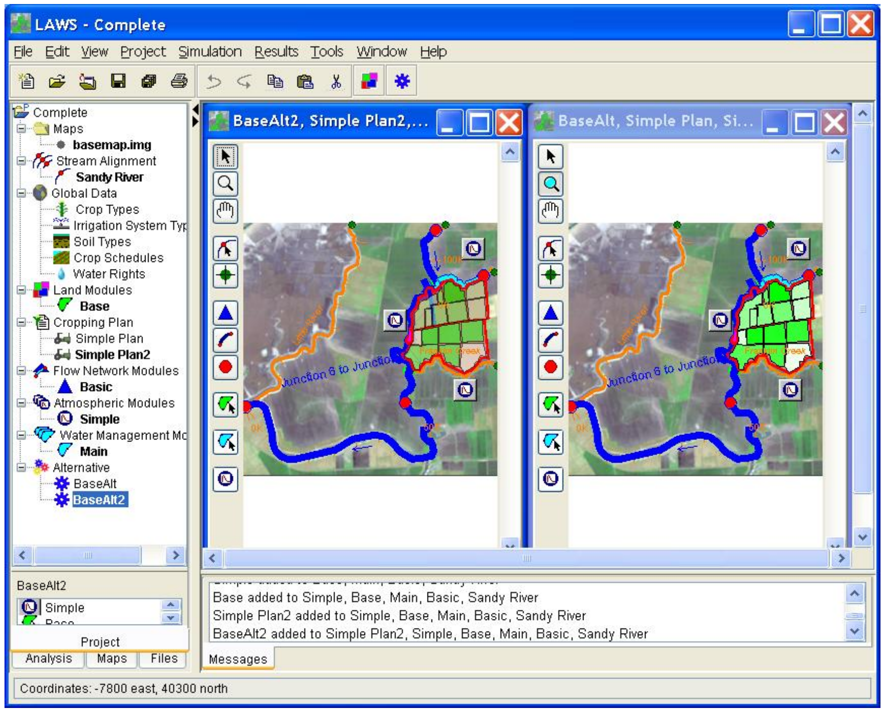


Figure 6.7 - Tile Map Panels

To Animating the Results:

- Select the **Land Module Display Properties Tool** on the main LAWS Toolbar. The **Land Module Display Properties** dialog will display.

Figure 6.8- Land Module Display Properties Dialog

- The model properties available for animation are listed on the left side of the **Land Module Display Properties** dialog.

- Select the **Crop Types** property and click **OK**.

- Notice a color legend appears in the Map Schematic. The legend indicates a color for each Crop Type. As the results are animated, the Land Managers will change color according to the Crop Type's assigned to then at the time step.

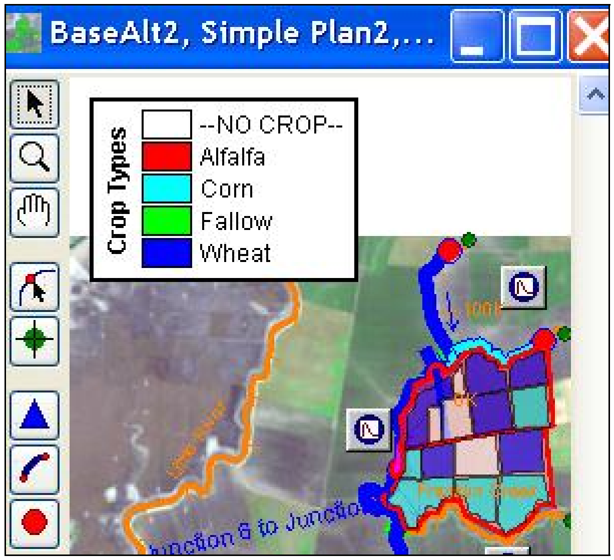
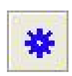


Figure 6.9 - Legend

- Select the next Alternative's Map Schematic window and add a Legend to it by repeating the steps above.

Animate both windows at once.

- Click on the **Animation Tool**  on the main toolbar.

- The **Animation Results** dialog appears.

Figure 6.10 - Animation Controls

- The dialog functions similar to a VCR. There is a play button, fast forward button, etc.

- Click on the play  button.

- To speed up the play, click the fast-forward button.

TIP: You can also speed up the play be increasing the **Play Delays** in the **Set Delays** dialog. To access this dialog select **Configure** -> **Delays** in the **Animation Results** dialog.

As the slider moves along in time, the color variations on the Land Managers will change according to there output values at the time step.

- Continue exploring different variables in the **Land Module Display Properties** dialog.

TIP: The only variables that show color variation when played are those with the gear icon next to them.

Saving the Project and Exiting LAWS

- **Save** the Project by selecting **Save Project** in the **File** menu.

- **Exit** LAWS from the **File** menu.