A.R.M. Loxahatchee National Wildlife Refuge

Simple Refuge Screening Model (v. 4.0) User's Manual

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A.R.M. Loxahatchee National Wildlife Refuge Simple Refuge Screening Model Version 4.00 Report #LOXA009-002

User's Manual

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1. Introduction

As restoration of the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) continues, there is a need for a simple, quantitative methodology for predicting impacts of proposed management changes on Refuge stage. The Simple Refuge Screening Model (SRSM) simulates the water budget, regulation schedule implementation, and constituent dynamics for chloride (Cl), sulfate (SO4), and total phosphorus (TP). This document presents the model in a format that provides users with an understanding of both the theory and implementation of the SRSM. The objective is to give users the ability to accurately simulate various water need scenarios for the Refuge in order to gain a better understanding of this wetlands system and its dynamics. This manual assumes that the reader is generally familiar with the location Refuge hydrologic features, and with water quality issues relevant to the Refuge. For more information, users are directed to the Refuge Comprehensive Conservation Plan (USFWS 2000).

This manual describes version 4.00 of the SRSM. SRSM version 1 was implemented by Jeanne Arceneaux and others (Arceneaux, 2007; Arceneaux et al., 2007; Meselhe et al., 2007) as a daily water budget using Microsoft Excel; the results from this model were then used to drive the constituent model. The constituents were modeled by WASP, a program developed by the United States Environmental Protection Agency. Although there were advantages in using a commonly available spreadsheet program paired with a proven, robust constituent modeling tool, there were also some clear disadvantages. The version 1 implementation was complex and did not easily lend itself to modification. The workbook file was large, and its size grew as more days were simulated. Additionally, the limitation of using a one-day step size required ad-hoc procedures to avoid instability of the solution. Finally, the constituent models in WASP are limited to those provided in the closed-source executable from the USEPA. These factors and a desire to have a single, consistent model platform led to porting the stage and water quality models to the STELLA (http://www.iseesystems.com/index.aspx) simulation platform (version 2). Version 3 of the models ported the earlier version programs to the Berkeley Madonna (http://www.berkeleymadonna.com/index.html) simulation platform. In versions 2 and 3, stage and constituent models were separate. In version 4, models for stage and constituent concentration were combined into a single Madonna program. Use of the Berkeley Madonna commercial numerical differential equation solver package allows greater clarity in coding, supports shorter time steps obviating the need for the ad-hoc procedures of version 1, and provides a well documented user interface.

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1.1. General Description of Model Structure

To calculate water volume the SRSM version 4.00 divides the Refuge into two compartments (also termed boxes or cells), Canal and Marsh, with assumed constant areas of 4.03 million m^2 and 560.02 million m^2, respectively. The rate of change of compartment volumes are calculated using the following differential equation which is based on the water budget for each compartment:

$$\frac{dV_i}{dt} = Q_{net} + A_i \cdot \left(P - G_i - ET_i \right)$$

where:

i = denotes compartment (marsh or canal),
V_i = the compartmental volume (m^3),
t = time (days),
Q_{net} = total flow into a compartment (m^3/day),
A_i = compartment surface area (m^2),
P = precipitation (m/day),
G_i = loss due to groundwater seepage (m/day), and
ET_i = loss due to evapotranspiration (m/day).

SRSM version 4.00 simulates the mass and concentration of chloride (Cl), total phosphorus (TP), and sulfate (SO4). Note that TP mass is measured as phosphorus, not phosphate, and SO4 mass is measured as sulfate, not sulfur. The compartmental design for these calculations differs from the water balance simulation. Here, a concentric arrangement of 4 compartments is used to represent the Refuge. Compartments 1-3 disaggregate the water-budget marsh compartment; compartment 4 represents the canal. Exchange flow is calculated in the marsh based on compartment surface area ratios. Calculation of flow between marsh cells 1-2 and 2-3 is made using a flat-pool assumption, and is analogous to a tidal prism flow calculation.

All constituents are simulated based on a mass balance equation. The loading terms of the mass budget (*qnet*, *gload*, and *aload*) are similar in all three constituents. However, the reactive load term (*rload*) is uniquely structured for each constituent. Chloride is modeled as a conservative constituent with zero reactive load. Its mass is lost or gained solely through the transport of water into or out of the system; therefore, the *rload* term in the following equation should be ignored when chloride is considered. Total Phosphorus (TP) dynamics are approximated with equations adapted from those presented in the Dynamic Model for Stormwater Treatment Areas (DMSTA) developed by Walker and Kadlec[3]. Finally, sulfate (SO4) dynamics are simulated using a Monod relationship. Thus, a general equation for the rate of change of constituent mass in a compartment is given by:

[3] http://wwwalker.net/dmsta/index.htm

$$\frac{dM_{i,j,k}}{dt} = qnet_{i,j,k} - gload_{i,j,k} + aload_{i,j,k} - rload_{i,j,k}$$

where:

i = constituent,
j = compartment number (1-4),
k = DMSTA calibration set (Phosphorus only),
M = mass (g),
t = time (days),
qnet = net mass flow in surface water (g/day),
gload = loss to groundwater seepage and evapotranspiration (g/day),
aload = gain from wet and dry deposition (g/day), and
rload = loss to storage uptake/release (TP) or reaction (SO4) (g/day).

Detailed descriptions of the above equations can be found in the companion model manuscript (Waldon et al., 2009).

1.2. Model Platform – Berkeley Madonna

The SRSM version 4.00 is implemented using the differential equations solver Berkeley Madonna version 8.3.9 (Madonna), which is a proprietary software developed by Robert I. Macey and George F. Oster. This program is the backdrop for the code of the SRSM, and while Madonna has some built-in functions, all SRSM components and processes are user-defined in the **Equations** window; the optional Madonna Flowchart window was not used in SRSM development (in terms used in Madonna documentation, SRSM is a "plain-text" rather than a "visual" model). Figure 1 shows the general format of the Madonna desktop. These windows may be resized or closed by the user. Each of these windows is discussed later in this document.

Madonna also has the capability to perform optimizations, curve-fitting, and sensitivity analyses. For a comprehensive description of all pre-programmed functions, users of the SRSM are encouraged to download the Madonna user's guide from www.berkeleymadonna.com. Additionally, users may download a demo version of this software from the Berkeley Madonna web site and run this version of the SRSM version 4.00[4]. However, while the demo version of the Madonna program allows users to modify and run models, the demo version does not allow the user to save model files or output of any kind.

[4] Available for download at: http://loxmodel.mwaldon.com/

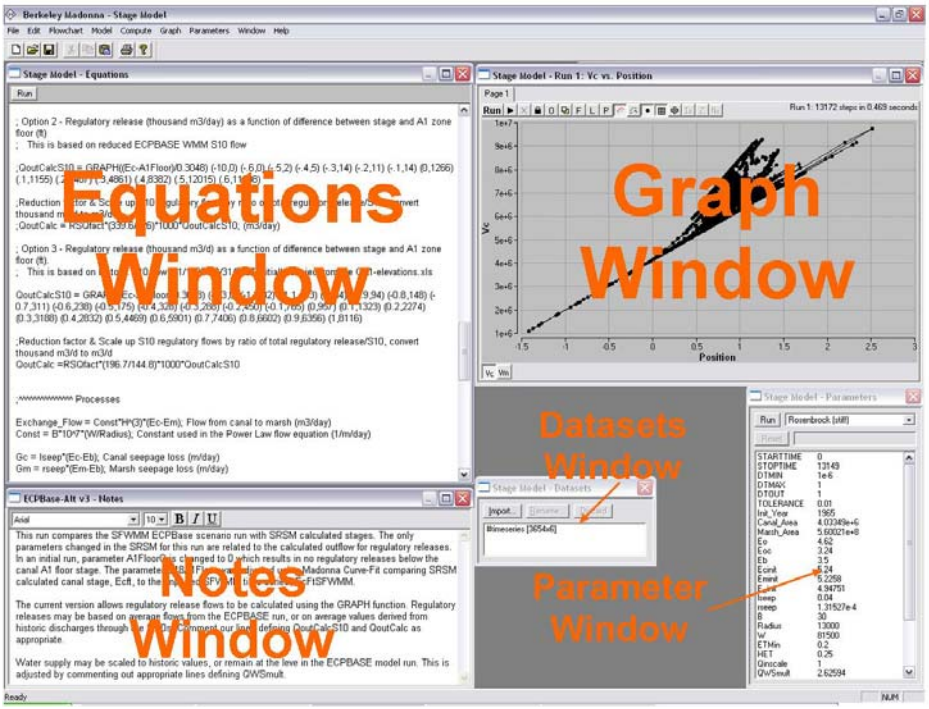

Figure 1 – Madonna model desktop

1.3. User's Manual Objectives

This manual presents the pertinent information required for users to understand the components of SRSM (i.e., imported data, SRSM equation format, and post-processing methods). Ultimately, users should use this document as a companion for the model to assure accurate execution and interpretation.

1.4. Caveats

1.4.1. If unfamiliar with Berkeley Madonna, SRSM users are strongly urged to consult the user's guide before attempting to run or manipulate any of the model components.

1.4.2. All parameter values represent those used to accurately validate and calibrate this model; discretion should be used when altering these values.

1.4.3. This model is set up to simulate a 13-year (1995-2007) period. All time series data needed to successfully run the model are stored within the model file. This manual provides the user with the background and understanding needed to revise this model simulation for other user-selected time periods or scenarios. Should the user want to simulate another time period or alternative conditions, the proper data must be obtained, properly formatted, and imported into the model.

1.4.4. Because of the level of spatial aggregation in the SRSM, the SRSM is not appropriate for applications that involve site-specific events. All results should be considered as spatial average values for the area of study.

1.4.5. This document offers a brief summary of model theory and equations. Users should consult the referenced documentation, the model code, and the companion manuscript for more in-depth descriptions of equations and calibration parameter values.

2. Data Preparation

This section describes how to import the necessary time series text files. The 7 separate data input files are outlined in Table 1.

Filename (alphabetical)	**Data Vectors**	**Summary**
CL.txt	14	Chloride concentration values (mg/L)
INFLOW.txt	20	Historic inflow values (m3/d)
OUTFLOW.txt	20	Historic outflow values (m3/d)
PET.txt	3	Precipitation and Evapotranspiration (m/d)
Regulation.txt	5	Water supply release from S-39 and hurricane releases from S-10 structures (m3/d)
SO4.txt	14	Sulfate concentration values (mg/L)
TP.txt	14	TP concentration values (mg/L)

Table 1 – SRSM input files

Users may create data files for import in any spreadsheet editing program. Madonna imports data files in either tab-delimited text format or comma-separated values (CSV) format. The preloaded input files in the SRSM are primarily derived from data downloaded from the South Florida Water Management District's database (DBHYDRO[5]). Although these data are readily available, and methods of preparation documented (Arceneaux, 2007; Meselhe et al., 2005), it is strongly suggested that the user first run model simulations with the preloaded datasets.

[5] http://www.sfwmd.gov/portal/page?_pageid=2894,19708232&_dad=portal&_schema=PORTAL

2.1. Spreadsheet Formatting

The Berkeley Madonna software imports time series data from a 2-dimensional array dataset. The first column of the array is the time value in days of the simulation beginning with zero and increasing monotonically to the final simulation day (in this case, 0 to 4747). Madonna applies linear interpolation between data values. In order to avoid interpolation in the time series data, the user is encouraged to format the time series such that there are two values (the same value) for each time period (e.g., $t_{1.000}$ = 5.656 and $t_{1.999}$ = 5.656); thus, the imported data become similar to a step function. To minimize the effort, a data organization subroutine may be written into a Visual Basic for Applications (VBA) module in Microsoft Excel. Additionally, the user must note that text and other non-numerical symbols will not be imported into Madonna; in fact, the importing process will cease if Madonna encounters such a symbol. As a reference, an abbreviated example spreadsheet, along with its VBA data organization subroutine, is provided in the Appendix of this document.

2.2. Importing Data

Once a dataset has been created, it may be imported into Madonna by choosing **Import Dataset** from the **File** menu. The user is then prompted to specify the dataset type and filename; in this case all datasets are entered as **2D** and given a specified filename per Table 1 (the file extension should not be included). Madonna syntax requires that the name of the input file be preceded by a pound sign (#). Typically, for 2-dimensional datasets a timing variable must be given; this variable tells Madonna at which times to read imported data. A simple solution is to use the build in function named **TIME**. In Madonna the syntax **TIME** represents a linear function that counts from the specified start time (**STARTTIME**) value to the specified stop time (**STOPTIME**) value based upon the time step (**DT**). The following equations set variables for precipitation (P) and evapotranspiration (ET) to the appropriate imported time series data values:

```
P = #PET(day,1); (m/day)
ET = #PET(day,2); (m/day)
```

where **#PET** indicates the file of imported data being used, **day** is the integer day of the simulation, and the numerical value indicates a column in the imported dataset. Once data are successfully imported, the file name will appear in the Datasets window on the Madonna desktop. Additionally, it is important to note that imported data are saved directly in the Madonna model file (*.mmd). There is no dynamic link between these data and the parent spreadsheet; therefore, any changes to the time series data must be made in the parent *.csv or *.txt file and then re-imported into the Madonna model.

3. Comments, Constant Values, Arrays, & Equations

Comments within the equation window provide model self-documentation, and are an important part of the SRSM documentation. There are two alternative syntaxes for comments in Madonna. Any text between left and right curly brackets, { }, is treated as a comment and not processed. This form of comment can span multiple lines of text. On a single line, all text following a semi-colon is also treated as a comment.

Additionally, in imported text data files, all characters on a line following the first non-numeric character are ignored. This allows comments identifying source or column names to be included within these files.

Equation syntax in Berkeley Madonna is similar to that in other programming languages such as Basic or FORTRAN. The value calculated on the right-hand-side of an equals sign is assigned to the variable on the left-hand-side. Unlike common programming languages, but similar to spreadsheets, Berkeley Madonna is non-procedural; meaning the ordering of the equations is not significant. Berkeley Madonna effectively sorts the equations in order to calculate the value of variables before they are used in subsequent calculations; the program recognizes circular references if such a sorting can not be accomplished (Macey et al., 2000).

Many of the SRSM equations have been consolidated by using arrays. Such equations are set up by using the square brackets ([]) for the values to be arrayed. There are 3 sets of arrayed variables: constituents, compartment, and DMSTA calibration sets. For all equations displayed in sections labeled **3.4.(3-8)** the user can see examples of arrayed initial conditions and differential equations. Labels for each of the arrayed variables are given below.

Arrays are used extensively in SRSM to express equations that are repeated for a range of cells or constituents. Many of the array index values have been programmed as constants to enhance clarity of the code. For example, the equation "tp=3" defines a constant named tp that can be used as an array index (subscript) in place of simply the more obscure number 3. Madonna does identify constants during compilation, and there is apparently no runtime cost associated with this programming style.

```
;DEFINE ARRAYS

  ;REFUGE GEOMETRY
    ncell=4; total number of cells, canal is cell ncell
    nm=ncell-1; number of marsh cells
    canal=ncell; cell number for canal (there is only 1 canal cell in version 4.00)

  ;CONSTITUENTS
    nconstit= 3
    cl= 1; chloride; conservative
    so4=2; sulfate; monod relationship;
    tp= 3; tp modeled with DMSTA equations

  ;DMSTA CALIBRATION SETS
    emerg = 1; Emergent marsh
    pew = 2; Pre-existing wetland
```

Madonna has a unique notation for array operations (Macey et al., 2000). Equations imply looping through a range of subscripts through ranges specified on the left-hand-side of the equation (see for examples sections 3.4.5 and 3.4.6 below). The variables i, j, and k are reserved in Madonna to refer on the right-hand-side of the equation to the first, second, and third array index, respectively, of the variable on the left. This notation replaces loops that are more commonly used in other programming languages.

3.1. Runtime Options

Madonna offers several numerical methods to solve ODEs. The SRSM may be executed accurately and expeditiously using the **RK4** (fourth order Runge-Kutta) method.

The current SRSM is set up to simulate the 13 year period from 1995 to 2007. The user may specify the simulation period with the **STARTTIME** and **STOPTIME** functions. Model coding for the runtime parameters is given below.

3.1.1. Code

```
METHOD RK4
STARTTIME =  0 {JAN95}; 3287 {JAN04}; 1826 {JAN00};
STOPTIME=   4747 {DEC07}; 3652 {DEC04}; 4382 {DEC06};
DT = 0.005
DTOUT = 1
```

By default, Madonna saves model output every calculation time step, which can become costly as model size and complexity increases. The built-in variable **DTOUT** defines the time period that elapses between data storage for a simulation run. Setting **DTOUT** can reduce memory requirements. Here, SRSM output is stored every one time unit (i.e., one day). If the user desires to store all output data, then **DTOUT** should be set equal to zero or, alternatively, the **DTOUT** statement can be removed.

3.2. Parameters

These values fall into two categories for the SRSM code – simulation option parameters, and model parameters. The simulation option parameters are given at the beginning of the model code (found in the **Equations** window). These allow some flexibility with model calculations, input data, and initial conditions. The user can choose outflow type, scale flow and constituent load, choose time series or constant values for boundary concentration, and choose different initial condition sets. The remaining parameters are calibrated and calculated values needed for an accurate base simulation of the SRSM.

All model parameters (constant values) that are not arrayed can also be viewed in the **Parameters** window, which allows the user to change values and reset them without directly changing the code. Parameters with values modified from those set in the **Equations** window are flagged by an asterisk in the **Parameters** window. Users are cautioned that if parameter values are changed using the **Parameter** window, the altered values may persist in future model runs until they are reset. Additionally, the **Overlay Plots** (Figure 3) button can be used to display multiple model runs on the same graph; this feature is very helpful when visually assessing parameter alterations. Lists of all parameters are given in the appendix of this document.

3.3. Processes

Model processes are those equations that contribute to state variable calculation (e.g. groundwater seepage, corrected evapotranspiration, and reaction losses). Such equations represent values that can change with each time step. The user should consult the referenced material for more in depth discussions and explanations of model processes.

3.4. State Variables

Berkely Madonna has several ways to code state variables. The SRSM uses the **d/dt()** option to define differential equations. All SRSM differential equations are given below. It is necessary to specify an initial value for all state variables using the **INIT** initializer syntax.

This version of the SRSM directly calculates the change in volume of the Canal and Marsh compartments as per the 2-compartment structure described by Arceneaux et al. (2007). The stage is then calculated from the volume. It must be noted that the area of the compartments is constant (i.e., it does not change with stage). The calculated value for the exchange flow (canal to marsh flow) is used to drive the volume differential equations for the 4-compartment constituent model.

3.4.1. Initial Volume Values: 2-compartment Model

```
INIT vol_canal = (Ecinit - Eoc) * Canal_Area; Initial Canal Volume (m3)
INIT vol_marsh = (Eminit - Eo) * Marsh_Area; Initial Marsh Volume (m3)
```

3.4.2. Volume Differential Equations: 2-compartment Model

```
d/dt(vol_canal) = NetInFlow - Exchange_Flow +((P- Gc - ETc)*Canal_Area)
d/dt(vol_marsh) =  Exchange_Flow +((P - Gm - ETm)*Marsh_Area)
```

3.4.3. Initial Volume Values: 4-compartment Model

```
INIT vol[1..nm] = (Eminit - Eo) * area[i]
INIT vol[canal] = (Ecinit - Eoc) * area[canal]
```

3.4.4. Volume Differential Equations: 4-compartment Model

```
d/dt(vol[canal])= Qin - Qout - Exchange_Flow + ((P-ETc-Gc)*area[canal])
d/dt(vol[1..nm])= ((P-ETm-Gm)*area[i]) + (Exchange_Flow*qmcfactor[i])
```

In addition to volume state variables the SRSM calculates storage and constituent mass similarly.

3.4.5. Initial Mass Values: Chloride Only

```
INIT mass[cl,1,emerg..pew]= D_M0*area[1]* INIT_Conc[i,j,k]
INIT mass[cl,2,emerg..pew]= D_M0*area[2]* INIT_Conc[i,j,k]
INIT mass[cl,3,emerg..pew]= D_M0*area[3]* INIT_Conc[i,j,k]
INIT mass[cl,canal,emerg..pew]= D_C0*area[canal]* INIT_Conc[i,j,k]
```

3.4.6. Mass Differential Equations

```
{COMPARTMENT 1}  d/dt(mass[1..nconstit, 1,emerg..pew]) =  qload[i, 1,k] - qload[i, 2,k]
+ aload[i, 1] - gload[i, 1,k] + rload[i, 1,k]
{COMPARTMENT 2}  d/dt(mass[1..nconstit, 2,emerg..pew]) =  qload[i, 2,k] - qload[i, 3,k]
+ aload[i, 2] - gload[i, 2,k] + rload[i, 2,k]
{COMPARTMENT 3}  d/dt(mass[1..nconstit, 3,emerg..pew]) =  qload[i, 3,k] + aload[i, 3] -
gload[i, 3,k] + rload[i, 3,k]
{COMPARTMENT 4}  d/dt(mass[1..nconstit, canal,emerg..pew]) = sload[i,j,k] - qload[i,
1,k] + aload[i, canal] - gload[i, canal,k] + rload[i, canal,k]
```

3.4.7. Initial Storage Values

```
INIT dmsta_store[tp, 1..nm, emerg..pew]= init_storage[i,j,k] ; g/m2
```

3.4.8. Storage Differential Equations

```
d/dt(dmsta_store[tp, 1..nm, emerg..pew])= upPrM2[i, j,k] - ((Release[i, j,k] + Burial[i,
j,k])/area[j])
```

3.5. Volume-Stage Relationship

SRSM version 4.00 is structured to incorporate a storage-stage relationship for both the marsh and canal compartments. To maintain consistency with the earlier model version, a constant surface area is currently assumed for each compartment resulting in a linear relationship between storage volume and stage. Canal (**Ec**) and marsh (**Em**) stage values in meters are calculated using the **GRAPH** capability of Madonna. Future versions of the SRSM could include a more detailed volume-stage relationship. However, performance of the model is good without the addition of this complexity.

```
;Stage (m) NGVD 29 is currently calculated using constant area

;                    ( Vc(m3), Ec(m))  Area Canal = 4033485.467 (m2)
Ec = GRAPH (Vc) (-13068492.91,0) (0, 3.24 {Canal bottom elevation}) (27266361.76, 10)
```

```
;                    ( Vm(m3), Em(m))  Area Marsh = 560021212.8 (m2)
Em = GRAPH (Vm) (-2587298003, 0) (0, 4.62 {Marsh bottom elevation}) (3012914125, 10)
```

4. Regulation Schedule

This document assumes that SRSM users are familiar with this WCA-1 Regulation Schedule (USACE 1994), as its specifics are not included here. A description of the Regulation Schedule is available in the *Arthur R. Marshall Loxahatchee National Wildlife Refuge Comprehensive Conservation Plan* (USFWS 2000). The following sub-sections present the Regulation Schedule model code which appears in the Madonna Equations window.

The variables A1FloorFeet and BFloorFeet are the stage in feet (NGVD) of the bottom of the A1 and B Regulation Schedule zones, respectively. For consistency with the SRSM, these variables are converted to meters.

```
A1FloorFeet = GRAPH(DayofYear) (0,17.2) (132, 15.75) (188, 15.75) (267, 17.5) (334, 17.5)
(366, 17.2); Floor of A1 Zone (ft)
BFloorFeet = 14; Floor of B Zone (ft)

A1Floor = A1FloorFeet*0.3048; A1 Floor (m)
BFloor = BFloorFeet*0.3048; B Floor (m)
```

4.1. SRSM Regulatory Release

A regulatory release is a discharge of water out of the Refuge that occurs as a result of the Refuge stage in relation to the Regulation Schedule. Magnitude of outflow during a regulatory release is not specified within the Regulation Schedule. It is therefore necessary to make assumptions related to water management in order to model regulatory releases. The prior version of the SRSM modeled regulatory releases based on historic discharges.

4.2. Regulatory Release Calculations

This section describes calculations used in the Regulation Schedule. Outflow is calculated when the **CalcQRo** value (in the simulation option parameters section) is set to a value of 1; conversely, a value of 0 uses historical outflow in the model simulation. The calculated outflow only represents regulatory releases from certain structures (S10ACDE and S39); therefore, historic outflows from other structures in the Refuge must be imported to supplement the calculated outflow.

```
Qout = IF (CalcQRo = 0) THEN (QoutHistoric) ELSE (QoutCalc + QWaterSupply +
Qout_HistStruct + Qout_hurricane)

Qout_HistStruct = G94A_out + G94B_out + G94C_out + G300_out + S5AS_out + G301_out
+ G338_out; Structures in the north and east involved with water supply
```

; Regulatory release (thousand m3/d) as a function of difference between stage and A1 zone floor (ft).
; This is based on historic S10 flow 1/1/1995 - 8/31/2007 initially copied from file CA1-elevations.xls

QoutCalcS10 = GRAPH((Ec-A1Floor)/0.3048) (-1.3,0) (-1.2,32) (-1.1,113) (-1,64) (-0.9,94) (-0.8,148) (-0.7,311) (-0.6,238) (-0.5,175) (-0.4,328) (-0.3,288) (-0.2,450) (-0.1,765) (0,957) (0.1,1323) (0.2,2274) (0.3,3188) (0.4,2832) (0.5,4469) (0.6,5901) (0.7,7406) (0.8,6602) (0.9,6356) (1,8116)

;Reduction factor & Scale up S10 regulatory flows by ratio of total regulatory release/S10, convert thousand m3/d to m3/d
QoutCalc =RSQfact*(196.7/144.8)*1000*QoutCalcS10

The ratio 196.7/144.8 is the historic average annual total Refuge regulatory release volume divided by the average annual S-10 volume.

5. Model Execution & Post-processing

Berkeley Madonna's user interface for model execution and post-processing is very simple; in fact, they can both be operated from a single location. All operations needed for a general simulation run can be performed in the **Graph** window. The provided image designates the pertinent buttons with which the user should be familiar; however, for explicit explanations on each button, the Berkeley Madonna user's guide (Macey et al., 2000) should be consulted. The model may be executed from the **Graph** window by pressing the **Run** button; otherwise, the user may select **Run** from the **Compute** menu.

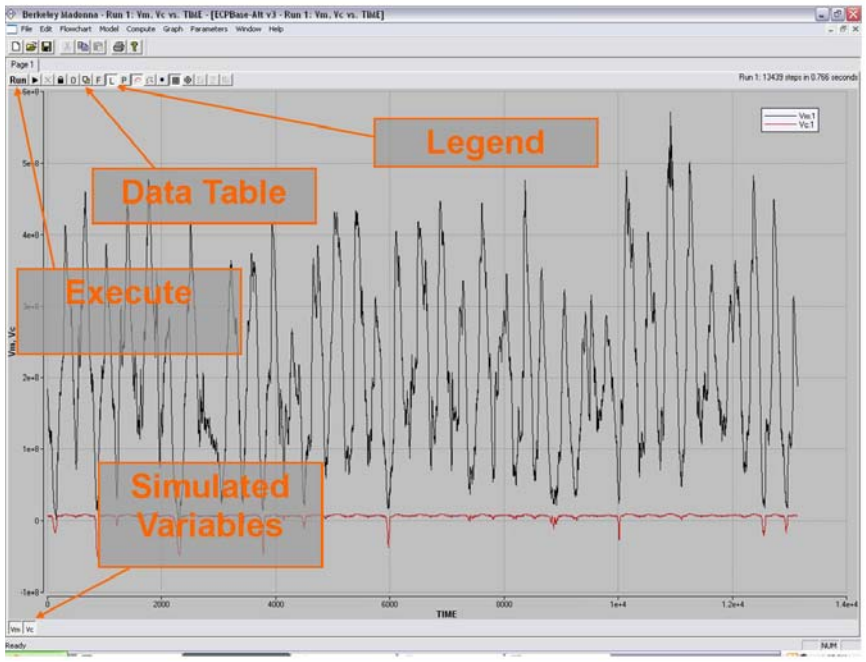

Figure 2 – Graphical Output

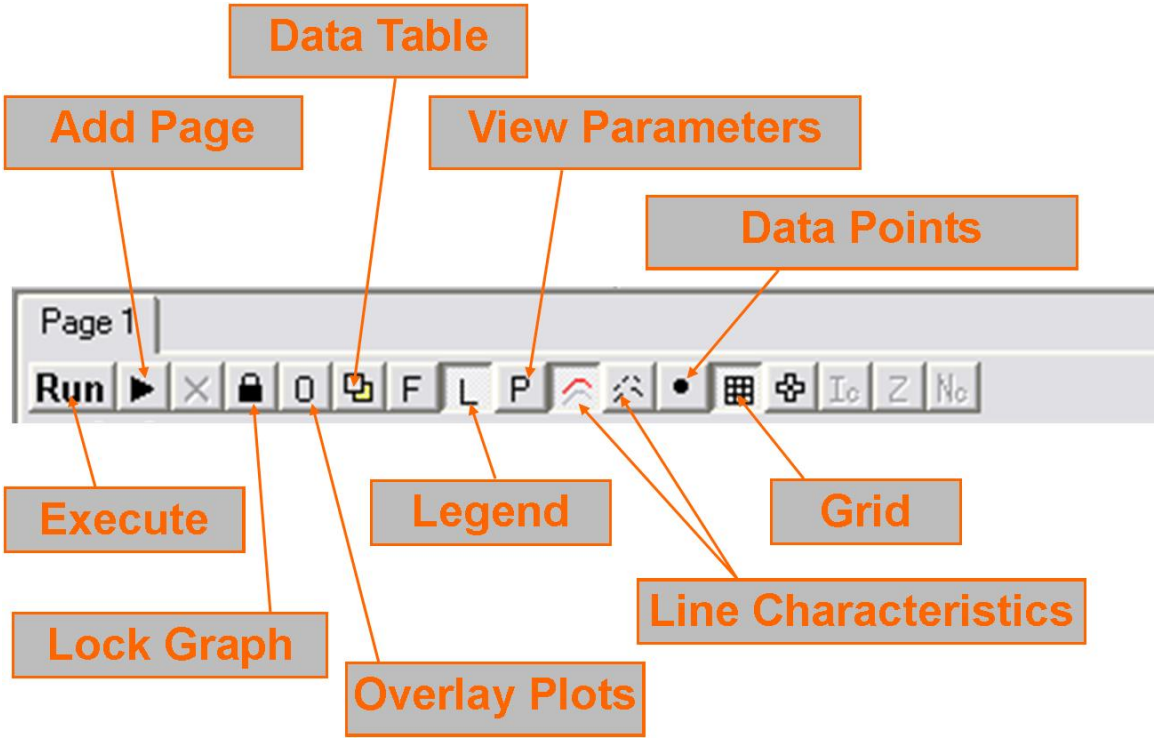

Figure 3 – Graph Toolbar

After pressing the **Run** button, Madonna will automatically output several variables from the model in the **Graph** window. To specify which variables to output, the user can double-click in the window and choose them from a list or select **Choose Variables** from the **Graph** menu. Once the desired variables are chosen and a model run is complete, the user may print the graph directly from Madonna or export the data as *.csv or *.txt. To export data the table must be displayed in the **Graph** window by clicking the **Data Table** button (see Figure 3). Then the user can select **Export Table** from the **File** menu, or use the **Copy Table** selection under the edit drop down menu.

For further information, users may contact the authors by email at:

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William Roth (wbr9736@louisiana.edu)

Citations

Arceneaux, J. (2007). "The Arthur R. Marshall Loxahatchee National Wildlife Refuge Water Budget and Water Quality Models," MS. Thesis, University of Louisiana, Lafayette, LA.

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Appendix

1. Example Spreadsheet Format

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	0	1	2	3	4	5	6	x	1 - Orig	2 - Orig	3 - Orig	4 - Orig	5 - Orig	6 - Orig
2	0	0.000087	0.00169	1838840	7106052	1	7106052	x	0.000087	0.00169	1838840	7106051.836	1	7106051.836
3	0.999	0.000087	0.00169	1838840	7106052	1	7106052	x	0	0.0024	1892298	7237825.712	2	7237825.712
4	1	0	0.0024	1892298	7237826	2	7237826	x	0.000097	0.0021	2162085	6986682.222	3	6986682.222
5	1.999	0	0.0024	1892298	7237826	2	7237826	x	0.008411	0.0019	646000.3	6033070.94	4	6033070.94
6	2	0.000097	0.0021	2162085	6986682	3	6986682	x	0.004089	0.001	2638046	5307923.166	5	5307923.166
7	2.999	0.000097	0.0021	2162085	6986682	3	6986682	x	0.000216	0.002	4257818	5555959.474	6	5555959.474
8	3	0.008411	0.0019	646000.3	6033071	4	6033071	x	0.005072	0.0008	1856578	5478255.458	7	5478255.458
9	3.999	0.008411	0.0019	646000.3	6033071	4	6033071	x	0.006708	0.0023	2683455	5464799.158	8	5464799.158
10	4	0.004089	0.001	2638046	5307923	5	5307923	x	0	0.0027	3006431	6728223.398	9	6728223.398
7300	3649	0.000097	0.0014	928998.5	861937.2	363	861937.2	x						
7301	3649.999	0.000097	0.0014	928998.5	861937.2	363	861937.2	x						
7302	3650	0.000093	0.0018	659921.4	443495.2	364	443495.2	x						
7303	3650.999	0.000093	0.0018	659921.4	443495.2	364	443495.2	x						
7304	3651	0	0.0026	435837.3	440314.6	365	440314.6	x						
7305	3651.999	0	0.0026	435837.3	440314.6	365	440314.6	x						
7306	3652	0.000957	0.0015	450883.9	319501.5	366	319501.5	x						
7307	3652.999	0.000957	0.0015	450883.9	319501.5	366	319501.5	x						

Figure 4 – Sample Excel Spreadsheet

2. Data Formatting with VBA

```
Sub LoopRange1()

'have x & z start at row 2
'have y start at row 3

x = 2
z = 2
y = 3

‘loop until a blank row is found
‘for the purposes of this we need a column of 7306 (3653*2) values
‘in order to separate the input data appropriately.
‘note that this is set up for data to be read only in column 2 (date column)
‘and for the sorted data to be output in columns B, C, D, E, F and G.

Do While Cells(x, 1).Value <> ""

    'This will put the values of the
    '9th column (I) in the 2nd
    'column (B) such that data
    'abcd... become aabbccdd...

    Cells(x, 2).Value = Cells(z, 9).Value
    Cells(y, 2).Value = Cells(z, 9)

    Cells(x, 3).Value = Cells(z, 10).Value
    Cells(y, 3).Value = Cells(z, 10)

    Cells(x, 4).Value = Cells(z, 11).Value
    Cells(y, 4).Value = Cells(z, 11)

    Cells(x, 5).Value = Cells(z, 12).Value
    Cells(y, 5).Value = Cells(z, 12)
```

```
    Cells(x, 6).Value = Cells(z, 13).Value
    Cells(y, 6).Value = Cells(z, 13)

    Cells(x, 7).Value = Cells(z, 14).Value
    Cells(y, 7).Value = Cells(z, 14)

    'increse the value of x by 2 in order to create the spacing and increase the
    'value of z by 1 to read the data in the correct order (ie row by row).
'Y increases by 2 to insert data in rows "skipped" by x+2 term.

    x = x + 2
    z = z + 1
    y = y + 2

Loop

End Sub
```

3. Imported Datasets

Provided below is a list of all imported datasets and their respective variable names used in the SRSM.

Variable Name	File	Column	Description
P	PET	1	Area average precipitation (m/day)
ET	PET	2	Observed evapotranspiration (m/day)
S39_out	OUTFLOW	1	Observed structure outflow (m3/day)
G94A_out	OUTFLOW	2	Observed structure outflow (m3/day)
G94B_out	OUTFLOW	3	Observed structure outflow (m3/day)
G94C_out	OUTFLOW	4	Observed structure outflow (m3/day)
G300_out	OUTFLOW	8	Observed structure outflow (m3/day)
S5AS_out	OUTFLOW	9	Observed structure outflow (m3/day)
G301_out	OUTFLOW	11	Observed structure outflow (m3/day)
G338_out	OUTFLOW	15	Observed structure outflow (m3/day)
S10E_out	OUTFLOW	16	Observed structure outflow (m3/day)
S10D_out	OUTFLOW	17	Observed structure outflow (m3/day)
S10C_out	OUTFLOW	18	Observed structure outflow (m3/day)
S10A_out	OUTFLOW	19	Observed structure outflow (m3/day)
G94A_in	INFLOW	2	Observed structure inflow (m3/day)
G94C_in	INFLOW	4	Observed structure inflow (m3/day)
G94D_in	INFLOW	5	Observed structure inflow (m3/day)
ACME1_in	INFLOW	6	Observed structure inflow (m3/day)
S362_in	INFLOW	7	Observed structure inflow (m3/day)
G300_in	INFLOW	8	Observed structure inflow (m3/day)
S5AS_in	INFLOW	9	Observed structure inflow (m3/day)
S5A_in	INFLOW	10	Observed structure inflow (m3/day)
G301_in	INFLOW	11	Observed structure inflow (m3/day)
G310_in	INFLOW	12	Observed structure inflow (m3/day)
G251_in	INFLOW	13	Observed structure inflow (m3/day)
S6_in	INFLOW	14	Observed structure inflow (m3/day)
G338_in	INFLOW	15	Observed structure inflow (m3/day)
S10A_hurricane	Regulation	1	Supplementary emergency water release (m3/day)
S10C_hurricane	Regulation	2	Supplementary emergency water release (m3/day)

S10D_hurricane	Regulation	3	Supplementary emergency water release (m3/day)
S39_WS	Regulation	4	Supplementary water supply release (m3/day)
G94A_TP	TP	1	Observed total phosphorus concentration (mg/L)
G94C_TP	TP	2	Observed total phosphorus concentration (mg/L)
G94D_TP	TP	3	Observed total phosphorus concentration (mg/L)
ACME1_TP	TP	4	Observed total phosphorus concentration (mg/L)
S362_TP	TP	5	Observed total phosphorus concentration (mg/L)
G300_TP	TP	6	Observed total phosphorus concentration (mg/L)
S5AS_TP	TP	7	Observed total phosphorus concentration (mg/L)
S5A_TP	TP	8	Observed total phosphorus concentration (mg/L)
G301_TP	TP	9	Observed total phosphorus concentration (mg/L)
G310_TP	TP	10	Observed total phosphorus concentration (mg/L)
G251_TP	TP	11	Observed total phosphorus concentration (mg/L)
S6_TP	TP	12	Observed total phosphorus concentration (mg/L)
G338_TP	TP	13	Observed total phosphorus concentration (mg/L)
G94A_Cl	CL	1	Observed chloride concentration (mg/L)
G94C_Cl	CL	2	Observed chloride concentration (mg/L)
G94D_Cl	CL	3	Observed chloride concentration (mg/L)
ACME1_Cl	CL	4	Observed chloride concentration (mg/L)
S362_Cl	CL	5	Observed chloride concentration (mg/L)
G300_Cl	CL	6	Observed chloride concentration (mg/L)
S5AS_Cl	CL	7	Observed chloride concentration (mg/L)
S5A_Cl	CL	8	Observed chloride concentration (mg/L)
G301_Cl	CL	9	Observed chloride concentration (mg/L)
G310_Cl	CL	10	Observed chloride concentration (mg/L)
G251_Cl	CL	11	Observed chloride concentration (mg/L)
S6_Cl	CL	12	Observed chloride concentration (mg/L)
G338_Cl	CL	13	Observed chloride concentration (mg/L)
G94A_SO4	SO4	1	Observed sulfate concentration (mg/L)
G94C_SO4	SO4	2	Observed sulfate concentration (mg/L)
G94D_SO4	SO4	3	Observed sulfate concentration (mg/L)
ACME1_SO4	SO4	4	Observed sulfate concentration (mg/L)
S362_SO4	SO4	5	Observed sulfate concentration (mg/L)
G300_SO4	SO4	6	Observed sulfate concentration (mg/L)
S5AS_SO4	SO4	7	Observed sulfate concentration (mg/L)
S5A_SO4	SO4	8	Observed sulfate concentration (mg/L)
G301_SO4	SO4	9	Observed sulfate concentration (mg/L)
G310_SO4	SO4	10	Observed sulfate concentration (mg/L)
G251_SO4	SO4	11	Observed sulfate concentration (mg/L)
S6_SO4	SO4	12	Observed sulfate concentration (mg/L)
G338_SO4	SO4	13	Observed sulfate concentration (mg/L)

4. Simulation Option Parameters

Variable Name	Default Value	Explanation
CalcQRo	1	Distinguishes between calculated (1) or historic outflow (0)

Qinscale	1	Scaling factor for structure inflow
QWSmult	1	Scaling factor for water supply demand
RSQfact	1	Scaling factor for regulatory release
SCALE_TPLOAD	1	Scaling factor for total phosphorus load
SCALE_CLLOAD	1	Scaling factor for chloride load
SCALE_SO4LOAD	1	Scaling factor for sulfate load
constTPConc	0	Distinguishes between timeseries data (1) or constant value (0) for inflow TP concentration
constCLConc	0	Distinguishes between timeseries data (1) or constant value (0) for inflow CL concentration
constSO4Conc	0	Distinguishes between timeseries data (1) or constant value (0) for inflow SO4 concentration
constTP_CONC	0.01	Constant value for TP inflow
constCL_CONC	80	Constant value for CL inflow
constSO4_CONC	30	Constant value for SO4 inflow
SET	1	Distinguishes between initial condition sets for start date (1) 1995 (2) 2004 (3) 2000

5. Model Parameters

Variable Name	Value	Description
Canal_Area	4033485.468	Canal surface area (m2)
Marsh_Area	560021212.8	Marsh surface area (m2)
Eo	4.62	Marsh bottom elevation (m)
Eoc	3.24	Canal bottom elevation (m)
Eb	3.5	Water stage outside Refuge (m)
lseep	0.042	Canal seepage constant (1/day)
rseep	0.000349076	Marsh seepage constant (1/day)
B	30	Transport coefficient (1/m-day)
Radius	13000	Average marsh radius (m)
W	81500	Average marsh width (m)
ETMin	0.2	ET reduction factor
HET	0.25	ET depth reduction boundary (m)
area[1]	89359148.07	Surface area of compartment 1 (m2)
area[2]	224100185	Surface area of compartment 2 (m2)
area[3]	246561879.8	Surface area of compartment 3 (m2)

area[canal]	4033485.467	Surface area of compartment 4 (m2)
evap	0.65	Fraction of ET that is evaporation
transp	0.35	Fraction of ET that is transpiration
WetDep[cl]	2	Chloride concentration in rainfall (mg/L)
DD[cl]	1136	Chloride dry deposition (mg/m2-yr)
WetDep[so4eco]	1	Sulfate concentration in rainfall (mg/L)
DD[so4eco]	138.2	Sulfate dry deposition (mg/m2-yr)
WetDep[dmsta_constit]	0.01	Phosphorus concentration in rainfall (mg/L)
DD[dmsta_constit]	10	Phosphorus dry deposition (mg/m2-yr)
khalfSO4	1	Sulfate half saturation constant (g/m3)
MaxSO4Removal	14.4	Maximum sulfate removal (g/m2-yr)
benthic	0	Internal loading rate for the canal (g/m2-day)
K1[emerg]	0.1064	Phosphorus (Emergent Wetland) maximum uptake rate (m3/mg-yr)
K1[pew]	0.221	Phosphorus (Pre-existing Wetland) maximum uptake rate (m3/mg-yr)
K2[emerg]	0.002	Phosphorus (Emergent Wetland) recycle rate (m2/mg-yr)
K2[pew]	0.0042	Phosphorus (Pre-existing Wetland) recycle rate (m2/mg-yr)
K3[emerg]	0.3192	Phosphorus (Emergent Wetland) burial rate (1/yr)
K3[pew]	0.6631	Phosphorus (Pre-existing Wetland) burial rate (1/yr)
mindepth	0.05	Minimum water depth (m)