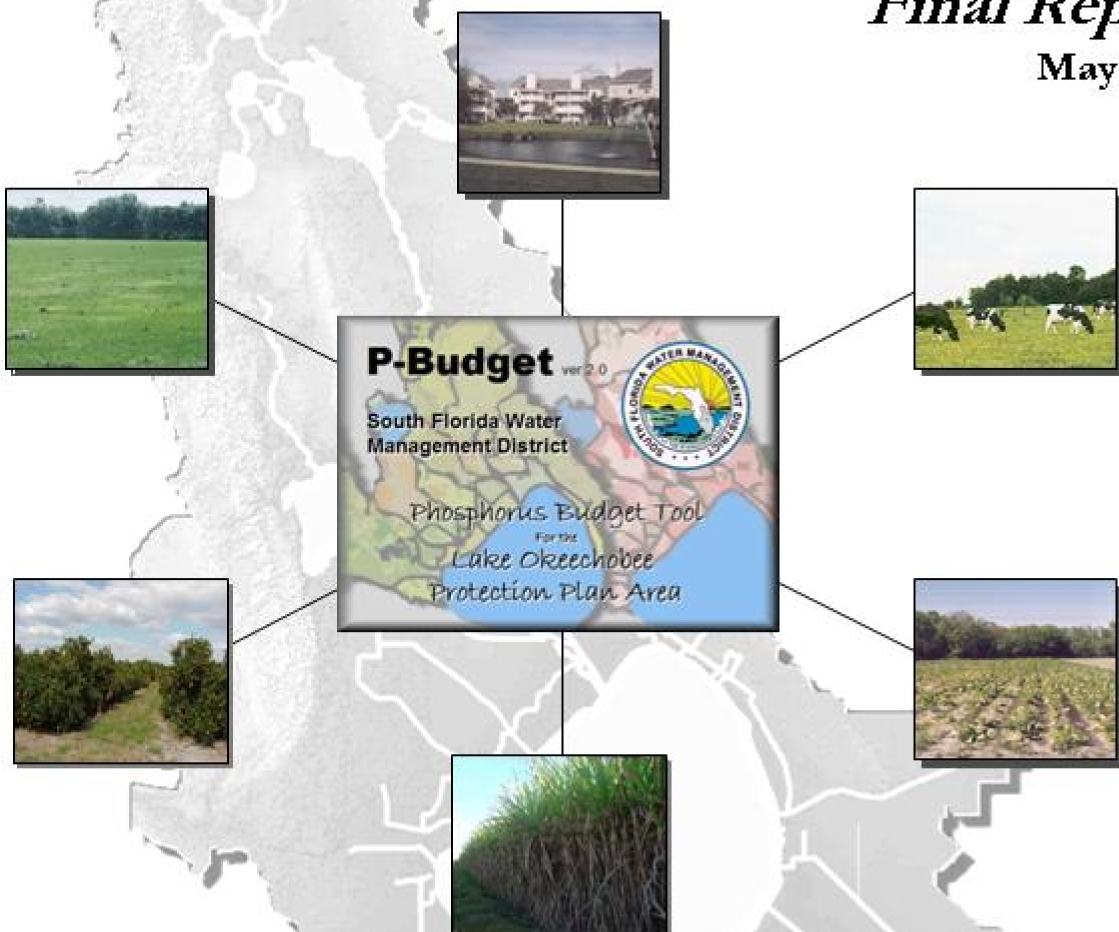
# Development of a Graphical User Interface for Analyzing Phosphorus Load and Import/Export in the Lake Okeechobee Protection Plan Area

Contract Number RS040634

*Final Report*

May 2005

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## ACKNOWLEDGMENTS

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## ENGINEER'S CERTIFICATION

I hereby certify, as a Professional Engineer in the State of Florida, that the information in this Final Report for project entitled Development of a Graphical User Interface for Analyzing Phosphorus Load and Import/Export in the Lake Okeechobee Protection Plan Area was assembled under my direct responsible charge. The information provided herein was based on the information that was available and obtained from the South Florida Water Management District and other sources identified herein**.** The certifying Engineer cannot be responsible for added or deleted information once distributed. This report is not intended or represented to be suitable for any reuse without specific verification or adoption by the Engineer. This Certification is provided in accordance with the Florida Board of Professional Engineers' Rule on Certification under Chapter 61G15-29.

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# Final Report

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**Appendix A**



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**List of Abbreviations**

AML - ARC/INFO Macro Language
AOI - Area of Interest
BMP - Best Management Practice
CERP - Comprehensive Everglades Restoration Plan
DEM - Digital Elevation Map
DOQ - Digital Ortho Quadrangle
EAA - Everglades Agricultural Area
EMC - Event Mean Concentration
ERP - Environmental Resource Protection
ESRI - Environmental Services Research Institute
FDACS - Florida Department of Agriculture and Consumer Services
FDEP - Florida Department of Environmental Protection
FEC - Fisheating Creek
FLUCCS - Florida Land Use Cover Classification System
GIS - Geographic Information System
GLEAMS - Groundwater Loading Effects of Agricultural Management Systems
GUI - Graphical User Interface
HUC - Hydrologic Unit Code
KREA - Kissimmee River Eutrophication Abatement
LOPP - Lake Okeechobee Protection Plan
LOWA - Lake Okeechobee Watershed Assessment
NHD - National Hydrologic Dataset
PCP - Phosphorus Control Plan
SFWMD - South Florida Water Management District
SLO - Southern Lake Okeechobee region
SSURGO - Soil Survey Geographic (database)
TCNS - Taylor Creek/Nubbin Slough
UFA - Upper Floridan Aquifer
USGS - United States Geological Survey
VBA - Visual Basic for Applications
WAM - Watershed Assessment Model
WOD - Works of the District

# Development of a Graphical User Interface for Analyzing Phosphorus Load and Import/Export in the Lake Okeechobee Protection Plan Area

## 1.0 Introduction and Background

The Lake Okeechobee watershed spans from just south of Orlando to areas bordering the lake on the south, east, and west and covers approximately 5,500 square miles. This watershed, known as the Lake Okeechobee Protection Plan (LOPP) area, includes several regions (Figure 1) that contribute runoff discharge to the lake. Phosphorus in the discharge has been identified as the primary cause of eutrophication of the lake. The contribution of phosphorus load to Lake Okeechobee from some locations has risen dramatically in recent years. Nutrient levels in the runoff are directly related to land use and land use practices.

The Lake Okeechobee Protection Program (SFWMD, 2004) is designed for the protection and restoration of Lake Okeechobee. This is to be accomplished by achieving and maintaining compliance with State water quality standards through a watershed-based protection program designed to reduce phosphorus loads and implement long-term solutions. This program is jointly administered by the South Florida Water Management District (District), the Florida Department of Environmental Protection (FDEP), and the Florida Department of Agriculture and Consumer Services (FDACS). The program was established under the 2000 Lake Okeechobee Protection Act (Florida Statutes, Chapter 373.4595) and consists of seven components:

- Lake Okeechobee Protection Plan (LOPP)
- Lake Okeechobee Construction Project
- Lake Okeechobee Watershed Phosphorus Control Program
- Lake Okeechobee Research and Water Quality Monitoring Program
- Lake Okeechobee Exotic Species Control Program
- Lake Okeechobee Internal Phosphorus Management Program
- Annual Progress Report

This is a multifaceted approach to reduce phosphorus loads through continued implementation of existing regulations and best management practices, development and implementation of improved best management practices, improvement and restoration of the hydrologic functions of the natural and managed systems and use of alternative technologies for nutrient reduction.

A materials balance approach to phosphorus management provides information about the total amount of phosphorus that enters and exits the watershed on an annual basis. Accounting for imports and exports of phosphorus containing materials provides a baseline for field research and a more detailed understanding of how changes in management practices affect phosphorus flow. Materials balance is a particularly useful tool when linked to a Geographical Information System (GIS) such as ArcGIS™ for spatial representation and analysis.

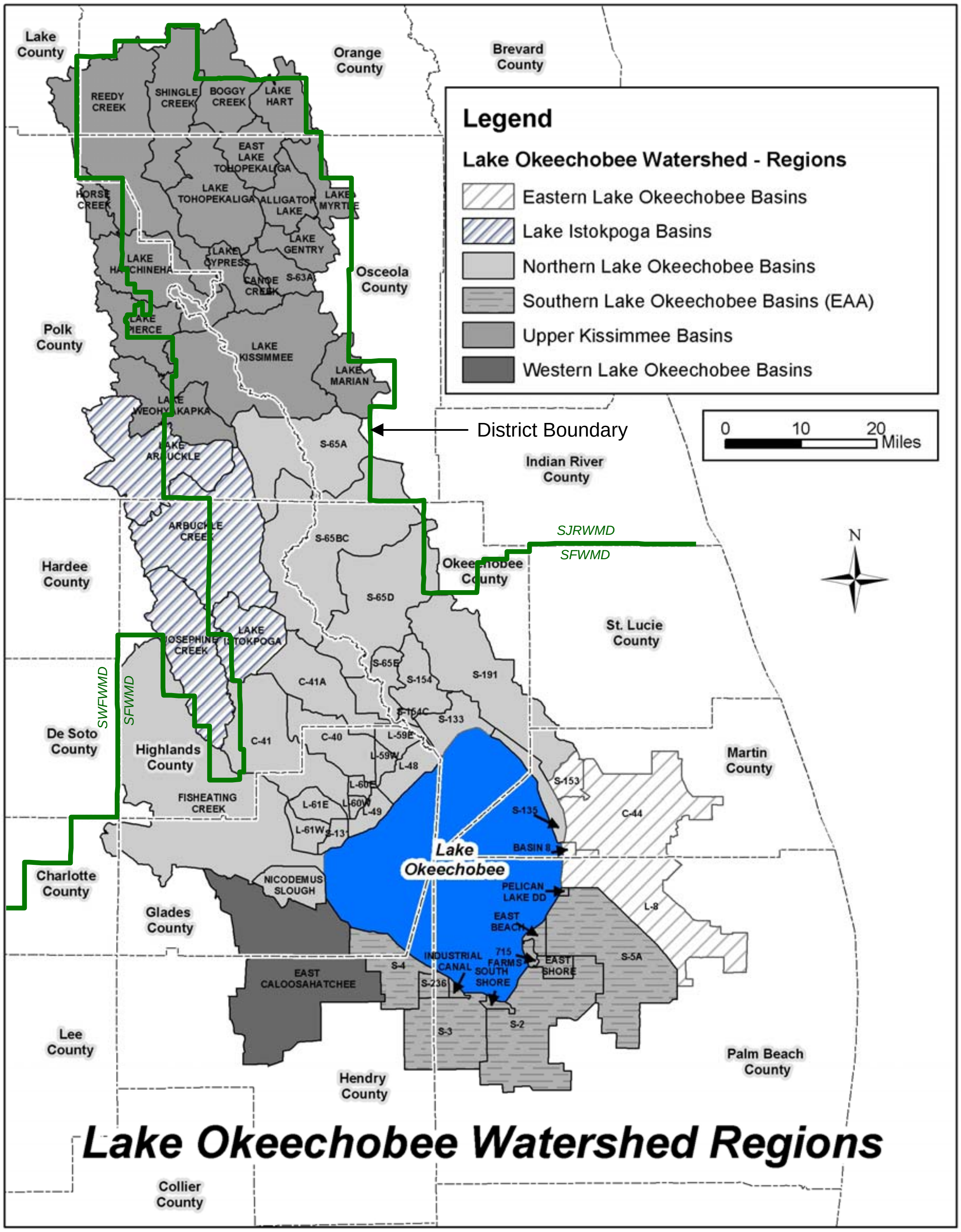


Figure 1: Lake Okeechobee Watershed with Six Drainage Regions

Phosphorus cycling in the environment is a function of both natural processes (e.g. plant uptake, senescence, and mineralization of organic matter) and anthropogenic factors (e.g. agriculture, fertilization, mining, and human consumption). The effects of these processes on water quality are determined by land use patterns and phosphorus discharge associated with each land use.

In 2002, a phosphorus budget analysis was conducted for the northern Lake Okeechobee drainage basins (Hiscock et al., 2003). This analysis included the development of a graphical user interface (GUI), known as P-Budget, written in ArcView™ (Version 3.2a) Avenue™. This interface allows a user to select one or more (or all) basins of the watershed within a GIS environment and apply phosphorus controls to the specified land uses to assess the effects on phosphorus import, export and net import.

The P-Budget interface includes of phosphorus coefficients in terms of grams per hectare based on landowner surveys and other research information from the 2002 P-Budget analysis. Coefficients were established for various import and export components (e.g., fertilizer and harvest rates) for each land use.

In 2003, a similar phosphorus budget analysis was conducted for the basins located within the Lake Istokpoga and Upper Chain of Lakes watersheds (Mock-Roos Team, 2003). These watersheds were added to the P-Budget interface. The interface was updated at this time to include the phosphorus runoff results from the public domain Watershed Assessment Model (WAM) to replace the Event Mean Concentration (EMC) approach used in the northern Lake Okeechobee watershed. WAM is a physical-based model that uses site-specific information such as soils, rainfall, fertilization practices, and location within the watershed to estimate phosphorus concentrations of both direct runoff and attenuated discharge to the lake.

The District has completed phosphorus budget analyses for the southern and eastern Lake Okeechobee drainage basins (Zhang et al., 2003a and 2003b). The western Lake Okeechobee drainage basin is the only remaining region that has not been analyzed. However, this basin contributes a relatively small amount of discharge and associated phosphorus load to the lake.

There are several limitations with the current version of the graphical user interface. First, the outputs can only be viewed at the basin or regional scale, not at a user-defined spatial scale. This prohibits the ability to obtain the phosphorus load in surface runoff and other important parameters from a user defined project area. Second, the graphical user interface was not available for the eastern and southern drainage basins. Third, the current interface can use EMCs or WAM results for estimates of phosphorus runoff. The EMC approach can not account for changes to fertilization rates or other phosphorus budget components. WAM can account for the changes, but currently requires separate model runs. The new interface will need a phosphorus runoff load “engine” that can incorporate user defined changes to phosphorus import and export and provide results on an average annual basis. Last, the graphical user interface was developed based on the ArcView™ platform, which has very limited support from the developer.

# 2.0 Project Objective

The overall objective of this project is to develop an ArcGIS™ based graphical user interface for the entire Lake Okeechobee Protection Plan Area (Figure 1). The enhancement includes adding the ability to select a user defined area as opposed to being limited to selecting entire basins. This will provide the ability to assess specific changes within the watershed. The results of these changes need to be viewed at the selected area, the lake and at any location along the flow path to the lake.

## *2.1 Project Goals*

JGH Engineering was authorized by the District to accomplish the project objective by performing the following three tasks within a twelve month period:

Task 1: Upgrade the graphical user interface from ArcView™ to ArcGIS™. Convert the relevant Avenue™ scripts and forms from the previous interface to Visual Basic for Applications™ (VBA) and add enhancements.

Task 2: Perform hydrological and water quality modeling for the remaining basins in the LOPP area where WAM has not been previously applied. Incorporate these basins into the upgraded graphical user interface. Add a graphical user interface feature to obtain the total drainage area for a site selected and compute the total phosphorus load in surface runoff from the drainage area to the site (including assimilation).

Task 3: Write final documentation that describes the work performed and includes technical data and analyses. Present the work and the graphical user interface to the District staff during a four hour training class.

## *2.2 Project Scope*

The tasks and subtasks associated with this project are described below:

TASK 1

<u>Subtask 1.1 Conceptual Design</u>

Attend kickoff meeting with the District to discuss concepts for the new interface. Discuss capabilities of new the interface in relation to the previous interface along with new enhancements. Discuss structure of the interface in regard to changes between ArcView™ and ArcGIS™. Create a "shell" based on the agreed upon conceptual design and present it to the District.

<u>Subtask 1.2 Software Conversion and Enhancements</u>

Convert the relevant Avenue™ scripts and forms from the previous interface to Visual Basic for Applications™ (VBA). There is no automated conversion process available. The language structure is similar, however, in that it is object oriented and includes code (or scripts), forms (or dialog boxes) and controls such as command buttons, list boxes and text lines. Add enhancements as described below to increase the functionality.

- Area of Control Tool – When creating a Phosphorus Control Plan (PCP), the previous interface allows the user to select one or more basins as the spatial extent where changes will be applied. A new tool is needed for the user to define an “Area of Control” which needs to function independently of hydrologic boundaries.

- Drainage Area Tool – A tool is needed to allow the user to view phosphorus runoff and budget results of a drainage area based on a selected site along the flow path.

Subtask 1.3 Data Entry and Testing

Combine suitable GIS datasets and databases from previous phosphorus budget analyses performed by the District’s previous contractors and incorporate the data in to the new interface. Format the data per the needs of the interface and perform several tests by comparing results to the previous interface, which has already undergone thorough testing.

Subtask 1.4 Task 1 Report

Prepare a draft report for the District that will document the graphical user interface design. Within three weeks of receipt, the District will review and forward, in letter format, Receive and review the District’s recommended revisions to the report for incorporation into the final submission.

TASK 2

Subtask 2.1 Data Acquisition

Collect available data as shown below and converted to the formats needed by the WAM model:

GIS Coverages:

- Land Use – FLUCCS
- Soils – SSURGO or other local source
- Topography – USGS DEMs
- Hydrogaphy –USGS NHD or District Datasets
- Subbasins – from previous studies. If not available, USGS HUCs
- Base Maps:
    - WOD Permits
    - Major Roads/Highways – line coverage (already available)
    - Counties – polygon coverage (already available)
    - Receiving Body – Lake Okeechobee
- Rainfall Stations –Point Coverage

Other Data:

- Rainfall – daily, corresponding to station point coverage
- Flow and Water Quality Monitoring Data

Subtask 2.2 Rainfall Datasets

The rainfall station data will be thoroughly reviewed for content and period of record. Stations with excessive "gaps" in data will be eliminated. Stations with moderate or minimal "gaps" will be "patched" with data from nearby stations. A rain distribution grid will be created using Thiessen's method. The rainfall datasets will be formatted as needed.

Subtask 2.3 Reach Delineation

Delineate hydrologic reaches using hydrography datasets and, where available, previous studies. Delineation tools provided in WAM will be used to code the reach network for each basin. Thus far, over 1,300 reaches have been coded in the LOPP area in previous studies using WAM.

Subtask 2.4 WAM Datasets

Apply WAM setup procedures to create datasets needed for its phosphorus assimilation model. This model uses assimilation algorithms developed by Soil and Water Engineering Technologies, Inc. (SWET, 2001). Distance and destination grids will be created to determine the closest downstream feature (wetland, depression or stream) and its distance as well as the next downstream feature and distance. This information is used to calculate attenuation of phosphorus through the system and ultimately to the lake. A byproduct of the WAM algorithms is a grid identifying the drainage areas of each individual reach. This grid will be used to determine total contributing drainage area and phosphorus runoff based on selected sites (Drainage Area Tool – Task 1.2).

Subtask 2.5 Model Integration

Modify the ArcGIS$^{TM}$ interface developed in Task 1 to include the BUCSHELL model used by WAM to estimate phosphorus loads, both attenuated and unattenuated. A stream attenuation algorithm will be incorporated to estimate phosphorus loads to the lake based on total stream distances and attenuation coefficients. At least two reliable monitoring stations will be used to calibrate the coefficients. VBA code will be written to automatically modify the land use parameters when a PCP is created to reflect the land use changes associated with the PCP (e.g. reduced fertilizer rates). VBA code will be written to activate the runoff model when a PCP is created. Files edited to reflect the PCP will be stored in the PCP folder.

Subtask 2.6 Data Entry and Testing

Incorporate datasets generated from the WAM model into the ArcGIS interface and perform several tests. Spreadsheet simulations will be performed to confirm the model results.

Subtask 2.7 Task 2 Report

Prepare a draft report that will document the procedures used to compute the phosphorus loads and changes to the graphical user interface design. Within three weeks of receipt, the District will review and forward, in letter format, recommended revisions to the report for incorporation into the final submission.

TASK 3

Subtask 3.1 Final Report and Data Transfer

Prepare a draft final report that will include interface design, technical data, findings, and analyses from all study components. All technical data collected during this study will be submitted in both hardcopy and electronic format. Hardcopy will be in the form of appendix tables; electronic data will be in a format acceptable to the District (e.g. Excel spreadsheets) and stored on compact disks. Provide the District with electronic copies of all spreadsheets and computer programs, as needed and used in the analysis of these data in the same format specified above for data. All data, computer programs, spreadsheets and any other electronic files generated during the course of this contract becomes the sole property of the District with the exception of any components of the WAM model, which is public domain.

Subtask 3.2 User Manual and Help File

Prepare a user manual, including examples, to instruct users how to review input and output and how to create PCPs.

Subtask 3.3 Training

Conduct a four hour training class on the usage of the new interface. Prepare training materials to be reviewed by the District prior to training. The District shall provide the location, computers and software (ArcGIS™ with Spatial Analyst™) as needed.

# 3.0 Interface Programming

## *3.1 Conceptual Design*

On May 27, 2004 a meeting was held at the South Florida Water Management District to "kick-off" the project and discuss the conceptual design of the new interface. Overall, it was agreed that the capabilities of the previous interface would be integrated into new interface. The structure and flow of the interface will follow the original ArcView™ interface, but will include the enhancements outlined in the scope. ArcMap lends itself well to the structure of the previous interface because it has a much more controlled environment. There is now only one fixed display that can show either a view or the layout as opposed to the previous version which included floating windows for each view and layout.

When viewing results, District Staff requested the option to use observed data instead of WAM output if the selected site corresponds to a monitoring location. It was agreed that, at a minimum, the interface would include a link to the data for comparison purposes. Flow information at these sites is very limited and it would be necessary to use WAM's annual flow with the measured average concentrations to produce average annual loads.

Some basins discharge out of the LOPP in addition to discharging to Lake Okeechobee. The amounts are driven by the operation of the lake. The percent of runoff from the southern and eastern regions entering the Lake varies and will certainly change after Comprehensive Everglades Restoration Plan (CERP) is implemented. It was agreed at the meeting that ratios would be used to represent how much runoff from a particular area flows to the Lake and how much flows out of the LOPP. Ratios are based on measured historical data and will be adjustable by the user. This provides the opportunity to account for other changes in the future related to CERP such as storage basins. These rations would be developed in Task 2.

A "shell" of the proposed interface was developed based on concepts discussed at the "kick-off" meeting. The "shell" consisted of buttons, tools, menu items, etc. that provided the appearance of the proposed interface, without the actual computer code that would perform the individual functions.

On June 15, 2004 a workshop was held at the District to demonstrate the "shell." The workshop was also intended to share information and make other departments, divisions and sections aware of the project and to solicit their input and to determine their resources.

Because of the structural differences between ESRI's old and new software programs, it is proposed that all of P-Budget features be contained in a single toolbar. The previous programming language would only allow tools to be added to existing toolbars and for menu items only to be added to existing menus. The new software allows menus, command buttons, tools and combo boxes to be added to a new unique toolbar. Similarly, many of ArcGIS's "add-on" extensions such as Spatial Analyst are represented as a single toolbar in ArcGIS's interface.

### *3.2 Coding Conventions*

Visual Basic for Applications™ (VBA) was used as the programming language. VBA is a form of Microsoft™'s Visual Basic and is designed to work specifically with program applications such as ESRI™'s ArcGIS software and is provided as part of the ArcGIS.

It should be noted that interface documentation is provided in Appendix A and in the User Manual (Appendix B). The purpose of this section is to document the efforts associated with VBA programming.

Standard conventions were followed as described in most VB/VBA manuals (Deitel et al., 1999 and Burke, 2003) and as discussed in internet forums (ESRI™ ArcObjects™ 9 Developer's Forum). VBA code exists in what are referred to as either modules or forms. Most of the code for this interface resides within the project module known as ThisDocument. New modules were created for repetitive tasks and are called upon by ThisDocument or by other modules. Forms and modules include subroutines and/or functions which consist of code designed to perform specific tasks.

It is important to provide sufficient comments in the coding so that other programmers may be able to decipher the code. Subroutines and functions include sections of code which perform subtasks. Each section begins with a comment line that describes the subtask to be performed in that section. A comment line is preceded with a single quotation mark which VBA recognizes as a line not to execute. Some subtasks, if long, have been divided into subsections. Each subsection also begins with a comment line, but is preceded with two single quotation marks.

Error handling has been incorporated into each subroutine and function. A line has been added to the beginning "On Error GoTo Errorhandler:" which directs the program to a line near the bottom of subroutine/function that reports the error and where it occurred. Other error trapping features have been added where it was felt that a problem could occur such as when the code tries to open a file that does not exist. More error trapping will be added as needed so solve any issues that may arise as the interface moves from programmer testing to user testing.

Unlike ESRI™'s Avenue programming language, variables in VBA must be declared before they can be used. Since modules can contain several subroutines and/or functions, it possible to declare variables at the beginning of the module so that they can be used by all of the subroutines/functions in that module. They are called module-level variables. It is the programmer's preference where he or she declares variables. For P-Budget, module-level variables were used at a minimum so that the declaration and use of the variables could be more easily tracked and controlled. Only variables that are used frequently or that are needed to share values from one subroutine to another were declared in the beginning of the modules.

Likewise, some programmers prefer to declare all variables together in the beginning of the subroutine or function. The general "rule of thumb" for P-Budget was to declare the variable immediately prior to its use. Again, this provides better tracking and control of the variable and it also simplifies the process of copying and pasting code to and from different locations.

Variable names for controls were named using a lower case prefix identifying the type of control followed by a title case name describing the function of the control. For example, a command button to cancel an operation would be named cmdCancel. Non-control variables are named using a similar style, but in the opposite order. Lower case "p" is often used as a prefix to a programming object, e.g., pRaster to represent a grid or image object. When several objects of the same type are using in same module, and abbreviation was used in place of "p" such as "lu" to identify the raster as a land use grid.

All object variables that are required to be "Set" in the code were set equal to "Nothing" at the end of each subroutine or function, e.g., "Set luRaster = Nothing." This is, in most cases, not necessary. But is has become a standard practice to avoid a programming conflict resulting from an uncleared variable.

Global variables are those variables that are used throughout the application. They are set within a separate module with a "Public" declaration. In P-Budget, global variables are used to track the status of the application and to enable or disable tools, buttons and menu items based on the status. For example, if a Phosphorus Control Plan (PCP) is open, a button in the toolbar will be enabled allowing the user to zoom to the spatial extent of the PCP.

### *3.3 Interface Datasets*

It should be noted that many of the terms used in this section are software dependant, i.e., they are used by ArcGIS™ to represent features of that software. These terms are described in ESRI™'s lastest version of its ArcGIS™ software documentation.

The interface is designed to work with specific GIS datasets that have been arranged in ArcMap's table of contents into three data frames (a.k.a. maps). The first two data frames are named "left view" and "right view" and are used to represent the left and right maps in ArcMap's page layout. The page layout is where maps, legends, graphics, etc. can be displayed together and printed.

The intent of the page layout is to display land use and the phosphorus net import results side-by-side with the appropriate legends. A layer consists of a GIS dataset that has been formatted by the user for display purposes. The left view data frame includes a layer of land use, while the right view includes a layer of net phosphorus import results.

A third data frame, called "Select Extent," is used for direct interaction between the map and the user. This data frame is not used in the layout. It appears when the user needs to select a spatial extent to represent a PCP or Area of Interest (AOI) extent. All three data frames include identical sets of base maps, which can be toggled on or off in the phosphorus budget toolbar.

A complete listing of the datasets and the required database fields and attributes will be provided in Task 3 – documentation phase.

### *3.4 Interface Description*

The concept of the P-Budget interface is to provide planners with the tools needed to assess the import and export of phosphorus in the Lake Okeechobee Protection Plan (LOPP) area. The tools are used to assess current conditions and to assess scenarios based on changes in land use practices. The scenarios are referred to as Phosphorus Control Plans (PCPs) and reflect changes to the quantities of phosphorus import/export associated with specific land uses.

It is important to note that the interface serves as a "read only" template. The ArcMap™ project file (P-Budget.mxd) can not be overwritten and the application has been set to close without prompting the user to save the project. This maintains the presence and format of the datasets for future use. PCPs are created, saved and accessed by the interface, but never become a permanent part of the interface.

The interface includes dual maps of land use versus net phosphorus import (see Figure 3). A toolbar provides a means of toggling on or off base maps such as roads, county boundaries, etc. The pan and zoom tools, standard with ArcMap™, were modified to work on both views simultaneously. This only works if applied to the left view. If applied to the right view, only the right view would be affected. This was designed intentionally to provide some flexibility in case the user wants the views to be shown at different scales and locations.

The toolbar (see Figure 2) includes menu items that begin with the creation and management of PCPs. When creating a new PCP a form appears prompting the user to enter a name and description and to select a region. The LOPP area is divided into six regions. Each region has been studied previously and has its own set of phosphorus budget coefficients based on the region's land use practices. Because of this, a PCP can only be applied to one region at a time. The information entered in this form is stored in a database that is used to manage the PCPs later (open, delete, etc.). The form also instructs the user to use the area selection tools in the toolbar, which are enabled at this point, to select a spatial extent for the PCP before continuing.

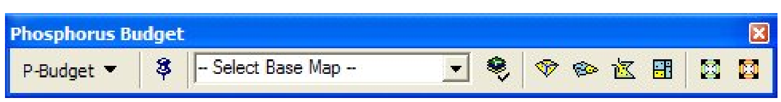

Figure 2: Phosphorus Budget ToolBar

There are four tools available for the selection of a spatial extent – select by reach, by basin, user-defined, and by permit. Selecting by reach results in an extent equal to the contributing drainage area of the selected reach. Selecting by basin allows the user to select one or more basins, as delineated by the District, e.g., S-191. The user-defined tool allows the user to draw one or more polygons. When selecting by permit the user is provided a list of Works of the District (WOD) permits to choose from to serve as the extent.

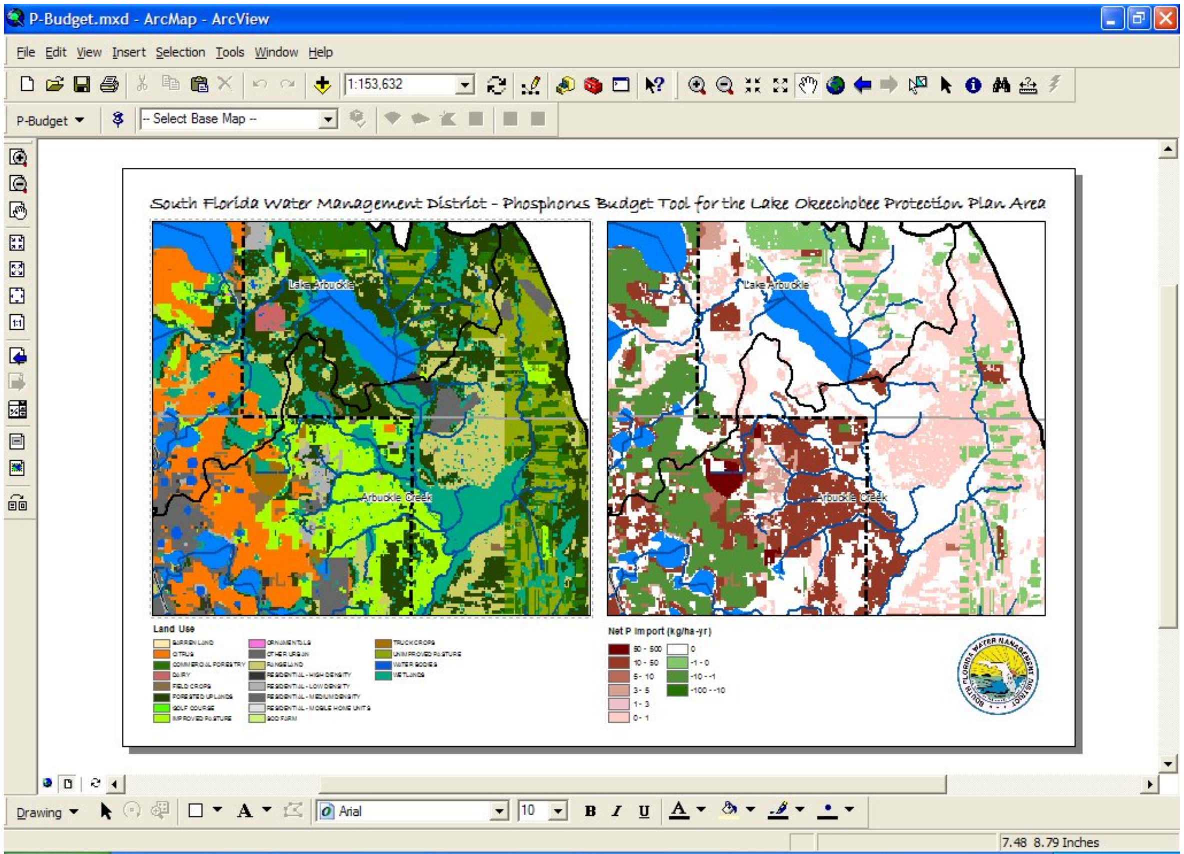

Figure 3: P-Budget Interface and Page Layout

After the extent is chosen the dual views will zoom to the selected extent which will be outlined with a yellow and blue border. A form will appear with a list of the land uses that exists within the selected area. The right side of the form includes parameter values for the import and export components for the selected land use. Each land use has been characterized into phosphorus import and export components. When selecting a land use, the area of the selected land use will be displayed below the list and a picture of the land use will appear in the bottom left corner of the form. Default parameters will appear on the right side of the form. The default parameters reflect current conditions in the selected region.

Calculators have been provided next to each phosphorus component to assist the user in calculating the phosphorus import or export for that component. Once a change has been made, the buttons along the bottom become activated to apply the change, replace the values with default parameters or revert the values to the previous values that were saved. When finished, the close button will save the changes in a dBase file located in the PCPs folder and named with the PCP name. Several grids of the selected extent will be created, one per phosphorus component along with grids for total import, total export and net import. These grids will be "burned" onto larger grids of the same type that cover the entire LOPP area.

The results are displayed in the right view of the page layout, but can also be viewed in tabular format. There are several table options to choose from. If a PCP is open, the tables will reflect the PCP. Otherwise the tables will reflect the default current conditions. Tables can also be controlled by selecting an Area of Interest (AOI). Menu options are provided to set or close an AOI. When setting an AOI, the same area selection tools are available as when selecting a PCP extent.

It is anticipated, however, that the PCP and AOI extents will often be different. For example, if the user has changed land use practices in a Works of the District (WOD) permit, he or she may wish to see the effects of on the basin where the permit resides. After the AOI extent is chosen the dual views will zoom to the selected extent which will be outlined with a yellow and red border. If no AOI is set, then the tables will reflect the entire LOPP area.

The first table available to the user is not found in the menus, but rather, has been incorporated into the area selection tool that selects a drainage area by reach. When using this tool to select an AOI, a check box will appear at the bottom of the message box associated with this tool. If the box is checked, then each time that a reach is selected a table will be produced providing phosphorus budget summary information associated with that reach's contributing drainage area.

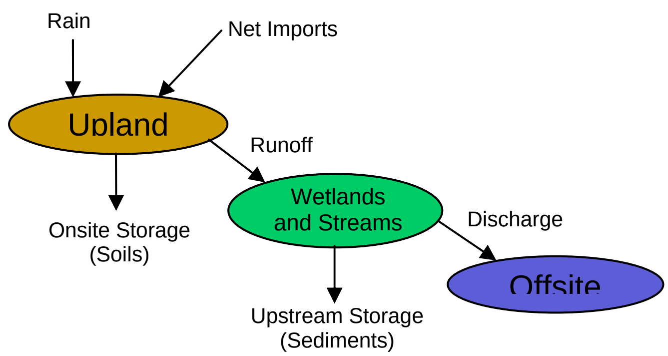

Figure 4: Phosphorus Budget Mass Balance

This feature has been added to this tool because it is the only tool that consistently provides an entire drainage area with a single discharge point. This provides an opportunity to report phosphorus load discharge at the outlet (the selected reach) and to relate that value to the loads upstream so that the entire mass balance (Figure 4) can be reported. For example, upstream storage is the amount of phosphorus stored in the stream and wetland conveyance system, which is calculated as the difference between the runoff load at the runoff source and the discharge load at the drainage area outlet. The tool also provides an opportunity to compare the results of the WAM water quality model to measured values that may have been taken at that location.

The P-Budget menu provides four different tables. The first table provides a breakdown by land use for each of the import/export components. The next three tables summarize the results and add the rainfall, runoff and storage components into the budget. These three tables are identical but differ in how they summarize the results – by land use, basin or region. If an AOI is set, the tables will only reflect the spatial extent of the AOI.

## 3.5 *Interface Objects and Controls*

As mentioned in the previous section, all of P-Budget's functions have been packaged into a single toolbar that can be opened and closed in ArcGIS$^{TM}$ ArcMap. The toolbar, named “Phosphorus Budget,” is project dependant in that its functions require the data that has been added to the project. Figure 5 illustrates the various components of the phosphorus budget toolbar.

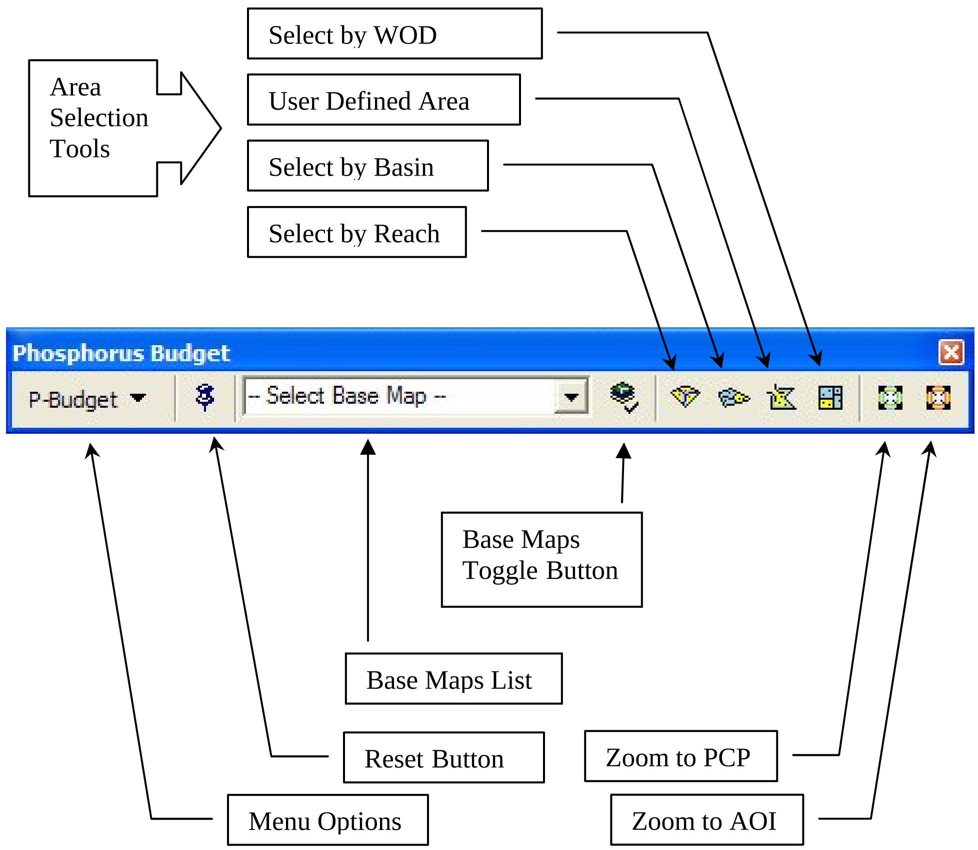


Figure 5: Phosphorus Budget Toolbar Controls

The Reset button is provided as a “clean-up” feature. It returns the interface to the page layout, zooms to the layout, closes the table of contents and resets the global variables and VBA listeners. Listeners are functions that the interface is constantly checking. For example, the interface checks to see if AcrMap’s standard pan/zoom tools have been applied to the left view of the layout. If so, the tool is applied to both views automatically. The reset button resets the variables and listeners in case the interface encounters an error or anomaly which can sometimes result in the loss of what are referred to as “threads.” Threads hold the interface into the user defined state, i.e., if the user has performed an action that has enabled other features, threads keep those features from reverting back to their default state.

The base maps function as described in the previous section. The Base Map Toggle button will display either a check mark (as shown in Figure 5) or an “x” to indicate whether the selected base map is currently on or off, respectively. For example, if the base map for roads is currently on, the button will appear with a checkmark. When the button is pressed, the base map will be turned off and an “x” will appear in the button image.

The Area Selection tools are used to select spatial extents for PCPs and AOIs as described in the previous section. There are two buttons located on the right side of the toolbar that will zoom the right and left views to the extents of the PCP or AOI.

The menu options provide the functions for managing PCPs, setting AOIs and viewing tabular output. There are several options associated with PCPs. Figure 6 illustrates the forms and information the user will encounter when using these options. A form appears when creating a new PCP that prompts the user for information regarding the PCP and instructs the user to use the area selection tools to select a spatial extent. Another form appears when opening or deleting a PCP. The form displays the saved PCPs and their attributes. The command button will indicate Open (as shown in Figure 6) or Delete depending on which option from the menu is selected.

After creating a new or opening an existing PCP, a form will appear for editing the phosphorus coefficients as described in the previous section. This form may also be accessed by selecting Edit from the menu, provided that a PCP has already been opened. Calculator buttons are provided for each import/export component. Each button opens a unique form designed to assist the user in applying changes.

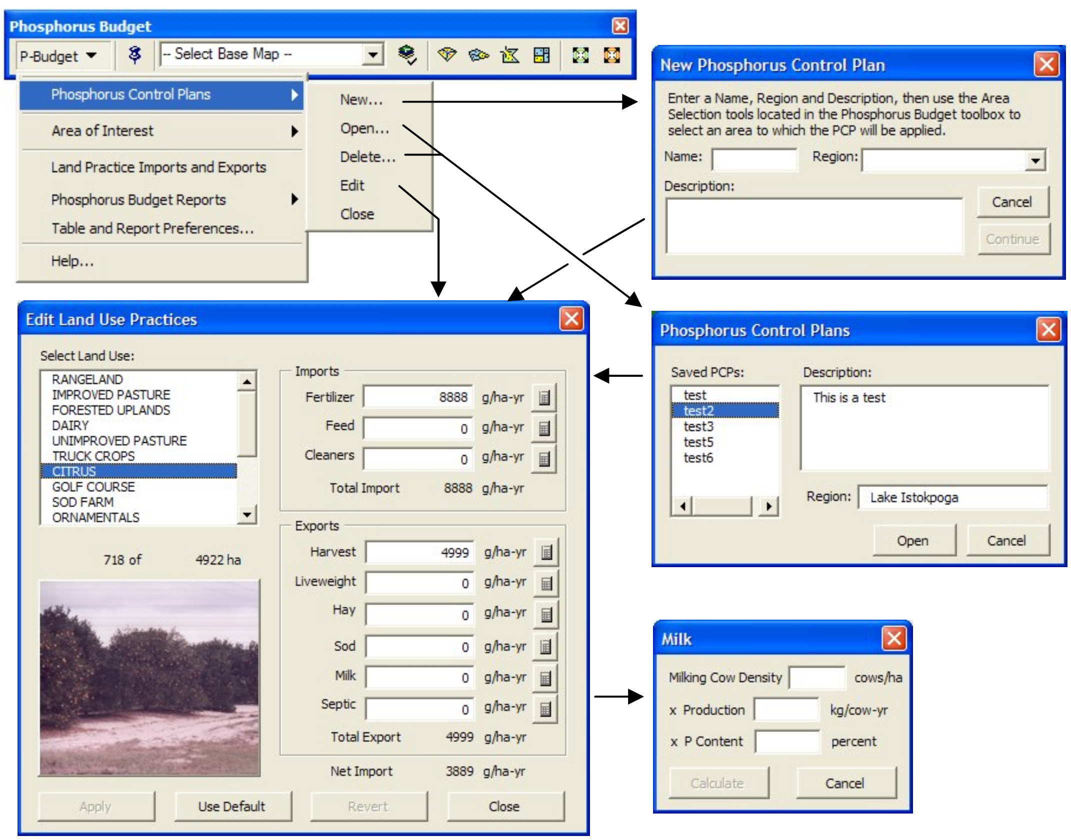

Figure 6: Phosphorus Control Plan Forms

The Edit and Close options are only enabled if a PCP is open. The New, Open and Delete options are only enabled if a PCP is not currently open.

The AOI, or Area of Interest, is simply the area that the user can set for reporting purposes. If an AOI is set, then the output tables will reflect only that area. The same tools used to select a PCP extent are also available for selecting an AOI extent. Figure 7 shows the message box that will appear when setting an AOI.

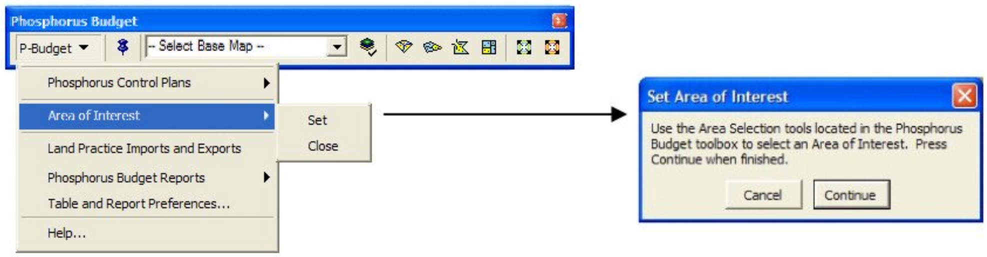


Figure 7: Selecting Area of Interest

Tabular output has been provided similar to the previous version of P-Budget but with two additional tables. There are a total of five tables available. The first table option is not found in the menu and is new to this interface. It is available while selecting an AOI with the Select by Reach/Drainage Area tool. A message box appears when each selection tool is pressed instructing the user how to use the tool. When the Select by Reach tool is used to select an AOI, the message box for this tool will include a check box as shown in Figure 8.

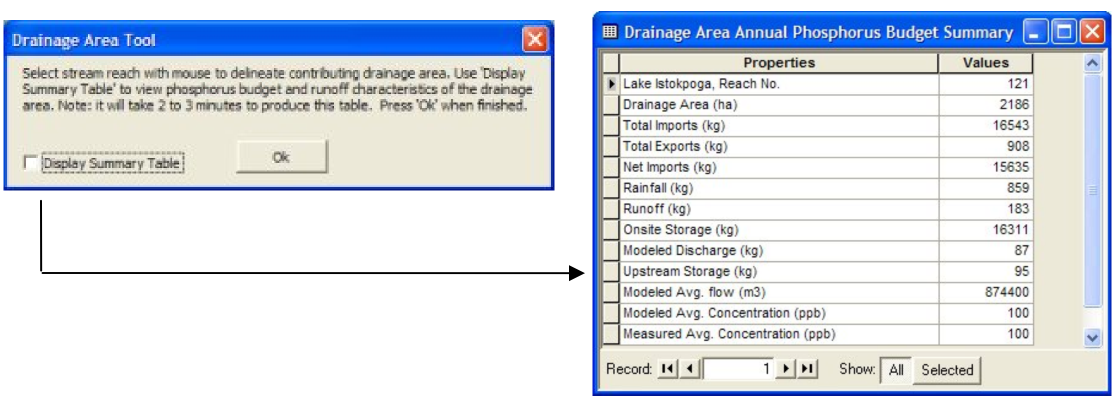


Figure 8: Drainage Area Annual Phosphorus Budget Summary Table

The remaining tables are available from the menu (see Figure 9). The land practice table provides a detailed breakdown of imports and exports. The Total P-Budget reports provide table summaries of the imports and exports along with rainfall, runoff and onsite storage. Onsite storage is the amount of phosphorus retained in the soils at the source of the phosphorus application and is equal to the runoff load minus the rainfall and net import loads as shown in Figure 4. The reports also include pie charts of net phosphorus import and a picture the left map of the main layout. These reports can be displayed by region (new to this interface), or by basin (as shown in Figure 9) or by land use. The tables are saved as dBase files, which can be accessed by other software programs. The reports are generated programmatically using Crystal Reports™, which is distributed with ArcMap™. The reports can be printed or exported to a variety of formats.

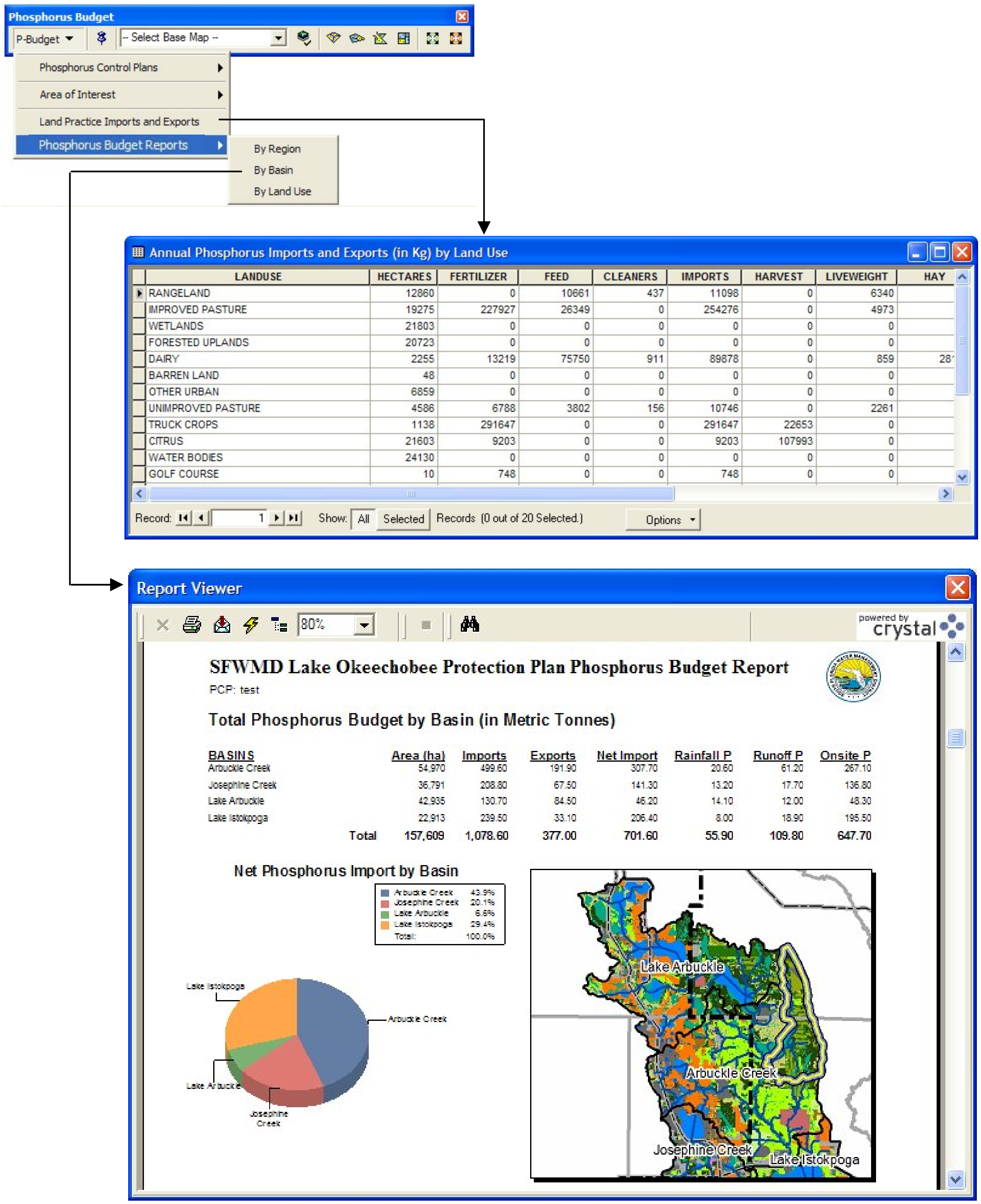


Figure 9: Annual Phosphorus Imports/Exports Table and Total Budget Summary Report

### 3.6 Testing and Evaluation

The only regions that have sufficient data for testing, including WAM output, are Lake Istokpoga and the Upper Chain of Lakes. Considering that either region would suffice for testing, Lake Istokpoga was chosen. It would have been possible to merge all of the datasets for both of these regions, but this would not have been of any more value, in terms of testing, than the use of one region. Regions include their own set of model coefficients and are run independently. The District has indicated that a revised dataset for land use would ultimately replace the previous land use datasets within the entire LOPP area. Results using a revised dataset would not be comparable to the results of the previous P-Budget interface and merging pervious datasets would not be of any benefit in future tasks.

Three comparisons were made between the previous ArcView P-Budget interface and the new ArcGIS™ interface. Tables 1 and 2 show comparisons of basins and land use summaries, respectively. Minor differences were observed that can be attributed to rounding of numbers with the exception of Rainfall_P. Rainfall_P represents the annual amount of phosphorus entering the region via rainfall. This value was calculated differently in the new interface by utilizing the rainfall zone dataset developed for the WAM model. This GIS coverage includes zones representing rainfall stations spatially located based on the Theissen Method. Each zone includes its own rainfall dataset which was averaged over the same period of time as the WAM model run. The previous method, used in ArcView P-Budget, applied a single value of average annual rainfall to the entire region.

Table 1: Comparison of P-Budget Results by Basin in Metric Tonnes

| ArcView P-Budget | IMPORTS | EXPORTS | NET_IMPORT | RAINFALL_P | RUNOFF_P |
|---|---|---|---|---|---|
| Arbuckle Creek | 467.1 | 193.1 | 273.9 | 19.6 | 61.4 |
| Josephine Creek | 208.8 | 67.5 | 141.3 | 13.2 | 17.9 |
| Lake Arbuckle | 130.7 | 84.5 | 46.2 | 15.4 | 12.2 |
| Lake Istokpoga | 239.5 | 33.1 | 206.4 | 8.2 | 18.9 |
| ArcGIS P-Budget | | | | | |
| Arbuckle Creek | 467.1 | 193.1 | 274.0 | 20.6 | 61.2 |
| Josephine Creek | 208.8 | 67.5 | 141.3 | 13.2 | 17.7 |
| Lake Arbuckle | 130.7 | 84.5 | 46.2 | 14.1 | 12.0 |
| Lake Istokpoga | 239.5 | 33.1 | 206.4 | 8.0 | 18.9 |

Table 2: Comparison of P-Budget Results by Land Use in Metric Tonnes

| ArcView P-Budget | IMPORTS | EXPORTS | NET_IMPORT | RAINFALL_P | RUNOFF_P |
|---|---|---|---|---|---|
| Rangeland | 11.1 | 8.5 | 2.6 | 4.6 | 0.9 |
| Improved Pasture | 254.3 | 5.0 | 249.3 | 6.9 | 24.6 |
| Wetlands | 0.0 | 0.0 | 0.0 | 7.8 | 22.1 |
| Forested Uplands | 0.0 | 0.0 | 0.0 | 7.4 | 1.4 |
| Dairy | 89.9 | 47.5 | 42.4 | 0.8 | 5.0 |
| Barren Land | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| Other Urban | 0.0 | 0.0 | 0.0 | 2.4 | 8.2 |
| Unimproved Pasture | 4.0 | 3.0 | 0.9 | 1.6 | 2.7 |
| Truck Crops | 291.6 | 22.7 | 269.0 | 0.4 | 13.5 |
| Citrus | 9.2 | 108.0 | -98.8 | 7.7 | 5.9 |
| Water Bodies | 0.0 | 0.0 | 0.0 | 8.6 | 1.8 |
| Golf Course | 0.7 | 0.0 | 0.7 | 0.0 | 0.0 |
| Sod Farm | 27.7 | 84.7 | -56.9 | 0.4 | 13.1 |
| Ornamentals | 0.0 | 4.5 | -4.5 | 0.1 | 1.1 |
| Commercial Forestry | 0.0 | 0.5 | -0.5 | 1.2 | 0.1 |
| Residential - Mobile Home Units | 0.4 | 0.0 | 0.4 | 0.0 | 0.0 |
| Residential - Low Density | 16.0 | 0.2 | 15.8 | 1.8 | 1.9 |
| Residential - Medium Density | 173.4 | 3.0 | 170.5 | 3.1 | 5.9 |
| Residential - High Density | 61.2 | 0.7 | 60.5 | 0.5 | 1.7 |
| Field Crops | 106.6 | 90.0 | 16.6 | 0.8 | 0.5 |
| ArcGIS P-Budget | | | | | |
| Rangeland | 11.1 | 8.5 | 2.6 | 4.6 | 0.8 |
| Improved Pasture | 254.3 | 5.0 | 249.3 | 7.0 | 24.5 |
| Wetlands | 0.0 | 0.0 | 0.0 | 7.7 | 22.0 |
| Forested Uplands | 0.0 | 0.0 | 0.0 | 7.3 | 1.3 |
| Dairy | 89.9 | 47.5 | 42.4 | 0.8 | 5.0 |
| Barren Land | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| Other Urban | 0.0 | 0.0 | 0.0 | 2.5 | 8.2 |
| Unimproved Pasture | 4.0 | 3.0 | 0.9 | 1.5 | 2.7 |
| Truck Crops | 291.6 | 22.7 | 269.0 | 0.4 | 13.5 |
| Citrus | 9.2 | 108.0 | -98.8 | 7.7 | 5.8 |
| Water Bodies | 0.0 | 0.0 | 0.0 | 8.5 | 1.7 |
| Golf Course | 0.7 | 0.0 | 0.7 | 0.0 | 0.0 |
| Sod Farm | 27.7 | 84.7 | -56.9 | 0.4 | 13.1 |
| Ornamentals | 0.0 | 4.5 | -4.5 | 0.1 | 1.1 |
| Commercial Forestry | 0.0 | 0.5 | -0.5 | 1.1 | 0.1 |
| Residential - Mobile Home Units | 0.4 | 0.0 | 0.4 | 0.0 | 0.0 |
| Residential - Low Density | 16.0 | 0.2 | 15.8 | 1.8 | 1.9 |
| Residential - Medium Density | 173.4 | 3.0 | 170.5 | 3.2 | 5.8 |
| Residential - High Density | 61.2 | 0.7 | 60.5 | 0.5 | 1.7 |
| Field Crops | 106.6 | 90.0 | 16.6 | 0.8 | 0.5 |

Table 3 shows the results of selecting reach no. 143 with the Drainage Area tool. This reach corresponds to the outlet of the Lake Arbuckle basin and, therefore, can be compared to the results in Table 1 for that basin. The values, though in kilograms, are virtually equal to the values presented in Table 1. It should be noted that the modeled discharge value and any related values were substituted with pro-rata estimates for this task. The estimates are based on area in relation to the overall area of the region and the region's total discharge. Actual values from the WAM model were derived from a new algorithm developed in Task 2 of this project.

Table 3: Drainage Area Tool Results for Reach No. 143

| Properties | Values |
|---|---|
| Lake Istokpoga, Reach No. | 143 |
| Drainage Area (ha) | 42935 |
| Total Imports (kg) | 130674 |
| Total Exports (kg) | 84485 |
| Net Imports (kg) | 46189 |
| Rainfall (kg) | 14051 |
| Runoff (kg) | 11974 |
| Onsite Storage (kg) | 48267 |
| Modeled Discharge (kg) | 1717 |
| Upstream Storage (kg) | 10256 |
| Modeled Avg. flow (m3) | 17174000 |
| Modeled Avg. Concentration (ppb) | 100 |
| Measured Avg. Concentration (ppb) | 100 |

Additional tests were performed with PCPs to verify that the change in results only occurred in those areas where the land use practices were changed and only within the selected PCP extent. The test results were positive.

A project summary and complete list of Visual Basic procedures are located in Appendix A. A user manual including a tutorial exercise is located in Appendix B. The user manual has also been incorporated into the interface as a Windows™ based help file.

# 4.0 Phosphorus Loading

## 4.1 Data Acquisition

The GIS datasets below have been collected and converted to the formats needed by the WAM model:

<u>GIS Datasets</u>:

- Land Use – FLUCCS as provided by SFWMD
- Soils – SSURGO
- Topography – USGS DEMs and CERP Datasets
- Hydrogaphy –USGS NHD and District Datasets
- Subbasins – from previous studies or processes described herein
- Base Maps:
    - WOD Permits
    - Major Roads/Highways – line coverage (already available)
    - Counties – polygon coverage (already available)
    - Receiving Body – Lake Okeechobee
- Rainfall Stations – point coverage derived from previous studies

Suitable GIS datasets of subbasins were not available in the areas where the WAM model had not been previously applied including S-65A, S-65B, S-65C, C-44, S-153 and the entire Southern Lake Okeechobee region (SLO). C-44, and SLO have been previously modeled using WASH and MIKE SHE, respectively. However, the subbasin datasets created for these models are much courser than the datasets used by (and in some cases created by) the WAM model.

To meet the goals of the P-Budget interface, a higher resolution of subbasins is required. The interface needs to delineate drainage areas based on a hydrologic reach selected by the user. The subbasins need to be as small as reasonably possible to provide a "best match" of the area desired by the user. It is also important that sufficient drainage divides (subbasin boundaries) be present to adequately direct the flow to the correct hydrologic reach. Subbasin delineation in the S-65A, B and C basins was performed in the same manner as performed for the LOW CERP WAM model (HDR, 2003). This model includes all of the basins in the Northern Lake Okeechobee region with the exceptions of S-65A, B and C. The subbasins were created using a coded stream network and USGS topography with ESRI™'s GRID Watershed tools. The subbasins were then added to the previously created subbasins to complete the Northern Lake Okeechobee region.

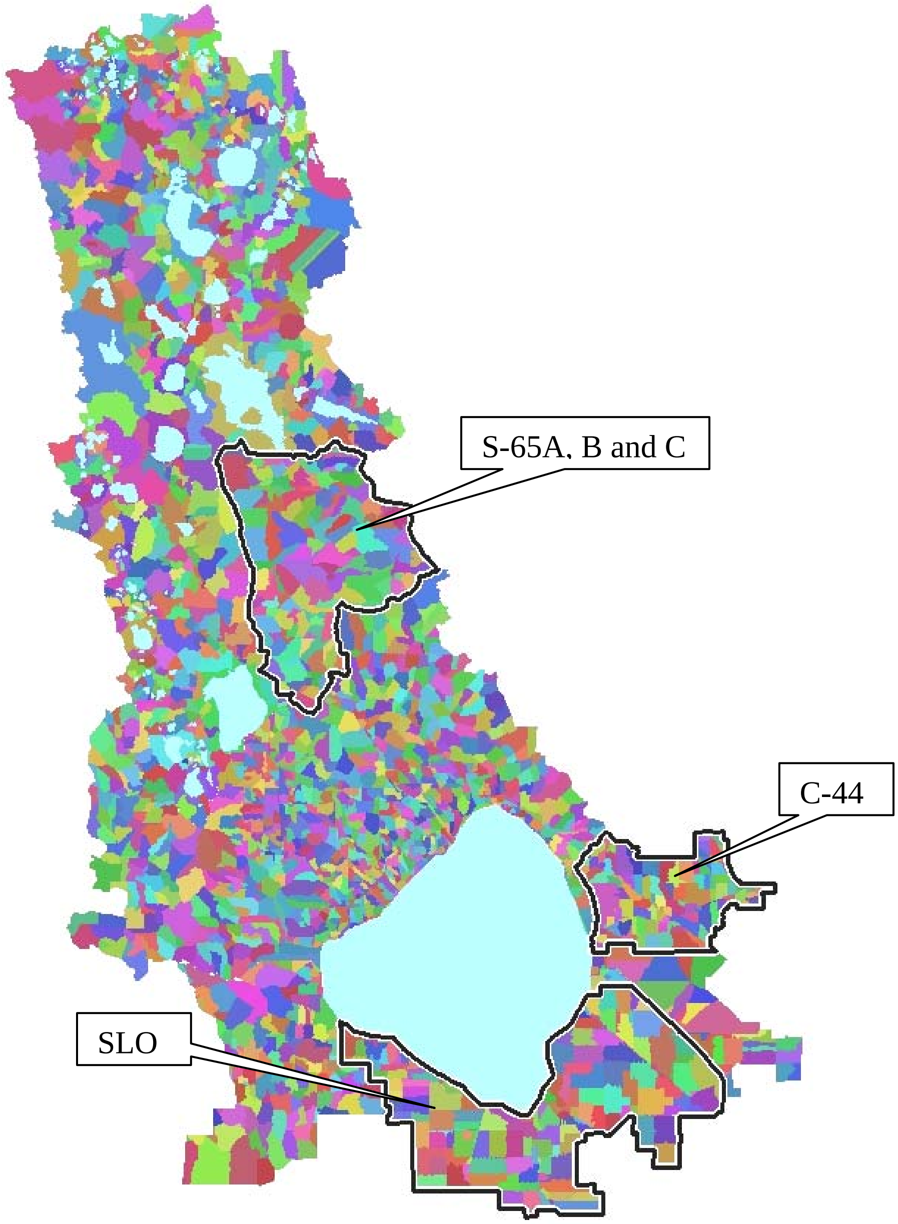


Figure 10: Subbasin delineation in Lake Okeechobee Protection Plan Area

Subbasin delineation in the C-44 basin and SLO region (Figure 10) was accomplished using the District's Environmental Resource Protection (ERP) permits and WOD permits, respectively. These areas are both relatively flat and heavily developed by agriculture. Existing farm boundaries are a good indicator of subbasins.

Some deviations from the District's standard basin coverage, dBasins, were made. A report by Kimley-Horn and Associates, Inc., "EAA Storage Reservoirs Phase 1, PIR – Task 2.2.1 Basin and Subbasin Delineation, (2002)" listed several deviations. These changes were reviewed and incorporated with the exception of Basin S-236, which contradicted the District's basin report, "An Atlas of the Everglades Agricultural Area

Surface Water Management Basins, (1989)" and could not be verified with Digital Ortho Quadrangle (DOQ) 1m aerial photos. Overall, the boundary of the LOPP was not changed.

### *4.2 Rainfall Datasets*

The rainfall station data was obtained and reviewed for content and period of record. Stations with excessive "gaps" in data (several consecutive months) were eliminated. Stations with moderate or minimal "gaps" (less than one or two consecutive months) were "patched" with data from nearby stations by using the data that matched the missing dates. The majority of the stations chosen were stations used in previous WAM models within the LOPP. A total of 42 rainfall stations were used. A rain distribution grid was created using Thiessen's method (Figure 11). The rainfall datasets were then formatted to meet the requirements of the WAM model. Table 4 presents the annual rainfall measured at these stations.

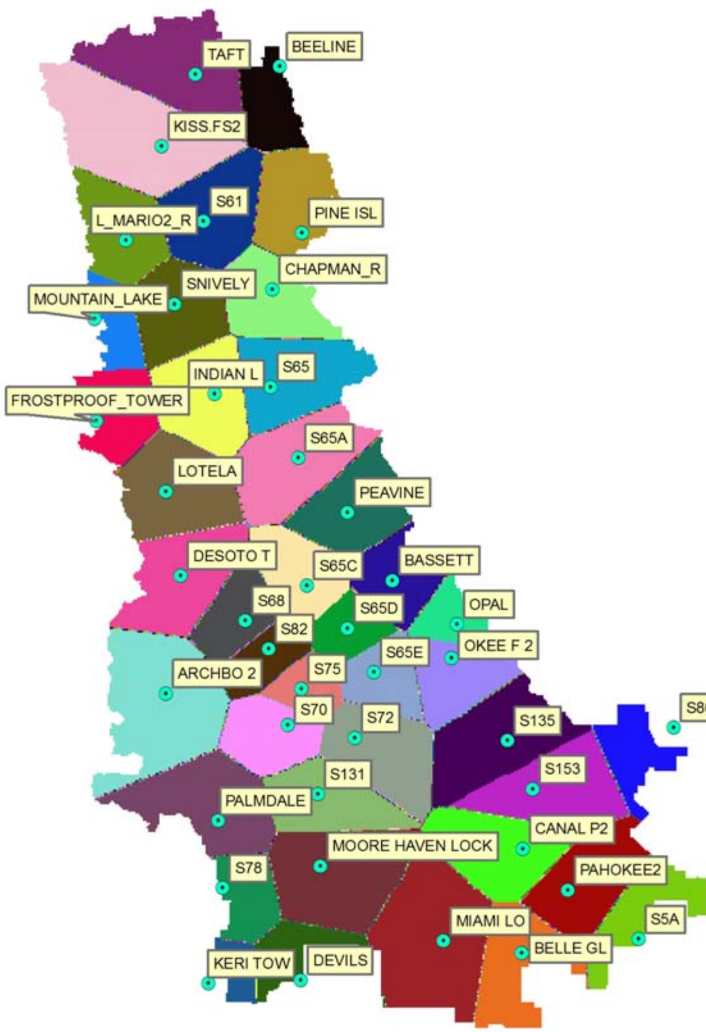


Figure 11: Rain Stations and Zones

Table 4: Annual Rainfall in inches

| STATION | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|
| ARCHBO | 50.4 | 59.1 | 56.8 | 36.8 | 55.2 | 51.0 | 58.2 | 28.3 | 59.2 | 72.1 |
| BASSET | 38.0 | 55.5 | 57.1 | 35.2 | 53.4 | 31.7 | 66.0 | 29.8 | 48.6 | 30.9 |
| BEELIN | 48.7 | 67.9 | 48.8 | 61.0 | 54.7 | 52.9 | 63.9 | 29.9 | 46.6 | 61.6 |
| BELLE_ | 52.1 | 77.0 | 57.0 | 50.7 | 52.3 | 51.1 | 50.3 | 41.1 | 48.1 | 39.6 |
| CANAL_ | 31.6 | 60.6 | 70.9 | 45.9 | 33.6 | 44.8 | 45.0 | 32.3 | 37.8 | 32.9 |
| DESOTO | 54.5 | 53.7 | 51.5 | 34.4 | 59.0 | 51.7 | 40.2 | 26.9 | 54.6 | 60.2 |
| DEVILS | 58.1 | 62.1 | 68.4 | 54.6 | 52.9 | 65.4 | 55.7 | 37.0 | 56.9 | 57.8 |
| INDIAN | 43.4 | 54.8 | 58.9 | 43.4 | 44.4 | 38.6 | 40.3 | 21.7 | 36.9 | 37.1 |
| KERITO | 54.6 | 57.2 | 55.2 | 71.7 | 63.7 | 72.7 | 67.1 | 46.3 | 53.5 | 34.1 |
| KISS_F | 46.5 | 68.3 | 49.4 | 57.3 | 61.9 | 55.7 | 46.8 | 38.5 | 51.9 | 75.5 |
| LOTELL | 54.5 | 60.0 | 61.6 | 47.0 | 65.0 | 66.4 | 47.4 | 42.9 | 58.7 | 57.9 |
| MIAMI_ | 45.6 | 66.9 | 57.8 | 50.2 | 49.5 | 56.2 | 46.2 | 41.5 | 45.4 | 33.7 |
| OKEE_F | 50.4 | 59.2 | 51.1 | 45.2 | 49.5 | 47.6 | 52.6 | 30.1 | 54.2 | 45.1 |
| OPAL_R | 45.8 | 54.3 | 48.9 | 45.4 | 58.6 | 60.4 | 60.6 | 29.5 | 62.0 | 45.1 |
| PALMDA | 49.4 | 46.8 | 53.6 | 37.5 | 49.9 | 52.9 | 54.9 | 34.5 | 42.8 | 50.7 |
| PEAVIN | 57.3 | 76.9 | 66.0 | 54.2 | 70.8 | 72.0 | 52.6 | 35.0 | 44.3 | 27.1 |
| PINE_I | 37.9 | 52.6 | 54.5 | 30.6 | 49.5 | 41.8 | 45.7 | 28.3 | 44.4 | 58.3 |
| S-131_ | 42.0 | 50.4 | 47.7 | 39.4 | 45.6 | 56.8 | 56.2 | 31.4 | 44.1 | 54.7 |
| S135_R | 49.3 | 57.5 | 56.4 | 43.2 | 48.7 | 49.6 | 48.3 | 34.5 | 45.0 | 49.3 |
| S153__ | 31.6 | 52.4 | 52.0 | 33.9 | 31.1 | 37.6 | 38.2 | 38.2 | 32.5 | 32.5 |
| S5A_R_ | 54.8 | 88.1 | 61.5 | 62.1 | 61.0 | 55.9 | 54.3 | 46.4 | 49.8 | 41.6 |
| S61_R_ | 45.0 | 70.0 | 58.2 | 49.8 | 52.4 | 44.7 | 46.9 | 39.4 | 50.8 | 56.4 |
| S65_R_ | 40.8 | 59.8 | 53.2 | 45.0 | 68.8 | 54.0 | 52.8 | 31.7 | 54.6 | 75.1 |
| S65C_R | 40.1 | 49.9 | 43.3 | 35.7 | 44.5 | 55.4 | 56.4 | 32.4 | 39.2 | 57.8 |
| S65D_R | 48.8 | 64.3 | 56.0 | 42.1 | 51.5 | 52.9 | 50.4 | 33.2 | 48.0 | 42.0 |
| S65E_R | 50.0 | 70.6 | 52.6 | 48.1 | 57.3 | 46.2 | 49.3 | 26.3 | 43.8 | 38.8 |
| S68_R_ | 45.4 | 47.9 | 41.0 | 29.1 | 45.2 | 52.7 | 40.2 | 24.2 | 35.8 | 49.3 |
| S70_R_ | 44.9 | 48.5 | 49.7 | 40.5 | 43.4 | 48.3 | 34.5 | 24.8 | 27.1 | 25.8 |
| S72_R_ | 43.4 | 43.0 | 49.6 | 36.2 | 50.7 | 43.2 | 49.2 | 27.1 | 37.1 | 37.1 |
| S75_R_ | 44.9 | 47.3 | 41.0 | 40.6 | 59.3 | 38.0 | 32.9 | 25.9 | 36.0 | 41.4 |
| S-78__ | 48.6 | 59.4 | 63.2 | 48.4 | 52.1 | 60.8 | 66.8 | 39.0 | 61.6 | 71.9 |
| S80___ | 68.9 | 95.3 | 87.1 | 59.1 | 53.0 | 73.6 | 72.3 | 46.9 | 69.3 | 48.8 |
| S82_R_ | 40.1 | 45.3 | 41.0 | 29.1 | 37.4 | 41.6 | 40.0 | 25.0 | 28.4 | 40.7 |
| SNIVEL | 43.3 | 54.8 | 52.5 | 54.6 | 46.4 | 53.8 | 50.5 | 28.3 | 52.2 | 64.3 |
| TAFT_R | 41.6 | 72.0 | 51.1 | 58.9 | 53.9 | 50.1 | 52.8 | 28.2 | 53.1 | 71.6 |
| PAHOKE | 60.6 | 70.5 | 52.4 | 49.4 | 59.2 | 48.1 | 54.8 | 41.3 | 48.6 | 42.8 |
| CHAPMA | 52.6 | 59.3 | 51.0 | 45.3 | 58.7 | 54.9 | 50.4 | 29.2 | 44.7 | 61.4 |
| LMARIO | 44.7 | 60.1 | 47.7 | 53.9 | 64.6 | 43.9 | 47.4 | 33.5 | 44.6 | 51.8 |
| MOUNTA | 43.2 | 57.8 | 55.4 | 53.2 | 48.9 | 42.3 | 40.8 | 28.9 | 56.6 | 59.1 |
| FROSTP | 47.1 | 58.9 | 55.7 | 35.3 | 50.9 | 44.7 | 45.4 | 22.9 | 60.9 | 69.9 |
| S65A_R | 58.2 | 56.9 | 53.0 | 47.8 | 64.5 | 66.2 | 52.4 | 35.9 | 55.3 | 69.2 |
| S77_R_ | 38.3 | 58.6 | 62.7 | 37.5 | 50.7 | 48.9 | 46.5 | 33.3 | 46.8 | 54.6 |
| AVERAGE | 47.3 | 60.3 | 54.8 | 45.7 | 52.9 | 51.8 | 50.6 | 32.9 | 47.9 | 50.7 |

### *4.3 Reach Delineation*

Hydrologic reaches were delineated in S-65A, S-65B, S-65C, C-44, S-153 and SLO using hydrography datasets and previous studies. As mentioned, C-44 and SLO have been previously modeled using WASH and MIKE SHE, respectively. However, like the subbasin datasets, the reach datasets created for these models were also found to be too course for the purpose of this project. The datasets did, however, provided some confirmation of flow directions.

Delineation tools provided in WAM were used to code the reach network for each area. USGS 24K hydrography, National Hydrologic Datasets (NHDs) and 1999 1m aerial photography (DOQs) were used to assist the coding process. The delineations within S-65A, B and C yielded an additional 137 model reaches in the Northern Lake Okeechobee region. Approximately 100 reaches were delineated in C-44 and S-153 and added to the East Lake Okeechobee region. In the SLO region, 164 reaches were delineated (see Figure 12, 13 and 14).

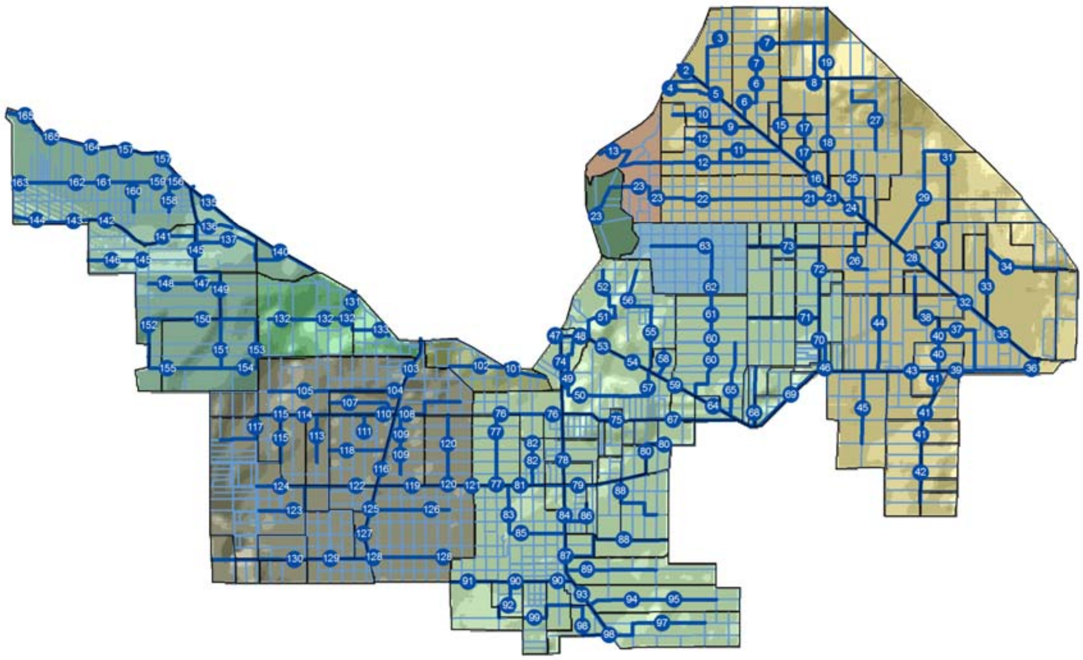

Figure 12: Reach Delineation in Southern Lake Okeechobee Region

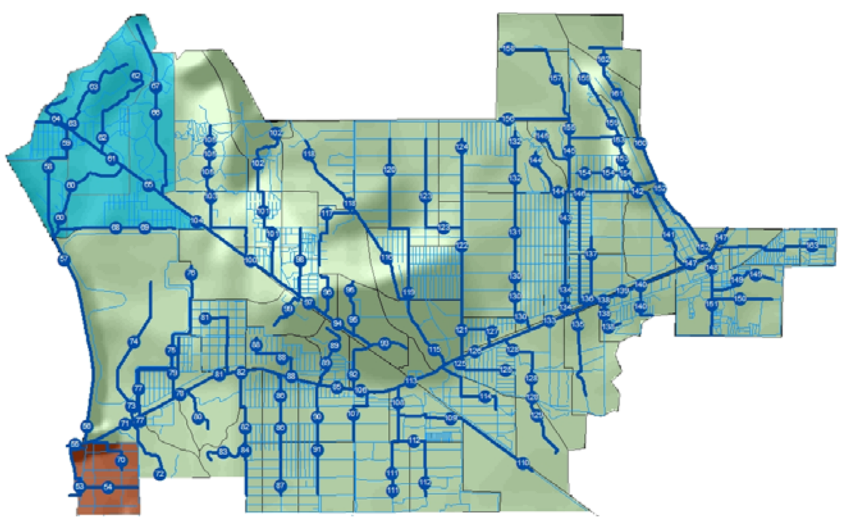

Figure 13: Reach Delineation in the C-44 Basin

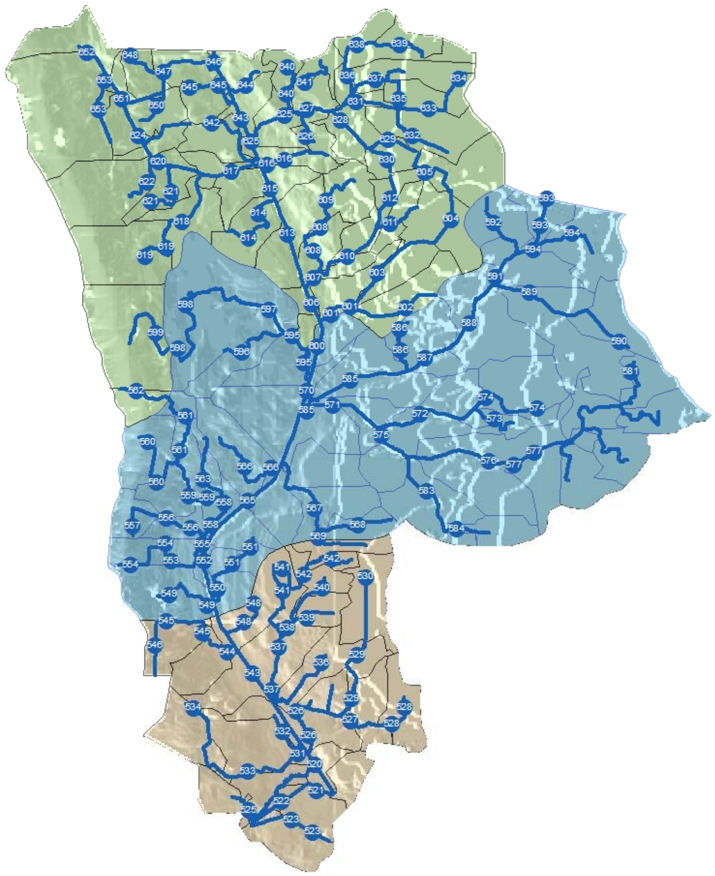

Figure 14: Reach Delineation in the S-65A, B and C Basin

### *4.4 WAM Datasets*

WAM setup procedures were followed to create datasets needed for its phosphorus assimilation model. Depressions were created using a WAM algorithm that searches for topographic sinks and other potential depressions based on land slope, soil types, wetlands and vicinity to streams. Distance and destination grids were created using another WAM algorithm. These grids will be used to determine the closest downstream feature (wetland, depression or stream) and its distance as well as the next downstream feature and distance. Figures 15, 16 and 17 each show three of the distance grids created for Basins S-65A, B and C; Basin C-44; and the SLO Region. This information is used to calculate attenuation of phosphorus through the system and ultimately to the lake. The following grids were created:

| | |
|---|---|
| Depress - | Grid of depression locations |
| Celldist1 - | Distance in meters from source cell to nearest stream |
| Celldist2 - | Distance in meters from source cell to nearest wetland |
| Celldist3 - | Distance in meters from source cell to nearest depression |
| Celldist5 - | Distance in meters from nearest wetland cell to its nearest stream |
| Celldist6 - | Distance in meters from nearest depression cell to its nearest stream |

Celldist7 - Distance in meters from cell to its appropriate stream for groundwater flow

Streamnode - This ASCII grid coverage contains the calculation stream reach code of the nearest stream reach.

Wetlandusecode - Land use code (wetland FLUCC code) of the nearest wetland to the source cell. This code is used to determine the attenuation coefficient to use based on the wetland type.

Wetlandnode - Stream reach code of the nearest stream reach to the nearest wetland cell found for the source cell.

Depressnode - Stream reach code of the nearest stream reach to the nearest depression cell found for the source cell.

GWnode - Stream reach code appropriate for the groundwater destination from each source cell.

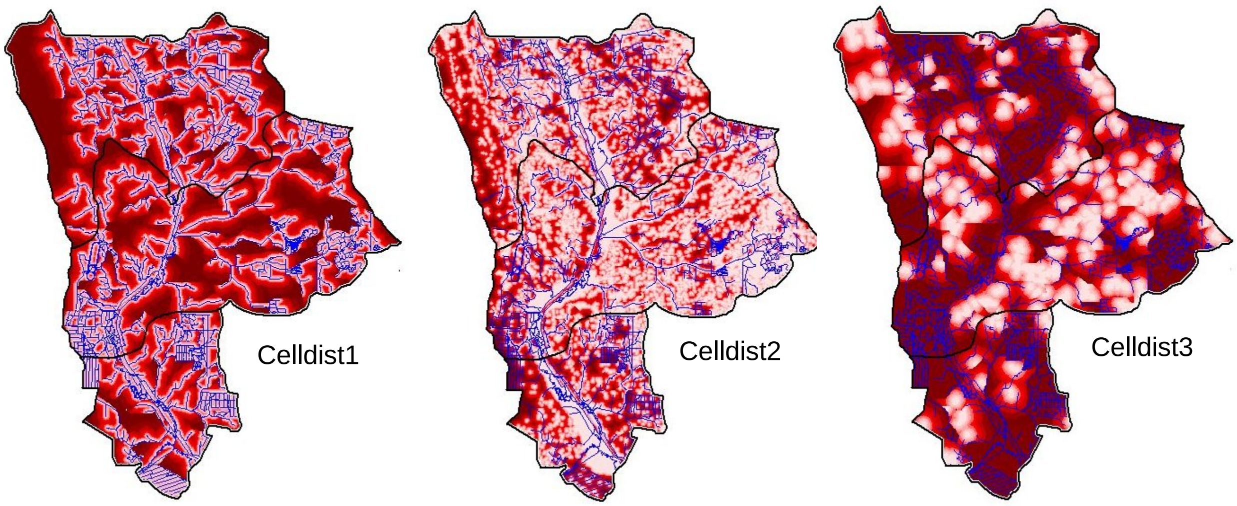


Figure 15: Distance Attenuation Grids for S-65A, B and C Basins

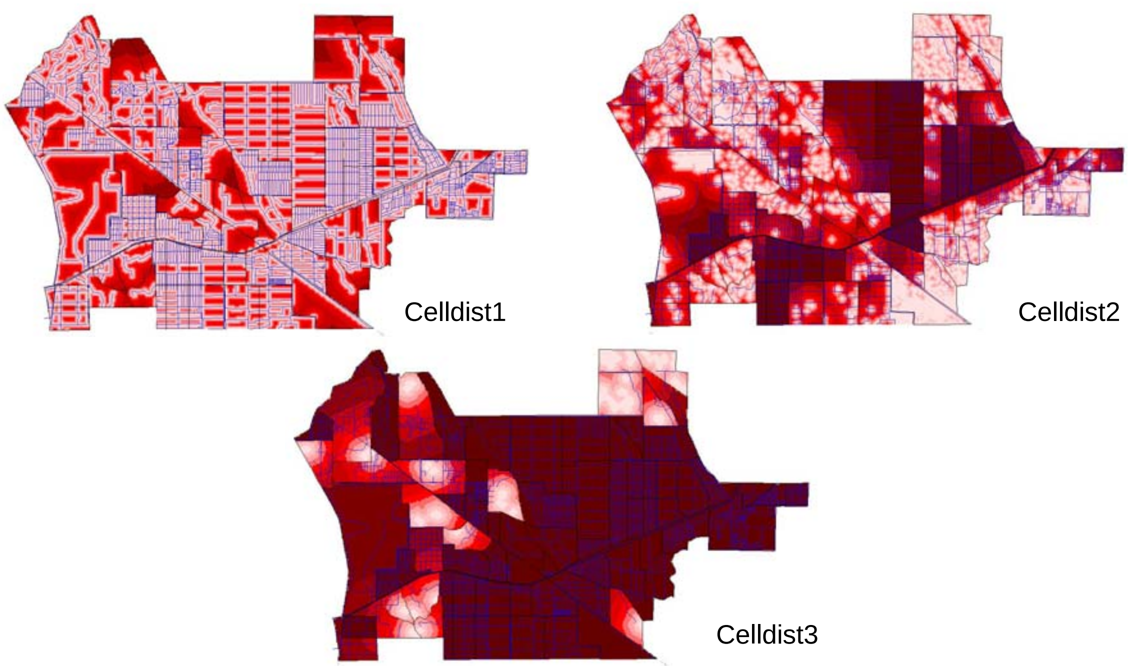


Figure 16: Distance Attenuation Grids for C-44 Basin

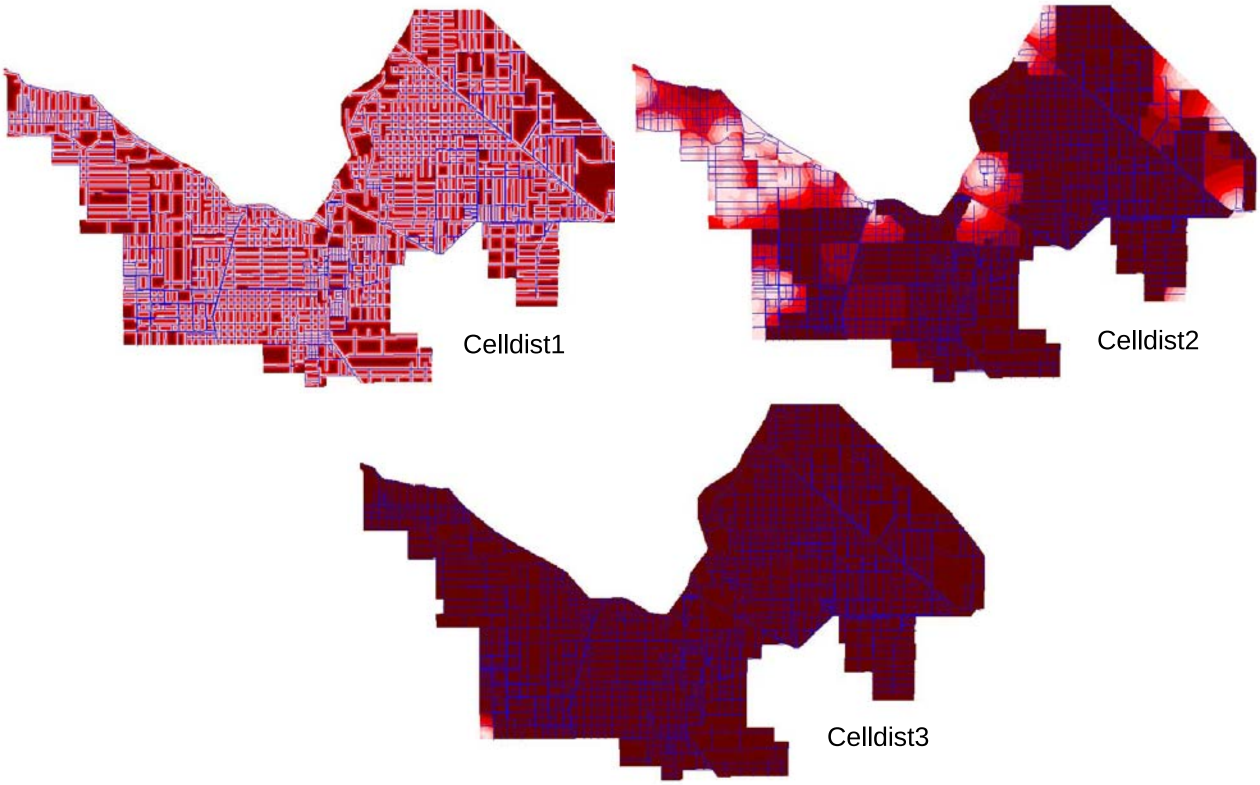


Figure 17: Distance Attenuation Grids for Southern Lake Okeechobee Region

### *4.5 WAM Model Integration*

#### 4.5.1 Background

WAM (Watershed Assessment Model) is a water quality assimilation model that was developed in the mid-1990's based on similar models written Dr. Del Bottcher of Soil and Water Engineering Technology, Inc. (SWET). The first version of WAM was written for the ARC/INFO Unix workstation platform. This version was written using ESRI's AML programming language. WAM was one of the first water quality assessment models that used the ARC/INFO component called GRID. GRID provided the ability to perform computations using rasters on a cell-by-cell basis. This resulted in output at a much smaller scale (typically 1 ha) than could be provided using polygons. The computations were also performed significantly faster than could be performed using polygon overlays.

The concept of WAM is to overlay land use, soils and rainfall zones to produce unique combinations that are submitted to three submodels – Groundwater Loading Effects of Agricultural Management Systems (GLEAMS; Knisel, 1993), Everglades Agricultural Area Model (EAAMod; Botcher et al., 1998; SWET, 1999), and a special-case model written specifically for WAM to handle wetland and urban landscapes. These submodels are bundled into one program called BUCShell, where BUC stands for Basin Unique Cell. BUCShell uses parameter dataset files for land use, soils and rainfall to produce an estimated annual average phosphorus runoff load in kilograms per hectare for each unique combination. The results are then spatially distributed onto the watershed by relating the output table to a grid of the unique combinations. The resulting grids represent the average annual phosphorus load at the source in both surface water runoff and groundwater.

The source runoff load is then attenuated via overland flow to the nearest downstream feature – stream, wetland or depression. If the feature is a wetland, the load is further attenuated through the wetland to the nearest stream. If the feature is a depression, the load is converted groundwater and also attenuated to the nearest stream. WAM assumes that approximately 90 percent of the phosphorus load that is contributed to the groundwater is retained in the soils. The other 10 percent enters the stream system.

At the stream, the attenuated surface runoff load is combined with the attenuated groundwater load and routed through the stream network where it is further attenuated. Dynamic routing of flows is accomplished within BLASRoute through the use of an algorithm that efficiently solves Manning's equations (Jacobson et al., 1998). BLASRoute handles the entire attenuation process from the source cells to the basin outlet and provides daily outputs from any stream in the network.

### 4.5.2 Approach

WAM's interface operates differently from P-Budget in regard to how modified land use/ practice scenarios are developed. The GLEAMS and EAAMOD submodels use preset parameters that reflect either existing conditions or predetermined Best Management Practices (BMPs). This excuses the user from having to make complicated and tedious editing of several parameter input files. WAM also keeps track of all previously run land use, soil and rainfall unique combinations so that each combination needs to only be run once and the results can be used in subsequent model runs.

P-Budget's interface allows the user to make more precise changes to parameters such as fertilizer rates and crop production. This presents a complication to WAM's ability to save and reuse output because the land use component of the unique combination becomes a variable. To solve this problem, a new set of unique combinations was developed specifically to track land use parameter sets. Each unique parameter set is numbered in sequential order. This number is then used in place of the land use code number when creating the unique land use, soil and rainfall combinations.

When a land use parameter is changed as the result of creating a PCP, the program checks to determine if the parameter value has been used before in conjunction with other land use parameters that form a parameter set. If so, the previously stored sequence number will be used. If not, a new parameter set will be created and provided with the next sequential number.

A determination is then made if the land use parameter sequence number has been modeled previously in conjunction with overlying soils and rainfall zones. If so, WAM

will not need to be run. If not, the unique combination will be run using WAM's BUCShell model and the results will be stored in a database for future use.
The selection of the submodel (GLEAMS, EAAMOD, or Special Case including wetlands) is three-step process within WAM. First, WAM will scan two files (LUSPEC.BNZ and SSPEC.BNZ) to determine if a special case land use or soil condition exists. Next, the land use codes listed in the LUMODEL.BNZ file are scanned to determine if the EAAMOD submodel should be used and, if found, the soil associated with this land use will checked against the available soils within the EAAMOD soils parameter file, SOIL-EAA.BNZ. If the soil is not within the SOIL-EAA.BNZ file or the land use code was not within LUMODEL.BNZ, then the GLEAMS submodel will be used. The land uses listed in LUMODEL are primarily agricultural land uses (pastures, vegetable, sugarcane, and citrus) where EAAMOD has been developed and verified. Since EAAMOD is a high water table model, the soils within the SOIL-EAA.BNZ are the coastal plain flatwoods and organic histosols. Such soils within the LOPP include adamsville, immokalee, pople, samsula and smyrna.

Since only average annual output is needed for P-Budget, WAM's hydrodynamic model, BLASRoute, is not used. This model, however, also performed the attenuation needed from the source cells to the basin outlet. A GIS algorithm was written to replace this feature using equations and coefficients specifically developed for the Northern Lake Okeechobee region

### 4.5.3 WAM Execution

The WAM model needs to run when, by creating a PCP, a change in land use practices affects WAM's land use model coefficients used to assimilate water quality runoff. The execution of WAM is accomplished through the creation and maintenance of several databases with the goal of minimizing model runtime. The files below represent the databases and text files used in the process:

| **File Name** | **Description** |
|---|---|
| coeff_def.dbf | Database of a region's default P import and export coefficients, copied from …\tables*region* folder to pcp folder and edited by interface |
| calc_def.dbf | Database of a region's default P calculator values, copied …\tables\region folder to pcp folder and edited by interface |
| wam_def.dbf | Database of a region's default WAM land use parameter combinations, copied …\tables\region folder to pcp folder and edited by interface |
| lu_seq.dbf | Database of all previously run land use parameter combinations stored in sequential order |
| unique.dbf | Empty database of rain zone, land use seq, and soil fields forming unique combinations for BUCShell |
| uniquex.dbf | Copied from unique.dbf for each model run, used to ultimately create Pload_unique.bnz |

| | |
|---|---|
| annualAll.dbf | Database of results from previously run unique combinations run by BUCShell |
| PLoad_Uniquex.txt | Temporary text file of previously unrun unique combinations for a particular run |
| PLoad_Unique.bnz | Copied from PLoad_Uniquex.txt to the ..\WAM\LocalInputs folder |
| annual.csv | Output file from BucShell containing results from a particular run, appended into annualAll.dbf if run is successful |

The following steps are performed to verify if WAM needs to run, create the model input data and manage the output:

**WAM Execution Procedure**

Step 1: When a PCP is created the following files are copied from ..\Tables\Regions*region name* folder to the ..\PCPs*pcp name* folder:

coeff_def.dbf --> coef_pcp.dbf
calc_def.dbf --> calc_pcp.dbf
wam_def.dbf --> wam_pcp.dbf

Step 2: The files are edited through the interface by changing P import/export coefficients (directly or via calculators)

Step 3: wam_pcp.dbf is compared row by row to ..\tables\luseq.dbf to determine if new parameter sets need to be created

If No: The previously established sequence number is added to the relevant row in wam_pcp.dbf

If Yes: The row from wam_pcp.dbf is added to lu_seq.dbf and a new sequence number is created and added to the relevant row in wam_pcp.dbf

Step 4: A grid is created of the land use sequence numbers based on the corresponding land uses within the PCP spatial extent

Step 5: A grid is created of the unique land use sequence, soil and rainfall zone combinations within the PCP spatial extent

Step 6: The list of unique combinations, generated from the previous grid, is compared to a list of previously run unique combinations found in the ..\tables\annualAll.dbf file. New unique combinations are written to a file, ..\tables\Pload_Uniquex.txt, including the rainfall zone, land use sequence, and soil codes along with the associated land use parameters from wam_pcp.dbf

Step 7: The ..\tables\Pload_Uniquex.txt file is copied to the ..\WAM\LocalInputs folder and renamed Pload_Unique.bnz

Step 8: BUCShell.exe. PLoadRuns.exe uses information from the Ploads_Unique.bnz file to create ..WAM\GlobalInputs\landuse.bnz and ..WAM\LocalInputs\unique.bnz. BUCShell.exe performs the water quality assimilation using GLEAMS, EAAMOD or a special case model. The output is stored in ..\WAM\Days\annual.csv

Step 9: The ..\WAM\Days\annual.csv file is converted to a database and the rows are appended to the ..\Tables\annualAll.dbf file

Step 10: The unique grid created in Step 5 is reclassified using the annualAll database to create grids of soluble, sediment and groundwater phosphorus in g/ha and runoff and percolation in mm

### 4.5.4 Attenuation

The drainage area tool that was developed in Task 1 includes the option (see Figure 10) for the user to obtain a drainage area summary table if using this tool to create an Area of Interest (AOI). The table includes phosphorus summaries of imports, exports, rainfall, runoff, etc. It also includes the WAM results attenuated to the outlet of the drainage area including total load, volume and concentration.

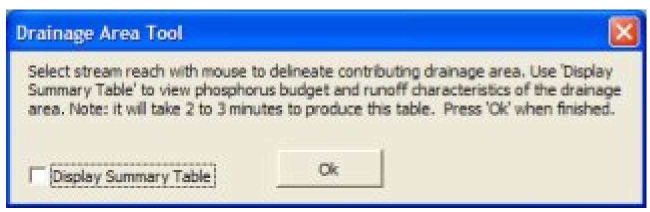


Figure 18: Prompt for Using Drainage Area Tool

The phosphorus assimilation algorithms developed for the Lake Okeechobee Agricultural Support System (LOADSS) program (SWET, 2001) were used to estimate the attenuation that occurs from the source of the phosphorus contribution to the outlet of the drainage area. The assimilation model, as shown in Equation 1, is a second-order exponential relationship.

$$C - (Co - Cb)e^{(-kD)} + Cb \qquad (1)$$

where,

| | |
|---|---|
| k | = $aQ^{-b}$ |
| C | = the concentration at the end of a reach (i.e., a sub-basin node) |
| Co | = the concentration at the beginning of a reach |
| Cb | = the background or minimum concentration expected |
| D | = reach length |
| a and b | = empirical coefficients and |
| Q | = stream discharge |

Values for a, b, and Cb are the actual calibration parameters for representing the influence of flow-rate on attenuation. The values for Q, D, and Co are acquired from physical parameters in the watersheds that are provided by WAM. The following datasets are used from the WAM model:

<u>Preprocessed</u> Note: "[ ]" denotes raster grid

| | |
|---|---|
| [celldist1] | grid of distances to nearest downstream lake, stream or slough |
| [celldist2] | grid of distances to nearest downstream wetland |
| [celldist3] | grid of distances to nearest downstream depression |
| [streamnode] | grid identifying the reach code number to which each cell ultimately drains |
| Reaches.shp | shapefile of hydrologic reaches including attributes for reach code number, type (stream, lake or slough), length, and accumulated length for downstream reaches (streams, lakes and sloughs) from each reach to Lake Okeechobee |

<u>Model Output</u> Note: "[ ]" denotes raster grid

| | |
|---|---|
| [solpcel1] | soluble phosphorus load in surface water runoff at source |
| [sedpcel1] | sediment phosphorus load in surface water runoff at source |
| [gwpcel1] | phosphorus load discharged to groundwater at source |
| [ro] | runoff (in depth) |
| [perc] | percolation (in depth) |

The preprocessed datasets represent static information that is utilized but not changed by the P-Budget interface. The preprocessed grids were created using the WAM setup interface as described in Section 3.4 individually for each region and then merged together. The reaches.shp file was also created using WAM's setup interface, but was supplemented with the downstream accumulated reach lengths.

Attenuation is applied in two sequential processes – overland flow and stream/lake/ wetland flow. To account for the influences of the three reach types (stream, lake or wetland), weighted coefficients are used to reflect the relative influence of the reach types. The following equations and coefficient definitions describe how the new assimilation equations are represented:

<u>Overland Flow Equation</u>

$$C_1 = (C_0 - Cb)*e^{-Ko*Do} + Cb \qquad (2)$$

Where,

$$Ko = Ao*qo^{-Bo} \qquad (3)$$

<u>Stream/Canal Flow Equation</u>

$$C_2 = (C_1 - Cb)*e^{-Kc*D} + Cb \qquad (4)$$

Where,

$$Kc = (As*Ds+Al*Dl+Aw*Dw)/D *qb^{-( Bs*Ds+Bl*Dl+Bw*Dw)/D} \quad (5)$$

And where,

[Do] = Distance of overland travel from cell to nearest stream, lake or wetland (m)
[Ds] = Distance of travel through streams between cell and drainage area outlet (m)
[Dl] = Distance of travel through lakes between cell and drainage area outlet (m)
[Dw] = Distance of travel through wetlands between cell and drainage area outlet (m)
[D] = Total flow distance in streams, lakes and wetlands (m)
[qo] = Discharge from cell in equivalent depth (in/yr)
[qb] = Average discharge from drainage area in equivalent depth (in/yr)
Ao = Constant A in K equation for overland flow
Bo = Constant B in K equation for overland flow
As = Constant A in K equation for stream flow portion of stream
Bs = Constant B in K equation for stream flow portion of stream
Al = Constant A in K equation for lake flow portion of stream
Bl = Constant B in K equation for lake flow portion of stream
Aw = Constant A in K equation for wetland flow portion of stream
Bw = Constant B in K equation for wetland flow portion of stream
Cb = Background concentration (mg/l)
[$C_0$] = Initial concentration of constituent in polygon (mg/l)
[$C_1$] = Concentration after overland flow attenuation (mg/l)
[$C_2$] = Concentration after stream flow attenuation (mg/l)
Note: "[ ]" denotes raster grid

**Attenuation Procedure:**

Step 1: Create [Do] is set equal to [celldist1]
Step 2: Create [Ds], [Dl] and [Dw] and [D] by reclassifying [streamnode] with data from reaches.shp
Step 3: Create [qo] by converting [ro] to inches
Step 4: Create [qb] by adding [ro] and [perc] together and obtaining the mean value
Step 5: Create [$C_0$] by adding [sedpcel1] and [solpcel1] together and converting to mg/l using [ro]
Step 6: Create [$C_1$] using overland attenuation formula
Step 7: Convert [$C_1$] to loads
Step 8: Replace [$C_1$] by adding attenuated surface water and groundwater loads together and converting to mg/l using the sum of [ro] and [perc]
Step 9: convert it to mg/l using the sum
Step 10: Create [$C_2$] using stream/lake/wetland attenuation formula

## 4.5.5 Incorporation of Monitoring Data

At an early planning meeting to discuss interface concepts, District staff expressed an interest in being able to view water quality monitoring data jointly with, or in place of output from the WAM model. The Lake Okeechobee Watershed Assessment (LOWA) monitoring program includes 127 sampling sites distributed over the Northern Lake Okeechobee Region. Many of the sites in this program are also sites used to monitor phosphorus for the District's Works of the District (WOD) permitting program. Of the

127 sites, 100 sites were matched up to hydrologic reaches in the model.  Sampling data was provided for 50 of the 100 sites.

Additionally, 37 sites from the Kissimmee River Eutrophication Abatement (KREA) and Taylor Creek/Nubbin Slough (TCNS) programs were incorporated.  Of the 37 sites, 33 sites were matched up to hydrologic reaches in the model.  Six of these sites, however, coincide with sites in the LOWA/WOD programs. Other miscellaneous sites corresponding to major District control structures were also added.  Table 5 shows all of the monitoring sites that were considered for incorporation into the interface.

Average phosphorus concentrations for each site were calculated over the period of record and assigned to field in the reaches.shp shapefile.  When the drainage area summary table is created, the program code determines if monitoring data is available for the selected reach and, if so, presents it in the table.

When comparing the modeled phosphorus concentrations to measured data in upstream locations such as these, it is important to consider that the model uses region-wide average data associated with land use practices.  A significant difference in the results may indicate a difference of land practices in the area upstream.

Table 5: Water Quality Monitoring Data

| Station Name | Reach No. | P (ppb) | Station Name | Reach No. | P (ppb) | Station Name | Reach No. | P (ppb) |
|---|---|---|---|---|---|---|---|---|
| BH043929.1NE | 806 | | KR013733.1NW | 170 | 246 | TC073535.1NE | 488 | 1340 |
| BH103829.1SE | | | KR023632.1NW | 264 | | TC093735.1SW | 554 | |
| BH323829.1SE | 808 | 511 | KR033733.3SW | 173 | 3150 | TC103735.1SW | 553 | |
| CH153634.1NE | 44 | 1554 | KR053733.1NW | 174 | 612 | TC153735.1SW | 550 | |
| CS123533.3SE | | | KR073733.3SE | | | TC173735.1SW | 46 | |
| CS143533.1SE | 230 | 634 | KR073734.1NE | 66 | 457 | TC183735.1NE | 47 | |
| CY053534.4SE | 222 | 382 | KR103733.1SE | 266 | 514 | TC273534.1SW | 495 | 687 |
| CY063634.1NW | 195 | 789 | KR143633.1SW | 180 | 701 | TS253634.1SW | | |
| CY173534.1SW | 223 | 720 | KR153532.1SE | | | TS263634.1NW | | |
| CY243533.1SW | 226 | 621 | KR163733.1SE | 160 | 1158 | TS363634.1NW | 40 | 5296 |
| FE033628.1SE | | | KR163734.1SE | 61 | 195 | WD023635.1SE | | |
| FE033829.1NW | 838 | 1330 | KR173734.1NW | 164 | | WD103635.1NE | 465 | 223 |
| FE203930.1SW | | | KR183734.1SW | 164 | | YM263633.1NE | 177 | 418 |
| FE213929.1SE | | | KR203734.1SW | | | KREA 01 | | |
| FE213929.1SW | 803 | | KR293533.3SE | 258 | 1073 | KREA 04 | 225 | 174 |
| FE313728.1SE | 835 | | KR303533.1NE | 260 | 509 | KREA 06A | 202 | 317 |
| FE323728.1SE | 831 | | KR343532.1SE | 266 | | KREA 17A | 177 | 379 |
| FE324032.1SE | 706 | | KR363633.1NE | | | KREA 19 | 160 | 579 |
| FE333728.1SE | 829 | | KR363633.1NW | | | KREA 20 | 58 | 1496 |
| FE343729.1SW | 839 | | LB293535.1SW | 482 | 411 | KREA 22 | | |
| FE353628.1NE | 869 | | LC063837.1SE | 422 | 445 | KREA 23 | 250 | 78 |
| FE353628.1NW | 873 | | LC073837.1SE | 425 | | KREA 25 | 44 | 837 |
| FS203434.1SW | 219 | | LC133836.1SE | 427 | 741 | KREA 28 | 35 | 965 |
| GG054030.1NW | 748 | | LC143837.1SE | 435 | | KREA 30A | 28 | 890 |
| GS234031.1SW | 709 | | LC163837.1SE | 431 | 305 | KREA 41A | | |
| GT074029.1NW | | | LC163837.1SW | 428 | 1308 | KREA 79 | 363 | 56 |
| HP063932.1NE | 1022 | 237 | LM053835.1SE | 558 | | KREA 91 | 368 | 56 |
| HP063932.3NE | 1014 | | LM293735.1SE | 560 | | KREA 92 | | |
| HP093831.2NW | | | LM293735.1SW | 563 | | KREA 94 | 280 | 108 |
| HP093831.5NW | 1064 | | LO043835.1NE | | | KREA 95 | | |
| HP103731.1SE | | | LO243834.1NE | 577 | | KREA 98 | 299 | 67 |
| HP103831.1NE | | | LO283735.1SW | | | KREA 99 | 300 | 8 |
| HP153731.1NE | 1078 | 431 | LO313736.1SW | 531 | | TCNS 201 | 485 | 492 |
| HP163831.2NW | 1062 | | MS043736.1SW | 449 | 352 | TCNS 204 | 482 | 1003 |
| HP163831.2SW | 1060 | 116 | MS053736.1SW | 447 | 1491 | TCNS 207 | 477 | 1023 |
| HP213831.2NW | 1049 | 205 | MS083736.1NW | | | TCNS 209 | 476 | 503 |
| HP223731.1NE | 1076 | 416 | MS083736.1SE | | | TCNS 212 | 475 | 264 |
| HP223932.1NW | 991 | 202 | MS163736.1SW | 444 | 646 | TCNS 213 | 472 | 475 |
| HP233731.1NW | | | MS193736.1NE | 443 | 711 | TCNS 214 | 457 | 235 |
| HP263731.1NW | 1071 | | MS343636.1SW | 452 | 101 | TCNS 217 | 496 | 370 |
| HP273731.1NE | 1075 | | OT293535.1SE | | | TCNS 220 | 446 | 668 |
| HP273831.2SE | 1034 | 370 | OT323535.1NW | 480 | 1048 | TCNS 222 | 442 | 556 |
| HP283831.1NE | 1039 | | OT343535.1SW | 475 | 134 | TCNS 228 | 411 | 517 |
| HP343731.2SE | 1065 | | PB243929.1NE | 800 | | TCNS 230 | 419 | 521 |
| HP353731.1SW | | | PB263929.1NW | 798 | 951 | TCNS 233 | 421 | 492 |
| HP363831.1NE | 1026 | 315 | PS043734.1SW | 63 | 974 | TCNS 249 | 417 | 400 |
| HR113836.1NE | 419 | 473 | RS234028.1NW | 782 | | ARBUCK | 2069 | 123 |
| HS064029.1NW | 787 | | SD033731.1NW | 124 | | FEC | 708 | 183 |
| IN133735.3NW | 454 | | SD133731.1NE | 117 | | FISHP | 764 | |
| IP013831.2NE | 931 | | SD133731.1NW | 118 | 367 | S191 | 409 | 500 |
| IP053832.1NW | 936 | | SD173732.1SE | | | S59 | 3127 | |
| IP093832.2NE | 928 | | SD253732.1NW | 94 | | S61 | 3104 | |
| IP143832.1SE | 916 | | SD283733.1NE | 82 | | S65 | 3002 | 119 |
| IP153832.1NE | 921 | | SD333631.1NW | 150 | | S65C | 272 | 79 |
| IP243832.1SE | | | SD333733.1SW | 83 | | S68 | 2002 | 66 |
| IP293833.1SW | 890 | | TC033735.1NW | 456 | | | | |
| JS113928.1NW | 815 | | TC033735.1SW | | | | | |

### *4.6 Evaluation of Results*

## 4.6.1 Flow Calibration

It is important to calibrate flows before all other parameters because of the impact flow can have on estimated phosphorus concentrations. It should be noted that measured data are subject to margins of error, which are difficult to quantify. Initial model runs showed that, while average annual flows were within acceptable ranges of measured values in the southern portions of the Northern Lake Okeechobee region, modeled flows were significantly higher in the Chain of Lakes and Lake Istokpoga regions. Two characteristics in those regions that are not present in the other regions include the high percentage of lakes and the ability to recharge groundwater to the Upper Floridan Aquifer (UFA).

Evaporation parameters were reviewed and adjusted based on measured evaporation rates in the regions. Recharge to the UFA is more difficult to quantify. Previous groundwater modeling in the regions (SFWMD, 2000) provided delineations of zones of both recharge and discharge to and from the UFA. Each zone is represented by a range of potential annual recharge or discharge amounts of water. These zones were digitized and subdivided into subzones to provide flexibility in calibrating the overall water budget. Values were entered for each zone in a "trial and error" exercise to obtain the best match of flow volume to measured values while remaining within the previously defined recharge/discharge ranges (Figure 19).

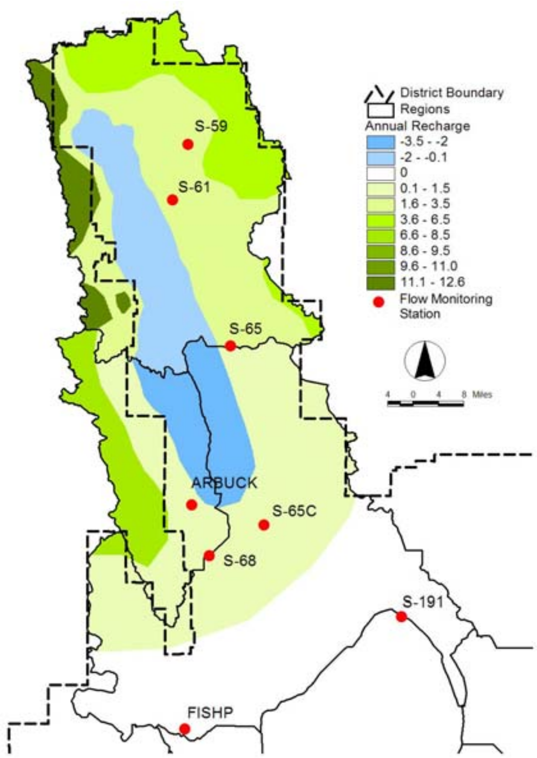


Figure 19: Flow Stations and Calibrated Zones of Annual Recharge in inches

Flow monitoring stations were chosen at locations where it was reasonable to assume that the station would represent a static upstream drainage area. The Eastern, Western and Southern Lake Okeechobee regions only partially flow to Lake Okeechobee. Basins located immediately along the border of the lake the Northern Lake Okeechobee region are subject to seepage and other unmonitored activities. C-40, C-41 and C-41A are subject to an operating schedule that would need to be simulated on a daily basis as opposed to annual. For purposes of this model, flow was directed based on normal operation of District control structures. Table 6 shows the results of the flow calibrations at the stations shown in Figure 19.

Table 6: Measured vs. Modeled Average Annual Flow Comparison

| Station | Measured flow (ac-ft) | Modeled flow (ac-ft) | Difference |
|---|---|---|---|
| S-191 | 92554.2 | 91203.0 | -1% |
| FISHP @SR27 | 224329.8 | 216803.1 | -3% |
| S-65 | 728392.3 | 782812.6 | 7% |
| S-65C | 1037777.7 | 1076222.1 | 4% |
| ARBUCK @ SR98 | 246792.7 | 241229.4 | -2% |
| S-68 | 313881.1 | 317685.1 | 1% |
| S-61 | 302844.0 | 305865.8 | 1% |
| S-59 | 105105.8 | 101870.6 | -3% |

The modeled flows were within acceptable differences compared to the measured flows at all of the stations considering the margins of error that exist in modeling and measuring. There are several explanations for the margins of error. The most notable in terms of the modeling is that rainfall in a given basin is only known at a few locations and is spatially applied using a statistical distribution. Actual rainfall will vary as the model moves away from the monitored sites. A common error associated with measured data is that the flow, in most cases, is measured once per day, but may vary during the 24 hours that it represents.

The largest difference occurred at S-65, which carried over to a lesser degree at S-65C. The explanation may be that there is some discharge from Lake Wechyakapka in the southwest portion of the Upper Chain of Lakes region entering the Lake Istokpoga region. There may be a hydrologic connection when stages in the lake permit the water to overflow. There also appears to be some discontinuity between the regions regarding recharge. This is most likely due to a gradient of change from north to south that is not depicted. The figure depicts average values at the centroids of the zones within each region. It could be due in part to an imbalance of flow between the regions causing the calibration to over compensate.

### 4.6.2 Phosphorus Load and Attenuation

Because WAM is a physical based model, there very little calibration needed. Rather, a validation of the input datasets is needed by comparing the phosphorus concentrations to measured values. For this project, the land use coverage was updated and provided by the District and the land use practices such as crops and fertilizer rates were obtained from the previous phosphorus budget studies that were performed (Hiscock et al., 2003, Mock-Roos Team, 2003 and Zhang et al., 2003a and 2003b). In addition, attenuation coefficients for overland, stream and wetland flow were obtained from a previous study in the Northern Lake Okeechobee region.

It is not the intent or goal of this project to revise any of this information. However, one change was made to the land use coverage after comparing the phosphorus concentrations at the S-191 station. Abandoned dairies were added. These areas exhibit higher than normal phosphorus discharges due to past activities despite the fact that the current import and export practices are consistent with improved pasture. The soil parameters and locations of these areas were obtained from on-going studies related to the Comprehensive Everglades Restoration Plan (CERP) being conducted in the Northern Lake Okeechobee region.

The only parameters that were not available are the attenuation coefficients associated with lakes. Several values for the a and b coefficients, as described in Section 4.5.5, were tried to obtain the best match to measured data in regions where lakes are present. The modeled concentrations at S-68 are higher than the measured concentrations, coupled with model concentrations at S-65 that were lower than measured, presented a complication in the calibration effort. Fortunately, a monitoring station, ARBUCK, is located immediately upstream of Lake Istakpoga providing an excellent comparison for lake attenuation. The resulting coefficients of a = 800 and b = 2.5 matched the reduction observed between ARBUCK and S-68. The coefficients also maintained an equilibrium between the results at S-68 and S-65, i.e., the absolute differences (high or low) between the modeled and measured concentrations were maintained as approximately equal. Table 7 shows the measured and modeled concentrations at various monitoring stations between 1998 and 2003. All of the stations coincide with flow stations shown on Figure 19 with the exception of FEC which is measured at the outlet of Fisheasting Creek to Lake Okeechobee.

Table 7: Measured vs. Modeled Average Annual Phosphorus Concentrations

| Station | Measured TP (mg/l) | Modeled TP (mg/l) | Difference |
|---|---|---|---|
| S-191 | 0.500 | 0.407 | -18.6% |
| S-65 | 0.119 | 0.071 | -40.3% |
| S-65C | 0.079 | 0.077 | -2.0% |
| ARBUCK @ SR98 | 0.123 | 0.162 | 31.6% |
| S-68 | 0.066 | 0.106 | 60.1% |
| FEC | 0.183 | 0.113 | -38.3% |

The modeled concentrations appear to generally follow the trend of the measured data. There are two observations that can be made. The difference in concentrations at S-65 and S-68 between the measured and modeled data are inversely related. Though these watersheds share many of the same characteristics for topography, land use and recharge, the modeled concentration at one station (S-68) is higher than the measured and the modeled concentration at the other (S-65) is below the measured. One possible cause could the drainage issued raised in Section 4.6.1. There may be some discharge from Lake Wechyakapka in the southwest portion of the Upper Chain of Lakes region entering the Lake Istokpoga region. A hydrologic connection may exist when stages in the lake permit the water to overflow. The modeled phosphorus concentrations in Lake Wechyakapka are relatively low (< 0.05 mg/l). A shifting of this water would result in lower concentrations in Arbuckle Creek/Lake Istokpoga (S-68) and higher concentrations in Lake Kissimmee (S-65).

The modeled phosphorus concentration from Fisheating Creek (FEC) is lower than the measured data indicates. A possible cause may be that the creek acts more like a stream than a slough with less interaction with the wetlands than a typical slough. The model may be over attenuating phosphorus as a result. Another explanation may be that the land use practices in FEC are not typical of the region. This is an important consideration when comparing the modeled to measured data in upstream locations.

# 5.0 Conclusion and Recommendations

A phosphorus budget tool has been updated and rewritten for the District covering the entire Lake Okeechobee Protection Plan area that, for the first time, includes a dynamic link to a phosphorus runoff model so that all aspects of the budget may be accounted for when applying phosphorus control measures. Previous approaches have utilized Event Mean Concentrations (EMCs) to estimate phosphorus runoff, which could not account for changes in land use applications.

P-Budget has been rewritten in ESRI™'s latest version of GIS software, ArcGIS 9.0. Furthermore, the programming language has changed from Avenue™, which only worked in ESRI's previous version of GIS software, ArcView 3, to Microsoft™'s Visual Basic for Application (VBA), which is used by several other type of software and is compatible with Visual Basic, a standard programming language. This migration will allow the software to be adapted for other applications, if the need arises. The use of a more standard programming language will also simplify future modifications of the software.

Some enhancements have been added as the software was rewritten. Besides the incorporation of the phosphorus runoff model, a drainage area summary tool has been added that will produce a table representing the contributing area of a selected hydrologic reach. This table includes phosphorus budget import and export values along with runoff model output data and, where available, monitoring data. The phosphorus runoff is routed through the stream network to account for attenuation and storage within the network.

Additional spatial area selection tools have be incorporated to provide more flexibility when applying phosphorus controls. These tools are also used for a new feature in the interface called Area of Interest, which sets the area for which tables and reports will represent. Another enhancement includes the incorporation of Crystal Reports™ to generate custom reports consisting of tables, figures and pie charts.

The following recommendations are made based on the results of the above effort:

- The drainage area tool provides an excellent means of comparing model output to measured output. Since model output represents estimated region-wide land use practices, large disparities between the two could be investigated in an effort to reduce phosphorus loads in areas exhibiting higher than expected measured concentrations.

- The results in the Lake Istokpoga and Upper Chain of Lakes regions suggest that there may be a hydrologic (possible subsurface) connection between the two regions from Lake Wechyakapka to Lake Arbuckle. It is recommended that any future studies in that area consider this possibility and verify if such a connection exists.

- The addition of Best Management Practices (BMPs) such as stormwater detention systems could be incorporated into the creation of PCPs to assess the effects of such measures on both runoff and net import.

- Updates of the import and export phosphorus coefficients should be performed periodically to consider changes in land use practices. To facilitate the process, it is recommended that the fields in the calc_def.dbf database file be utilized when collecting updated information (see Appendix B, User Manual: Updating P-Budget).

- Though not originally planned, the addition of Crystal Reports to the interface has resulted in a vast improvement over previous reporting methods. To further improve the functionality of the interface, it is recommended that District staff consider ways that they may wish to view these and other such reports in future enhancements.

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Zhang, J. W. Donovan, D. Moss, E. Colborn, D. Pescatore, and R. Shah, 2003b. Phosphorus Budget Analysis for the Southern Drainage Basins in the Lake Okeechobee Watershed. Final report to the South Florida Water Management District, West Palm Beach, Florida.

# Appendix A

## Table A-1: VBComponent Summary

| Name | Type | Procedures | DLL Declarations | Lines of Code | Module Size |
|---|---|---|---|---|---|
| ThisDocument | Class Module | 67 | 0 | 3619 | 157.1 K |
| ThisDocumentUPD | Class Module | 2 | 0 | 8 | 0.4 K |
| AttenuateMOD | Standard Module | 1 | 0 | 229 | 14.1 K |
| AttenuateUPD | Standard Module | 1 | 0 | 148 | 8.0 K |
| BackupVBAComponentsMOD | Standard Module | 1 | 0 | 27 | 1.9 K |
| BackupVBAComponentsUPD | Standard Module | 1 | 0 | 27 | 1.9 K |
| CalcJnFld2FldMOD | Standard Module | 1 | 0 | 55 | 2.1 K |
| ClearGeodatabaseMOD | Standard Module | 1 | 0 | 38 | 1.4 K |
| ClearSelectionMOD | Standard Module | 1 | 0 | 22 | 1.1 K |
| CopyRasterMOD | Standard Module | 1 | 0 | 21 | 0.9 K |
| CopyRasterUPD | Standard Module | 1 | 0 | 23 | 1.0 K |
| CreateListMOD | Standard Module | 1 | 0 | 11 | 0.4 K |
| CreateReportMOD | Standard Module | 1 | 0 | 51 | 2.4 K |
| CreateShapeFileMOD | Standard Module | 1 | 0 | 48 | 2.5 K |
| dBase2GeodatabaseMOD | Standard Module | 1 | 0 | 59 | 2.9 K |
| DeleteRasterMOD | Standard Module | 1 | 0 | 23 | 0.9 K |
| DeleteRasterUPD | Standard Module | 1 | 0 | 23 | 0.9 K |
| ExportMapMOD | Standard Module | 1 | 0 | 49 | 2.2 K |
| ExportTableToTextMOD | Standard Module | 1 | 0 | 31 | 1.4 K |
| FindLayerMOD | Standard Module | 1 | 0 | 34 | 1.8 K |
| GetDBASEFileMOD | Standard Module | 1 | 0 | 14 | 0.8 K |
| GetDBASEFileUPD | Standard Module | 1 | 0 | 14 | 0.8 K |
| GetSelectionIDsMOD | Standard Module | 1 | 0 | 17 | 0.7 K |
| GetTextFileMOD | Standard Module | 1 | 0 | 13 | 0.8 K |
| GetTextFileUPD | Standard Module | 1 | 0 | 13 | 0.8 K |
| GetUserNameLIB | Standard Module | 0 | 1 | 2 | 0.2 K |
| Graphics2ShapefileMOD | Standard Module | 1 | 0 | 22 | 0.9 K |
| LoadCalcValuesMOD | Standard Module | 1 | 0 | 90 | 5.2 K |
| OpenTableMOD | Standard Module | 1 | 1 | 67 | 4.1 K |
| QueryFLayerMOD | Standard Module | 1 | 0 | 25 | 1.3 K |
| ReplaceDefaultGridsUPD | Standard Module | 1 | 0 | 520 | 31.2 K |
| SaveCalcValuesMOD | Standard Module | 1 | 0 | 78 | 4.7 K |
| SelectByPointMOD | Standard Module | 1 | 0 | 86 | 4.2 K |
| SetGlobalsMOD | Standard Module | 1 | 1 | 104 | 3.7 K |
| SetGlobalsUPD | Standard Module | 1 | 1 | 23 | 0.9 K |
| SetRasterAnalEnvMOD | Standard Module | 1 | 0 | 16 | 0.8 K |
| SetRasterAnalEnvUPD | Standard Module | 1 | 0 | 16 | 0.8 K |
| SortTableMOD | Standard Module | 1 | 0 | 62 | 2.4 K |
| SortTableUPD | Standard Module | 1 | 0 | 62 | 2.5 K |
| ZoomToRegionMOD | Standard Module | 1 | 0 | 18 | 0.7 K |
| BaseMapIcons | UserForm | 1 | 0 | 3 | 0.6 K |
| frmBanner | UserForm | 1 | 0 | 3 | 0.6 K |
| frmCalcClnrs | UserForm | 4 | 0 | 30 | 1.5 K |
| frmCalcFeed | UserForm | 8 | 0 | 41 | 1.8 K |
| frmCalcFeed2 | UserForm | 4 | 0 | 29 | 1.5 K |
| frmCalcFert | UserForm | 9 | 0 | 48 | 2.1 K |
| frmCalcHarv | UserForm | 11 | 0 | 66 | 2.4 K |
| frmCalcHay | UserForm | 3 | 0 | 22 | 1.1 K |
| frmCalcLivew | UserForm | 6 | 0 | 34 | 1.5 K |
| frmCalcMilk | UserForm | 6 | 0 | 34 | 1.5 K |
| frmCalcSept | UserForm | 7 | 0 | 38 | 1.7 K |
| frmCalcSod | UserForm | 3 | 0 | 22 | 1.1 K |
| frmDATool | UserForm | 1 | 0 | 4 | 0.6 K |
| frmEditPCP | UserForm | 28 | 0 | 947 | 49.4 K |
| frmNewPCP | UserForm | 6 | 0 | 329 | 14.7 K |
| frmOptions | UserForm | 5 | 0 | 27 | 1.3 K |
| frmPCPs | UserForm | 4 | 0 | 240 | 11.1 K |
| frmReportViewer | UserForm | 0 | 0 | 1 | 0.6 K |
| frmSetAOI | UserForm | 2 | 1 | 145 | 8.3 K |
| frmUpdate | UserForm | 10 | 0 | 109 | 3.6 K |
| frmWODs | UserForm | 3 | 0 | 180 | 7.8 K |

# Appendix A

## Table A-2: List of VBA Procedures

**AttenuateMOD**
***Performs attenuation of phosphorus source grids
Public Function attnLoad(strmD0 As Long, lakeD0 As Long, slghD0 As Long) As IRaster

**AttenuateUPD**
***Performs attenuation of phosphorus source grids when updating default runs
Public Sub attnLoad()

**BackupVBAComponentsMOD**
***Copies all VBA code to backup drive
Public Sub BackupVBAComponents()

**BackupVBAComponentsUPD**
***Copies all VBA code to backup drive
Public Sub BackupVBAComponents()

**BaseMapIcons**
***Form used to programmatically retrieve base map toggle icons
Private Sub UserForm_Click()

**CalcJnFld2FldMOD**
***Joins tables together
Public Sub CalcJnFld2Fld(baseTbl As ITable, jnDispTbl As IDisplayTable, strFrJnFld As String, strToFld As String, strUnits As String)

**ClearGeodatabaseMOD**
***Deletes existing tables for geodatabase
Sub ClearGeodatabase()

**ClearSelectionMOD**
***Clears selections in ArcMap layers
Public Sub ClearSelection(pMxDoc As esriArcMapUI.IMxDocument, theTheme)

**CopyRasterMOD**
***Copies a raster from one name to another
Function CopyRaster(rasterPath As String, fromName As String, toName As String) As Boolean

**CopyRasterUPD**
***Copies a raster from one name to another

# Appendix A

## Table A-2: List of VBA Procedures

Function CopyRaster(fromPath As String, fromName As String, toPath As String, toName As String) As Boolean

**CreateListMOD**
***Creates an empty list
Public Sub CreateList(newList)

**CreateReportMOD**
***Creates, formats and displays report using Crystal Reports
Sub CreateReport(rptName As String, pRecSet As RecordSet)

**CreateShapeFileMOD**
***Creates a new empty shapefile
Public Function createShapefile(featWorkspace As IFeatureWorkspace, strName As String, geomType As esriGeometryType
Optional pFields As IFields, Optional pCLSID As UID) As IFeatureClass

**dBase2GeodatabaseMOD**
***Adds dBase file to a geodatabase for creating reports
Public Function dBase2Geodatabase(tblName As String)

**DeleteRasterMOD**
***Deletes a raster
Function DeleteRaster(rasterPath As String, rasterName As String) As Boolean

**DeleteRasterUPD**
***Deletes a raster
Function DeleteRaster(rasterPath As String, rasterName As String) As Boolean

**ExportMapMOD**
***Creates an image file of the left dataframe map for reports
Public Sub ExportMap()

**ExportTableToTextMOD**
***Exports a table to a comma-delimited text file
Sub ExportTableToText(pTable As ITable, txtFilePath As String, txtFileName As String)

**FindLayerMOD**
***Finds a layer in a map
Public Function FindLayer(map As esriCarto.IMap, name As Variant) As esriCarto.ILayer

# Appendix A

## Table A-2: List of VBA Procedures

**frmBanner**
***Form used to display opening banner
Private Sub UserForm_Click()

**frmCalcClnrs**
***Form for calculating P associated with cleaners
Private Sub cmdCalc_Click()
Private Sub cmdCancel_Click()
Private Sub txtAmt_Change()
Private Sub txtArea_Change()

**frmCalcFeed2**
***Form for calculating P associated with feed (residential)
Private Sub cmdCalc_Click()
Private Sub cmdCancel_Click()
Private Sub txtDens_Change()
Private Sub txtPeff_Change()

**frmCalcFeed**
***Form for calculating P associated with feed (ag)
Private Sub cmdCalc_Click()
Private Sub CalcEnable()
Private Sub cmdCancel_Click()
Private Sub txtDens_Change()
Private Sub txtPc1_Change()
Private Sub txtPc2_Change()
Private Sub txtRate1_Change()
Private Sub txtRate2_Change()

**frmCalcFert**
***Form for calculating P associated with fertilizers
Private Sub cmdCalc_Click()
Private Sub cmdCancel_Click()
Private Sub CalcEnable()
Private Sub txtArea1_Change()
Private Sub txtArea2_Change()
Private Sub txtPc1_Change()
Private Sub txtPc2_Change()
Private Sub txtRate1_Change()

## Table A-2: List of VBA Procedures

Private Sub txtRate2_Change()

**frmCalcHarv**
***Form for calculating P associated with harvests
Private Sub cmdCalc_Click()
Private Sub CalcEnable()
Private Sub cmdCancel_Click()
Private Sub txtArea1_Change()
Private Sub txtArea2_Change()
Private Sub txtNum1_Change()
Private Sub txtNum2_Change()
Private Sub txtPc1_Change()
Private Sub txtPc2_Change()
Private Sub txtRate1_Change()
Private Sub txtRate2_Change()

**frmCalcHay**
***Form for calculating P associated with hay
Private Sub cmdCalc_Click()
Private Sub cmdCancel_Click()
Private Sub txtRate_Change()

**frmCalcLivew**
***Form for calculating P associated with live weight
Private Sub cmdCalc_Click()
Private Sub cmdCancel_Click()
Private Sub txtDens_Change()
Private Sub txtPc_Change()
Private Sub txtWt_Change()
Private Sub CalcEnable()

**frmCalcMilk**
***Form for calculating P associated with milk production
Private Sub cmdCalc_Click()
Private Sub cmdCancel_Click()
Private Sub txtDens_Change()
Private Sub txtPc_Change()
Private Sub txtWt_Change()
Private Sub CalcEnable()

# Appendix A

## Table A-2: List of VBA Procedures

**frmCalcSept**
***Form for calculating P associated with septic systems
Private Sub cmdCalc_Click()
Private Sub cmdCancel_Click()
Private Sub txtDens_Change()
Private Sub txtNum_Change()
Private Sub txtPeff_Change()
Private Sub txtPRem_Change()
Private Sub CalcEnable()

**frmCalcSod**
***Form for calculating P associated with sod
Private Sub cmdCalc_Click()
Private Sub cmdCancel_Click()
Private Sub txtRate_Change()

**frmDATool**
***Form used to instruct user how to use drainage area tool
Private Sub cmdOK_Click()

**frmEditPCP**
***Form used to edit land use applications for PCPs
Private Sub CheckBox1_Click()
Private Sub ckbSW_Click()
Private Sub cmdApply_Click()
Private Sub cmdCalcClnrs_Click()
Private Sub cmdCalcFeed_Click()
Private Sub cmdCalcFert_Click()
Private Sub cmdCalcHarv_Click()
Private Sub cmdCalcHay_Click()
Private Sub cmdCalcLivew_Click()
Private Sub cmdCalcMilk_Click()
Private Sub cmdCalcSeptic_Click()
Private Sub cmdCalcSod_Click()
Private Sub cmdClose_Click()
Private Sub cmdDefault_Click()
Private Sub cmdRevert_Click()
Private Sub lbLandUse_Change()

## Table A-2: List of VBA Procedures

Private Sub UpdateButtons()
Private Sub picLandUse_Click()
Private Sub txtFert_Change()
Private Sub txtFeed_Change()
Private Sub txtClnrs_Change()
Private Sub txtHarv_Change()
Private Sub txtLivew_Change()
Private Sub txtHay_Change()
Private Sub txtSod_Change()
Private Sub txtMilk_Change()
Private Sub txtSeptic_Change()
Private Sub UserForm_Initialize()

**frmNewPCP**
***Form used to create new PCPs
Private Sub cbRegion_Change()
Private Sub cmdCancel_Click()
Private Sub cmdContinue_Click()
Private Sub txtName_Change()
Private Sub txtName_Exit(ByVal Cancel As MSForms.ReturnBoolean)
Private Sub UserForm_Initialize()

**frmOptions**
***Form used to set units for tables and reports
Private Sub cmdOK_Click()
Private Sub optEnglish_Click()
Private Sub optMetric_Click()
Private Sub UserForm_Click()
Private Sub UserForm_Initialize()

**frmPCPs**
***Form used to open or delete previously saved PCPs
Private Sub cmdButton_Click()
Private Sub cmdCancel_Click()
Private Sub lstBoxPCPs_Change()
Private Sub UserForm_Initialize()

**frmReportViewer**
***Form used to display Crystal Reports object

## Table A-2: List of VBA Procedures

**frmSetAOI**
***Form used to instruct user how to select an Area of Interest
Private Declare Function SetFocus Lib "user32" (ByVal hwnd As Long) As Long
Private Sub cmdCancel_Click()
Private Sub cmdContinue_Click()

**frmUpdate**
***Form used to provide options for updating default runs
Private Sub cbAll_Click()
Private Sub cbEast_Click()
Private Sub cbLakeI_Click()
Private Sub cbNorth_Click()
Private Sub cbSouth_Click()
Private Sub cbUpperK_Click()
Private Sub cbWest_Click()
Private Sub cmdClose_Click()
Private Sub cmdUpdate_Click()
Private Sub UserForm_Click()

**frmWODs**
***Form used to provide a list of Works of the District permits to choose from
Private Sub cmdApply_Click()
Private Sub cmdCancel_Click()
Private Sub UserForm_Initialize()

**GetDBASEFileMOD**
***Opens a dBase file
Public Function GetDBASEFile(pTablePath As String, pTableName As String) As ITable

**GetDBASEFileUPD**
***Opens a dBase file
Function GetDBASEFile(pTablePath As String, pTableName As String) As ITable

**GetSelectionIDsMOD**
***Gets ID numbers of a selection set
Public Sub GetSelectionIDs(psTableSel As esriGeoDatabase.ISelectionSet, selRecsList)

**GetTextFileMOD**

# Appendix A

## Table A-2: List of VBA Procedures

***Creates a table from a text file
Function GetTextFile(pTablePath As String, pTableName As String) As ITable

**GetTextFileUPD**
***Creates a table from a text file
Function GetTextFile(pTablePath As String, pTableName As String) As ITable

**GetUserNameLIB**
***Gets the name of the logged on user
Public Declare Function GetUserName Lib "advapi32.dll" Alias "GetUserNameA" (ByVal lpBuffer As String, nSize As Long) As Long

**Graphics2ShapefileMOD**
***Converts graphics to a shapefile
Public Sub Graphics2Shapefile(pOutFC As IFeatureClass, pGC As IGraphicsContainer)

**LoadCalcValuesMOD**
***Loads default/saved  values fr0m pcp database to calculator forms
Public Sub LoadCalcValues(compName As String)

**OpenTableMOD**
***Opens a table window and sets the name
Private Declare Function SetWindowText Lib "user32" Alias "SetWindowTextA" (ByVal hwnd As Long, ByVal lpString As String) As Long
Public Sub OpenTable(pStandaloneTable As IStandaloneTable, tblName As String)

**QueryFLayerMOD**
***Queries a feature layer
Public Sub queryFLayer(pMxDoc As esriArcMapUI.IMxDocument, pMap As esriCarto.IMap, pFeatureLayer As IFeatureLayer, aQueryString, setType)

**ReplaceDefaultGridsUPD**
***Replaces all default grids when updating
Sub ReplaceDefaultGrids(regionName As String, replGrids As Boolean)

**SaveCalcValuesMOD**
***Saves entered calculator values in pcp database
Public Sub SaveCalcValues(compName As String)

**SelectByPointMOD**
***Selects a feature based on a point
Public Sub SelectByPoint(pMxDoc As esriArcMapUI.IMxDocument, elmntTheme, thePoint As esriGeometry.IPoint, selTol, setType)

# Appendix A

## Table A-2: List of VBA Procedures

**SetGlobalsMOD**
***Sets global varialbes
Public Declare Function SetForegroundWindow Lib "user32" (ByVal hwnd As Long) As Long
Public Sub SetGlobals()

**SetGlobalsUPD**
***Sets global varialbes
Public Declare Function SetForegroundWindow Lib "user32" (ByVal hwnd As Long) As Long
Public Sub SetGlobals()

**SetRasterAnalEnvMOD**
***Sets the analysis environment for rasters
Public Function SetRasterAnalEnv(pRasterDataset As IRasterDataset) As IRasterAnalysisEnvironment

**SetRasterAnalEnvUPD**
***Sets the analysis environment for rasters
Public Function SetRasterAnalEnv(pRasterDataset As IRasterDataset) As IRasterAnalysisEnvironment

**SortTableMOD**
***Sorts table so it can be use for lookups
Public Function SortTable(pTable As ITable, sOutName As String, sFldName As String, bAscending As Boolean) As ITable

**SortTableUPD**
***Sorts table so it can be use for lookups
Public Function SortTable(pTable As ITable, sOutName As String, sFldName As String, bAscending As Boolean) As ITable

**ThisDocument**
***Runs procedures associated with P-Budget Toolbar objects
Sub StartListener()
Private Sub AOIClose_Click()
Private Function AOIClose_Enabled() As Boolean
Private Sub AOISet_Click()
Private Function AOISet_Enabled() As Boolean
Private Sub BaseMapOnOff_Click()
Private Function BaseMapOnOff_Enabled() As Boolean
Private Function BaseMapOnOff_Message() As String
Private Function BaseMapOnOff_ToolTip() As String

# Appendix A

## Table A-2: List of VBA Procedures

Private Sub BaseMaps_SelectionChange(ByVal newIndex As Long)
Private Function BaseMaps_Message() As String
Private Function BaseMaps_ToolTip() As String
Private Sub DispTransEvt_VisibleBoundsUpdated (ByVal sender As IDisplayTransformation, ByVal sizeChanged As Boolean)
Sub SynchExtents()
Private Function MxDocument_CloseDocument() As Boolean
Public Function MxDocument_OpenDocument() As Boolean
Public Sub GetSpatialAnalystLicense()
Public Sub Startup()
Private Function MxDocument_BeforeCloseDocument() As Boolean
Public Sub Sleep(sleepTime As Variant)
Private Sub Options_Click()
Private Sub PCPClose_Click()
Private Function PCPClose_Enabled() As Boolean
Private Sub PCPDelete_Click()
Private Function PCPDelete_Enabled() As Boolean
Private Sub PCPEdit_Click()
Private Function PCPEdit_Enabled() As Boolean
Private Sub PCPNew_Click()
Private Function PCPNew_Enabled() As Boolean
Private Sub PCPOpen_Click()
Private Function PCPOpen_Enabled() As Boolean
Private Function SelectBasinTool_Message() As String
Private Sub SelectBasinTool_Select()
Private Sub SelectBasinTool_MouseDown(ByVal Button As Long, ByVal Shift As Long, ByVal x As Long, ByVal Y As Long)
Public Function SelectDrainageAreaTool_Enabled() As Boolean
Private Function SelectDrainageAreaTool_Message() As String
Private Function SelectDrainageAreaTool_ToolTip() As String
Public Function SelectBasinTool_Enabled() As Boolean
Private Function SelectBasinTool_ToolTip() As String
Public Function SelectUserDefinedTool_Enabled() As Boolean
Private Function SelectUserDefinedTool_Message() As String
Private Function SelectUserDefinedTool_ToolTip() As String
Private Sub SelectWODPermit_Click()
Private Function SelectWODPermit_Enabled() As Boolean
Private Function SelectWODPermit_Message() As String
Private Function SelectWODPermit_ToolTip() As String
Private Sub SelectDrainageAreaTool_MouseDown(ByVal Button As Long, ByVal Shift As Long, ByVal x As Long, ByVal Y As Long)
Private Sub SelectDrainageAreaTool_Table(measPConc1 As Long, measPSta1 As String, measPConc2 As Long, measPSta2 As String, measPConc3 As Lon

## Table A-2: List of VBA Procedures

measPSta3 As String, measPConc4 As Long, measPSta4 As String, measFlow As Long, strmD0 As Long, lakeD0 As Long, slghD0 As Long)
Private Sub SelectDrainageAreaTool_Select()
Private Sub SelectUserDefinedTool_MouseDown(ByVal Button As Long, ByVal Shift As Long, ByVal x As Long, ByVal Y As Long)
Private Sub SelectUserDefinedTool_Select()
Public Sub SnapToInterface_Click()
Private Function SnapToInterface_Message() As String
Private Function SnapToInterface_ToolTip() As String
Private Sub LandPracticeImportsExports_Click()
Private Sub TotalPBudgetBasin_Click()
Public Sub TotalPBudgetLU_Click()
Private Sub TotalPBudgetRegion_Click()
Private Sub UIButtonControl1_Click()
Private Sub ZoomAOI_Click()
Private Function ZoomAOI_Enabled() As Boolean
Private Function ZoomAOI_Message() As String
Private Function ZoomAOI_ToolTip() As String
Private Sub ZoomPCP_Click()
Private Function ZoomPCP_Enabled() As Boolean
Private Function ZoomPCP_Message() As String
Private Function ZoomPCP_ToolTip() As String

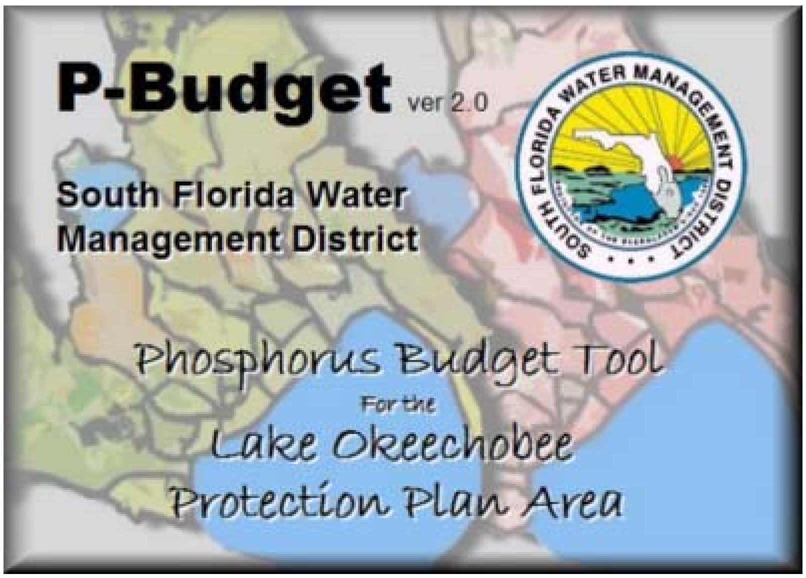
**ThisDocumentUPD**
***Runs procedures associated with P-Budget Update objects
Private Function MxDocument_OpenDocument() As Boolean
Private Sub PBudUpdateButton_Click()

**ZoomToRegionMOD**
***Zooms to the selected region when creating a PCP
Public Sub ZoomToRegion(pMap As IMap, pActiveView As IActiveView, strBookmarkName As String)

**Appendix B**

# P-Budget GIS Interface
# Phosphorus Budget Tool for the
# Lake Okeechobee Protection Plan Area

## User Manual




JGH Engineering, 2005

Please note that this document was created from a Microsoft Windows Help file. The formatting is consistent with the Help file (no section, figure or table numbers). Underlines may represent a file linkage that can not be conveyed in hard copy form and text such as ‘Next Step’ may represent instructions to the computer user.

# Table of Contents

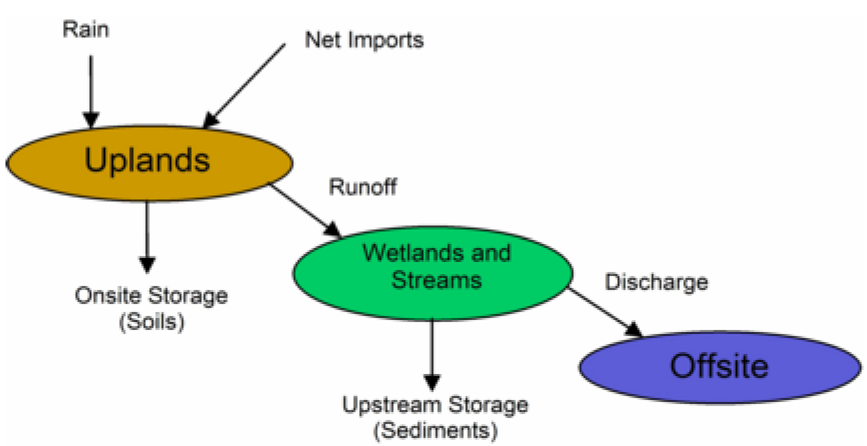
# General Information

## What is P-Budget?

P-Budget allows engineers and planners to analyze phosphorus budget characteristics within the Lake Okeechobee Protection Plan area. Users may view the results of phosphorus budget analyses with tables and maps, edit phosphorus import or export parameters on landowners parcels, and create Phosphorus Control Plans (PCPs) to evaluate phosphorus control alternatives.

The Lake Okeechobee Protection Program is designed for the protection and restoration of Lake Okeechobee (SFWMD, 2004). This is to be accomplished by achieving and maintaining compliance with State water quality standards through a watershed-based protection program designed to reduce phosphorus loads and implement long-term solutions. This program is jointly administered by the South Florida Water Management District (District), the Florida Department of Environmental Protection (FDEP), and the Florida Department of Agriculture and Consumer Services (FDACS).

A materials balance approach to phosphorus management provides information about the total amount of phosphorus that enters and exits the watershed on an annual basis. Accounting for imports and exports of phosphorus containing materials provides a baseline for field research and a more detailed understanding of how changes in management practices affect phosphorus flow. The mass balance can be described as follows:




Net import is the net phosphorus contribution resulting from anthropogenic land use activities. Onsite storage is the amount of phosphorus retained in the soils and is calculated as phosphorus in rainfall plus net phosphorus import minus phosphorus in runoff. Upstream storage is the amount of phosphorus stored in the stream and wetland conveyance system as sediments and is calculated as the difference between the runoff load at the runoff source and the discharge load at the drainage area outlet.

By determining which land uses contribute the most phosphorus to the land, solutions can be derived to help reduce accumulation and discharge of phosphorus. This interface is designed to allow planners to create "what if" scenarios to target particular land use practices in an attempt to reach targeted reductions.

All models will be limited by their ability to represent reality. Therefore, it is important for users to understand the assumptions and related limitations for any model they attempt to use. Though, P-Budget is based on scientific research and measured data, it can not possibly account for every process that exists. Even if it could account for these processes, there would always be insufficient data to parameterize it. Therefore, the user is encouraged to learn and understand these limitations prior to using the model by thoroughly reviewing the final report associated with the development of this interface.

## System Requirements

P-Budget's interface uses ESRI's ArcGIS 9.0 with Spatial Analyst. The interface will not run on any prior versions of ArcGIS. P-Budget is designed to run on the Windows XP operating systems.

It is recommended that your computer meet the following specifications:

500 megabytes of free hard disk space (300 megs minimum)
256 megabytes of RAM (64 megs minimum)
1.0 gHz co-processor (500 mHz minimum)
1024x768 screen resolution (600x800 minimum)

Because of the complexity of the Grid operations within the model, it is recommended that P-Budget be installed on the fastest computer available.

## Installation

Before installing, make sure you meet the System Requirements.

To install P-Budget:

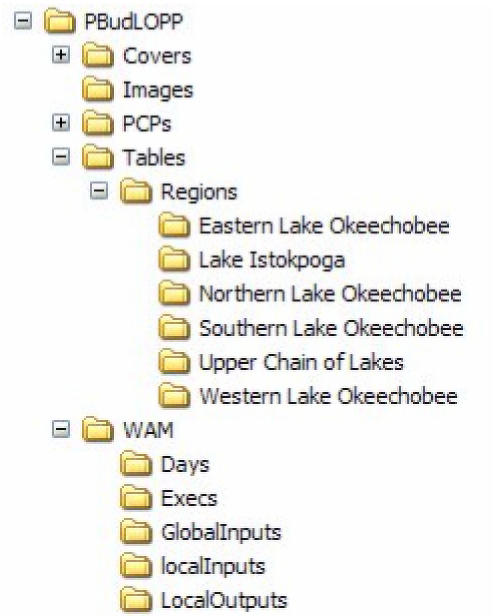
Insert the CD in your CD ROM drive
Go to Start --> Run
Type <cd drive>:\pbudlopp (e.g. d:\pbudlopp)

A window will appear prompting you to specify a folder. It is recommended that a network drive be entered that has been set up specifically by the system administrator for the user's data.

Press Unzip and close when finished.

## File and Grid Management

Once installed, the file structure for P-Budget is as follows:




There are a series of folders and two ArcGIS project files located within the PBudLOPP folder. P-Budget.mxd is the project file that runs the GIS interface. P-Bud Update.mxd is a project file that is used to update default model results.

The **covers** folder contains shapefiles including base maps and ARC/INFO GRID datasets such as land use. It also includes output grids of phosphorus for each phosphorus component as well as output from the Watershed Assessment Model (WAM). Each grid contains a set of geographically distributed cells that are one hectare in size. Therefore the units shown below are on a 'per hectare' basis:

| Import/Export Grids | |
|---|---|
| fertgrid | Fertilizer import (g) |
| feedgrid | Feed import (g) |
| clnrsgrid | Cleaners import (g) |
| harvgrid | Harvest export (g) |
| livewgrid | Liveweight export (g) |
| haygrid | Hay export (g) |
| sodgrid | Sod export (g) |
| milkgrid | Milk export (g) |
| septgrid | Septic system export (g) |
| imp_grid | Total import (g) |
| exp_grid | Total export (g) |
| net_grid | Net import (g) |

| WAM Model Output Grids | |
|---|---|
| ro | Surface Runoff Volume (mm) |
| perc | Groundwater Percolation Volume (mm) |
| solpcel1 | Soluble Phosphorus Source Load (g) |
| sedpcel1 | Sediment Phosphorus Source Load (g) |
| gwpcel1 | Groundwater Phosphorus Source Load (g) |

There are two sets of these output grids stored in the covers folder. A set with a "t" suffix and a set with no suffix. The set with no suffix represents a backup copy of the most recently saved default output based on current land use practices. The "t" set is used for intermediate mapping and calculations.

The **images** folder contains bitmaps of land uses that are utilized when editing phosphorus related parameters associated with land use practices. The folder also contains miscellaneous graphics including logos, the P-Budget opening screen, etc.

The **pcps** folder contains folders, named after saved PCPs, that include databases and phosphorus output grids reflecting phosphorus parameters based on proposed or potential changes to land use practices (see Phosphorus Control Plans). The same grid names as shown above are used, but with an "x" suffix to distinguish them. When a PCP is created or opened, the data source of the net phosphorus import layer is changed from '../covers/net_impt' to '../pcps/*pcpname*/net_impx' and the interface is directed to use the files in the PCP folder when producing tables and reports. Each PCP folder also contains three databases that are used to store import/export coefficients, import/export calculator values and WAM land use parameters.

The **tables** folder contains several databases used to manage WAM output. It also includes folders for each region that include default database files for import/export coefficients, import/export calculator values and WAM land use parameters. These files are described below:

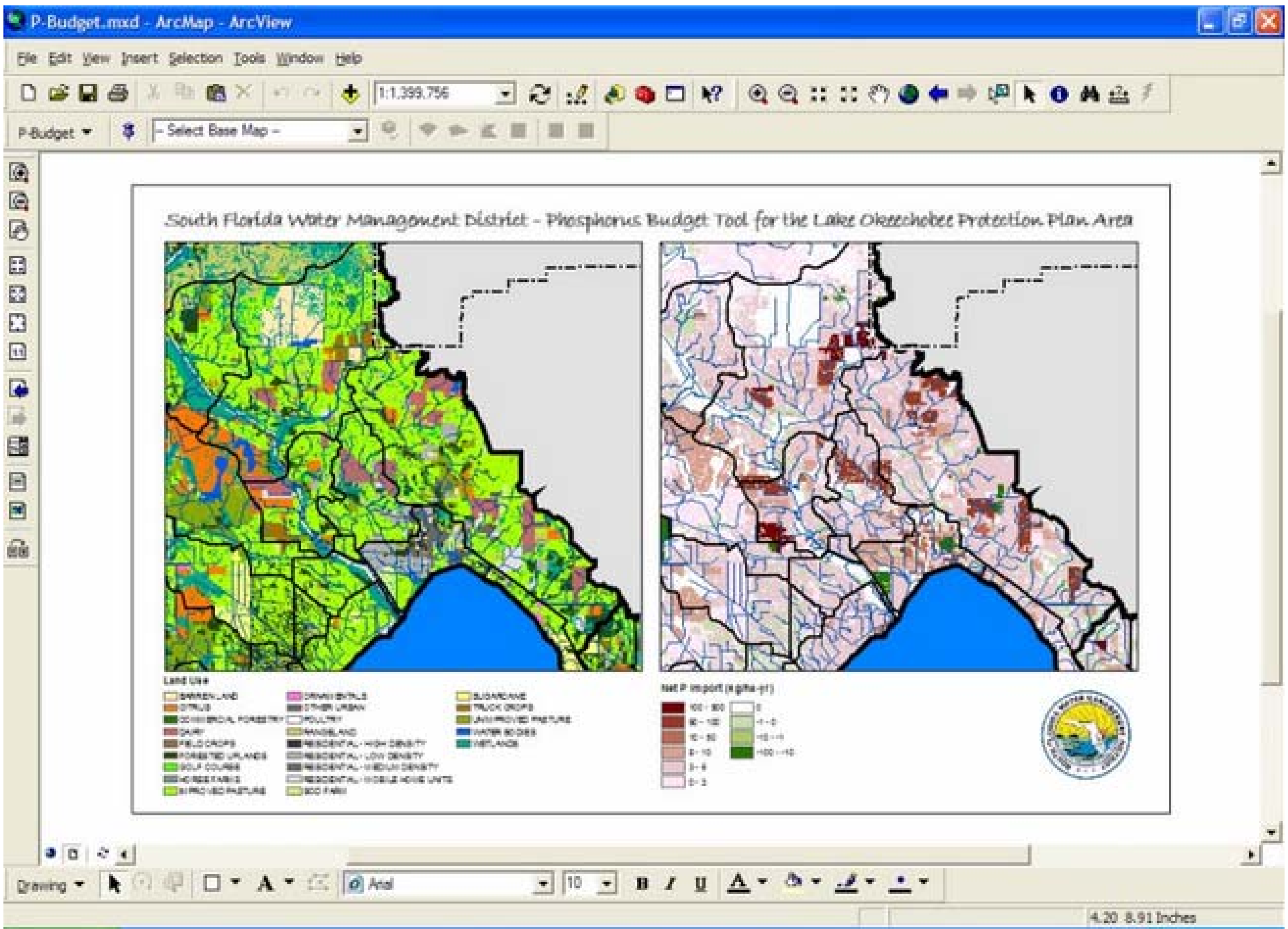
| File Name | Description |
|---|---|
| coeff_def.dbf | Database of a region's default P import and export coefficients, copied from …\Tables\Regions*region* folder to pcp folder and edited by interface |
| calc_def.dbf | Database of a region's default P calculator values, copied …\tables\Regions*region* folder to pcp folder and edited by interface |
| wam_def.dbf | Database of a region's default WAM land use parameter combinations, copied …\tables\Regions*region* folder to pcp folder and edited by interface |
| lu_seq.dbf | Database of all previously run land use parameter combinations stored in sequential order |
| unique.dbf | Empty database of rain zone, land use seq, and soil fields forming unique combinations for BUCShell |
| uniquex.dbf | Copied from unique.dbf for each model run, used to ultimately create Pload_unique.bnz |
| annualAll.dbf | Database of results from previously run unique combinations run by BUCShell |
| Pload_Uniquex.txt | Temporary text file of previously unrun unique combinations for a particular run |

The **WAM** folder includes files necessary to run the Watershed Assessment Model. The files are stored in a set of folders based on WAM's previously named file structure. For the purposes of P-Budget, the output is stored in /days folder. The /execs folder includes all of WAM's executable files. the /GlobalInputs folder includes defaults rainfall, soils and land use parameter datasets. The /LocalInputs folder contains parameter datasets specifically created to reflect a PCP. The /LocalOuputs folder includes error and log files of the most recent WAM run.

# Using P-Budget

## Getting Started

To get started, open ArcMap and navigate to the PBudLOPP folder where P-Budget was installed. Open P-Budget.mxd. An opening screen will appear for a few seconds. Then a layout will appear with two view ports and legends. This layout serves as the main screen for the interface. By default, the left view port is set to display the land use and the right view port is set to display the P-Budget results based on existing land use practices. A toolbar will also appear that includes a menu along with display and selection tools specific to the P-Budget interface.




The dual views (or data frames) are intended to operate simultaneously when the standard zooming and panning tools are applied to the left view. When these tools are applied to the right view, only the right view is affected. This provides the some flexibility when producing exhibits.

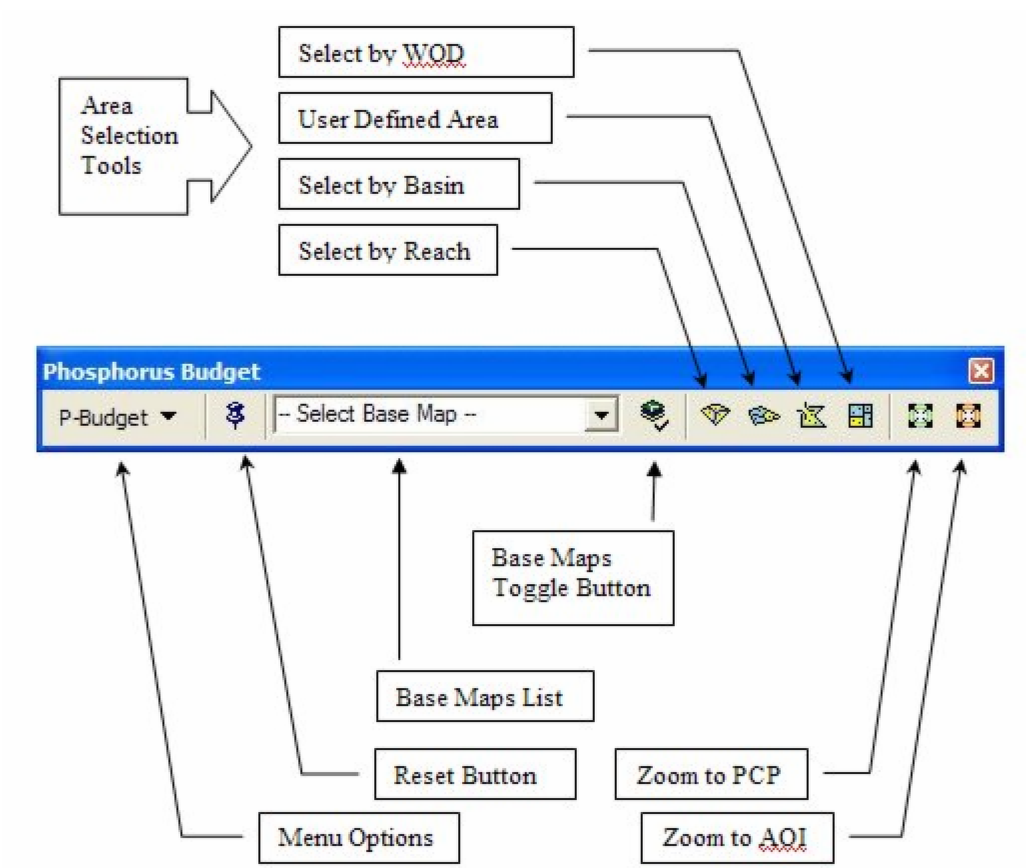
The functionality of ArcMap has been preserved. Experienced ArcMap users may want to utilize other features within the project such as views, tables or charts. This can be done without interfering with the operation of the interface.

When the user is finished using other ArcMap features, he or she can simply press the reset button to return to the main display. If for some reason the interface has been compromised by use of other functions, the user can simply close the project and restart P-Budget.mxd without losing any data. P-Budget.mxd simply serves as a template for the interface and is never replaced. The user will not be prompted to save when exiting. Nor is anyone allowed to overwrite the file.

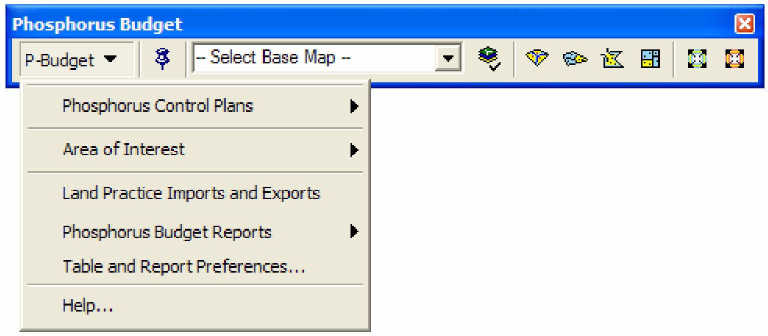
-o-

## Phosphorus Budget Toolbar

All of P-Budget's functions have been placed into a single toolbar called Phosphorus Budget, which can be opened or closed from the Main menu -> View -> Toolbars... like any other toolbar. By default, the toolbar is opened automatically when P-Budget.mxd is opened in ArcMap. The toolbar includes a menu, a reset button, a dropdown list of base maps that can turned on or off, spatial area selection tools and zooming tools.




The menu includes functions related to creating and editing Phosphorus Control Plans (PCPs), setting an Area of Interest (AOI), and viewing tables and reports.




The Reset button is provided as a “clean-up” feature. It returns the interface to the page layout, zooms to the layout, closes the table of contents and resets the global variables and VBA listeners. Listeners are functions that the interface is constantly checking. For example, the interface checks to see if ArcMap’s standard pan/zoom tools have been applied to the left view of the layout. If so, the tool is applied to both views automatically. The reset button resets the variables and listeners in case the interface encounters an error or anomaly which can sometimes result in the loss of what are referred to as “threads.” Threads hold the interface into the user defined state, i.e., if the user has performed an action that has enabled other features, threads keep those features from reverting back to their default state.

The toolbar includes a dropdown list of base maps that can be toggled on or off. The Base Map Toggle button, located next to the dropdown list, will display either a check mark or an “x” to indicate whether the selected base map is currently on or off, respectively. For example, if the base map for roads is currently off, the button will appear with an “x”. By pressing the button, the base map will be turned on.

The Area Selection tools are used to select spatial extents for PCPs and AOIs. There are two buttons located on the right side of the toolbar that will zoom the right and left views to the extents of the PCP or AOI.

## Area Selection Tools

There are two aspects of the interface that require the user to select a spatial extent. The first is when a Phosphorus Control Plan (PCP) is being created. Changes to land use practices associates with a PCP are limited to the chosen spatial extent. The second aspect is when creating an Area of Interest (AOI). The P-budget results that are presented in tables and reports reflect the spatial extent of the AOI, if created. This is useful if the user wishes to assess the effects at a basin level, for example, of changes to a smaller area within the basin.

There are four tools available for the selection of a spatial extent:

Drainage Area Tool 

This tool allows the user to create a spatial extent that corresponds to the contributing drainage area of a selected hydrologic reach. If creating a spatial extent for a PCP, the drainage area will only extend to the boundaries of the region for which the PCP is being developed for and will not include areas from other regions that may be passing through.

If creating a spatial extent for an AOI, the extent will include the entire contributing drainage area regardless of region boundaries. A small message box will appear instructing the user to select a reach. There is a checkbox in the lower left corner of the message box that when checked will produce a Drainage Area Summary Table. This feature is only available when using this tool to create an AOI.

Select by Basin Tool 

This tool allows the user to create a spatial extent based on selected basins. If creating a spatial extent for a PCP, only basins that exist within the boundaries of the region for which the PCP is being developed for can be selected. Multiple basins can be selected by holding down the shift key after selecting the first basin.

User Defined Area Tool 

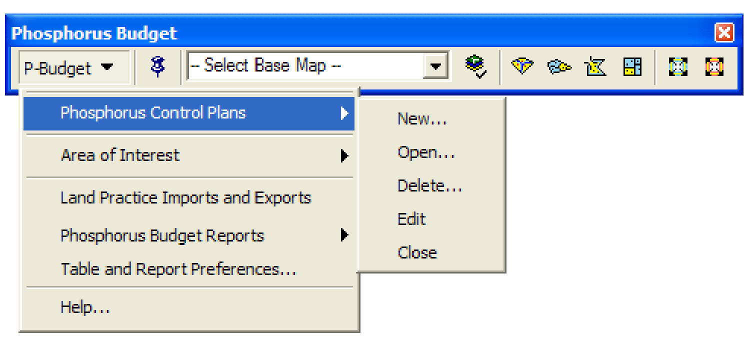
This tool allows the user to create a spatial extent based on one or more polygons created by the user. If creating a spatial extent for a PCP, any portions of polygons extending outside of the boundaries of the region for which the PCP is being developed for will be ignored. Multiple areas can be created by holding down the shift key after creating the first polygon.

Select by Permit Tool 

This tool allows the user to create a spatial extent based on selected Works of the District (WOD) permits. A list of permit numbers will appear. Multiple permits can be selected by holding down the shift key after selecting the first permit. If creating a spatial extent for a PCP, only permits that exist within the boundaries of the region for which the PCP is being developed for will be displayed. A coverage of WOD permits is available as a base map that can be toggled on or off to assist in the selection. WOD permits exist primarily in the Northern Lake Okeechobee region.

## Phosphorus Control Plans (PCPs)

Phosphorus Control Plans (PCPs) represent proposed or potential changes in land use practices within a selected extent. By creating a PCP, the user can assess the effects of altering land use practices such as fertilizer application. By selecting 'Phosphorus Control Plans' from the P-Budget menu, a submenu of options will appear as shown below allowing the user to create and manage PCPs:



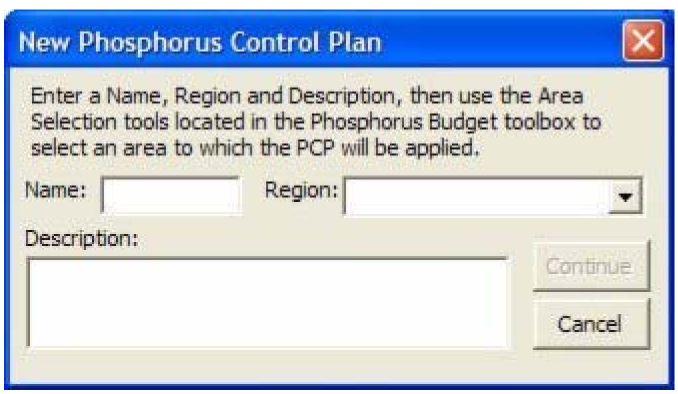
'New...' allows the user to create a new PCP which opens a dialog where general information such as the PCP name and region are entered. The user is also prompted to select a spatial extent using the Area Selection Tools. This is followed by another dialog that allows the user to edit the land use practices.

'Open...' and 'Delete...' will open a dialog box that includes a list of all previously saved PCPs. When a PCP is selected from the list, the description and region associated with the selected PCP will appear in the dialog box. The selected PCP can be opened or deleted depending on which option was originally chosen from the submenu.

The 'Edit' and 'Close' options are only available if a PCP is currently open. 'Edit' will open the same dialog box that appears in the final process of creating a new PCP. 'Close' will close the currently opened PCP and return the mapped results to the default "existing practices" scenario.

## Creating a New PCP

Phosphorus Control Plans (PCPs) represent proposed or potential changes in land use practices within a selected extent. By creating a PCP, the user can assess the effects of altering land use practices such as fertilizer application. By selecting the 'New...' option from the 'Phosphorus Control Plans' submenu, a dialog as shown below will appear:



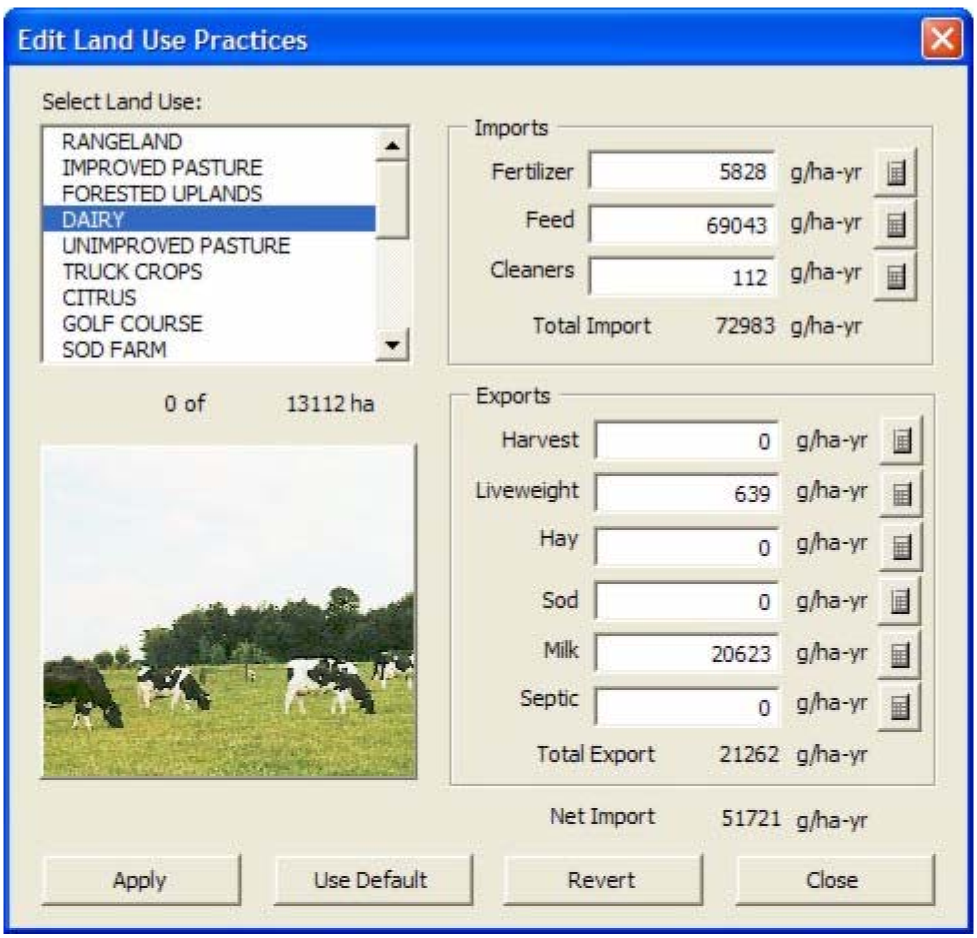

A name, region and selected spatial extent are needed before the user can continue. A description is optional, but recommended to assist the user in tracking and managing the PCP in the future. The Area Selection Tools have been enabled in the Phosphorus Budget toolbar and the layout in the background has changed to a single map. This serves as a selection map and works in conjunction with the area selection tools. Note that any base maps that had been turned on in the previous dual map layout are also applied to the selection map and can be changed in the same manner using the P-Budget toolbar.

There are six regions within the Lake Okeechobee Protection Plan area that consist of their own set of default phosphorus coefficients based on region-wide assumptions and estimates of land use practices. A PCP can only be applied to a single region at a time in order for the interface to extract the appropriate set of default coefficients. Note that when a region is selected, the selection map will zoom to that region. Once a name and region are entered, the user must use the Area Selection Tools to create a spatial extent for which the PCP will represent.

After the extent is chosen and the 'Continue' button is pressed, the dual views will zoom to the selected extent which will be outlined with a yellow and blue border. A folder will be created baring the name of the PCP. The following files are copied from the ..\Tables\Regions*region name* folder to the ..\PCPs*pcp name* folder (see File and Grid Management for a description of these files):

coeff_def.dbf --> coef_pcp.dbf
calc_def.dbf --> calc_pcp.dbf
wam_def.dbf --> wam_pcp.dbf

A dialog box will appear with a list of the land uses that exists within the selected area. The right side of the dialog box includes parameter values for the import and export components for the selected land use. Each land use has been characterized into phosphorus import and export components. When selecting a land use, a picture of the land use will appear in the bottom left corner of the dialog box and the default parameters will appear to the right. The area in hectares of the selected land use will also appear immediately above the picture.



Calculators have been provided next to each phosphorus component to assist the user in calculating the phosphorus import or export for that component. Once a change has been made, the buttons along the bottom will become activated. The 'Apply' button will register the change and calculate the total import, total export and net import for the selected land use. The 'Use Default' button will replace the values with the default values associated with the selected region. The 'Revert' button will return the previously saved values. After pressing 'Apply' to register the changes, other land uses may be selected and edited in a similar manner.

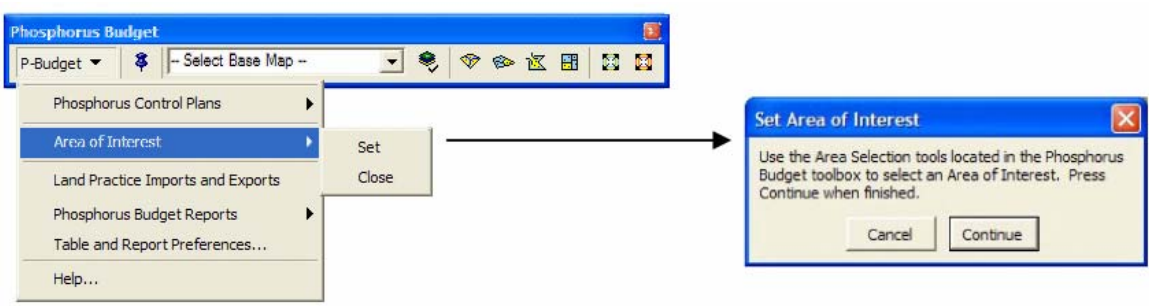
When finished, the 'Close' button will prompt the user to confirm the changes. The changes will be saved to the appropriate dBase file located in ...\pcps*pcp name* folder. Several grids of the selected extent will be created, one per phosphorus component along with grids for total import, total export and net import. These grids will be "burned" onto larger grids of the same type that cover the entire Lake Okeechobee Protection Plan area. The grids are stored in the ..\pcps*pcp name* folder. The source location of the Net P Import layer in the right view/data frame is then changed to reflect the new net import grid in the ..\pcps*pcp name* folder and the view is refreshed.

The changes are assessed to determine if the WAM model needs to be run. This assessment is described in WAM Watershed Assessment Model along with a description of the overall WAM modeling process. If WAM needs to run, then the output grids from the model, as described in File and Grid Management, will be saved to the ..\pcps*pcp name* folder.

At this point, a PCP has been created and opened. While it remains open, maps, tables and reports will reflect the results of the PCP.

## Area of Interest

The AOI, or Area of Interest, is simply the area that the user can set for reporting purposes. If an AOI is set, then the output tables and reports will reflect only that area. The user may 'Set' or 'Close' an AOI from the P-Budget menu as shown below. When setting an AOI, the dual view layout will be replaced with a map used for the selection of a spatial extent and a dialog box will appear prompting the user to select the extent. The same Area Selection Tools used to select a PCP extent are also used for selecting an AOI extent.



Once set, the dual view layout appears again and the extent of the selected AOI will be outlined with a red and yellow border in each view. The AOI will remain in effect until it is closed from the P-Budget menu. At which time, the results presented in the tables and reports will reflect the entire Lake Okeechobee Protection Plan area.

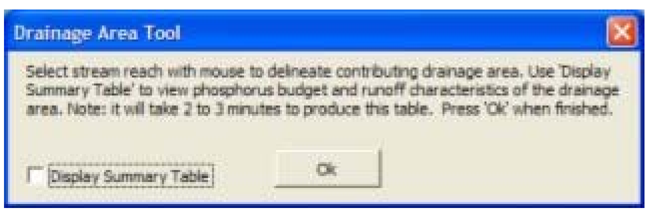
# Tables and Reports

## Table and Report Preferences

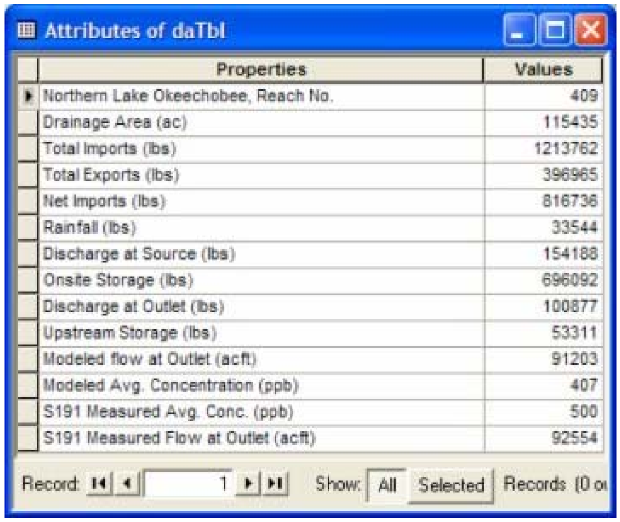
Table and report preferences can be set from the P-Budget menu. When selected, a dialog box appears including two options. The units in all tables and reports can be set in metric or english. The map that is displayed in the Phosphorus Budget Reports can be set to display the left or right view of the main layout (land use or Net P Import, respectively).


## Drainage Area Summary

The Drainage Area Summary table is not found in the menu. It is only available while selecting an Area of Interest (AOI) with the Select by Reach/Drainage Area tool. When this tool is used to select an AOI, the message box for this tool will include a check box as shown below.




If the box is checked, then each time that a reach is selected, a table will be produced providing phosphorus budget summary information associated with that reach's contributing drainage area. This feature has been added to this tool because it is the only tool that consistently provides an entire drainage area with a single discharge point. This provides an opportunity to report phosphorus load discharge at the outlet (the selected reach) and to relate that value to the loads upstream so that the entire mass balance can be reported. For example, upstream storage is the amount of phosphorus stored in the stream and wetland conveyance system, which is calculated as the difference between the runoff load at the runoff source and the discharge load at the drainage area outlet. The tool also provides an opportunity to compare the results of the WAM water quality model to measured values that may have been taken at that location. Measured flow and phosphorus concentration that have been associated with the selected reach are displayed. More than one sampling station may exist on the same reach. In which case, they are all displayed along with the name of the sampling station(s).



| Properties | Values |
|---|---|
| Northern Lake Okeechobee, Reach No. | 409 |
| Drainage Area (ac) | 115435 |
| Total Imports (lbs) | 1213762 |
| Total Exports (lbs) | 396965 |
| Net Imports (lbs) | 816736 |
| Rainfall (lbs) | 33544 |
| Discharge at Source (lbs) | 154188 |
| Onsite Storage (lbs) | 696092 |
| Discharge at Outlet (lbs) | 100877 |
| Upstream Storage (lbs) | 53311 |
| Modeled flow at Outlet (acft) | 91203 |
| Modeled Avg. Concentration (ppb) | 407 |
| S191 Measured Avg. Conc. (ppb) | 500 |
| S191 Measured Flow at Outlet (acft) | 92554 |



As pointed out in the message box, it is cautioned that the process to create this table will take two to three minutes. This is due to the complex nature of the attenuation algorithm that has been incorporated into this feature. A progress bar is used to indicate the status of the computations.

## Attenuation

The phosphorus assimilation algorithms developed for the Lake Okeechobee Agricultural Support System (LOADSS) program (SWET, 2001) were used to estimate the attenuation that occurs from the source of the phosphorus contribution to the outlet of the drainage area. The assimilation model, as shown in Equation 1, is a second-order exponential relationship.

$$C - (Co - Cb)e^{(-kD)} + Cb \quad (1)$$

where,

| | |
|---|---|
| k | = aQ-b |
| C | = the concentration at the end of a reach (i.e., a sub-basin node) |
| Co | = the concentration at the beginning of a reach |
| Cb | = the background or minimum concentration expected |
| D | = reach length |
| a and b | = empirical coefficients and |
| Q | = stream discharge |

Values for a, b, and Cb are the actual calibration parameters for representing the influence of flow-rate on attenuation. The values for Q, D, and Co are acquired from physical parameters in the watersheds that are provided by WAM. The following datasets are used from the WAM model:

<u>Preprocessed</u> Note: "[ ]" denotes raster grid

| | |
|---|---|
| [celldist1] | grid of distances to nearest downstream lake, stream or slough |
| [celldist2] | grid of distances to nearest downstream wetland |
| [celldist3] | grid of distances to nearest downstream depression |
| [streamnode] | grid identifying the reach code number to which each cell ultimately drains |
| Reaches.shp | shapefile of hydrologic reaches including attributes for reach code number, type (stream, lake or slough), length, and accumulated length for downstream reaches (streams, lakes and sloughs) from each reach to Lake Okeechobee |

<u>Model Output</u> Note: "[ ]" denotes raster grid

| | |
|---|---|
| [solpcel1] | soluble phosphorus load in surface water runoff at source |
| [sedpcel1] | sediment phosphorus load in surface water runoff at source |
| [gwpcel1] | phosphorus load discharged to groundwater at source |
| [ro] | runoff (in depth) |
| [perc] | percolation (in depth) |

The preprocessed datasets represent static information that is utilized but not changed by the P-Budget interface. The preprocessed grids were created using the WAM setup interface individually for each region and then merged together. The reaches.shp file was also created using WAM's setup interface, but was supplemented with the downstream accumulated reach lengths.

Attenuation is applied in two sequential processes – overland flow and stream/lake/wetland flow. To account for the influences of the three reach types (stream, lake or wetland), weighted coefficients are used to reflect the relative influence of the reach types. The following equations and coefficient definitions describe how the new assimilation equations are represented:

<u>Overland Flow Equation</u>

C1 = (C0 - Cb)*e^(-Ko*Do) +Cb (2)

Where,

Ko = Ao*qo^(-Bo) (3)

<u>Stream/Canal Flow Equation</u>

C2 = (C1 - Cb)*e^(-Kc*D) + Cb (4)

Where,

Kc = (As*Ds+Al*Dl+Aw*Dw)/D *qb^(-( Bs*Ds+Bl*Dl+Bw*Dw)/D) (5)

And where,

| | |
|---|---|
| [Do] | = Distance of overland travel from cell to nearest stream, lake or wetland (m) |
| [Ds] | = Distance of travel through streams between cell and drainage area outlet (m) |
| [Dl] | = Distance of travel through lakes between cell and drainage area outlet (m) |
| [Dw] | = Distance of travel through wetlands between cell and drainage area outlet (m) |
| [D] | = Total flow distance in streams, lakes and wetlands (m) |
| [qo] | = Discharge from cell in equivalent depth (in/yr) |
| [qb] | = Average discharge from drainage area in equivalent depth (in/yr) |
| Ao | = Constant A in K equation for overland flow |
| Bo | = Constant B in K equation for overland flow |
| As | = Constant A in K equation for stream flow portion of stream |
| Bs | = Constant B in K equation for stream flow portion of stream |
| Al | = Constant A in K equation for lake flow portion of stream |
| Bl | = Constant B in K equation for lake flow portion of stream |
| Aw | = Constant A in K equation for wetland flow portion of stream |
| Bw | = Constant B in K equation for wetland flow portion of stream |
| Cb | = Background concentration (mg/l) |
| [C0] | = Initial concentration of constituent in polygon (mg/l) |
| [C1] | = Concentration after overland flow attenuation (mg/l) |
| [C2] | = Concentration after stream flow attenuation (mg/l) |

Note: "[ ]" denotes raster grid

Attenuation Procedure:

| | |
|---|---|
| Step 1: | Create [Do] is set equal to [celldist1] |
| Step 2: | Create [Ds], [Dl] and [Dw] and [D] by reclassifying [streamnode] with data from reaches.shp |
| Step 3: | Create [qo] by converting [ro] to inches |
| Step 4: | Create [qb] by adding [ro] and [perc] together and obtaining the mean value |
| Step 5: | Create [C0] by adding [sedpcel1] and [solpcel1] together and converting to mg/l using [ro] |
| Step 6: | Create [C1] using overland attenuation formula |
| Step 7: | Convert [C1] to loads |
| Step 8: | Replace [C1] by adding attenuated surface water and groundwater loads together and converting to mg/l using the sum of [ro] and [perc] |
| Step 9: | Convert it to mg/l using the sum |
| Step 10: | Create [C2] using stream/lake/wetland attenuation formula |

## Land Practice Import and Exports

This table is accessible directly from the P-Budget menu on the Phosphorus Budget Toolbar. It includes detailed information regarding annual phosphorus imports and exports per land use for each component including fertilizer, feed, cleaners, harvest, liveweight, hay, sod, milk and septic tanks. The values are created by summarizing each component grid stored in the either the ..\Covers or PCP folder depending if a PCP is open. An analysis mask corresponding to the Area of Interest (AOI) is applied if an AOI is selected.


Annual Phosphorus Imports and Exports (in Kg) by Land Use

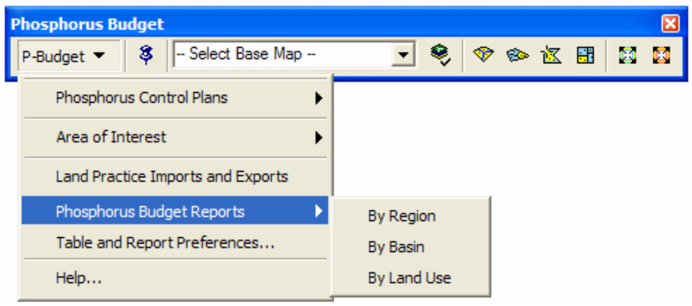
| LANDUSE | HECTARES | FERTILIZER | FEED | CLEANERS | IMPORTS | HARVEST | LIVEWEIGHT | HAY |
|---|---|---|---|---|---|---|---|---|
| RANGELAND | 12860 | 0 | 10661 | 437 | 11098 | 0 | 6340 | |
| IMPROVED PASTURE | 19275 | 227927 | 26349 | 0 | 254276 | 0 | 4973 | |
| WETLANDS | 21803 | 0 | 0 | 0 | 0 | 0 | 0 | |
| FORESTED UPLANDS | 20723 | 0 | 0 | 0 | 0 | 0 | 0 | |
| DAIRY | 2255 | 13219 | 75750 | 911 | 89878 | 0 | 859 | 28 |
| BARREN LAND | 48 | 0 | 0 | 0 | 0 | 0 | 0 | |
| OTHER URBAN | 6859 | 0 | 0 | 0 | 0 | 0 | 0 | |
| UNIMPROVED PASTURE | 4586 | 6788 | 3802 | 156 | 10746 | 0 | 2261 | |
| TRUCK CROPS | 1138 | 291647 | 0 | 0 | 291647 | 22653 | 0 | |
| CITRUS | 21603 | 9203 | 0 | 0 | 9203 | 107993 | 0 | |
| WATER BODIES | 24130 | 0 | 0 | 0 | 0 | 0 | 0 | |
| GOLF COURSE | 10 | 748 | 0 | 0 | 748 | 0 | 0 | |

Record 1 Show: All Selected Records (0 out of 20 Selected) Options

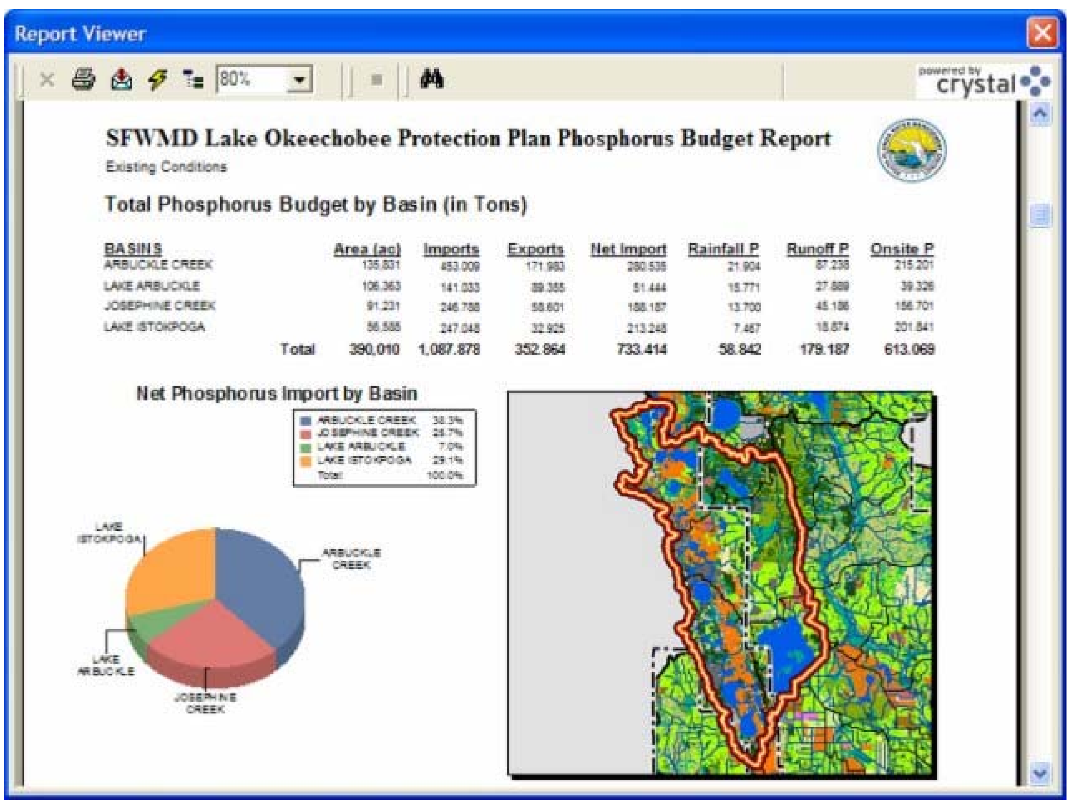
The table is stored in dBase format in the ..\Covers folder and is called landp.dbf. This file is replaced each time that the table is created.

## Phosphorus Budget Reports

There are three options for reviewing Phosphorus Budget Reports - by region, by basin and by land use. These reports include a table, a pie chart and an image captured from the left or right view of interface layout. The table consists of summaries of the phosphorus imports and exports along with rainfall, runoff and onsite storage. Onsite storage is the amount of phosphorus retained in the soils at the source of the phosphorus application and is equal to the runoff load minus the rainfall and net import loads .




The reports are generated programmatically using Crystal Reports, which is distributed with ArcMap. The reports can be printed or exported to a variety of formats.



# WAM Watershed Assessment Model

## What is WAM?

WAM (Watershed Assessment Model) is a water quality assimilation model that was developed in the mid-1990's based on similar models written by Dr. Del Bottcher of Soil and Water Engineering Technology, Inc. (SWET). The first version of WAM was written for the ARC/INFO Unix workstation platform. This version was written using ESRI's AML programming language. WAM was one of the first water quality assessment models that used the ARC/INFO component called GRID. GRID provided the ability to perform computations using rasters on a cell-by-cell basis. This resulted in output at a much finer scale (typically 1 ha) than could be provided using polygons. The computations were also performed significantly faster than could be performed using polygon overlays.

The concept of WAM is to overlay land use, soils and rainfall zones to produce unique combinations that are submitted to three submodels – Groundwater Loading Effects of Agricultural Management Systems (GLEAMS; Knisel, 1993), Everglades Agricultural Area Model (EAAMod; Botcher et al., 1998; SWET, 1999), and a special-case model written specifically for WAM to handle wetland and urban landscapes. These submodels are bundled into one program called BUCShell, which uses parameter dataset files for land use, soils and rainfall to produce an estimated annual average phosphorus runoff load in kilograms per hectare for each unique combination. The results are then spatially distributed onto the watershed by relating the output table to a grid of the unique combinations. The resulting grids represent the average annual phosphorus load at the source in both surface water runoff and groundwater.

## Integration with P-Budget

The WAM model needs to run when, by creating a PCP, a change in land use practices affects WAM's land use model coefficients used to assimilate water quality runoff. The execution of WAM is accomplished through the creation and maintenance of several databases with the goal of minimizing model runtime. The files below represent the databases and text files used in the process:

The following steps are performed to verify if WAM needs to run, create the model input data and manage the output:

### WAM Execution Procedure

Step 1: When a PCP is created the following files are copied from ..\Tables\Regions*region name* folder to the ..\PCPs*pcp name* folder:

coeff_def.dbf --> coef_pcp.dbf
calc_def.dbf --> calc_pcp.dbf
wam_def.dbf --> wam_pcp.dbf

Step 2: The files are edited through the interface by changing P import/export coefficients (directly or via calculators)

Step 3: wam_pcp.dbf is compared row by row to ..\tables\luseq.dbf to determine if new parameter sets need to be created

If No:The previously established sequence number is added to the relevant row in wam_pcp.dbf

If Yes:The row from wam_pcp.dbf is added to lu_seq.dbf and a new sequence number is created and added to the relevant row in wam_pcp.dbf

Step 4: A grid is created of the land use sequence numbers based on the corresponding land uses within the PCP spatial extent

Step 5: A grid is created of the unique land use sequence, soil and rainfall zone combinations within the PCP spatial extent

Step 6: The list of unique combinations, generated from the previous grid, is compared to a list of previously run unique combinations found in the ..\tables\annualAll.dbf file. New unique combinations are written to a file, ..\tables\Pload_Uniquex.txt, including the rainfall zone, land use sequence, and soil codes along with the associated land use parameters from wam_pcp.dbf

Step 7: The ..\tables\Pload_Uniquex.txt file is copied to the ..\WAM\LocalInputs folder and renamed Pload_Unique.bnz

Step 8: WAM\run.bat is executed which in turn executes PLoadRuns.exe and BUCShell.exe. PLoadRuns.exe uses information from the Ploads_Unique.bnz file to create ..WAM\GlobalInputs\landuse.bnz and ..WAM\LocalInputs\unique.bnz. BUCShell.exe performs the water quality assimilation using GLEAMS, EAAMOD or a special case model. The output is stored in ..\WAM\Days\annual.csv

Step 9: The ..\WAM\Days\annual.csv file is converted to a database and the rows are appended to the ..\Tables\annualAll.dbf file

Step 10: The unique grid created in Step 5 is reclassified using the annualAll database to create grids of soluble, sediment and groundwater phosphorus in g/ha and runoff and percolation in mm

## Other WAM Datasets

There are several parameter datasets associated with WAM that are stored in the ..\WAM\\GlobalInputs folder as text files.

Control.ctr - *control file for EAAMOD*
Default.bnz - *default information used by models including years of simulation*
Defaultn.in - *default information used by models including rates*
Eaamod.inp - *list of files and sensitivity run control for EAAMOD*
Files.fin - *list of input files and unit numbers for EAAMOD*
Files.in - *lists I/O files that are used by GLEAMS*
Field.# - *field geometry and conditions for EAAMOD*
FldCtrFiles.in - *list of field and control files for EAAMOD*
Landuse.bnz - *land use specific model parameters for GLEAMS*
Lu-eaa.bnz - *land use specific model parameters for EAAMOD*
Lumodel.bnz - *list od land uses that are to be run using EAAMOD*
Luspec.bnz - *information for land uses simulated by the special case model*

Rainfiles.in - *list of rain stations and corresponding zone numbers*
Soil-eaa.bnz - *soil specific model parameters for EAAMOD*
Soils.bnz - *soil specific model parameters for GLEAMS*
Sspec.bnz - *information for soils simulated by the special case model*
StationName.ran - *daily rainfall information*
Temp.tem - *temperature information for EAAMOD*
Wtfield.wtf - *field water table file used by EAAMOD*

# Updating P-Budget

## Land Use

Periodic updates of land use spatial datasets may result in the need to update the default model runs associated with P-Budget.

The GIS raster dataset called lu_grid located in the ..\Covers folder includes cells, 1 hectare in size, with values created using a lookup table called flu2codes.dbf located in the ..\Tables folder and based on the Florida Land Use Classification Code System (FLUCCS). A qualified GIS technician should join this table to the FLUCCS code (level 3 or higher) of the land use polygon coverage using the Fluc_code field of the lookup table. The attribute table should be carefully examined to make sure that every FLUCCS code has a matching code in the lookup table. If not, the lookup table will need to be updated to include the missing FLUCCS codes. The most appropriate P-Budget codes will need to be chosen. When every land use has a match in the lookup table, a raster dataset (or grid) will need to be created using the same extent and cell size of the previous lu_grid raster and with the values found in the Pbud_code field of the joined lookup table.

Abandoned dairies, which have been converted to pasture, were added to the previous land use dataset because the runoff characteristics differ from pasture. If, at the time of the update, these sites still exhibit high phosphorus runoff, they should be retained in the land use raster dataset by the GIS technician.

An additional field needs to be added to the attribute table of the new raster dataset. The field needs to be called 'Landuse2'. It should be a string type of field, 32 characters long. To populate this field, the flu2codes.dbf lookup table should be joined to the dataset using the value field of the dataset and the Pbud_code field of the lookup table. The Landuse2 field should then be calculated and set equal to the joined Pbud_desc field. The lookup table can then be unjoined and the new raster dataset should be saved as lu_grid to replace the previous dataset.

P-Bud Update Interface is an ArcGIS mxd file created to replace the default model runs if land use, import/export coefficients or WAM datasets have changed.

## Import/Export Coefficients

Surveys or other updated information regarding land use practices may make it necessary to update the default phosphorus import and export coefficients. These coefficients are stored in dBase files in the ..\Tables\Regions*RegionName* folders. There are three files that need to be edited per region:

| | |
|---|---|
| coeff_def.dbf | Database of a region's default P import and export coefficients |
| calc_def.dbf | Database of a region's default P calculator values |
| wam_def.dbf | Database of a region's default WAM land use parameter combinations |

The coef_def.dbf file includes a record (or row) for each land use and the following fields:

| Field | Description |
|---|---|
| FERT_IMP | Fertilizer Import Coefficient in g/ha |
| FEED_IMP | Feed Import Coefficient in g/ha |
| CLNRS_IMP | Cleaners Import Coefficient in g/ha |
| TOTAL_IMP | Total Import Coefficient in g/ha |
| HARV_EXP | Harvest Export Coefficient in g/ha |
| LIVEW_EXP | Liveweight Export Coefficient in g/ha |
| HAY_EXP | Hay Export Coefficient in g/ha |
| SOD_EXP | Sod Export Coefficient in g/ha |
| MILK_EXP | Milk Export Coefficient in g/ha |
| SEPT_EXP | Septic Tank Export Coefficient in g/ha |
| TOTAL_EXP | Total Export Coefficient in g/ha |
| NET_IMP | Net Import Coefficient in g/ha |
| LU_GROUP | Land Use Description in g/ha |
| PICTURE | Image File Name in g/ha |

Before the above fields are edited, it is recommended that the fields of the calc_def.dbf file be edited first and then used to create coef_def.dbf. It is further recommended that calc_def.dbf be used when performing new surveys (or other data collection) of land use practices. The calc_def.dbf file includes a record (or row) for each land use and the following fields:

| Field | Description |
|---|---|
| FERTRATE1 | Annual amount of fertilizer applied on Farm Area 1 in kg/ha |
| FERTP2O51 | Amount of P2O5 in applied fertilizer on Farm Area 1 in percent |
| FERTAREA1 | Percentage of Farm Area 1 over entire farm |
| FERTRATE2 | Annual amount of fertilizer applied on Farm Area 2 in kg/ha |
| FERTP2O52 | Amount of P2O5 in applied fertilizer on Farm Area 2 in percent |
| FERTAREA2 | Percentage of Farm Area 2 over entire farm |
| FEEDDENS | Animal density in number of animals / ha |
| FEEDRATE1 | Annual amount of feed for Feed Supplement 1 in kg/animal |
| FEEDPCON1 | Average P content in Feed Supplement 1 in percent |
| FEEDRATE2 | Annual amount of feed for Feed Supplement 2 in kg/animal |
| FEEDPCON2 | Average P content in Feed Supplement 2 in percent |
| FEED2PEFF | Annual amount of P in human effluent per housing unit (assuming 2.5 people per unit) in Kg |
| FEED2DENS | Average number of housing units per ha |
| CLNRSAMT | Annual amount of P in cleaners in kg (used only for dairies) |
| CLNRSAREA | Average farm size in ha (used only for dairies) |
| HARVRATE1 | Annual harvest rate from Crop Area 1 in kg/ha |
| HARVNUM1 | Number of crops per year on Crop Area 1 |
| HARVPCON1 | Average P content in crop from Crop Area 1 in percent |
| HARVAREA1 | Percentage of Crop Area 1 over entire farm |
| HARVRATE2 | Annual harvest rate from Crop Area 2 in kg/ha |

| | |
|---|---|
| HARVNUM2 | Number of crops per year on Crop Area 2 |
| HARVPCON2 | Average P content in crop from Crop Area 2 in percent |
| HARVAREA2 | Percentage of Crop Area 2 over entire farm |
| LIVEWDENS | Annual number of culled livestock per ha |
| LIVEWWT | Average weight of culled livestock in kg/animal |
| LIVEWPCON | Average P content of culled animal in percent |
| HAYRATE | Annual amount of hay harvested in kg/ha |
| SODRATE | Annual amount of sod harvested in kg/ha |
| MILKDENS | Average number of milking cows per ha |
| MILKPROD | Annual amount of milk produced in kg/cow |
| MILKPCON | Average P content in milk in percent |
| SEPTTANKS | Percentage of homes on septic tanks |
| SEPTPEFF | Annual amount of P in human effluent per housing unit in Kg/unit |
| SEPTPREM | Average percentage of P removed when a tank is cleaned |
| SEPTDENS | Average number of housing units per ha |

A spreadsheet file called calc2coef.xls, located in the ..\Tables folder can be used to create coef_def.dbf from calc_def.dbf.

The WAM land use parameter file, wam_def.dbf, is not be edited like coef_def.dbf and calc_def.dbf. Rather, it is recreated when P-Budget Update is run. The P-Bud Update Interface is an ArcGIS mxd file created to replace the default model runs if land use, import/export coefficients or WAM datasets have changed.

## WAM Datasets

Besides the land use parameter datasets that are edited through the P-Budget interface, the WAM Watershed Assessment Model includes several other parameter datasets that will most likely never need to be edited for the purposes of P-Budget. It may, however, be necessary to update the rainfall information and the modeling run period.

If at all possible, the same rainfall stations should be used. These stations can be found in the rainsta.shp shapefile located in the ..\Covers folder. If the station locations change, it will be necessary for a GIS technician to recreate a raster in the ..\Covers folder called rainzone which is created by using proximity functions with the station shapefile. This, in effect, applies Thiessens Method to create the rainfall station zones. The stations must be numbered sequentially starting with one and the values of the zones in the raster must match the station numbers. If rain stations change, then the rainfiles.in file located in the ..\WAM\GlobalInputs folder will also need to be edited to reflect the change.

The rainfall datasets will need to be supplemented if the modeling run period is being extended. Each rainfall file is names after the rainfall station (click here to see file format). The values are in cm. If a new rainfall station is introduced, then an entire new file will need to be created. Make sure that the record sets are complete. Any gaps in the data should be supplemented with data from nearby stations. Calculate the total annual rainfall and compare it to the annual rainfall of other stations to assess whether the data is within a reasonable range of the other stations.

To change the model run period, edit the BEGYR and ENDYR parameters in the default.bnz file located in the ..\WAM\GlobalInputs folder. It is recommended that a ten year span be used. The first five years of the model are used to bring the model to equilibrium and are then discarded. The model results will only reflect the last five years of the specified model run period.

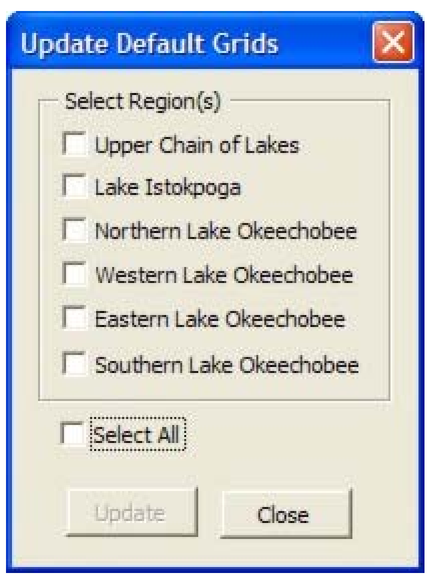
The P-Bud Update Interface is an ArcGIS mxd file created to replace the default model runs if land use, import/export coefficients or WAM datasets have changed.

## P-Budget Update Interface

The P-Bud Update Interface is an ArcGIS mxd file created to replace the default grids if land use, import/export coefficients or WAM datasets have changed. This interface does not have to be used if only the water quality sampling data has been updated.

If the WAM datasets are changed in any way, then the luseq.dbf, luseqx.dbf and annualall.dbf files should be edited prior to performing this update by deleting all of the records in these files. This does not need to be done is only the land use or import/export coefficients have changed.

The interface will run for each of the selected regions. The runs may take several hours and even days if all of the regions are selected and if the WAM datasets have changed.



## Water Quality Sampling Data

The sampling data is viewed in conjunction with the Drainage Area Tool and Summary Table. A variety of sources were used to incorporate water quality sampling data into the interface including:

Lake Okeechobee Water Assessment (LOWA)
Kissimmee River Eutrophication Abatement Program (KREA)
Taylor Creek Nubbin Slough (TCNS)
Miscellaneous District Structures (Struc)

The sampling sites were reviewed spatially to determine if there is a matching hydrologic reach that the site could represent. The sampling data was then averaged over the same period of record used by the model and the values were saved in fields of the reaches.shp shapefile located in the ../Covers folder. Attributes were added in the fields below for each matching reach in the attribute table of the reaches.shp shapefile.

| Field | Description |
|---|---|
| CALCREACH | Hydrologic reach number |
| TCNS_STA | TCNS station name |
| TCNS_PPB | TCNS average P concentration in ppb |
| KREA_STA | KREA station name |
| KREA_PPB | KREA average P concentration in ppb |
| LOWA_STA | LOWA station name |
| LOWA_PPB | LOWA average P concentration in ppb |
| STRUCT_STA | District structure name |
| STRUCT_PPB | District structure average P concentration in ppb |
| STRUCT_M3 | District structure annual average flow in m3 |

The interface is programmed to search for values in these fields that are greater than zero. Any such values are presented in the Drainage Area Summary Table along with the corresponding station name.

## Base Maps

Base maps consist of shapefiles located in the ..\Covers folder that overlay onto the left and right views of the main layout. They are activated in the interface by using a dropdown list and toggle button located in the Phosphorus Budget toolbar. Base maps are intended to provide reference information and typically include roads, county boundaries, etc.

**Updating Base Maps**
With the interface open (p-budget.mxd), go to 'Window' on the main ArcMap menu and select 'Table of Contents' to view the layers. Notice that there are three dataframes - Left View, Right View and Select Extent. Each dataframe includes the same set of base map layers. The names of these layer match exactly the names in the dropdown list found in the Phosphorus Budget toolbar. Take note of the base map you wish to update. Find it in the Left View dataframe and double click on it. Click on the 'Source' tab and note the name of the shapefile. For example, the Subbasins layer source is sbas.shp. Close everything including p-budget.mxd.

Most base maps can simply be replaced with updated versions by replacing the corresponding shapefile in the ..\Covers folder with the following exceptions:

- Stream Reaches (reaches.shp) should not be spatially edited or replaced. The information in this shapefile is used to generate the drainage areas. Attributes in the fields associated with the sampling sites, however, may be edited (see Water Quality Sampling Data).

- Regions (regions.shp) needs a string field called 'Primaries' that includes the names of the regions.

- Basins (basins.shp) needs a string field called 'Basin_' that includes the names of the basins.

- WOD Permits (wod.shp) needs a string field called 'Permit_par' that includes permit numbers followed by a letter indicating the parcel within the permit that the respective polygon represents, e.g., '47-00052-QA', where 'A' represents the parcel.

- Aerial (dataview.asp) is not located in the ..\Covers folder because of it's size. Rather it is centrally located on the District's Citrix server.

To preserve the interface, the p-budget.mxd file is write-protected and therefore can not be saved once edited. It is recommended that any editing required to create an updated base map be performed in separate mxd file, then exported to replace the original version in the ..\Covers folder. The next time p-budget.mxd is opened, the layers will automatically be updated with

**Adding New Base Maps**
Adding a base map to the interface requires the use of ArcMap functions and minor changes in the VBA code.

To preserve the interface, the p-budget.mxd file is write-protected. It is necessary to turn off the 'Read only' property for this file before proceeding. It is recommended that a backup copy of the file be created before proceeding. Be careful while editing this file that only the changes listed below be made. Any other changes may have undesired results.

It is recommended, for file management purposes, that the base map file (usually a shapefile) be saved in the ..\Covers folder. However, if it is a large dataset or one that other users may also wish to access, the file may be located centrally on the District's server in an accessible and protected location.

Open the p-budget.mxd file in ArcMap and go to 'Window' on the main ArcMap menu and select 'Table of Contents' to view the layers. Add the new base map layer to the Left View dataframe and format the layer symbols, etc. as needed. Change the name of the layer to a name that is appropriate, but simple. Once satisfied with the format and appearance of the new layer, copy the layer to the other two dataframes - Right View and Select Extent. Make sure that each of the newly added layers are turned off and collapse the layers so that the symbols do not show. Close the table of contents.

From the ArcMap main menu, go to Tools --> Macro --> Visual Basic Editor. Visual Basic of Applications will open. In the Project Explorer window, locate the ThisDocument module under the ArcMap Objects folder. Open the module, if it is not already open. At the top of the document, there are several statements that begin with 'Dim'. Locate the one that says 'Dim baseMapsOnList(14) As Boolean' and change the number in the parentheses to the next sequential number.

There are two dropdown list boxes at the top of the window. The left box needs to be set on '(General)'. In the right list box, select 'Startup'. The document will automatically scroll down to that portion of the code. There are several statements that begin with 'BaseMaps.AddItem', followed by the name of the base map. After the last statement like this, add 'BaseMaps.AddItem' followed by the name of your base map, in quotes, exactly as it appears in the layers that were previously added to the three dataframes.

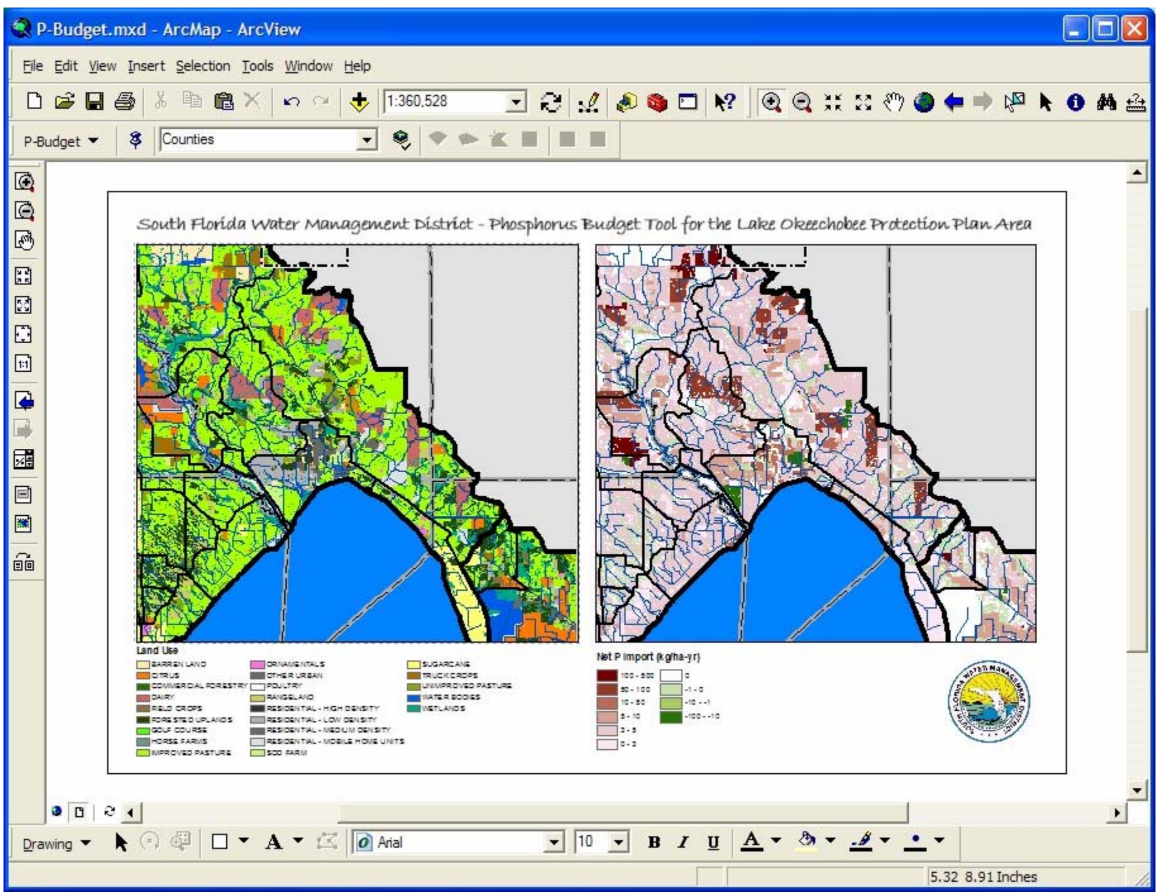
The next section of code below this is used to set the basemaps on or off at startup. Add the line 'baseMapsOnList(#) = True' to the bottom of this section, where # equals the next sequential number. (Note: This number should be one less than the number entered with the Dim statement)

Close Visual Basic of Applications and return to ArcMap. Save the project and exit ArcMap. Be sure to save it before exiting because you will not be prompted to save it (as occurs when usually exiting a program). Change the p-budget.mxd file attributes to read-only again. The next time you open the file, the added base map should appear in the dropdown list of base maps and the base map should appear in the right and left views when toggled on.

# Tutorial

## STEP 1: Getting Started

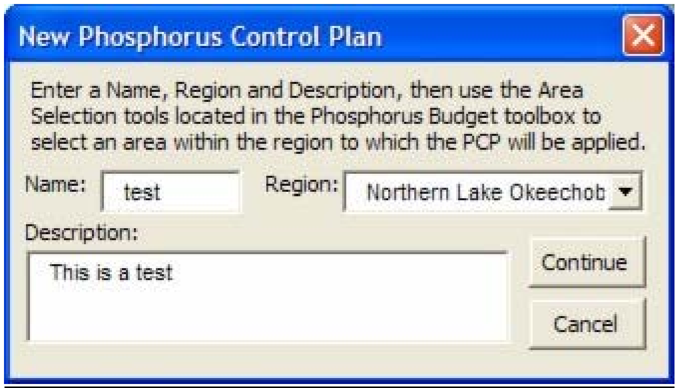
- Start ArcMap and open P-Budget.mxd located in the C:\PBudLOPP folder
- Locate the Phosphorus Budget toolbar and place it somewhere in the top of the screen (if it is not already there)
- Close any unnecessary toolbars and maximize the ArcMap application window
- Press the Reset Interface button to refresh the screen
- Use the pan and zoom tools in the standard toolbar on the left view
    - o Notice that both views change simultaneously
- Use the pan and zoom tools on the right view
    - o Notice that both views do not change simultaneously
- Press the Reset Interface button again to refresh the screen
- Select 'Counties' from the drop-down list of base maps
    - o Notice that the 'Toggle Base Map' button is now enabled with an "x"
- Click the 'Toggle Base Map' Button to turn on the base map
    - o Notice that county boundaries are now shown and the toggle button now includes a check mark in place of the "x"



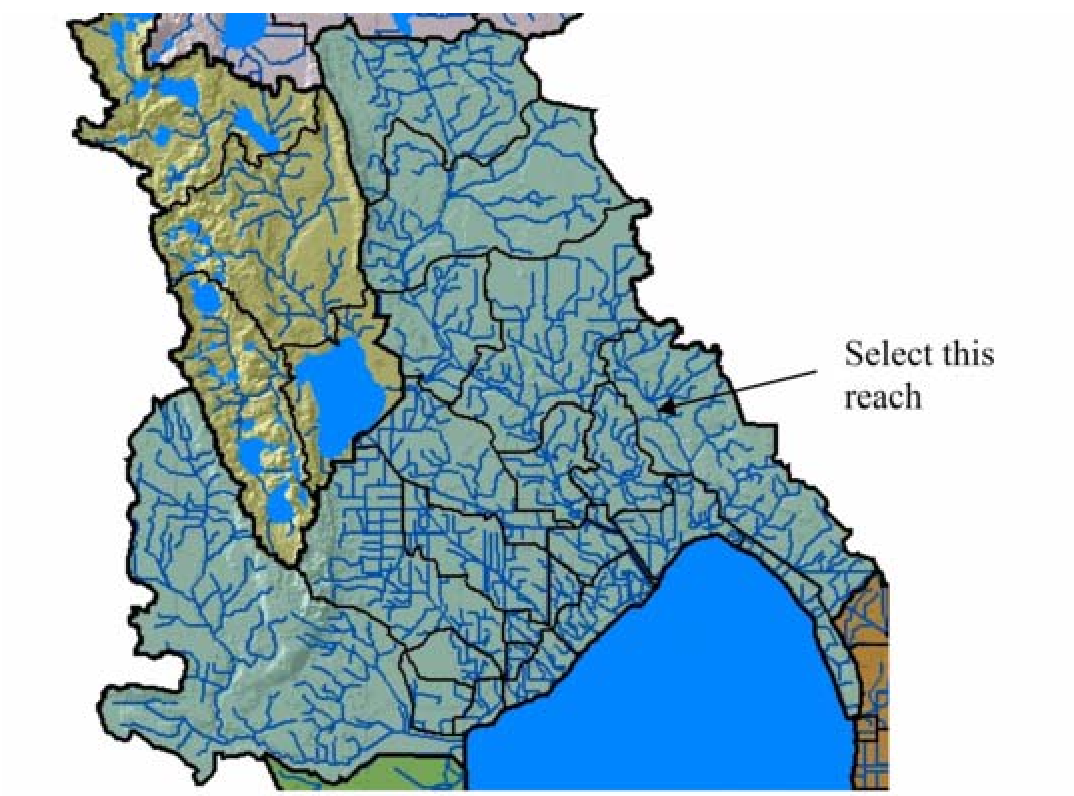
Next Step

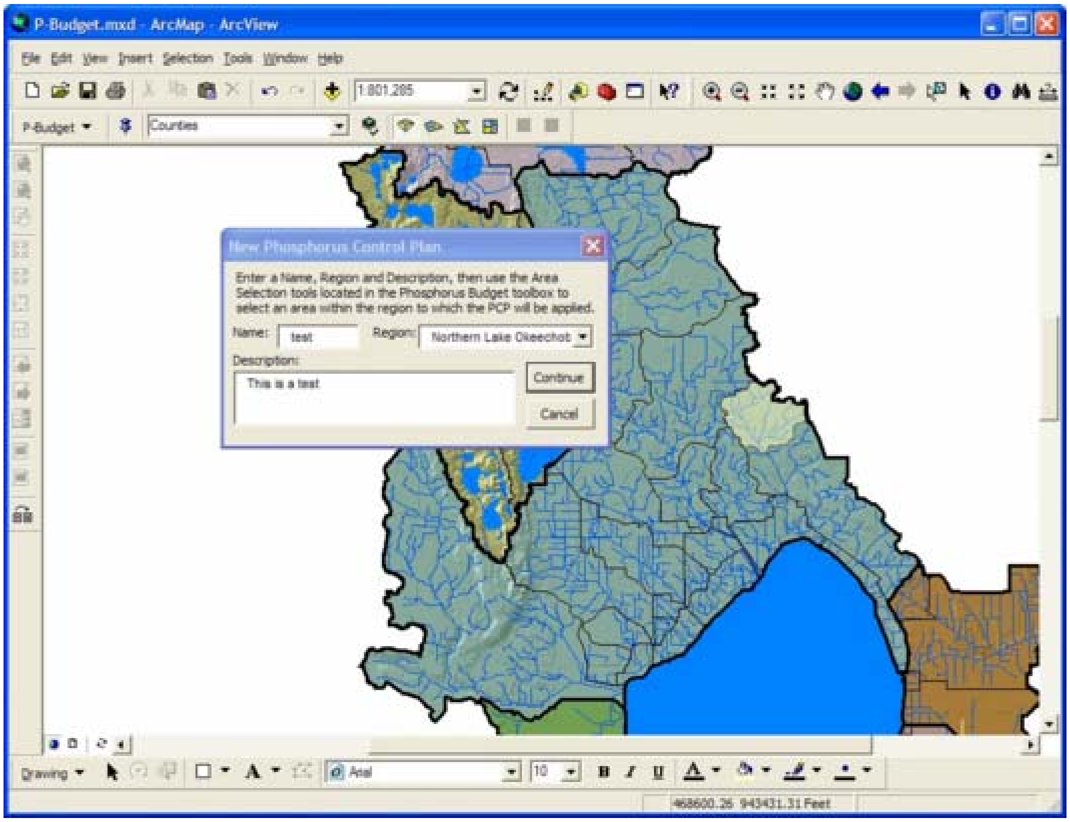
## STEP 2: Creating a PCP

- From the Phosphorus Budget toolbar go to P-Budget → Phosphorus Control Plans → New

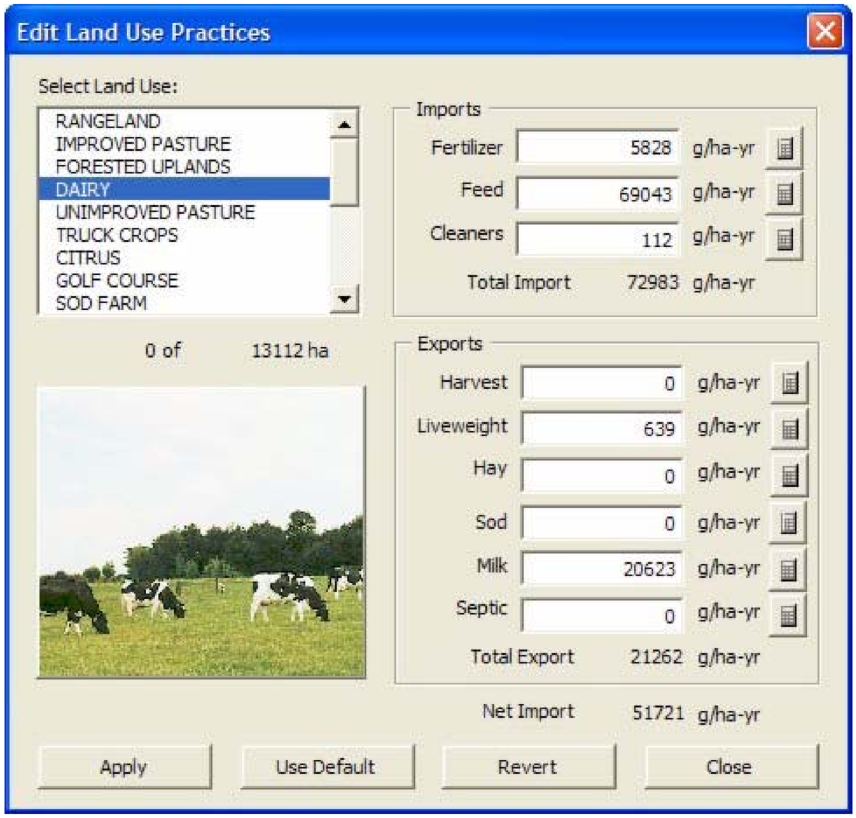



- Read the instructions, enter the name "Test" and select the "Northern Lake Okeechobee" region
  - o Notice that the screen zooms to the extent of the selected region
- Enter "This is a test" for the description
- Click on the 'Select by Reach' tool , read the message and click 'OK'
- Click on the reach shown below and wait for the screen to refresh showing the reach's drainage area






- Click on ‘Continue’ then click ‘Yes’ when asked to replace the PCP
- On the Edit Land Use Practices form click on ‘Dairy’
  - Notice that the picture has changed and the area in hectares is displayed

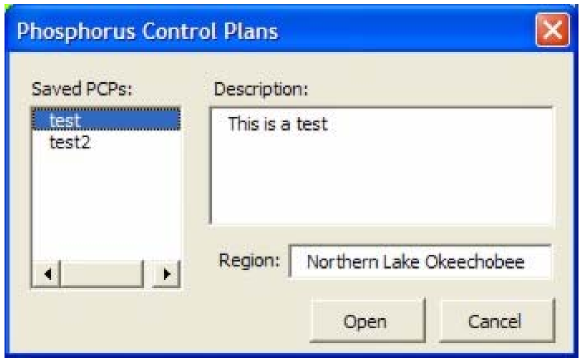



- Click on the fertilizer 'Calculator' button located near the top right corner of the form
- For Area 1: Application Rate, enter any number between 100 and 250 (try to select a random number that no one has used before.
- Click 'Calculate' and notice that the phosphorus coefficient for fertilizer has changed
- Click 'Apply' to apply the changes and notice that the Net Import value has been updated
- Repeat this procedure for 'feed' – change the animal density from 4 to 2 animals/ha (click 'Calculate and 'Apply' again)
- Click 'Close' and 'Yes' to save changes
  - o The message bar at the bottom of the screen will most likely display "1 new WAM land use parameter combination found" (if the message says "0 new WAM land use parameter combination found" then the value you entered was previously used and WAM will most likely not need to run
  - o The next message to appear will indicate how many new WAM unique soil and land use combinations need to be run (if > 0 a DOS window will appear and WAM will begin running the uniques)
  - o When WAM is finished, the DOS window will close automatically and P-Budget will add the results to a master list of results and begin preparing the runoff grids (this takes about a minute and the screen may go blank)
  - o The next set of messages to appear in the bottom of the screen indicate which import/export component is being processed (this may take a few minutes)
  - o When the processing is completed, the results will be displayed in the right view
  - o Notice that the areas corresponding to dairies within the PCP extent may appear significantly lower in net phosphorus import depending on the fertilizer value that was entered

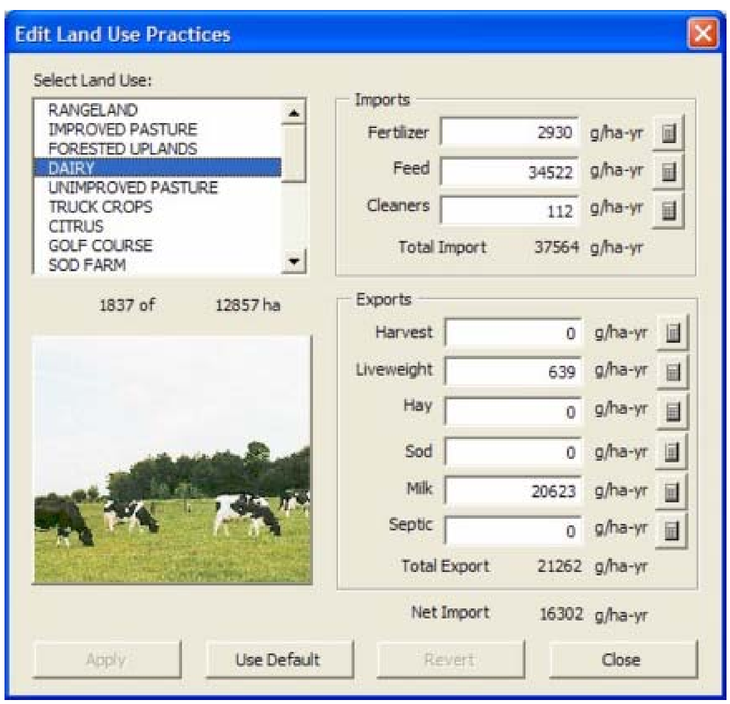
Next Step

## STEP 3: Managing PCPs

- From the Phosphorus Budget toolbar go to P-Budget → Phosphorus Control Plans → Close
  - o The right view will return to the default net import results
- Go to P-Budget → Phosphorus Control Plans → Open and click on to 'Test' in the list of saved PCPs
  - o Attributes associated with the PCP will appear

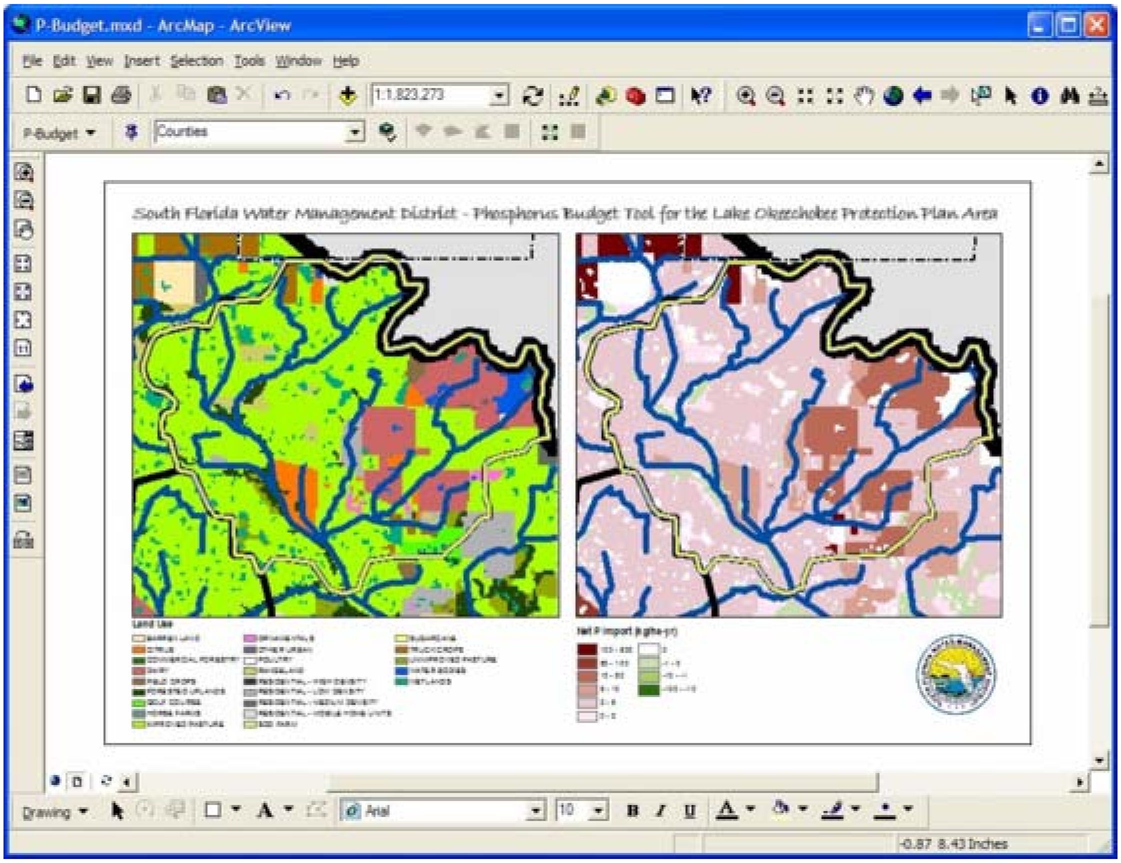



- Click 'Open' and notice that the right view has once again changed back to reflect the net import results of the PCP
- The 'Edit Land Use Practices' form has also appeared assuming that the user wants to make additional changes
- Do not make any changes and click 'Close'
- The form may be opened again by going to P-Budget → Phosphorus Control Plans → Edit
  - o Notice that the 'Use Default' button is now enabled




- Press 'Use Default' and notice that the fertilizer coefficient returns to the default value established fir the Northern Lake Okeechobee Region.

- The 'Revert' button is now enabled. Press this button to restore the previously saved coefficients associated with this land use.
- Press 'Close'. You should not be prompted to save since no changes were made.

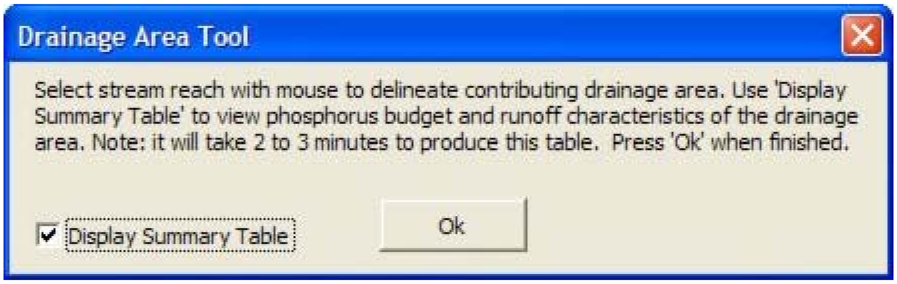



Next Step

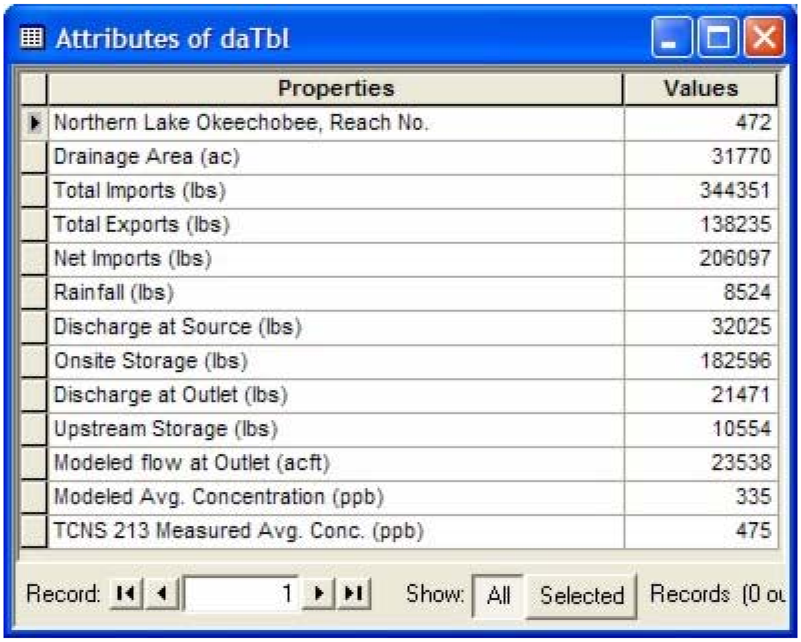
## STEP 4: Using Drainage Area Tool and Setting An AOI

- From the Phosphorus Budget toolbar go to P-Budget → Area of Interest → Set
- Read the message in the 'Set Area of Interest' dialog. Do not press any buttons in this dialog yet


- Click on the 'Select by Reach' tool  and notice that the message box for this tool now includes a check box indicating if a summary table is to be displayed – check the box and click 'OK'




- Click on the same reach you used to create the PCP (a status bar will eventually appear at the bottom of the screen (it will take 2-3 minutes to produce this table)
- When the table appears, review the results (notice that the "Discharge at Outlet" reflects the average annual attenuated load at the selected reach)
    - o The selected reach should correspond sampling station TCNS 213 which will be displayed in the table for comparison to the modeled concentration

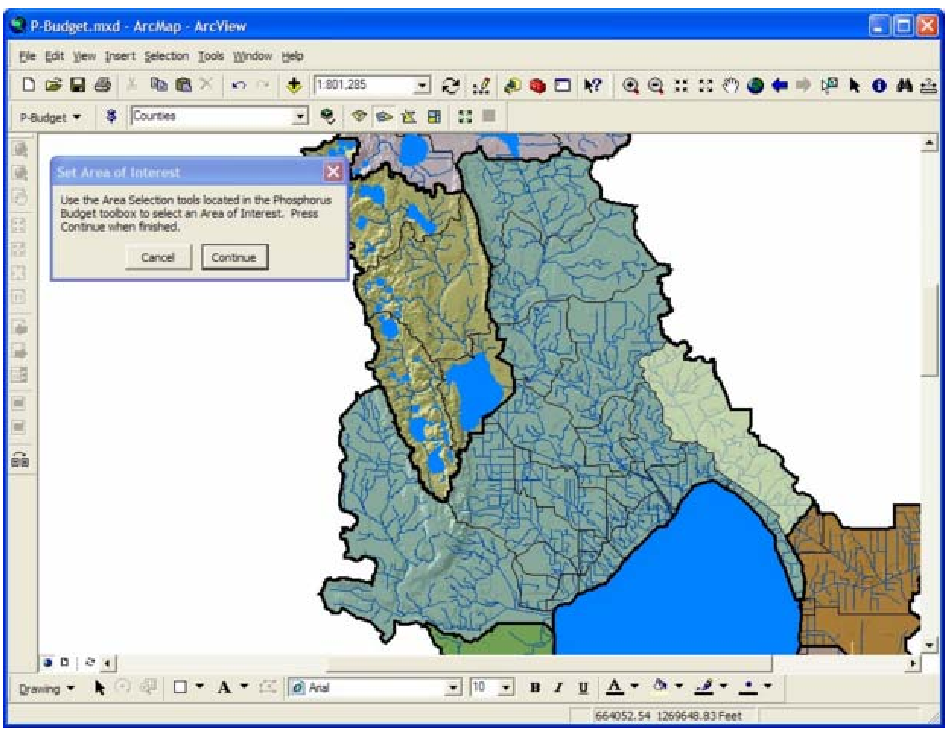


Attributes of daTbl

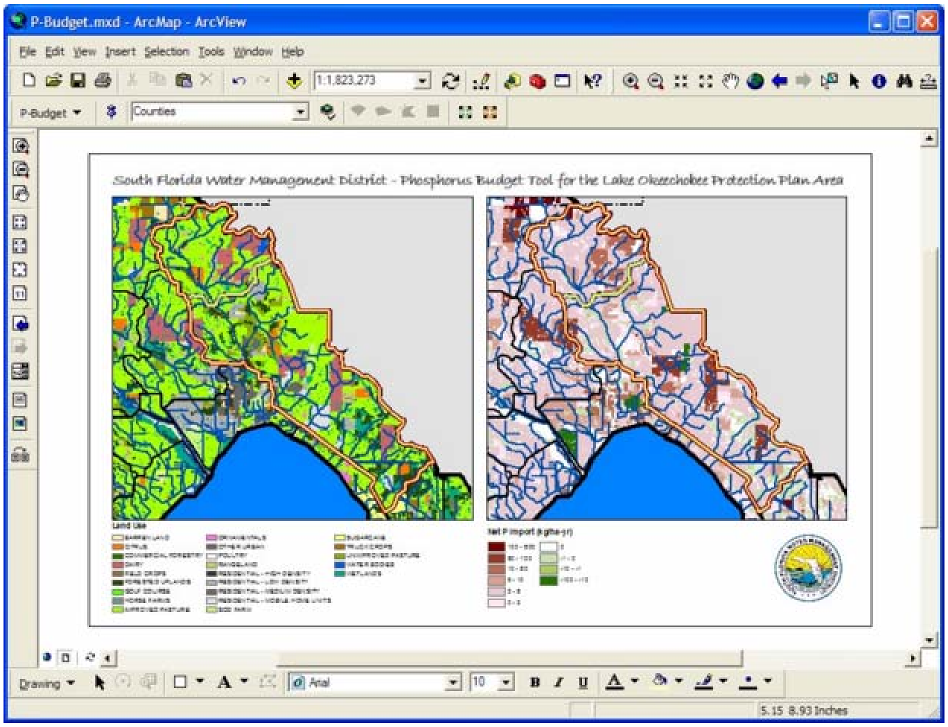
| Properties | Values |
|---|---|
| Northern Lake Okeechobee, Reach No. | 472 |
| Drainage Area (ac) | 31770 |
| Total Imports (lbs) | 344351 |
| Total Exports (lbs) | 138235 |
| Net Imports (lbs) | 206097 |
| Rainfall (lbs) | 8524 |
| Discharge at Source (lbs) | 32025 |
| Onsite Storage (lbs) | 182596 |
| Discharge at Outlet (lbs) | 21471 |
| Upstream Storage (lbs) | 10554 |
| Modeled flow at Outlet (acft) | 23538 |
| Modeled Avg. Concentration (ppb) | 335 |
| TCNS 213 Measured Avg. Conc. (ppb) | 475 |

Record: 1 Show: All Selected Records (0 ou

- Close the table and click on the 'Select by Basin' tool 
- Click 'Yes' to replace the previous extent and 'OK' to begin selecting a basin




- Click on to the S-191 basin, then click the 'Continue' button in the 'Set Area of Interest' dialog
  - o Notice that the entire basin becomes outlined
- Click on the 'Zoom to PCP'  and 'Zoom to AOI'  buttons in the Phosphorus Budget toolbar




Next Step

## STEP 5: Displaying Output Tables and Reports

- From the Phosphorus Budget toolbar go to P-Budget → Land Practice Imports and Exports
- In the table that appears, scroll horizontally to see the fields this table offers
    - o This table provides a detailed account of the various components of phosphorus imports and exports within the spatial extent of the AOI

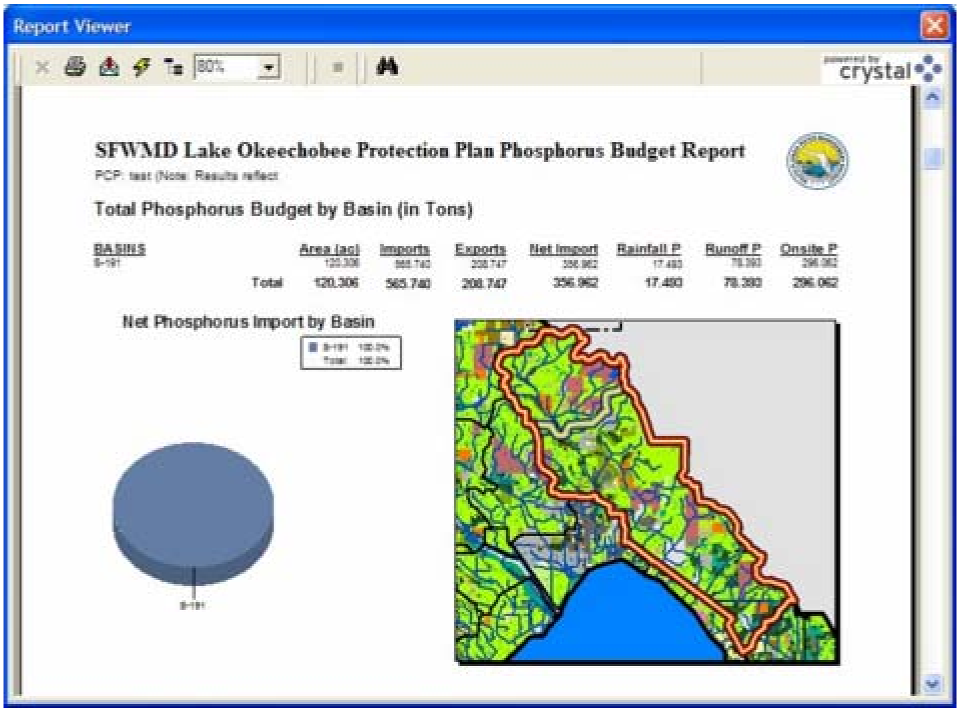
Attributes of landpe

| LANDUSE | ACRES | FERTILIZER | FEED | CLEANERS | IMPORTS | HARVEST | LIVEWEIGHT | HAY |
|---|---|---|---|---|---|---|---|---|
| RANGELAND | 2071 | 0 | 1062 | 39 | 310 | 0 | 672 | 0 |
| IMPROVED PASTURE | 63459 | 532462 | 70980 | 0 | 264635 | 0 | 33859 | 1314 |
| WETLANDS | 9998 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FORESTED UPLANDS | 10620 | 0 | 0 | 0 | 0 | 159 | 0 | 0 |
| DAIRY | 11567 | 48620 | 350427 | 2987 | 622269 | 0 | 4977 | 78148 |
| BARREN LAND | 376 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| OTHER URBAN | 1315 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| UNIMPROVED PASTURE | 4426 | 0 | 3046 | 123 | 663 | 0 | 1831 | 0 |
| TRUCK CROPS | 539 | 85598 | 0 | 0 | 100464 | 9216 | 0 | 0 |
| CITRUS | 3375 | 12449 | 0 | 0 | 31190 | 12950 | 0 | 0 |
| WATER BODIES | 1332 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GOLF COURSE | 467 | 10682 | 0 | 0 | 4283 | 0 | 0 | 0 |
| SOD FARM | 887 | 17565 | 0 | 0 | 14930 | 0 | 0 | 0 |
| ORNAMENTALS | 561 | 3405 | 0 | 0 | 13327 | 8582 | 0 | 0 |
| AQUACULTURE | 146 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| POULTRY | 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WILD GAME | 3832 | 34578 | 7045 | 3 | 15982 | 0 | 747 | 82 |
| RESIDENTIAL - MOBILE HOME UNITS | 47 | 0 | 1423 | 0 | 1732 | 0 | 0 | 0 |
| RESIDENTIAL - LOW DENSITY | 3912 | 4729 | 8545 | 0 | 24331 | 0 | 0 | 0 |
| RESIDENTIAL - MEDIUM DENSITY | 670 | 1601 | 10393 | 0 | 16119 | 0 | 0 | 0 |
| FIELD CROPS | 568 | 21652 | 0 | 0 | 20005 | 18010 | 0 | 0 |
| HORSE FARMS | 72 | 373 | 862 | 0 | 1238 | 0 | 0 | 0 |

Record: 1 Show: All Selected Records (0 out of 22 Selected) Options

- Close the table and go to P-Budget → Table and Report Preferences
    - o Select English units and Left View for the map display and press 'Ok"

- Go to P-Budget → Phosphorus Budget Reports → By Basin
  - o A report including a table, pie chart and map will appear. Notice that only one record appears in the table because the AOI is set within only one basin




- Close the report, go to P-Budget → Phosphorus Control Plans → Close and press 'Yes'
  - o This closes the PCP and restores the default (existing practices) scenario
- Go to P-Budget → Phosphorus Budget Reports → By Land Use
  - o Take note of the values for phosphorus net import and Runoff P for Dairy (277.2 and 3.9 tons, respectively – default values)
- Close the report and go to P-Budget → Phosphorus Control Plans → Open and click on to 'Test' in the list of saved PCPs and click 'Open'. When the 'Edit Land Use Practices' window appears, press 'Close'.
- Go to P-Budget → Phosphorus Budget Reports → By Land Use again
  - o Notice that the Net Import and Runoff P values for dairy have been reduced as a result of the PCP
- Close the report

Next Step

## STEP 6: Exiting P-Budget

- P-Budget can be closed at anytime regardless of whether a PCP is open or whether an AOI is set. P-Budget is a read-only template for creating/editing PCPs and viewing results. P-Budget can be closed from the main menu File → Exit or by clicking "x" in the top right corner of the application. The user will not be prompted to save.

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Bottcher, A.B, N.B. Pickering, and A.B. Cooper. 1998. EAAMOD-FIELD: A Flow and Phosphorous Model for High Water Tables. Proceedings of the 7th Annual Drainage Symposium. American Society of Agricultural Engineers, St. Joseph, MI.

Knisel, W. G. 1993. GLEAMS: Groundwater Loading Effects of Agricultural Management Systems. UGA-CPES-BAED Publication no. 5.

SFWMD, FDEP, FDACS, 2004. Lake Okeechobee Protection Program – Lake Okeechobee Protection Plan, West Palm Beach, Florida.

SWET , K. Remesh Reddy, Mock, Roos & Associates, Inc., Entel Environmental Companies, Inc. 2001. Development of Phosphorus Retention Assimilation Algorithms for the Lake Okeechobee Watershed - Final Report to the SFWMD, West Palm Beach, Florida.

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