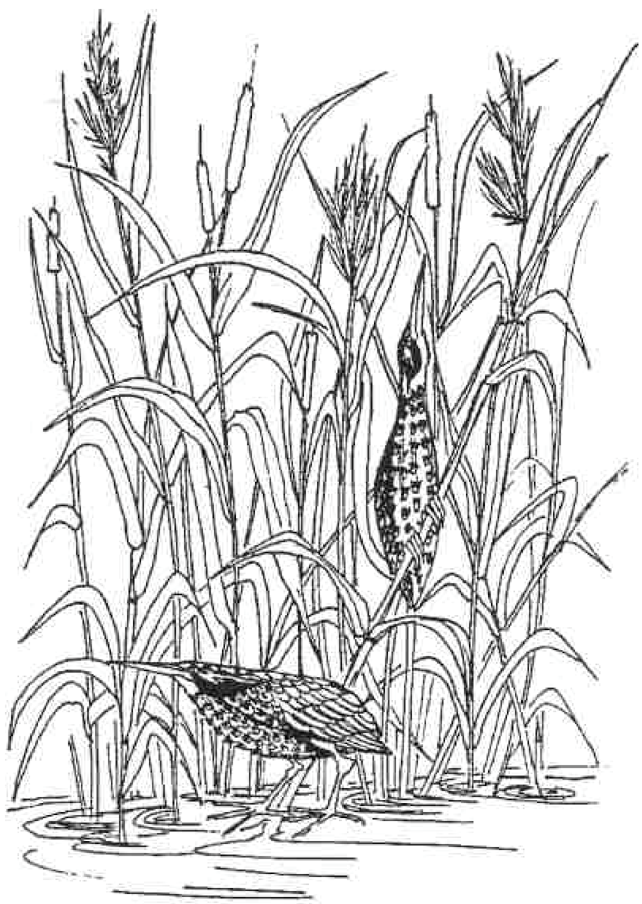
Wisconsin Lake Modeling Suite

Program Documentation and User's Manual

Version 3.3 for Windows



Lake
Management
Program

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Introduction

The Wisconsin Lake Modeling Suite (WiLMS) model is a lake water quality-planning tool. The model uses an annual time step and predicts spring overturn (SPO), growing season mean (GSM) and annual average (ANN) total phosphorus concentration in lakes. WiLMS should not be used for time steps other than one year. First time users are encouraged to consult the getting started section in the help section for assistance in using the program.

The WiLMS model structure is organized into four (4) principal parts, which include the front-end, phosphorus prediction, internal loading and trophic response. The front-end portion or model setup includes the Lake Characteristics, watershed loading calculation inputs and the observed in-lake TP. The front-end inputs to WiLMS can be saved and recalled for later use. Both the phosphorus prediction and internal load estimator both use the front-end portion of the model for lake and watershed inputs. The phosphorus prediction portion contains the 13 phosphorus prediction regressions and the Uncertainty Analysis routines. The internal load estimation portion contains 4 methods to estimate and bracket a lake's internal loading. The inputs to these portions of WiLMS are not saved after each model run but the output can be saved as a rich text file or printed out. The trophic response portion of the program contains 2 levels of trophic evaluation, summary and expanded. The summary portion contains only Wisconsin trophic response relationships while the expanded contains Wisconsin regressions plus other commonly used regressions and allows for user defined regressions.

Because WiLMS uses export values in its watershed loading module, the user is advised to use local export values derived from similar land use, topography, and soil types whenever possible. Watershed export monitoring data from the lake and watershed system being modeled should always be used when such data is available.

Selection of an empirical lake model requires that the model parameters fit the data for the lake and watershed system. The parameter range feature in WiLMS is designed to facilitate the necessary checking. The original technical publications, which contain information on the development of each model, should also be referenced prior to final model selection.

The models used in WiLMS are empirical methods developed via statistical analysis of lake and reservoir systems. The lake models themselves have an uncertainty associated with them, which WiLMS combines with the loading uncertainty to obtain the total prediction uncertainty. The user is encouraged to use the uncertainty analysis module to quantify the prediction uncertainty and to be aware of the prediction uncertainty when interpreting results.

Although the Wisconsin Department of Natural Resources (WDNR) has tested this program, no warranty, expressed or implied, is made by WDNR as to the accuracy and functioning of the program and related program material. Neither shall the fact of distribution constitute any such warranty nor responsibility is assumed by WDNR in connection therewith. The contents of this manual are not to be used for advertising, publication, or promotional purposes.

Getting Started

The following step-by-step outline is an introduction to WiLMS and summarizes the operations necessary to use the model for most applications. WiLMS has a comprehensive system of HELP screens to assist the user. The model's HELP can be accessed in a number of ways, which include the HELP menu item, located at the top of the WiLMS main screen, through the F1 key and the help button located at the bottom of each input screen. Accessing HELP through the F1 key provides assistance specific to the data input cells. The HELP menu contains a number of features that include a topical contents (denoted by the open book at the top of the HELP screen), an index (denoted by a key) and a search feature (denoted by a pair of binoculars). Main subject areas and key words can all be accessed using the help search features. To remove a help page from the screen click on the input screen from which help was called or press the escape key. For an overview of WiLMS see Wisconsin Lake Modeling Suite.

Step 1

The first step in using WiLMS is to setup the basic lake and watershed information. To do this use the menu bar at the top of the WiLMS main screen and select Models | Lake Total Phosphorus Prediction | Setup. The Phosphorus Loading Data Setup screen will appear and you are ready to begin entering data. The General input tab contains buttons to allow existing files to be loaded. Press this button to load the Example data file.

Step 2

If you would like to use default data for the net precipitation and annual runoff, WiLMS will use the file specified in the Default Data Filename cell. If a file name is not present, it will be necessary to load the default file using the open file button located on the right edge of the Default Data Filename cell. For additional information on the use of default data see Using Default data and to create a default data file for your state see the Update Default Data. If you are using WiLMS in Wisconsin, the default data file name is wilms.wi. You will notice that the drop down menu in the in the Location for Default Data Usage contains the names of Wisconsin counties. Enter the ID information and observed conditions.

Step 3

The other inputs for WiLMS include the hydrologic and morphometric inputs and the point and non-point source loading inputs. For more information see Hydrologic and Morphometric Overview. Default phosphorus export coefficients have been included along with up to 6 user defined point source and land use types. For more information see Phosphorus Load Models Overview. At any time, double clicking the left mouse button within a cell will high light the entire value within that cell for editing, while the right mouse button can be used to cut, copy, paste or delete values.

Results from any page can at any time be written to a text file and saved, printed or later imported into a report document via the Write Results button on each page. Each time an input screen is printed, a unique scenario value is assigned. The scenario counter can be reset at any time using the reset selection under the Options menu item at the top of the main screen menu bar. Once data entry is complete, return to the general screen and save your input file. You are now ready to exit the Setup portion of the program by selecting the Leave button.

Step 4

At this point you are now ready to move into the water body phosphorus prediction portion of the program. Return to the Models menu item and under the Lake Total Phosphorus Prediction item select either the Internal Load Estimator or the Prediction and Uncertainty Analysis modules.

The Total Phosphorus Prediction model will display the TP prediction using 13 empirical regressions. This model also contains the user defined uncertainty bounds. The default value is 70% and can be interpreted to mean that the true value will fall within the specified range 70% of the time. For more information see Uncertainty Analysis Overview. This model also contains a load back calculation routine that allows the user to enter a concentration and the model will back calculate an annual loading. The Internal Load estimator uses 4 methods along with the watershed loading to bracket the internal loading to the water column. The internal load estimator also contains an index to indicate the potential for lake mixing based on mean depth and surface area. For additional information on phosphorus prediction or the internal load estimator see phosphorus prediction overview and internal load estimator overview, respectively.

The water and nutrient outflow screen allows the user to estimate the flow volume and total phosphorus loading leaving a lake via the outlet. This information is useful when lakes are networked and the outflow from the upstream lake becomes the inflow to the downstream lake. For additional information see Water And Nutrient Outflow Overview.

Step 5

Once an in-lake model has been selected, the predicted water column total phosphorus concentration can be entered into one of the trophic response models. As shown under the models menu item WiLMS contains two trophic state evaluation options. The trophic evaluation routines are stand-alone routines requiring the user to enter the total phosphorus, Chlorophyll a and Secchi depth values for the water body and can be used as such. The Summary Option includes TSI and predictive equations for Wisconsin only. The Expanded Option includes additional Wisconsin predictive equations as well as the Carlson TSI equations and other predictive trophic regressions. User defined relationships can be established to predict Chlorophyll_a and Secchi depth. For more information see Trophic State Index Overview.

WiLMS contains a Lake Eutrophication Analysis Procedure (LEAP). This procedure uses an ecoregion-based data set of minimally impacted lakes to evaluate and rank the subject lake. Basic watershed and lake characteristic data (including observed water quality) are input for the subject lake. An analysis is made against minimally impacted lakes in the ecoregion to facilitate a relative comparison. Prior to using LEAP the ecoregion data set must be developed. See LEAP initial set up. The model contains default data for Wisconsin and Minnesota ecoregions but user defined ecoregion data can be added, see adding ecoregion data.

In evaluating lake water quality conditions it is valuable to know the magnitude and frequency of algal blooms. The WiLMS Expanded Trophic Response Module contains a routine to estimate algal nuisance frequency. The user enters the growing season mean Chlorophyll a range, the Chlorophyll a temporal coefficient of variation and the nuisance level. For additional information on the Chlorophyll a nuisance frequency module, see algal nuisance frequency.

Removing WiLMS

To remove (uninstall) WiLMS from your computer go to the start menu select control panel and then the Add/Remove Programs icon. Scroll down through the list until you locate Wisconsin Lake Modeling Suite and press the Add/Remove button. This will remove the entire program and help files, but not any data and report files. To remove the remaining files use Windows Explorer and delete the files and/or folders manually. The default directory for the WiLMS model is c:\program files\Wisconsin DNR\WiLMS.

File Menu

New File

This menu option will close the existing window and create a new one. If the contents of the window have been modified, you will be given an opportunity to save the contents before the new window is created.

Open File

Opens any text or RTF (rich text format) file that is then displayed in the active window.

Save File

Saves the contents of the window. If the file has not been previous saved then the Save As dialog box will automatically be opened.

Save as File

Allows you to save the contents of the window with a different name if the contents had been saved previously. This option is also used when you are saving the contents for the first time.

Close File
Closes the window. If you have unsaved information in the window, you will be given an opportunity to save the window's contents or cancel the closing process.

Printer Setup
Sets the options to use when printing.

Print
To print the model results, click on the Print button or select Print from the File menu. A model run must be loaded or entered and calculated, otherwise an error will be generated.

Exit
To quit the Wisconsin Lake Modeling Suite application. If you have unsaved information in the window, you will be given an opportunity to save the window's contents or cancel the exiting process.

Program Operation

General

Leave
This will close the setup window. If you have selected the option to automatically save your data when you leave the data will be saved. If you have not set this option then you will be asked whether or not to save the data.

Write Results
This will write the information in the dialog box to a text file. Some windows have several pages, e.g. the Expanded Trophic Response Module. Only the current page's information will be written to the editor. The only exception to this rule is the Setup window. All the information contained in the Setup Phosphorus Load dialog is written at one time. Each time you write the information to the editor, the date and a scenario number is printed. This will keep a history of changes for you to review. There is a scenario number for each module. Scenario numbers can be reset in the Options|Reset menu.

After writing the desired text to the write file, the text can be saved to a file for later import into a document or printed immediately.

Options

Reset
This dialog controls application features. If the Show Auto Save For Phosphorus Load Setup selection box is not checked, input data from Phosphorus Load Setup Module will automatically be saved each time you select Leave to exit this module.

Set User Defines
User defines describe point and non-point source entities that vary from study area to study area. Up to six user defines are allowed for each point and non-point source areas. For example a specific type of vegetation or the name of specific point source. Each time the point or non-point user defines are modified, you are given the option to make these changes as your default values for all other data sets to use. However, if you choose not to save these values as your default data sets then these values will only be available for the current data set. Changing the default values will not affect existing data sets.

Print

Prints the contents of the window.

Reset - Options

Each time a page is printed, WiLMS records a unique scenario value for that case. The scenario values are automatically incremented by WiLMS and can be manually reset here.

Select A Graph

WiLMS will generate pie and bar graphs showing percent loading by source type or total loading by source type.

Copying

To copy the graph, right-click anywhere in the graph and a popup menu is displayed. Select copy to clipboard. Then go to the application you want to use the graph in and paste it.

Saving

It is not possible to save a graph directly. However, you can save the graph indirectly. First copy the graph and then paste into your imaging program or word processor.

Printing

To print the graph, right-click anywhere in the graph and pop up menu is displayed. Select print.

Zooming

To zoom in, left click (hold the mouse button down) in the upper left corner of the graph. This will become the left edge of the graph. Next, drag the cursor to the bottom right corner and let the mouse button up. This will become the right edge of the graph.

To zoom out, left click (hold the mouse button down) in the graph and drag the cursor to the left. Let up on the mouse button. You cannot zoom out further than the original size.

Adjusting View

To move the graph up, down, left, or right, right click and hold down the mouse button at the point in the graph you want to move. Then move the graph. Left click anywhere in the graph to remove the pop up menu. To get the graph back to the original view, follow the steps for zooming out above.

Hydrologic & Morphometric Module

Overview

The lake response models in WiLMS require information on the runoff volume reaching the lake as well as the surface area and volume of the lake.

All inputs in this module are entered in English units and converted automatically to metric units by WiLMS. For the first input parameter, the user enters the tributary watershed area and the annual unit runoff volume. The annual runoff can also be entered using the automatic lookup feature. A watershed runoff methodology was not included in WiLMS, thus allowing the user to select the hydrology. The lake surface area and volume) can be measured directly and entered. Lake mean depth is automatically calculated by WiLMS.

To assist with the estimation of the annual watershed runoff volume, the WiLMS model contains an automatic data look-up feature. The look-up feature provides average annual values for runoff and the net precipitation (rainfall - evaporation) in inches by Wisconsin county. To use this feature the user must first have loaded the Wisconsin default data file (WiLMS.WI) into the model by selecting the open-a-file symbol located at the right side of the default data filename window in the setup menu. The Use default data box must be then be selected and the user can choose the name of the county from the drop down list. The default values represent average conditions for a county where the tributary watershed is located. WiLMS will automatically enter the average annual runoff volume and net precipitation into the model. The look-up values are average annual estimates and monitoring data should be used if it is available. These values can be manually overwritten if needed.

The net annual precipitation is equal to the annual precipitation falling on the lake less the annual lake evaporation. The annual precipitation can be taken from local records or loaded automatically using the WiLMS look-up feature. WiLMS automatically calculates the hydraulic loading, areal water loading, and flushing rate.

Tributary Drainage Area
The tributary drainage area is the area contributing surface water runoff and nutrients to the receiving water. Typical units are acres or square meters.

Total Unit Runoff
The total unit runoff is the annual runoff volume from the tributary drainage area divided by the area. After applying the appropriate unit conversions this results in a depth value, which is in essence the runoff volume, distributed over the drainage area. WiLMS multiplies the unit runoff by the watershed area to get a total volume. The WiLMS default look up feature contains unit area runoff values for all counties in Wisconsin. Typical units are inches or meters.

Lake Surface Area
The lake surface area is a user-input parameter that can be measured directly using a planimeter from a lake bathymetric (contour) map.

Lake Volume
Using a planimeter and map, the lake's volume can be determined by direct area measurement of each of the contour intervals with the resultant values entered into an equation (not repeated herein). Volume units are typically acre-feet or cubic meters.

Precipitation – Evaporation (net precipitation)
In calculating an annual water budget WiLMS uses the net precipitation on the lake surface. The net precipitation is the annual precipitation less the annual evaporation. If site specific data don't exist, the default data look -up feature can be used. The default data for Wisconsin are contained in the WiLMS.WI file. Default data for any state can be placed in a similar file with the same format, however the file name **must** be changed. Default data can be loaded using the file button located to the right of the Default Data File name window and updated using the update button.

Annual Runoff Volume
The annual runoff volume is the total water yield from a tributary drainage area reaching the water body. This volume includes both surface runoff and base flow. In WiLMS the annual runoff volume from the watershed is entered as a unit water yield in inches or the total volume divided by the tributary drainage area. The annual runoff volume from point source inputs is entered directly by the user and added the watershed runoff volume to get the total annual runoff volume for use in model predictions

Lake Mean Depth
The lake mean depth is automatically calculated by WiLMS as the lake volume divided by the surface area. Typical units are length (feet or meters).

Hydraulic Loading

The hydraulic loading as used in WiLMS represents the total annual water loading to the water body. This includes point and nonpoint sources as well as the net (precipitation-evaporation) to the lake surface. Typical units are volume per time (acre-feet or m^3 per year).

Areal Water Load

The areal water load is the total annual flow volume in cubic meters or acre-feet reaching the water body divided by the surface area of the water body in square meters or acres. The units of areal water loading are typically length per time (m or Ft. per year).

Lake Flushing Rate

The lake's flushing rate (p) is the hydraulic loading divided by lake volume or the number of lake volumes replaced per year by inflow. Typical units are 1/time (yr^{-1}). Its reciprocal value, Tw, is the lake's water residence time, or in other words, the amount of time it takes for the lake's volume to be replaced

Water Residence Time

The water residence time is calculated as the lake volume divided by the annual inflow or the time it takes one lake volume to be replaced by inflow. The typical units are years. The reciprocal of the water residence time is the flushing rate with units of (lake volumes) per year.

Non-Point Source Module

Nonpoint Source Module Overview

WiLMS permits the representation of phosphorus loading from many different land use/cover types. The user enters the area and phosphorus export coefficient for each land use/cover type. The default export values for row crop agriculture, mixed agriculture, pasture/grassland, high, medium and low density residential, forest, urban, wetland and precipitation are shown in the phosphorus loading module when the data file is loaded. All land use and export values can be modified by the user. The default land use categories can be modified for loading inputs from more specific land uses. For example, a user may have more detailed agricultural data such as pasture, row-crop, no-till, etc., which could be input instead of using the default value. The high, most likely and low predicted in-lake levels are used to determine the confidence limits in the uncertainty analysis module. The user is cautioned to remember to zero-out the area column for any land use not to be included in the calculations. The loading percentages shown along the right-hand side of the phosphorus-loading module are automatically calculated by WiLMS for each nutrient-loading source.

Because export coefficients can vary greatly within and between different land use types and geographic regions, it is highly recommended that local export values be used whenever possible. Monitoring data for the watershed should also be used whenever possible to determine export coefficients. WiLMS accounts for phosphorus loading from precipitation and dry fallout in kg/ha-year over lake's surface using the default values. The user can also modify the dry fallout values. Regional precipitation and dry fallout loading values are usually available and are adequate for input into WiLMS.

In addition to phosphorus sources from the drainage area and precipitation upon the lake surface, WiLMS permits the user to input up to six point sources and one septic system loading value. Direct annual nutrient loading in kilograms and water loading in cubic meters can be entered as point sources such as wastewater treatment plants, augmentation pumpage, etc. Actual monitoring data collected over a suitable period of time, coupled with the flow-weighted mean nutrient concentration and hydraulic loading, is one way to obtain point source loading estimates. For more information on septic input for WiLMS see Septic Tank.

The total loading to the lake in kilograms of phosphorus is output in the total loading section of the setup module. Total phosphorus loading for point and nonpoint sources is output on a lake surface area basis in both English (lb./acre) and metric (mg/m2) units. The WiLMS phosphorus-loading module also allows the user to evaluate future planning scenarios with the % SOURCE CHANGE slide bar. By selecting a value between 0 and 100%, WiLMS calculates corresponding future percent increase or decrease in the annual non-point source or point source total and areal loading in English and metric units. WiLMS applies the reduction to all nonpoint loading sources except atmospheric deposition on the lake's surface and septic tank loading. On the point source side, the change is applied to the total point source load value. Setting the % SOURCE CHANGE value to 0 will output the existing total and areal phosphorus loading to the lake without reduction.

Phosphorus Export Coefficients

Because export coefficients can vary greatly within and between different land use types and geographic regions, it is highly recommended that local export values be used whenever possible. One source of this data is a WDNR Bureau of Research study on the recommended export coefficients for agricultural and forested land and a U.S. Geological Survey fact sheet. Monitoring data for the watershed should be used when possible to determine export coefficients. WiLMS accounts for phosphorus loading from precipitation and dry fallout in Kg / Ha / Yr over the lake's surface. Regional precipitation and dryfall loading values are usually available and are adequate for input into WiLMS.

Panuska, John C. and R.A. Lilly, 1995. Phosphorus Loadings from Wisconsin Watersheds: Recommended Export Coefficients for Agricultural and Forested Watersheds. WDNR Research Management Findings. No. 38, 4p.

Corsi, S. R., Graczyk, D. J., Owens, D.W. and R. T. Bannerman. 1997. Unit-area loads of suspended sediment, suspended solids, and total phosphorus from small watersheds in Wisconsin. USGS fact sheet No. FS-195-97. 5p.

Phosphorus Reduction

WiLMS contains a slide bar feature that allows the user to increase or decrease the non-point source or point source loading a specified amount. By moving the bar to the right the lump sum TP loading from the land use driven non-point sources is changed (increased or decreased) by the noted percentage. Moving the point source pointer performs the same operation on the total point source TP loading. The track ball feature for the nonpoint source loading applies only to the upland sources (each land cover class) and does not apply to septic loads or atmospheric deposition. To advance the slider bar up or down by a single percentage point, simple left mouse click in the white slide area to the right or left of the pointer

Point Source Module

Point Sources

In addition to phosphorus sources from the drainage area and precipitation upon the lake surface, WiLMS permits the user to input up to 6 point sources and net septic system loading values. Direct annual nutrient loading in kilograms and water loading in cubic meters can be entered as point sources such as wastewater treatment plants, augmentation pumping, etc. Actual monitoring data collected over a suitable period of time, coupled with the flow- weighted mean nutrient concentration and hydraulic loading, is one way to obtain point source loading estimates.

Septic Tanks

The septic system phosphorus loading is calculated using drain field outflow values in kilograms/capita-year. One capita-year is equal to one person occupying a dwelling for a period of one year. Use of this subroutine in the model requires the collection of population survey data for the number of individuals along the shoreline served by septic systems. Such a population survey determines usage data for both permanent and seasonal dwellings adjacent to the lake for inclusion into the following equations from Reckhow, K. H. and J. T Simpson (1980):

Total No. of Capita Years = Permanent Capita Years + Seasonal Capita Years

Nutrient output from septic systems is calculated internally in WiLMS as the product of the total number of capita years and kilograms of phosphorus contribution. Loading to the lake from septic systems is determined by the capability of the drainfield system and underlying soils to immobilize phosphorus. To simulate how well phosphorus is retained in the soils, a retention coefficient of 0 to 1.0 may be selected. If it is assumed that nearly all the phosphorus reaches the lake, then a low retention value should be chosen. Conversely, if little phosphorus reaches the lake, a larger retention value is more appropriate. Soil chemical and physical characteristics, topography, and surficial ground water levels and flow direction may vary significantly around a lake. Caution is therefore warranted when using the septic loading component parameter because of its uncertainty as a source of nutrient loading.

Selecting Soil Retention Values

The table below contains some recommended phosphorus retention coefficients based on soil type. When selecting a soil phosphorus retention value, system age, the presence of groundwater and distance from the lake should be considered. In general, old systems in close proximity to groundwater located adjacent to a lake will export more phosphorus than new "dry" systems set back from the lake. Phosphorus retention values for systems that are not functioning properly would typically fall in the 40 + 5% range while functional systems would be in the 90 + 8% range. The default soil retention values shown in Appendix A-3 of 98, 90 and 80 for low, most likely and high loading conditions respectively apply to proper functioning systems. For applications with both functional and failing systems, the overall soil retention values should be calculated via a weighted average of the functional and failing systems. When calculating septic system loading it is also important to consider the direction of groundwater flow. If the groundwater is flowing away from the lake, the septic systems located along the outflow shore of the lake will not be impacting lake water quality.

Phosphorus Retention Coefficients By Soil Type for Proper Functioning Systems

	SOIL MATERIAL*	**R**
1.	22 in. sand (D10 = 0.24 mm)	0.76
	8 in. mixture 4% red mud, 96% sand	
2.	30 in. sand (D10 = 0.30 mm)	0.34
3.	30 in. sand (D10 = 0.60 mm)	0.22
4.	30 in. sand (D10 = 0.24 mm)	0.48
5.	30 in. sand (D10 = 1.0 mm)	0.01
6.	30 in. sand (D10 = 2.5 mm)	0.04
7.	15 in. sand (D10 = 0.24 mm)	
	15 in. mixture 10% red mud, 90% sand	0.88
8.	15 in. sand (D10 = 0.24 mm)	
	15 in. mixture 50% limestone, 50% sand	0.73
9.	30 in. silty sand	0.63
10.	15 in. sand (D10 = 0.24 mm)	
	15 in. mixture 50% clay-silt, 50% sand	0.74

D10 is the effective grain size, or the size in which 10 per cent of the soil by weight is finer.

Source: Brandes et al., 1974.

References

Brandes, M., N.A. Chowdry, and W.W. Cheng. 1974. Experimental study of removal of pollutants from domestic sewage by underdrained soil filters. National Home Sewage Disposal Symposium. Am. Soc. Agric. Eng., Chicago, Ill.

Reckhow, K. H., and M. N. Beaulac, and J. T Simpson, 1980. Modeling phosphorus loading in lake response under uncertainty: A manual and compilation of export coefficients. U.S. Environ. Prot. Agency. EPA- 440/5- 80- 011.

Phosphorus Loading Totals

WiLMS will automatically sum the annual phosphorus loading from all sources for the Low Most likely and High cases and display them on the total loading screen. The total load is also displayed on an areal basis as calculated via dividing by the lake surface area. The sum of total phosphorus loads is displayed in both U.S customary (LB) and metric (kg) units. The total loading values are subsequently used by the in-lake total phosphorus prediction regression equations.

Lake Total Phosphorus Prediction Module

Overview of Total Phosphorus Prediction

The observed spring (April-May) and growing season (May-September) mean total phosphorus concentrations are in milligrams per cubic meter (mg/m^3) (the same as micrograms per liter), if available, are entered as the first step in using the phosphorus prediction module. The observed value is used for comparison to the predicted total phosphorus concentrations. To facilitate comparison between models, the phosphorus prediction module displays both the absolute and percentage differences between the value predicted by each model and the observed in-lake concentration. This module will return NA for models which do not have the appropriate corresponding observed phosphorus concentration against which to compare the predicted concentration

The lake models in WiLMS predict either a spring overturn (SPO), growing season's mean (GSM) or annual average (ANN) phosphorus concentration. In comparing against the predicted annual mean, if either a spring overturn or growing season value are input, the input value will be used. Should both values be input, the average of the two will be used in comparing against an annual TP prediction model. The phosphorus prediction module in WiLMS only calculates a value using those models for which an observed phosphorus value has been entered. If no observed values are available and a prediction is needed, entering any non-zero value for the observed total phosphorus will allow a prediction to display. Models that are not calculated will display NA.

The observed in-lake value that was entered in the setup screen is displayed and used in calculating the difference between predicted and observed. The observed values are save with other setup data and retrieved at a later date if needed.

WiLMS will allow the user to input a water column total phosphorus value and the model will back calculate the TP loading using the current flow conditions that results in the specified concentration. Water column concentration values are entered in mg/m^3.

The Nurnburg 1984 Oxic Lake Model allows the user to input a value for internal loading in kilograms. Using this input for internal loading, the user can manually fit the predicted and observed water column concentrations thus resulting in an estimate of internal loading.

Confidence Range
The confidence range is an expression of the prediction uncertainty and includes uncertainty in all terms of the model and the model itself. The specified range is the prediction value plus and minus the prediction uncertainty. The confidence limits are determined using the user specified uncertainty range. A 70 percent confidence range can be interpreted to mean that 70 percent of the time the observed average in-lake phosphorus concentration can be expected to fall within the limits shown. The confidence limits provide the user with a feel for the variability in the lake phosphorus predictions for each model.

The Canfield-Bachmann models predict a growing season mean (GSM) TP for one year as do the other models. The 95 percent confidence limits in the Canfield-Bachmann models are determined using a percentage of the predicted lake phosphorus level as presented in Canfield-Bachmann (1981). The user input confidence range value therefore will not effect the range displayed for the Canfield-Bachmann models. For all other models, the user can select the desired confidence range.

Uncertainty Analysis
The uncertainty analysis module allows the user to have information on the range of predicted phosphorus values to be expected when selecting the lake response model that best describes the lake in question. Uncertainty analysis in WiLMS follows the specific method outlined in Reckhow and Chapra (1983), pages 287-291 and Reckhow and Simpson (1980). The reader is urged to examine either document to become familiar with the lake management analysis discussion and the necessity to implement uncertainty analysis in specific projects. The uncertainty analysis feature in WiLMS generates the confidence range displayed in the phosphorus prediction module.

General Information

Load Data Set
Loads a previously saved data set. WiLMS will allow the user to save all information entered in the setup window. Should the user desire to save model output, this can be done after writing results.

Save Data Set
Saves the input information entered into the Setup Phosphorus Load module. The user has the option to either save the data as a new filename or overwrite an existing file

New Data Set
Erases all information contained in the Setup Phosphorus Load menu of the model.

Lake Id
The name and description of the lake being modeled.

Watershed Id
Description of the watershed that is tributary to the lake in question.

Default Data Filename
This file contains the county name, average annual precipitation minus evaporation (net precipitation) and average annual runoff (water yield) values used when the Use Default Data option is checked. The average annual values were developed from 30 years of record. The default data for Wisconsin are contained in the WiLMS.WI file. Default data for any state can be placed in a similar file with the same format, however the file name **must** be changed. Default data can be loaded using the file button located to the right of the Default Data File name window and updated using the update button.

Update Default Data

When the Wisconsin Lake Modeling Suite was installed a default data set was also copied into the same directory as the application. This default data set is a comma delimited text file that you can modify for your area. The default values in this data set are for each county in the state of Wisconsin. You can use multiple default data sets depending upon your situation. Customization of the default data file is accomplished by modifying the values as needed and changing the filename that the Setup Phosphorus Load dialog uses.

The default data set only holds three values: location, precipitation, and evaporation.

A built-in editor is available under the General tab where you can create or edit a default data set. You can also use a spreadsheet program to create the default data set, however you should verify the output text file has the correct formatting (i.e. no extra commas, etc.) prior to use.

Location for Default Data Usage

This drop-down menu which allows the user to select the county from which the average annual runoff and net precipitation default values will be taken.

Use Default Data

Check this option if you want to use the default data. You will then need to specify a location.

WiLMS will allow the user to save all information entered in the setup window. Should the user desire to save model output, this can be done after writing results.

Model Types

The total phosphorus concentration values in WiLMS are predicting over three time periods as determined by the model development data sets. These time periods include Growing Season Mean (GSM), Spring Overturn (SPO) and Annual Average (ANN).

Spring Overturn (SPO)

The Spring Overturn mean or SPO is also more commonly applied to northern temperate lakes. This time period is typically April or May, shortly after ice-out when the lake is completely mixed. This designation is used in WiLMS to represent the time period over which model regression is predicting an average total phosphorus concentration.

Growing Season Mean (GSM)

The growing season mean or GSM is most commonly applied to northern temperate climates when vegetative growth is occurring. This time period is typically May through September and is used in WiLMS to represent the time period over which a given model regression is predicting an average total phosphorus concentration.

Annual Average (ANN)

The Annual Average or ANN represents a single year time period In WiLMS over which model regression is predicting an average total phosphorus concentration.

Phosphorus Prediction Regressions

Model Variables

Symbols	Definition	Unit
P	Predicted mixed lake total phosphorus concentrations	mg/m^3 or $\mu g/L$ (parts per billion)
L	Areal total phosphorus load L_{Ext} = External loading L_{Int} = Internal loading	mg/m^2 of lake area/yr
z	Lake mean depth	meter
T_w	Lake hydraulic retention time	year
p	Lake flushing rate	yr^{-1}
q_s	Areal water loading or surface overflow rate	m/yr or z/T_w
R	Fraction of inflow total phosphorus retained in lake	dimensionless
P_{in}	Average inflow total phosphorus concentration Note: $P_{in} = LT_w/z$	mg/m^3 (parts per billion)
K_2	Second order decay rate	m^3/mg-yr
N_r	Reaction rate	Dimensionless
mg/L	Milligrams per litter	
$\mu g/L$	Micrograms per litter	
e	base of a natural logarithm	

Equations

Canfield-Bachmann Models; 1981

Natual Lakes

$$P = \frac{L}{z\left(0.162\left(L/z\right)^{0.458} + p\right)}$$

Artificial Lakes

$$P = \frac{L}{z\left(0.114\left(L/z\right)^{0.589} + p\right)}$$

Dillon-Rigler-Kirchner Model

1975 General Lake Model

$$P = \frac{L\left(1 - R\right)}{zp}$$

Larsen-Mercier Model

1976 General Lake Model

$$P = P_{in}\left(1 - R\right)$$

where

$$R = \frac{1}{1 + \sqrt{p}}$$

Nurnberg Model

1984 Oxic Lake Model

$$P = \frac{L_{Ext}}{q_s}\left(1 - R\right) + \frac{L_{Int}}{q_s}$$

where

$$R = \frac{15}{18 + q_s}$$

Rechhow Models

1979 Natural Lake Model

$$P = \frac{1000L}{11.6 + 1.2q_s}$$

1977 Anoxic Lake Model

$$P = \frac{L}{0.17z + 1.13\, z/T_w}$$

1977 Oxic Lake Model
where $z/T_w < 50$ m/yr

$$P = \frac{L}{\left(18z/10 + z\right) + 1.05\left(z/T_w\right)e^{0.012z/T_w}}$$

1977 Oxic Lake Model
where $z/T_w > 50$ m/yr.

$$P = \frac{L}{2.77z + 1.05\left(z/T_w\right)e^{0.0011z/T_w}}$$

Vollenweider Models

1982 Combined OECD $$P = 1.55\left[\frac{P_{in}}{1+\sqrt{T_w}}\right]^{0.82}$$

1982 Shallow Lake and Reservoir $$P = 1.02\left[\frac{P_{in}}{1+\sqrt{T_w}}\right]^{0.88}$$

Walker Models

1987 Reservoir Model $$P = P_{in}(1-R)$$

where $$R = 1 + \frac{1-\sqrt{1+4N_r}}{2N_r}$$

$$N_r = K_2 P_{in} T_w$$

$$K_2 = \frac{0.17 q_s}{q_s + 13.3}$$

1977 General Lake Model $$P = P_{in}\left[\frac{1}{1+0.824 T_w^{\,0.454}}\right]$$

Phosphorus Prediction and Nutrient Loading References

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Internal Load Estimator Module

Internal Load Estimator Overview

The intention of WINTLOAD is to predict the trophic response of those drainage lakes where internal loading is thought to play a significant role in the lake's phosphorus budget. The Wisconsin Internal Load Estimator (WINTLOAD) uses four methods for estimating an internal loading in a lake experiencing anoxic conditions. Method 1 considers a mass budget analysis. Method 2 calculates the internal load by subtracting the total hypolimnetic phosphorus mass at the start of stratification from the pre-overturn hypolimnetic total phosphorus mass. Method 3 is similar to method 2 except it uses the post-overturn whole lake total phosphorus mass rather than the pre-overturn value. Method 4 uses empirical sediment phosphorus release rates applied to the anoxic sediment area multiplied by the period of anoxia. This model is not intended to provide daily or monthly simulation results. WINTLOAD estimates an annual external load and corresponding internal load during the anoxic period.

Mass Budget Method

Method No 1 uses a complete TP mass budget to estimate internal loading. The mass budget approach implicitly considers internal loading because the mass of phosphorus in the outflow is greater than that of the inflow in lakes with internal loading. A typical phosphorus mass balance can be written as follows:

Outflow Pmass = External Load Pmass + Internal Load Pmass - Sedimentation

To calculate an internal load value the lake is first assumed to be oxic. We use the phosphorus retention coefficient fit to oxic lakes of R = 15/(18+qs) to describe the percentage of phosphorus that would be typically retained in the lake under oxic conditions. In this expression, R is the phosphorus retention and as is the water-loading rate in meters per year. Knowing the inflow P concentration from external loadings, the average annual water column P concentration which is assumed the same as the outflow P concentration (entered by user), and the R as described above, the additional phosphorus necessary to achieve the observed in-lake concentration can be determined. This additional load is attributed to the internal loading.

This method tends to predict the smallest value of the four methods because sedimentation will occur over the annual time period. In other words, much of the total sediment released phosphorus settles back down to the lake bottom over the year time period. This method works best with an annual phosphorus budget analysis for the reasons listed above.

Growing Season Method

Method No. 2 uses growing season in-situ P increases to estimate internal loading. This method calculates the increase in mass of phosphorus in the hypolimnion during anoxia to come up with a total internal load. The user enters the observed volume weighted mean hypolimnetic P concentrations, hypolimnetic volumes, and anoxic sediment areas at the start of anoxia and just prior to the fall turnover. In addition the time period of stratification is entered and used to calculate a change in hypolimnetic P mass over the stratified period. The time and release rate data are then used to calculate a change in mass, which is the internal load.

This method will also account for the small amount of sedimentation that occurs within the hypolimnion. The value calculated via this method is greater than that from Method 1 Mass Budget because it does not consider any sedimentation through the metalimnion.

In Situ Phosphorus Method

Method No. 3 for internal load estimation uses data quantifying the increase in phosphorus concentration in the fall. Method 3 is similar to Method 2 except that the endpoint of observation is just after fall turnover rather than before. This method will yield a slightly lower value than Method 2 because it will account for the immediate sedimentation occurring as the hypolimnetic waters move through the metalimnion during turnover. This method will account for the small amount of sedimentation that occurs within the hypolimnion.

Phosphorus Release Method

Method No. 4 is the final method of calculating internal phosphorus release. This method uses empirical P release rates (low, most likely and high) and applies them to the average anoxic sediment area over the period of anoxia. This method should predict the largest value as it does not account for any P sedimentation.

Internal Load Comparisons

This module simply displays the internal load estimates for each of the methods. Also listed is the percentage of total load that the internal load makes up assuming the individual internal load is included in the total load figure.

Internal Load Output

The final module displays a low, most likely and high value for both the internal and external total phosphorus loads. Method 1 is used for the low value, the average of Methods 2 and Method 3 is used for the most likely value and Method 4 is used for the high value.

Richard Osgood, a limnologist with the Metropolitan Council of the Twin Cities developed the Osgood (1988) index from a data set of 96 lakes in the Minneapolis-St. Paul, Minnesota. The index can be used as an indicator of a lake's mixing behavior. Index values in the 1 to 5 range indicate a complete polymictic lake, while values in the 5 to 7 range indicate a transitional lake and values in the 7 to 14 range represent stable dimictic behavior. Polymictic and transitional lakes would tend to be more effected by internal loading.

The equation to predict lake mixing potential is calculated as mean depth (m) / (Surface Area) $^{0.5}$ (km^2).

Reference

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Internal Load Estimator Monitoring Data Requirements

This section outlines the phosphorus-monitoring plan required to successfully implement the four internal load estimating procedures listed above. This outline is organized in the order of the four methods. If sufficient data are available, all total phosphorus concentrations should be volume-weighted means.

Temperature and dissolved oxygen profiles for the period of time between the start and end of summer stratification.

The average annual water column phosphorus concentration requires a phosphorus profile at the lake's deep hole. The average concentration is calculated by volume weighting the concentrations using vertical increments that are appropriate to define the variability of concentration with depth.

The average hypolimnetic phosphorus concentration is a volume weighted average using a phosphorus concentration profile of the hypolimnion in the deep hole. Appropriate vertical increments should be used.

The hypolimnetic volume and the anoxic sediment area are also needed and can be calculated using a bathymetric map and a planimeter.

Prediction and Uncertainty Analysis Module

Parameter Range Overview

The parameter range module is essential to the selection of the best lake model. Correct model application requires that input parameters fall within the ranges shown in the parameter range module for that model. To check the parameter ranges for each model, the parameter values for the current model application are displayed when the display parameter values button located at the bottom of the Phosphorus Prediction and Uncertainty page is selected. WiLMS checks whether or not the parameter ranges are satisfied; if satisfied <FIT> is displayed; if not, those parameters not within range are displayed; if the model is not calculated, N/A is displayed.

WiLMS offers a variety of lake response models presented in a framework to facilitate comparison between models. The types of lakes used to develop the models in WiLMS span a variety of geographic regions and lake characteristics. To see a list of parameter range values see display parameter list.

The table below summarizes the lake types used in the development of each model. The user should try to select a model that is similar to the lake in question.

Display Parameter List

Each of the phosphorus prediction regressions used in WiLMS was derived from a data set containing specific lakes and their corresponding characteristics. In order for the application of a model regression to be valid, the site-specific characteristics must fall within the range of the model's regression. The WiLMS parameter range feature checks the model parameter range automatically and displays "fit" if all values are within range or displays the parameter code for those values which are out of range.

Parameter Range Values for the Phosphorus Prediction Regressions

WALKER, 1985 RESERVOIR MODEL

$1.5 < z < 58$ m	$0.13 < Tw < 1.91$ yr
$0.014 < Pin < 1.047$ mg/l	

CANFIELD-BACHMANN, 1981 NATURAL LAKE MODEL

$4 < P < 2600$ mg/m^3	$30 < L < 7600$ mg/m^2-yr
$0.2 < z < 307$ m	$0.001 < p < 183$/yr

CANFIELD-BACHMANN, 1981 ARTIFICIAL LAKE MODEL

$6 < P < 1500$ mg/m^3	$40 < L < 820{,}000$ mg/m^2/yr
$0.6 < z < 59$ m	$0.019 < p < 1800$ /Yr

RECKHOW, 1979 NATURAL LAKE MODEL

$4 < P < 135$ mg/m^3	$70 < L < 31{,}400$ mg/m^2-yr
$0.75 < qs < 187$ m/yr	

RECKHOW,1977 ANOXIC LAKE MODEL

$17 < P < 610$ mg/m^3	$0.024 < Pin < 0.621$ mg/l

RECKHOW, 1977 OXIC LAKES WITH qs < 50 m/yr

$P < 60$ mg/m^3	$Pin < 0.298$ mg/l

RECKHOW, 1977 LAKES WITH qs > 50 m/yr

$P < 135$ mg/m^3	$Pin < 0.178$ mg/l
$Tw < 0.25$ yr	$z < 13$ m

WALKER, 1977 GENERAL LAKE MODEL

$P < 900$ mg/m^3	$Pin < 1.0$ mg/l

VOLLENWEIDER, 1982 COMBINED OECD

$0.016 < Tw < 700$ yr $\quad$ $0.0047 < Pin < 1425$ mg/l

$3.0 < P < 750$ mg/m^3

DILLON-RIGLER-KIRCHNER, LAKE MODEL

$P < 15$ mg/m^3 $\quad$ $107 < L < 2210$ mg/m^2-yr

$1.5 < qs < 223$ m/yr $\quad$ $0.21 < p < 63$/yr

VOLLENWEIDER, 1982 SHALLOW LAKE AND RESERVOIR

$3.0 < P < 750$ mg/m^3

$0.016 < Tw < 700$ yr $\quad$ $0.0047 < Pin < 1425$ mg/l

LARSEN-MERCIER, 1976

$0.0014 < p < 22.7$ /Yr $\quad$ $0.008 < Pin < 0.10$ mg / l

$P < 15$ mg/m^3

NURNBERG, 1984 OXIC LAKE MODEL

$30 < L < 3390$ mg/m^2/yr $\quad$ $0.42 < qs < 196$ m/yr

$3.0 < P < 60$ mg/m^3

Data Set Information for the Phosphorus Prediction Models

Model	***Data Base Information***
Walker, 1985 Reservoir Model	Forty-one (41) Corps of Engineers reservoirs throughout the U.S.
Canfield-Bachmann, 1981Natural Lake Model	Two hundred ninety (290) lakes located in Canada, Northern Europe, and the U.S.
Canfield-Bachmann, 1981 Artificial Lake Model	Four hundred thirty-three (433) lakes from the EPA-Natl. Eutrophic Survey located in the U.S.
Reckhow, 1979 Natural Lake Model	Forty-seven (47) north temperate lakes from the EPA-National Eutrophication Survey.
Reckhow, 1977 Anoxic Lake Model	Twenty-one (21) north temperate lakes.
Reckhow, 1977 Oxic Lake Modelqs < 50 m/yr	Thirty-three (33) north temperate lakes.
Reckhow, 1977 Oxic Lake Modelqs > 50 m/yr	Twenty-eight (28) north temperate lakes.
Walker, 1977 General Lake Model	One hundred five (105) north temperate lakes.
Vollenweider, 1982 OECD, Combined	Eighty-seven (87) lakes of various types located throughout the world.

Dillon-Rigler-Kirchner, 1975 and Ostrofsky, 1978	Eighteen (18) Canadian shield lakes. Fifty-three (53) Canadian shield lakes.
Vollenweider, 1982 OECD, Shallow Lake /Res.	Twenty-four (24) shallow lakes and reservoirs.
Larsen and Mercier, 1976	Twenty (20) oligotrophic and mesotrophic lakes located throughout North America.
Nurnberg, 1984 Oxic	Fifty-two (52) oxic lakes

Water and Nutrient Outflow Module

The water and nutrient outflow module in WiLMS summarizes the outlet nutrient loading and flow for use as inputs to a downstream water body. This feature is useful when water bodies are networked in series (outflow from one is the inflow to the next downstream water body). The user must enter the annual in-lake total phosphorus concentration from which the model calculates the load.

Lake Eutrophication Analysis Procedure (LEAP) Module

LEAP Background

LEAP was originally written in QBASIC in 1988 for the state of Minnesota, and later converted to Windows in 1997. It was then re-designed in May 2001 to work in areas other than in the state of Minnesota. Addition of the LEAP routine to the WiLMS model framework was completed in November 2001. LEAP theory of operation was developed as a collaborative effort between William Walker and Bruce Wilson. LEAP uses empirical relationships derived from a database of lake water quality in each ecoregion.

A complete discussion on the development of the original LEAP model can be found at:

LAKE AND RESERVOIR MANAGEMENT, 1989 5(2): 11-22.
North American Lake Management Society

LEAP Overview

The Lake Eutrophication Analysis Procedure (LEAP) was developed by the Minnesota Pollution Control Agency and was modified to run in areas other than Minnesota. No modeling code was changed. LEAP is a computer program designed to predict eutrophication indices in lakes based upon area watershed, depth, and ecoregion. Ecoregion is used to predict runoff and average stream phosphorus concentration. The program formulates water and phosphorus balances and uses a network of empirical models to predict phosphorus, Chlorophyll a, and transparency values in the lake. The program is intended primarily as a screening tool for estimating conditions in the lake with minimal input data and for identifying "problem" lakes. Included in the program output are: (1) statistical comparisons of observed and predicted phosphorus, Chlorophyll a, and transparency values; (2) uncertainty estimates; and (3) estimates of Chlorophyll a interval frequencies (nuisance frequencies), for observed and predicted conditions. The model should be used to approximate water quality expectations in the lake and acknowledging that individual lakes may deviate greatly for regionally defined patterns.

LEAP Setup

Initial Setup

When the LEAP program is first run, it is necessary to select an ecoregion data set to use. The initial release of LEAP contains default ecoregion data sets for Wisconsin and Minnesota. As other states provide the Wisconsin DNR with their ecoregion data, this data will be included in the model. The model can however be setup by defining ecoregion data specific to an area. Once an initial ecoregion data set has been selected it is not necessary to repeat this step.

To select a default ecoregion data set do the following:

Under the tools menu select Ecoregion setup.

Select the Add existing ecoregion button in the upper right corner.

Select the states/ecoregions of interest by checking the boxes.

You can review the selected ecoregions by using the navigation buttons located across the top of the Ecoregion setup form.

To add new, edit existing, or delete existing Ecoregion data see Ecoregion Setup.

Ecoregion Setup

The initial release of the LEAP model contains default ecoregion data for Wisconsin and Minnesota. As other states provide the Wisconsin DNR their ecoregion data, this data will be included in the model as well. If ecoregions have not been made available for the LEAP model to use, see Initial setup. The model framework allows the user to create a state or project specific data set.

If you have not yet entered the Ecoregion set up page, select Tools | Ecoregion Setup from the LEAP menu.

If an ecoregion data set is contained within a state that has been added to the default data set organized by state, press the 'Add Existing Ecoregions' button and select the desired option. Any undesired ecoregions can be deleted.

Use the navigation buttons located along the top of the ecoregion setup frame to move through the listed ecoregions. The navigation buttons allow you to do the following:

Go to the first ecoregion in the data set.

Go to the previous ecoregion in the data set.

Go to the next ecoregion in the data set.

Go to the last ecoregion in the data set.

Add a new ecoregion to the data set.

Delete an ecoregion and the plus sign button adds a new ecoregion.

Place the current ecoregion in edit mode or a specific field in the data can be selected and begin typing to automatically place the current ecoregion in edit mode.

Save the changes made to the current ecoregion.

Cancel changes to the current ecoregion or press the escape (Esc) key.

Note: To view the current calibration values, select the Show Calibration Values button from the main LEAP window. This button will not allow you to alter any of the values.

LEAP Input

There are two sets of input data required for LEAP operation: 1) Lake and Watershed Constants; 2) Lake Water Quality Variables. In order for the model to run it's calculations all values must be entered. If the input data fields are left blank an error dialog box will appear and calculations will be halted. Values can be entered in the default units or any other units appearing in the drop-down boxes to the right of the input field.

Lake and Watershed Constants

Watershed Area - The total watershed area for the lake minus the lake surface area. This is used as a basis to estimate watershed Phosphorus loading and surface water runoff to the lake.

Surface Area - The Surface Area of the lake.

Mean Depth - The lake volume divided by the surface area.

Lake Water Quality Variables - "summer-mean" concentrations

Total Phosphorus - The average Total Phosphorus value for the lake.

Chlorophyll a - The average Chlorophyll a value for the lake.

Secchi Disk - The average Secchi Disk depth for the lake.

LEAP Operation

Calibrate

The LEAP model was calibrated when it was developed to fit most lakes in the selected ecoregion. An advanced user with a good understanding of the model can however change the calibration values. Click on the Calibrate button or select Calibrate from the Tools menu to access the calibration values.

Calculate

After input parameters are entered, click on the Calculate button or select Calculate from the Tools menu to run the LEAP calculations.

Save

To save the model results, click on the Save button or select Save from the File menu. The model results are written to a RTF (rich text format) file. Calibration values are saved with each model run along with the model input parameters. Model output is not saved with the file, instead the calculation procedure is run when a saved file is opened.

Open

To open a saved file, click on the Open button or select Open from the File menu. The saved file contains model input parameters and calibration values. The calculation procedure is run at the time the file is opened. If the file is not a compatible format an error will occur.

Clear

To clear the model input and output, click on the Clear button or select Clear from the Tools menu.

Contact

For questions on the equations used with this model please contact Bruce Wilson of the Minnesota Pollution Control Agency at (651) 282-2619. For other questions please contact the Wisconsin Department of Natural Resources.

LEAP Output

Output values by LEAP are estimates based on empirical relationships derived from ecoregion values. LEAP output consists of four tabbed pages on the bottom of the screen, clicking on the tab brings it to the front, to view each tabbed page.

Output Tabbed Page

The Output tabbed page contains the general output values for the LEAP model.

Average TP Inflow - The estimated average value for inflow of Total Phosphorus to the lake. The Average TP Inflow is based, in part, on typical phosphorus concentrations for minimally impacted streams in the ecoregion.

TP Load - The estimated Total Phosphorus loading rate to the lake.

P Retention Coef - An estimated coefficient indicating the fraction of inflow Total Phosphorus that is retained in the lake system.

Lake Outflow - The estimated volume of water flowing out of the lake. For seepage lakes this is a very crude estimate since the "outflow" from the lake is via groundwater or evaporation.

Residence Time - The estimated time that water stays in the lake before it flows out. In cases of seepage lakes it may only be a crude estimate since groundwater inputs are not taken into account and there is no simple means to measure outflow.

Areal Water Load - A calculated value of Lake Area divided by Lake Outflow, with units in m/yr.

Chl a Tabbed Page

The Chlorophyll a tabbed page contains the observed and predicted Chlorophyll interval frequencies for the lake. Values are calculated for 10, 20, 30, and 60 ppb. The output indicates the percent of time the specified level of Chlorophyll a level will be exceeded. Three cases are also predicted:

Case A - seasonal variation is considered
Case B - seasonal variation and long term variation considered
Case C - seasonal and long-term variation, and model error considered

Predictions Tabbed Page

The Predictions tabbed page indicates the relationship between the observed values of Total Phosphorus, Chlorophyll a, and Secchi Disk to the predicted values. Model error is indicated along with residual and t-test values. A t-test value greater than two indicates that the subject lake is statistically different that then average ecoregion values at the 90% confidence level.

TSI Tabbed Page

The Trophic Status Index (TSI) tabbed page graphically shows the relationship between the calculated TSI for the lake and the average ecoregion values. TSI is an indication of the trophic level of the lake, with a higher number being more eutrophic (nutrient rich). The Carlson TSI values are calculated.

Trophic Response Module

Wisconsin Statewide Prediction Equations

The Wisconsin statewide prediction equations allow the user to predict Secchi depth using Chlorophyll a, Secchi depth using total phosphorus and Chlorophyll a using total phosphorus for natural or artificial lakes mixed or stratified. Predictive equations represent statewide average conditions. For regional regressions and the original reference see Wisconsin Regional Equations.

Wisconsin Regional Equations

Lake trophic state predictive equations developed by WDNR specifically for Wisconsin lakes and organized into regions of the state. These relationships allow the user to predict Chlorophyll a from Secchi depth, Secchi depth from total phosphorus and Chlorophyll a from total phosphorus considering geographic area (south, central or north), lake type (seepage or drainage) and lake mixing type (stratified or mixed).

Reference

Lillie, R. A., S. Graham and P. Rasmussen. 1993. Trophic state index equations and regional predictive equations for Wisconsin lakes. Research Management Findings No. 35. WDNR Publication No. PUBL-RS-735 93. 4p.

Trophic State Index

The trophic state index (TSI) is a lake trophic state scale from 0 to 100 used to evaluate the level of productivity for a water body. Each major division of the scale (10, 20, 30, etc.) represents a doubling in algal biomass and decreased water clarity. WiLMS 3.0 contains both the Carlson and Wisconsin TSI regressions.

Wisconsin Trophic State Index

Trophic state regression equations that summarize the nutrient enrichment level on a scale of 0 to 100 derived using data from Wisconsin lakes

Expanded Trophic Response Module Overview

The expanded trophic response menu in WiLMS evaluates water body trophic response using total phosphorus, Chlorophyll a and Secchi depth transparency. The purpose of this feature is to allow stand-alone or model generated trophic response conditions to be evaluated. This part of WiLMS consists of four evaluation components driven by total phosphorus, Chlorophyll a and Secchi depth transparency inputs. The four evaluation components are:

Carlson trophic state evaluation equations
Wisconsin statewide predictive equations
Wisconsin regions predictive equations
Commonly used regressions including user defined.

Reference

Lillie, R. A., S. Graham and P. Rasmussen. 1993. Trophic state index equations and regional predictive equations for Wisconsin lakes. Research Management Findings No. 35. WDNR Publication No. PUBL-RS-735 93. 4p.

Carlson TSI Equations

The Carlson TSI is a lake trophic state scale of 0 to 100. Each major division (10, 20, 30, etc.) represents a doubling in algal biomass. The index number can be calculated from any of several parameters, including Secchi disk transparency, Chlorophyll and total phosphorus.

Reference

Carlson, Robert E. 1977. A trophic state index for lakes. Limnology and Oceanography. 22(2).

Other Regressions

In addition to the trophic state regressions for Wisconsin, WiLMS also contains three other regression options. These include a Chlorophyll and Secchi depth regression from Rast and Lee, a Chlorophyll regression from Bartsch and Gaksatter and user defined regressions for Chlorophyll and Secchi depth.

The user defined regressions are of the form predictor = (constant) x (input ^{power}) where the exponent equals the slope and constant equals the intercept of a best-fit line of a plot of TP and Chl a or Chl a and Secchi depth. All concentration values are in mg/m^3 or meters.

Reference

Bartsch, A.F., and J. H. Gakstatter, 1978. Management decisions for lake systems on a survey of trophic status, limiting nutrients and nutrient loadings in american-soviet symposium on use of mathematical models to optimize water quality management, 1975, ERL, ORD, USEPA Gulf Breeze , FL, pp 371-394. EPA-600/9-78-024.

Rast, W. and G. F. Lee, 1978. Summary analysis of the North American (US portion) OECD eutrophication project: nutrient loading-lake response relationships and trophic state indicies, USEPA, Corvallis Environmental Research Laboratory, Corvallis, OR 454 pp. EPA-600/3-78-008.

Algal Nuisance Frequency

When using the Chlorophyll a nuisance frequency feature of WiLMS, check the range of mean growing season Chlorophyll a values and the increment to be certain that this range and increment covers the range of growing season mean Chlorophyll a values applicable to the lake you are analyzing. The next input to consider is the Chl A criteria or Chlorophyll a level for which the frequency is needed. The table below may be helpful in selecting a threshold value for management applications. The final input to consider is the Chlorophyll a temporal variability. This input is equivalent to the coefficient of variation (standard deviation/mean) of observed growing season mean Chl a values.

Suggested nuisance condition threshold levels are as follows:

Chl. a (ppb)	Nuisance condition
0 – 10	No problems encountered
10 – 20	Algal scums evident
20 – 30	Nuisance conditions encountered
> 30	Severe nuisance conditions encountered

Chlorophyll a concentration values are often used to indicate the trophic state of receiving waters. The mean growing season value is typically used however, impairments are more typically the result of extreme or bloom conditions. The method of bloom frequency calculation included in WiLMS is developed and discussed in Walker, (1984). The nuisance frequency model suggests a threshold arithmetic mean Chlorophyll a of approximately 10 ppb, below which expected bloom frequencies are minimal. The model was developed using 3 independent (1 inland lake and 2 reservoirs) data sets.

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