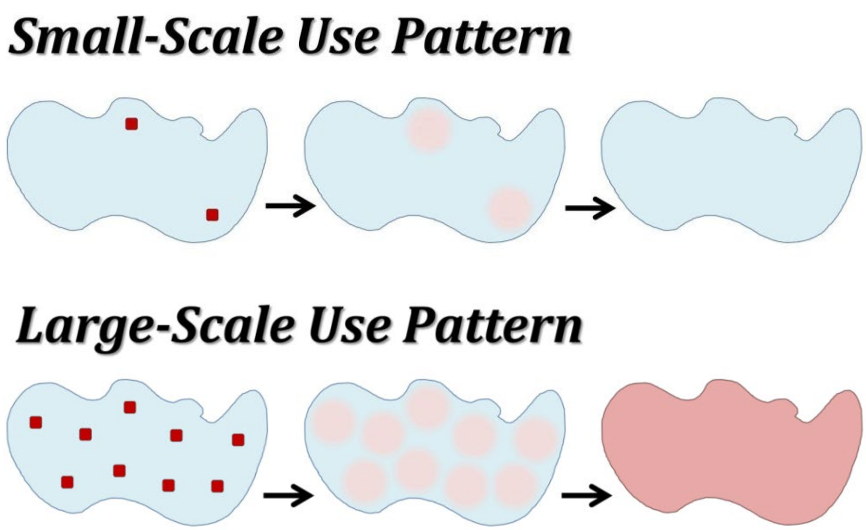
Whole Waterbody Concentration Calculations

GUIDELINES FOR CALCULATING THE WHOLE WATERBODY CONCENTRATION OF LARGE-SCALE TREATMENTS

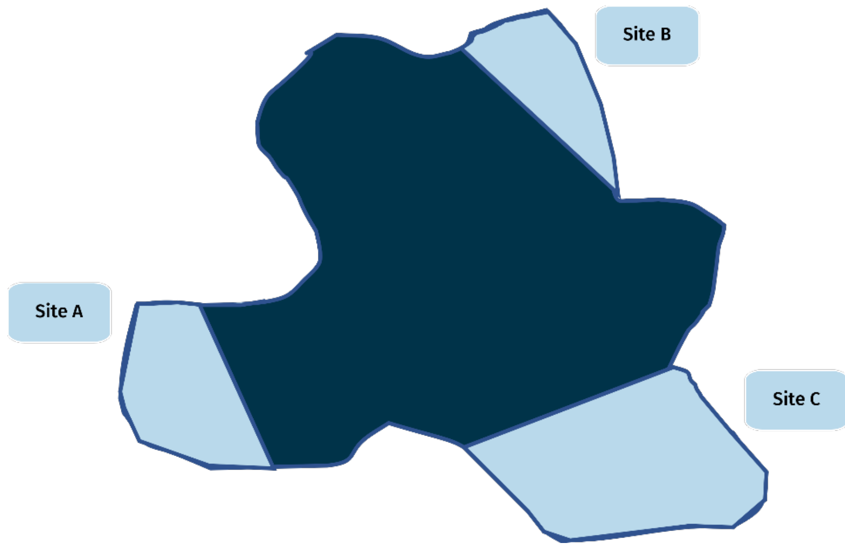
When discussing chemical management of aquatic plants in lakes, management activities are generally divided into two spatial scales. Small-scale treatments are those where the herbicide product will be applied at a concentration rate and scale where dissipation of the herbicide is not anticipated to result in significant lakewide concentrations, and effects to the plant community are anticipated to occur on a localized scale. In contrast, large-scale treatments are those in which the herbicide will be applied at a concentration rate and scale where dissipation will result in significant lakewide concentrations, and impacts to the plant community are anticipated to occur on a whole waterbody scale. When planning an herbicide treatment, it is important to calculate the whole waterbody concentration of the proposed herbicide to fully assess the potential for lakewide impacts to plants from the chemical application.



STEP 1: CALCULATE VOLUME OF TREATMENT AREA

Treatment Area (acres) ✖ Average Depth (ft) = Treatment Area Volume (acre-feet)

The treatment area volume (in acre-feet) can be calculated by multiplying the area of the lake where treatment will occur (in acres) by the average mean depth of the treatment area (in feet).



If there are multiple treatment sites (as shown in the above map), the treatment area volume will need to be calculated for each individual site and added together to obtain the total treatment area volume.

Site A: [Treatment Area (acres) ✖ Average Depth (ft)] ✚ Site B: [Treatment Area (acres) ✖ Average Depth (ft)] ✚ Site C: [Treatment Area (acres) ✖ Average Depth (ft)] = Treatment Area Volume (acre-feet)

STEP 2: CALCULATE AMOUNT OF HERBICIDE NEEDED FOR TREATMENT

Treatment Area Volume (acre-feet) ✖ Target Herbicide Concentration (ppm) ✖ 2.7 = Amount of Herbicide Needed (lbs a.e.)

Multiplying the treatment area volume (in acre-feet) calculated in Step 1 by the target herbicide concentration (in ppm) and then by 2.7[1] will yield the total amount of herbicide acid equivalent (in pounds acid equivalent, or lbs a.e.) needed to reach the target herbicide concentration in the treatment area. Ensure that herbicide units are in ppm when using this equation; target herbicide concentrations in other units will need to first be converted to ppm (e.g., 1 ppm = 1000 ppb). For ProcellaCOR™ EC, an application rate of 1 PDU/ac-ft is equivalent to 0.001926 ppm.

[1] 2.7 (in millions of lbs) is the weight of water in 1 acre-foot

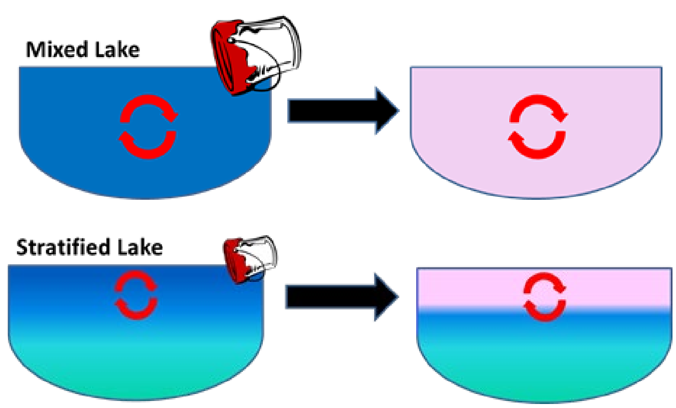
$$\frac{\text{Amount of Herbicide Needed (lbs a.e.)}}{\text{Acid Equivalent Concentration of Product (a.e./gallon)}} = \text{Amount of Herbicide Product Needed (gallons)}$$

Although not necessary for calculating the whole waterbody concentration, the gallons of herbicide product needed to reach the target concentration can be calculated by dividing the amount of herbicide needed (in lbs a.e.) by the acid equivalent concentration of the product. The acid equivalent concentration can usually be found on the first page of the product label. The Wisconsin Department of Agriculture, Trade and Consumer Protection maintains a database with current label information for all the herbicides registered for use in Wisconsin.

STEP 3: CALCULATE THE WHOLE WATERBODY CONCENTRATION

The volume of the waterbody proposed to be treated is needed to calculate the whole waterbody concentration of a chemical application. The volume used in the equation is dependent on whether the lake is likely to be stratified (separated into distinct thermal layers) or mixed at the proposed time of treatment. If the lake is not stratified (i.e., mixed), the herbicide is anticipated to move throughout the entire water column, so the entire lake volume should be used to calculate the whole waterbody concentration. However, if the lake is stratified, the herbicide is anticipated to primarily stay within the epilimnion (the upper thermal layer of a stratified lake), so only the volume of the epilimnion should be used to calculate the waterbody concentration.

The term “whole waterbody concentration” will be used to refer to both whole-lake concentrations and epilimnion concentrations throughout the remainder of this guide. Keep in mind that the “whole waterbody concentration” entered on permitting forms for stratified lakes should only account for the epilimnetic water volume and not the entire waterbody volume.



3.1 Determining Stratification

A recent temperature profile is needed to determine whether a lake is likely to be stratified during the proposed treatment and determine the maximum treatment volume. A temperature profile should be collected as close to the treatment date as possible (if not the day of treatment) to re-evaluate stratification and adjust dosing rates if necessary. However, for the purposes of estimating the whole waterbody concentration for the permit submission process, the following methods can be used for estimating stratification. Temperature profiles for many Wisconsin lakes can be found on the Wisconsin DNR's Lake Water Quality Data page. Lake monitoring reports from sites labeled "Deep Hole" are generally from the deepest portions of the lake and are most likely to contain a full temperature profile if data is available. If there are multiple temperature profiles available from different months, use the temperature profile from the month closest to when the chemical treatment is proposed. If there is no existing data available, it is recommended that a temperature profile be collected in the field prior to submitting a permit so that the potential for stratification can be accurately assessed. Temperature profile data can be collected by measuring the water temperature at intervals of at least every meter (or approximately every three feet) from the surface to the bottom of the lake.

To determine whether a lake is stratified, look for the thermocline (the transition area between the warmer, top layer and the cooler, bottom layer) in the temperature profile. The thermocline is approximately at the depth(s) in the temperature profile where the temperature changes by more than one degree Celsius per meter of depth (or roughly one degree Fahrenheit per two feet of depth). If the temperature profile does not change by more than one degree Celsius per meter at any depth, the lake may not have been stratified at the time the profile was taken or the profile was not deep enough to capture the thermocline.

3.2 Estimating Whole Lake Volume

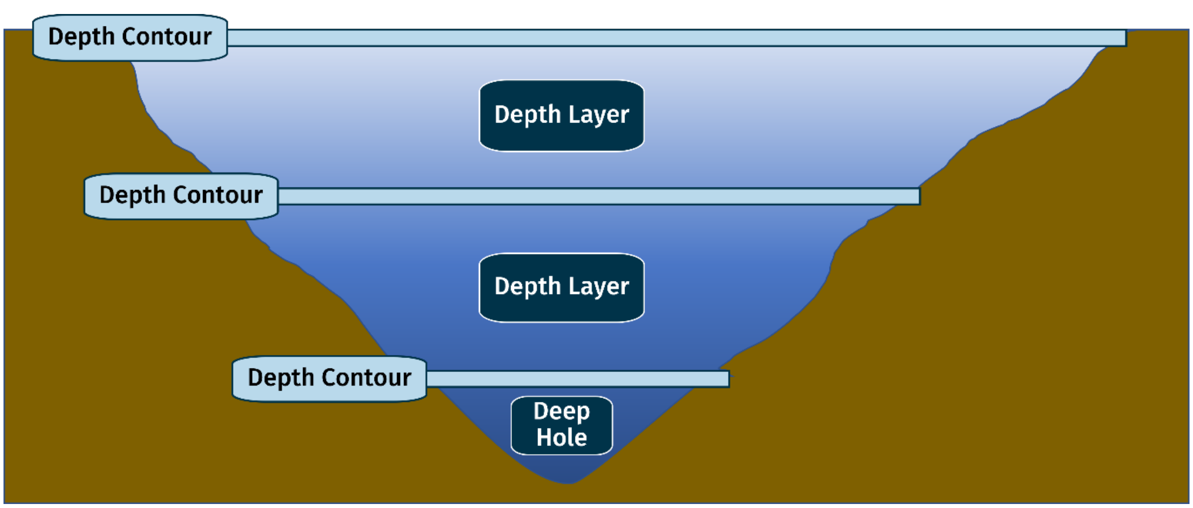
If the lake is not anticipated to be stratified at the time of the proposed treatment, the volume of the entire lake should be used to calculate the whole waterbody concentration. The whole lake volume of many Wisconsin lakes can be found in the bathymetry maps on the Wisconsin DNR's Wisconsin Lake Maps page. When available, the volume is generally listed in a corner of the map. The lake volume will likely be listed in acre-feet, but pay close attention to the units, as it may need to be converted to acre-feet if not.

$$\text{Depth Layer Volume (acre-feet)} = \frac{1}{3} \times \left[\text{Depth of Deep Contour (ft)} - \text{Depth of Shallow Contour (ft)}\right] \times \left[\text{Area of Deep Contour (acres)} + \text{Area of Shallow Contour (acres)} + \sqrt{\text{Area of Deep Contour (acres)} \times \text{Area of Shallow Contour (acres)}}\right]$$

If the whole lake volume is not readily available, it can be estimated by dividing the lake into depth strata and calculating the volume separately for each layer using the above equation, which is the equation for the volume of a frustum (a cone or pyramid with the top and/or bottom cut off by a plane parallel to the base). The area for each depth layer can be derived using depths from an aquatic plant point-intercept (PI) survey, planimeter, GIS software, or based on the areas of individual depth contours within the bathymetric map. Add the depth layer volumes together to yield the whole lake volume.

$$\text{Deep Hole Volume (acre-feet)} = \frac{1}{3} \times \left[\text{Depth of Deep Hole (ft)} - \text{Depth of Deepest Contour (ft)}\right] \times \text{Area of Deepest Contour (acres)}$$

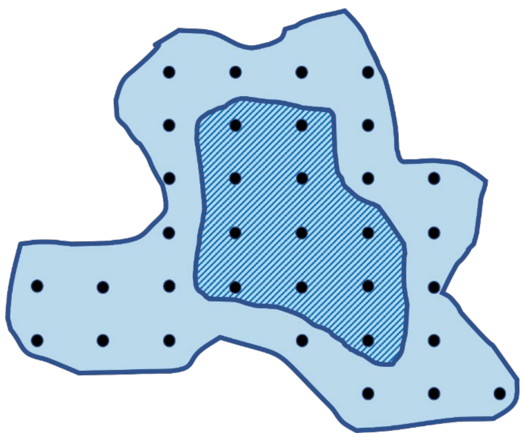
The above simplified equation can be used for calculating the volume from the deepest layer to a deep hole. It is the equation for the volume of a pyramid, so it is most accurate if the deep hole has a relatively small area, as the deep hole forms the narrow end of the pyramid.



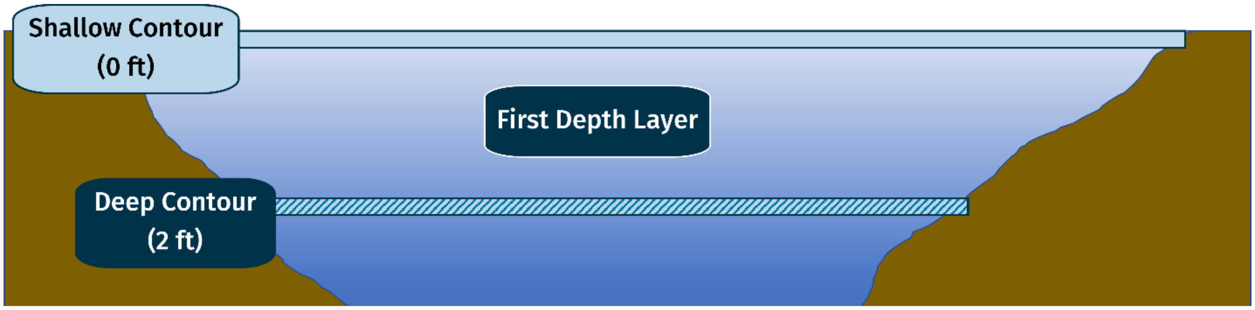
The above diagram demonstrates how the depth layers and contours would look in a cross-section of a lake.

$$\text{Area of Contour Layer (acres)} = \text{Total Area of Lake (acres)} \times \left[\frac{\text{Number of Points Deeper Than Contour Depth}}{\text{Total Number of Points on PI Grid}}\right]$$

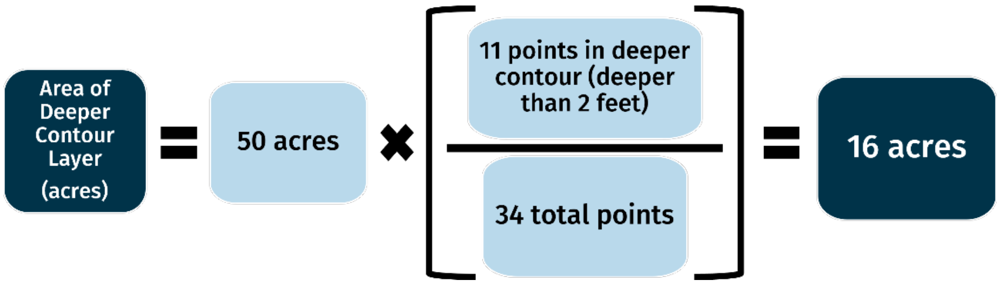
If using water depths collected during a point-intercept survey to estimate lake volume, the area of each contour layer can be found by multiplying the percentage of points surveyed in each contour layer by the total surface area of the lake, as illustrated in the above equation. The contour layers will need to be manually delineated. The number of points used in the equation should reflect all points on the grid, not just the points that were sampled (e.g., “Number of Points Deeper Than Contour Depth” should include unsampled deep sites, and any unsampled non-navigable or shallow sites should be binned appropriately). This method may not work well for lakes with many unsampled deep points, especially if there is a large difference between the maximum depth of plant colonization and maximum lake depth.



As a conceptual example, the volume of the above lake needs to be determined using a previous PI survey. PI sampling points are represented by the black dots. The dots in the light blue section range in depth from 0-2 feet, and the dots in the darker blue section are greater than 2 feet deep. The total area of the lake is 50 acres. If the first depth layer is delineated as 0-2 feet deep, the area of the darker blue section would form the bottom of the frustum, and the area of the lighter blue AND the darker blue section together would form the top of the frustum, as illustrated in the below cross-section diagram.



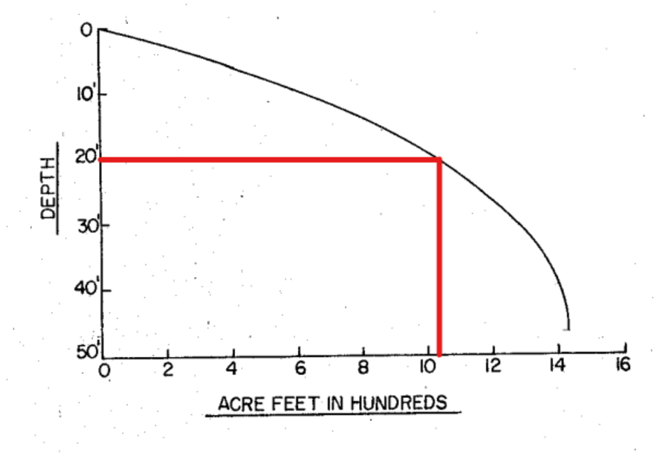
The area of the shallow contour in this example (i.e., the top of the frustum) would then be equal to 50 acres, since it is the entire surface area of the lake. The area of the deeper contour would be:



3.3 Estimating Epilimnetic Volume

If the lake is likely to be stratified at the time of the proposed treatment, the volume of the epilimnion should be used as the lake volume in the whole waterbody concentration equation. The methods for calculating the epilimnetic volume use a single value for the thermocline depth, however the thermocline may be several meters wide. For the purposes of estimating the whole waterbody concentration for the permit submission process, the middle depth of the thermocline should be used. A temperature profile collected immediately prior to treatment should be collected and the thermocline re-evaluated to determine final dosing rates. Using the top depth of the thermocline in final dosing calculations will be more protective against exceeding the targeted lakewide rate, and may be appropriate depending on the strength of the waterbody's stratification pattern at the time of treatment.

The volume of the epilimnion can be found using a hypsographic curve, which shows the cumulative volume of a lake at depth. Hypsographic curves are specific to each individual waterbody and are often available in the bathymetry maps on the Wisconsin DNR's Wisconsin Lake Maps page.



The above example shows how to calculate the epilimnion volume for a lake using its hypsographic curve. In this case, if the thermocline depth were at 20 feet, the epilimnion volume would be approximately 1,050 acre-feet.

If a hypsographic curve is not available, the epilimnion volume can be estimated by using the equations in Step 3.2 ("Estimating Whole Lake Volume"). The same methods for calculating the volume of each depth layer can be used, but the volume should only be calculated from the surface down to the thermocline depth. As such, the depth layers should be defined in a way so that the epilimnion is estimated as accurately as possible in the calculated volume (e.g., if the bathymetric contours for a lake were manually defined at every 5 feet but the thermocline is at 3 feet, calculating the volume of the depth layer from 0-5 feet would overestimate the volume of the epilimnion).

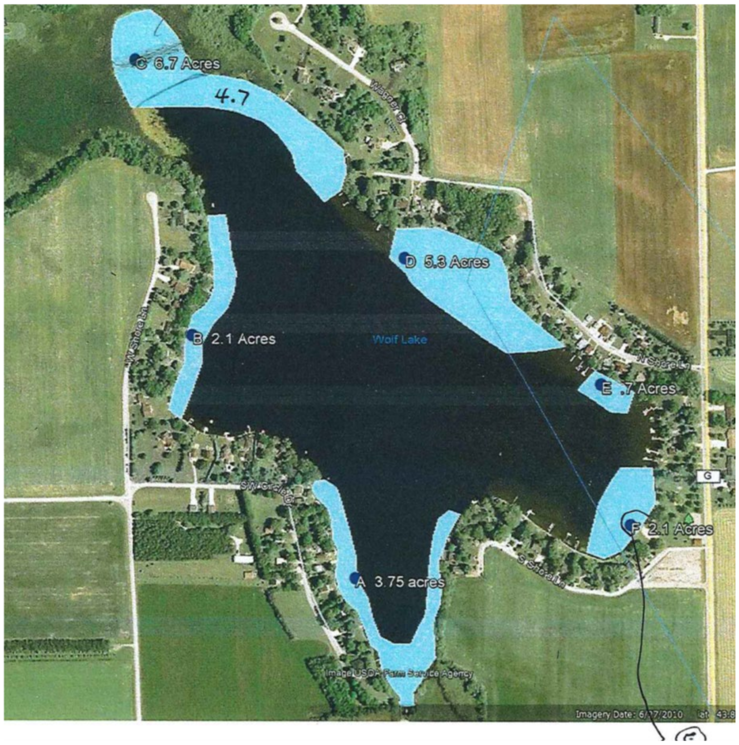
3.4 Calculating Whole Waterbody Concentration

$$\frac{\text{Amount of Herbicide Needed (lbs a.e.)}}{\left[\text{Lake Volume* (acre-feet)} \times 2.7\right]} = \text{Whole Waterbody Concentration (ppm)}$$

*Use volume of epilimnion if lake is stratified, otherwise use whole lake volume

Finally, the whole waterbody concentration, which is the value required to be entered on permitting forms, can be found by dividing the amount of herbicide needed (calculated in Step 2) by the lake volume multiplied by 2.7.

EXAMPLE CALCULATION



Treatment Area	Estimated Acreage	Average Depth (ft)
A	3.75	3.5
B	2.10	4.0
C	4.7	3.0
D	5.3	3.0
E	0.7	3.0
F	2.1	2.5

Multiple “spots” of Eurasian watermilfoil (see above map) are proposed to be treated with 2,4-D at the maximum label rate (4.0 ppm a.e.). Treatment depth varies within each area (see above table). The surface area of the lake is 76 acres, the maximum depth is 47 feet, and it is anticipated to be thermally stratified at ~15 ft at time of treatment. A bathymetry map and a hypsographic curve are available. What is the estimated whole waterbody 2,4-D concentration (in ppm)?

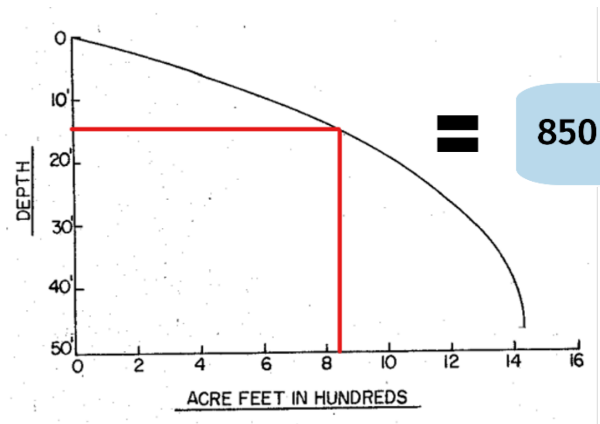
First, calculate the volume of the treatment area using the equations in Step 1:

Treatment Area	Estimated Acreage	Average Depth (ft)	Treatment Area Volume (acre-feet)
A	3.75	3.5	3.75 * 3.5 = 13.125 acre-feet
B	2.10	4.0	2.10 * 4.0 = 8.4 acre-feet
C	4.7	3.0	4.7 * 3.0 = 14.1 acre-feet
D	5.3	3.0	5.3 * 3.0 = 15.9 acre-feet
E	0.7	3.0	0.7 * 3.0 = 2.1 acre-feet
F	2.1	2.5	2.1 * 2.5 = 5.25 acre-feet
		TOTAL TREATMENT AREA VOLUME	58.875 acre-feet

Next, calculate the amount of herbicide needed for the application using the calculated treatment area volume inserted into the equations in Step 2:

$$58.875 \text{ acre-feet} \times 4.0 \text{ ppm a.e.} \times 2.7 = 635.85 \text{ lbs a.e.}$$

Then, use the hypsographic curve and anticipated thermocline depth (15 feet) to calculate the volume of the epilimnion:



= 850 acre-feet

Finally, enter the lake volume (in acre-feet) and amount of herbicide needed (in lbs a.e.) into the equation from Step 3 to yield the whole waterbody concentration (in ppm).

$$\frac{635.85 \text{ lbs a.e.}}{\left[850 \text{ acre-feet} \times 2.7\right]} = 0.227 \text{ ppm a.e.}$$