Docket No. ______
Exh. TDI-AT-2

Lake Champlain Water Quality Modeling Report

New England Clean Power Link

Prepared by HDR

Prepared for TDI-NE

December 2014

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1 Introduction

Champlain VT, LLC, d/b/a TDI-New England (TDI-NE) is proposing the New England Clean Power Link project (NECPL or Project). The NECPL is a high voltage direct current (HVDC) electric transmission line that will provide electricity generated by renewable energy sources in Canada to the New England electric grid. The line will run from the Canadian border at Alburgh, Vermont to Ludlow, Vermont along underwater and underground routes. Figure 1 presents the Lake Champlain study area along with the proposed underwater cable route.

The transmission line will be comprised of two approximately 5-inch diameter cables – one positively charged and the other negatively charged – and will be solid-state dielectric and thus contain no fluids or gases. The nominal operating voltage of the line will be approximately 300 to 320 kV, and the system will be capable of delivering 1,000 megawatts (MW) of electricity.

The proposed underwater portion of the transmission line is approximately 98 miles in length, will be buried to a target depth of 3-4 feet in the bed of Lake Champlain except at water depths of greater than 150 feet where the cables will be placed on the bottom and self-burial of the cables in sediment will occur. In shallower waters where there are obstacles to burial (e.g. existing infrastructure, bedrock), protective coverings will be installed.

At water depths less than 150 feet, two different cable installation techniques are proposed based on the location in the lake: jet-plow installation north of Crown Point, New York near Chimney Point, Vermont; and shear-plow installation south of Crown Point. These two methods are similar in that they provide a trench to lay the cable but the jet-plow method uses water jets to fluidize the sediment in the trench before cable laying. The jet-plow fluidizes the sediment in front of the installation plow and the cable slides into the trench from the back, settles to the bottom of the trench and is buried with the resuspended sediment. The shear-plow installation uses a smaller trench and does not resuspend as much sediment as the jet-plow installation because the water jets are not used to fluidize the trench before installation.

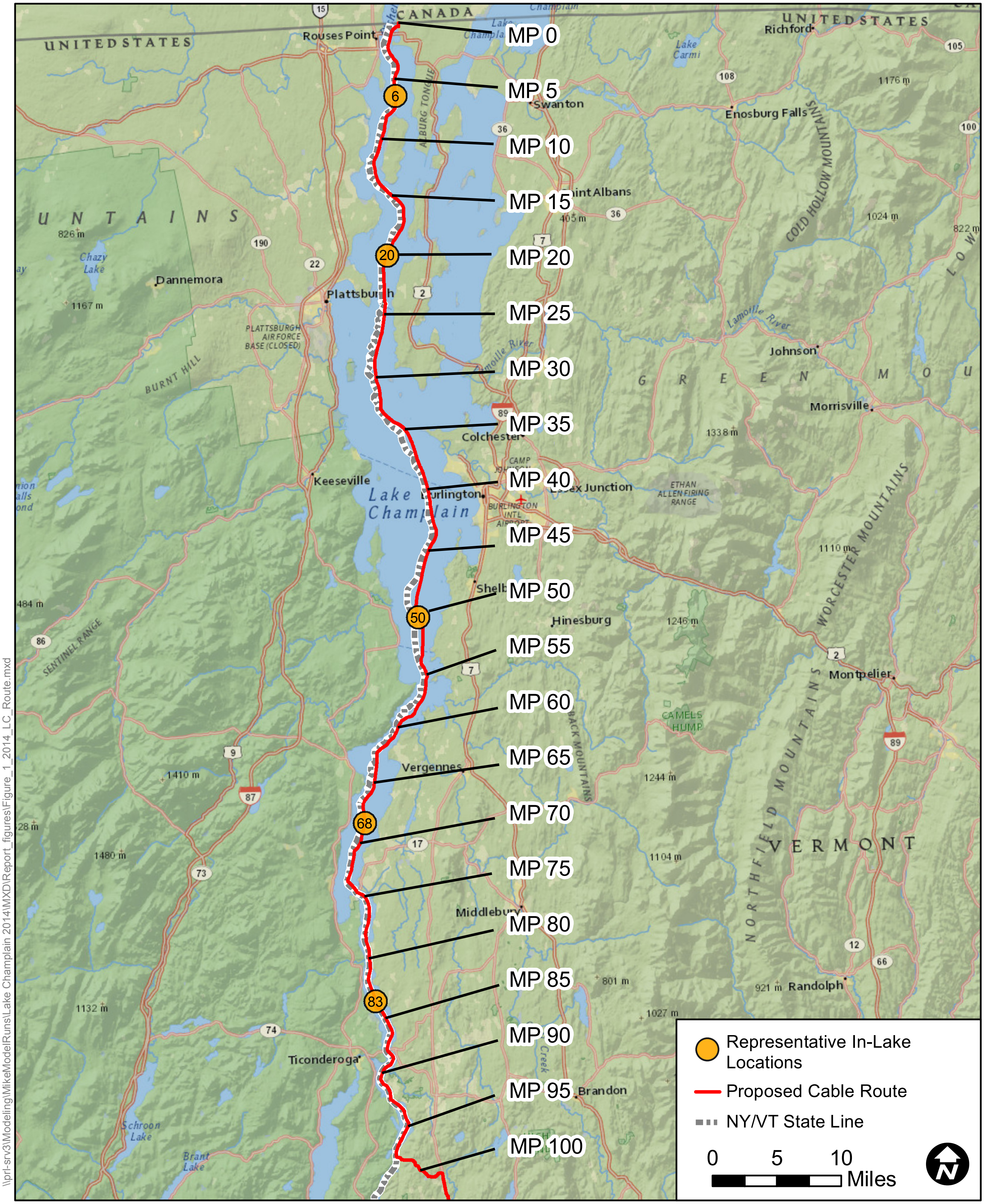
In order to assess the Project's potential impact on water quality in Lake Champlain, water quality modeling was completed to estimate the potential dispersion of sediment and other constituents during the cable installation. The modeling analyzes the expected impact associated with both the shear-plow and jet-plow installation method. For those locations deeper than 150 feet, the present proposal is to lay the cables on the bottom to allow for self-burial without using either plow installation method. However, to provide a conservative analysis of potential impacts, it was assumed for purposes of the modeling that a jet-plow would be used in these deeper locations.

This report provides a description of the water quality model used in this study, the model data inputs, and model outputs used to assess the potential water quality impacts. The intent of this work is to provide sufficient information for resource agency review of the lake-related water quality impacts of the Project, including compliance with applicable

Vermont Water Quality Standards (VWQS). Vermont Agency of Natural Resources (VTANR) staff was consulted at various stages in the development of this model information, and feedback from VTANR staff helped inform and refine the analysis presented below. The modeling completed in this study followed the modeling work plan (HDR, 2014a) and the final set of sediment characteristics used for model inputs (HDR, 2014b) submitted to the VTANR.

The water quality assessment presented in this report focuses on five representative in-lake locations (see Figure 1), which include:

- Milepoint (MP) 6 – this location is in the northern lake and is representative of jet-plow installation in shallower water depths;
- MP20, MP50 and MP68 – these locations are in the main lake at deeper depths where the majority of the cable installation will occur and are representative of where jet-plow installation (MP20 and MP68) and cable laying on the lake bottom (MP 50) will occur; and
- MP83 – this location represents a shallow more riverine section of the lake, where the shear-plow installation will be used.



New England Clean Power Link
Lake Champlain Study Area and Proposed Cable Route

Figure 1

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2 Hydrodynamic Lake Circulation Model

The model used in this project is the Danish Hydraulic Institute (DHI) three-dimensional hydrodynamic and water quality model called MIKE3 Flow Module (FM). This is an industry standard model, which is commonly used by experts in the water quality field to model and analyze complex hydrodynamic conditions that may impact water quality. The modeling system is based on the numerical solution of the three-dimensional incompressible Reynolds averaged Navier-Stokes equations subject to the assumptions of Boussinesq and of hydrostatic pressure (DHI, 2009). The model consists of continuity, momentum, temperature, salinity and density equations and is closed by a turbulence closure scheme. The density does not depend on pressure but only on temperature and salinity. The free surface is taken into account using a sigma-coordinate transformation approach.

The following effects are accounted for in the model:

- Flooding (wetting) and drying of model segments;
- Momentum dispersion;
- Bottom shear stress;
- Coriolis force;
- Wind shear stress;
- Precipitation/evaporation;
- Heat exchange;
- Sources and sinks of modeled parameters; and
- Water quality.

The solution technique uses the cell centered finite volume method with the spatial domain discretized by subdivision of the spatial and vertical continuum into non-overlapping elements. In the horizontal plane, an unstructured mesh is used, while a structured mesh is used in the vertical domain. Elements can be prisms or bricks whose horizontal faces are triangles or quadrilateral elements.

2.1 Model Mesh

The MIKE3 model uses a multi-layer triangulated or rectangular mesh to calculate water circulation, water elevation, temperature and water quality concentrations. Based on lake bathymetry and shoreline features, the horizontal mesh for Lake Champlain used coarse triangular elements except in the areas of interest (i.e., representative locations) where much finer rectangular elements were used. The finer rectangular mesh was developed for five representative locations of interest along the proposed cable route that provided for a 15 meter (50 foot) square element resolution. Figure 2 presents the model mesh used for the representative location at MP50, which shows the fine elements at MP50 and the coarser elements at other locations.

The bathymetry (water depths) in Lake Champlain are presented in Figure 3 and are relative to the Lake Surface Datum (28.35 m, NGVD), which is also referred to as the low lake level (VTDEC/NYSDEC, 1997). The bathymetric data were obtained from the Vermont Center for Geographic Information (www.vcgi.org) (VCGI), which were digitized from NOAA nautical charts and other data sources by VCGI.

The vertical model segmentation uses 10 sigma layers with variable fractions of the total depth depending on the location in the lake. Sigma layers provide for the same number of vertical segments in all model elements. The irregular sigma layer fractions was necessary to maintain an approximately 0.6 to 3 meter bottom layer thickness, which was used to assign the sediment resuspension sources as discussed in Section 3.3.

2.2 Model Setup

The model was previously developed and applied to data from 2009, and was calibrated to lake-outflow and vertical temperature profiles from that year[1]. The 2009 data set was considered as an acceptable time period for model application in this project as it is not believed that any lake conditions have significantly changed since 2009 that would warrant applying the model to a more recent year. Therefore, the model was set up using data for 2009 as described below, with the model calibration to observed water temperature vertical profiles and lake-outflow in the Richelieu River[2].

2.2.1 River Inputs

The model inputs include daily flow and temperature for the 30 rivers listed in Table 1. Data was obtained from the USGS, Environment Canada or the Quebec Ministry of Sustainable Development, Environment and Parks for assigning these river inputs for the year 2009.

[1] This earlier model application was extensively reviewed and accepted by the New York State Department of Environmental Conservation (NYSDEC) staff as part of the TDI Champlain Hudson Power Express Project.

[2] Model calibration is described further in the Lake Champlain Water Quality Model report for the Champlain Hudson Power Express Project (HDR, 2010).

Table 1. River Inputs Assigned in Model		
Missisquoi	Little Otter	East (South Fork)
Poultney	LaPlatte	Stevens
Lamoille	Rock	Malletts-Indian
Bouquet	Saranac	Stonebridge
Putnam	Ausable	LaChute
Pike	Mettawee	Mt. Hope
Little Chazy	Great Chazy	Mill-Pt. Henry
Winooski	Salmon	Highlands Forge
Otter-New Haven	Putnam	Mill-Putnam Sta.
Lewis	Little Ausable	Hoisington

The flows at gaging stations were adjusted to include the entire drainage area at the confluence with Lake Champlain based on linear extrapolation and published drainage areas (VTDEC/NYSDEC, 1997). These river flow inputs exit the northern part of the lake through the Richelieu River. The flow in the Richelieu River was not specified but calculated and is used for model calibration.

2.2.2 Meteorological Data

Hourly meteorology data for 2009 was obtained from the Northeast Regional Climate Center for the Burlington Airport weather station. The data obtained and used in the modeling included:

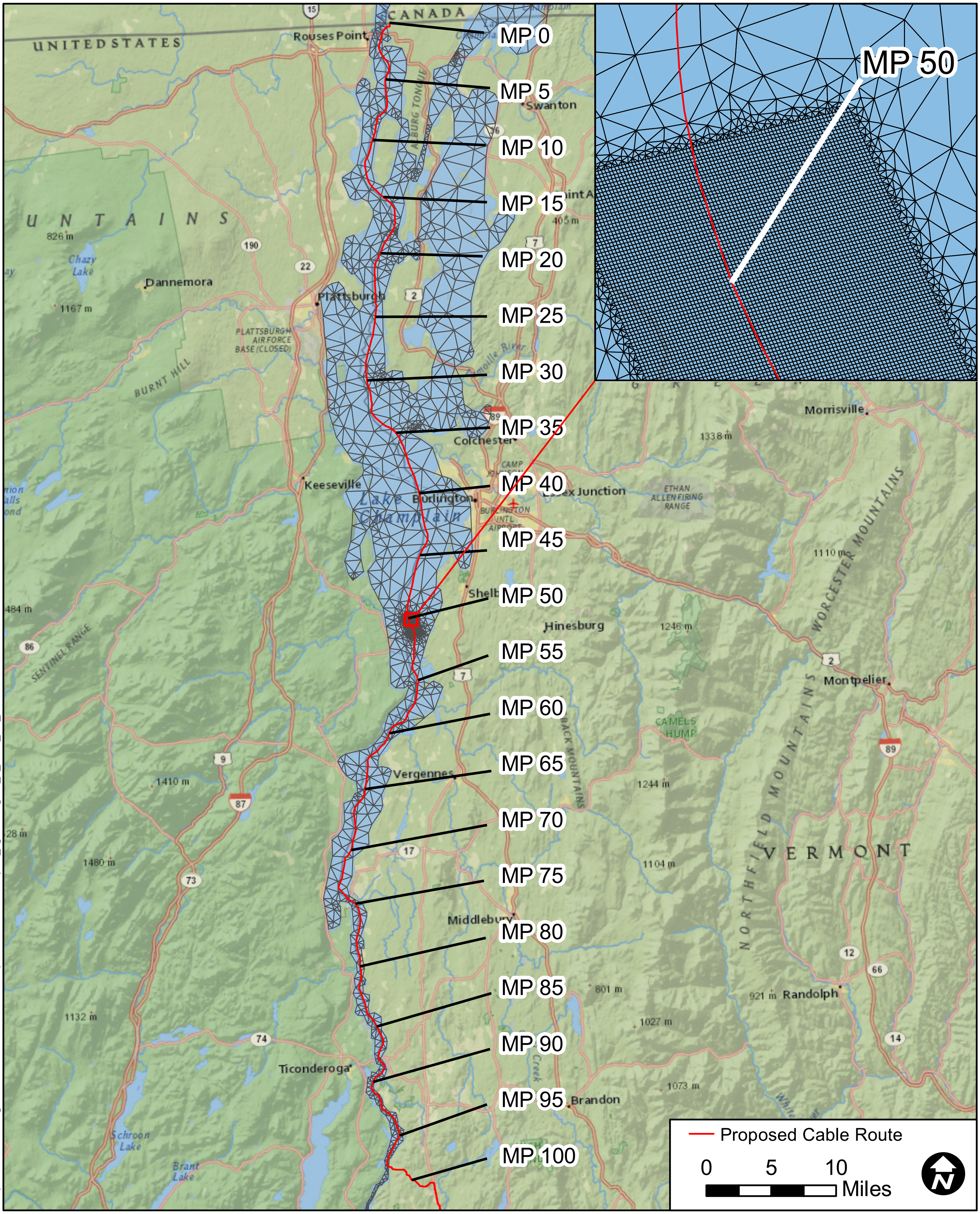
- Wind speed and direction;
- Precipitation;
- Evaporation;
- Air temperature;
- Humidity; and
- Cloud cover.

2.3 Hydrodynamic Model Calibration

The model was calibrated to measured vertical temperature profiles (VTDEC, 2010) and measured flow in the Richelieu River (Environment Canada, 2010) as presented in the 2010 water quality modeling report for the Champlain Hudson Power Express Project (HDR, 2010a). Overall the model captures the general flow patterns and the overall flow decrease from April through October. During the proposed cable installation months of May to September for north of Crown Point and September to December for south of Crown Point, the model reproduces the observed river outflow well and also reasonably represents the observed temperatures and vertical temperature structure at most stations. This includes reproducing observed temperatures ranging from 5-22℃ and completely mixed to vertically stratified temperature conditions. Given the good comparisons between model output and observed data, the hydrodynamic model is considered well calibrated and capable of representing water circulation in the lake for the subsequent water quality modeling.

2.4 Calculated Water Velocities

The model calculated current velocities show higher currents at the surface as would be expected and bottom currents at each of the five representative locations of approximately 0.01-0.02 m/s (1-2 cm/s). At the time of cable installation that was modeled, the calculated currents were generally flowing in a northward direction. These model calculated currents compare favorably with conservative estimates of bottom currents provided by Dr. Tom Manley (Manley, 2014a).



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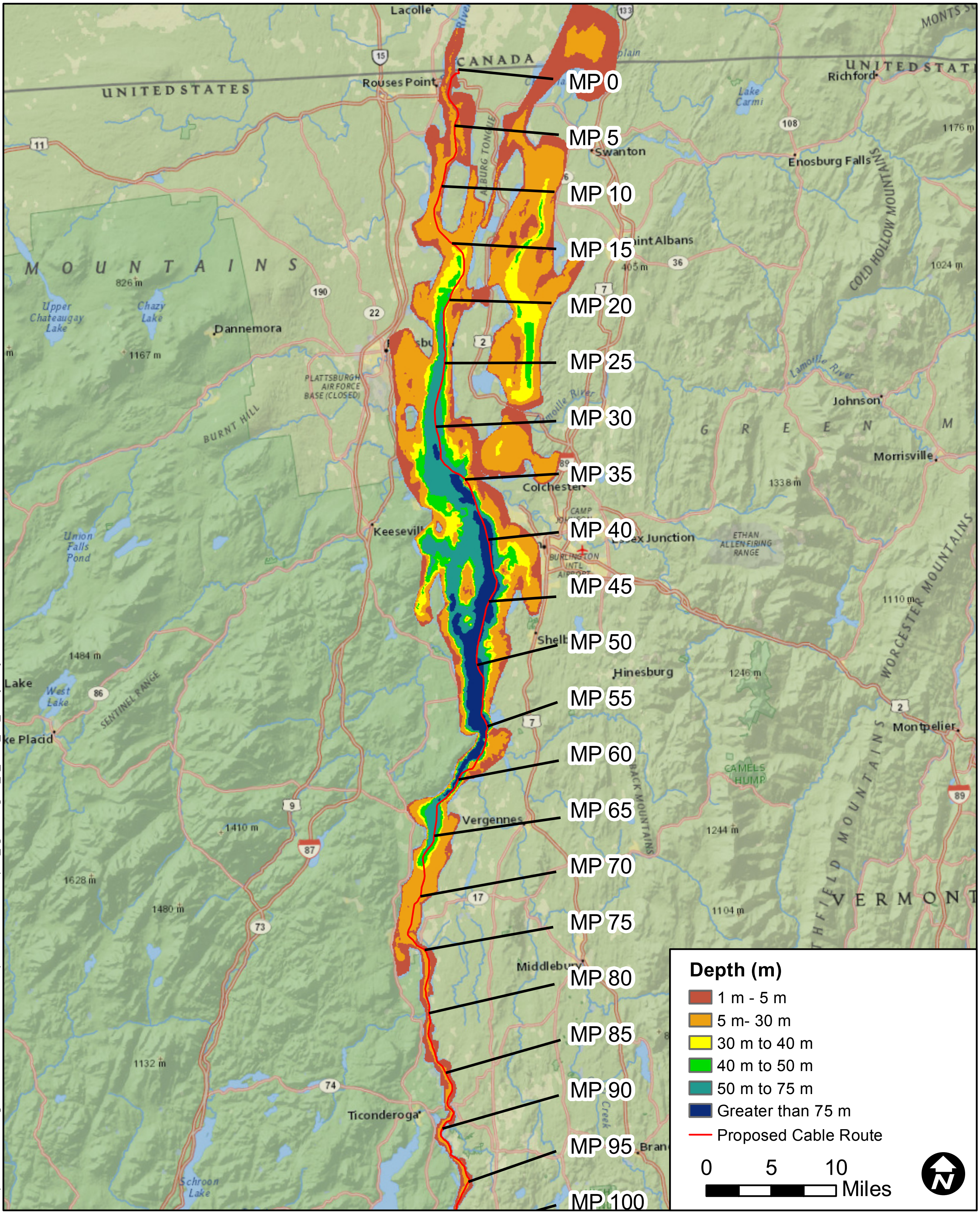
New England Clean Power Link
Lake Champlain Model Grid
Used for Representative Location at MP50

Figure 2

November 17, 2014



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New England Clean Power Link
Lake Champlain Bathymetry (Water Depths)

Figure 3

November 17, 2014

3 Water Quality Model of Cable Installation

The water quality parameters to be modeled were based on the potential short-term impact of re-suspended sediment and associated constituents as a result of the cable installation process, including metals and nutrients. The VWQS for metals are set based on protecting aquatic life over short-term (acute) and long-term (chronic) time periods. Aquatic life standards address acute and chronic toxicity with acute toxicity resulting from short exposure duration (1-hour) and chronic toxicity resulting from a longer exposure (4-day). While water quality increases associated with the cable installation will be of short duration at any one location and the associated sediment resuspension will be transient, the water quality modeling for the proposed cable installation will be compared to both acute standards (1-hour average) and chronic standards (4-day average) for metals.

The metals concentration in the water column consists of particulate and dissolved forms. The sediment released by the cable installation will increase the chemical concentration in the water primarily via the particulate form, because of the chemical's affinity for adsorption onto solids (i.e., partitioning) but the dissolved form is more important for water quality assessments because it allows a direct comparison to the VWQS for dissolved metals.

The water quality component of the MIKE3 model was used to calculate the distribution of a number of parameters associated with the sediments where the cable installation is proposed. These parameters included both particulate and dissolved fractions and, therefore, the water quality model included the advective and dispersive transport of these parameters along with settling of the particulate fractions. The water quality assessment for the cable installation north of Crown Point was completed assuming use of a jet-plow for the entire cable route (even in water depths greater than 150 feet where the cable is proposed to be laid on the lake bottom). This area in which the cable will be laid on the bottom represents approximately 43% of the entire lake cable route, and thus use of the jet-plow installation assumption in this area represents a very conservative modeling assumption because sediment disturbance due to laying the cable on the bottom of the lake will be minimal compared to the assumed jet-plow installation method. The water quality assessment south of Crown Point was completed based on the planned use of the shear-plow installation method.

As discussed above, the water quality assessments were completed at the five representative in-lake locations of MP6, MP20, MP50, MP68 and MP83. The remainder of this section presents the modeled parameters, applicable VWQS, data sources and sediment resuspension source calculations.

3.1 Selected Constituents and Water Quality Standards

The water quality model was setup for total suspended solids (TSS), particulate phosphorus (PP), dissolved phosphorus (DP), and for eight metals. In order to compare the model output to the VWQS for total phosphorus (TP), the model results for PP and DP were summed. Table 2 presents the metals included in the water quality model and the associated acute and chronic standards contained in the VWQS (Environmental

Protection Rule Chapter 29, State of Vermont Agency of Natural Resources, Department of Environmental Conservation, Effective Date: October 30, 2014), and where appropriate, recomputed for a hardness of 66 mg/L as $CaCO_3$. The hardness value of 66 mg/L used was the average calculated from calcium and magnesium data at Stations 2, 4, 7, 9, 19, 33, 36 and 46 from the VTDEC long-term monitoring data (1996-2013). Figure 4 presents the locations of the long-term lake monitoring stations along the cable route.

Table 2. Metals Parameters and VT Water Quality Standards

Parameter	Acute Standard (µg/L)	Chronic Standard (µg/L)
Arsenic	340	150
Cadmium*	1.34	0.18
Copper*	9.09	6.28
Lead*	41.0	1.60
Nickel*	329	37
Zinc*	82	82
Silver*	1.57	n.a.
Mercury	1.4	0.012

* - Hardness based water quality standard
Notes:
Acute standard is applied as a 1-hour average not to be exceeded more than once in 3 years
Chronic standard is applied as a 4-day average not to be exceeded more than once in 3 years

Table 3 presents the total phosphorus (TP) water quality standards for the different segments of Lake Champlain where the five representative locations assessed are located.

Table 3. Lake Champlain VT TP Standards		
Lake Segment	**Assessment Point**	**TP Standard (mg/L)**
Isle La Motte	MP6	0.014
Isle La Motte	MP20	0.014
Main Lake	MP50	0.010
Port Henry	MP68	0.014
South Lake A	MP83	0.025

TP standard applied as an annual mean in the euphotic zone.
Euphotic zone equals the depth to the 1% light depth.

The model calculated concentrations of these metals and TP will be used to complete the water quality assessment for the proposed cable installation project. That is, the model calculated parameter concentrations will be compared to the water quality standards to determine whether the proposed cable installation would cause exceedances of specific VWQS.

3.2 Data Sources

In order to determine the characteristics of the sediment that may be re-suspended during installation, available sediment data along the cable installation route was compiled and used to represent the spatially varying sediment characteristics in Lake Champlain. The sediment data was available from the following sources:

- Marine Research Corp. – *Acoustic Similarity between the NY and VT HVDC Corridors* (August, 2014). This study provided saturated bulk density and porosity information for Lake Champlain (LC) sediments.

- Champlain Hudson Power Express, Inc. – *Marine Route Survey Report* (July, 2010). This study provided sediment sorbed metals and PCB concentrations along with sediment physical properties.

- University of Maryland Center for Environmental Services – *Benthic Phosphorus Cycling in Lake Champlain* (7/24/1999). This study provided sediment sorbed and dissolved phosphorus concentrations.

- Lake Champlain Basin Program Toxics Assessment Program (1994). This database provided sediment sorbed silver and mercury data along the cable route.

- Lake Champlain Long-Term Water Quality and Biological Monitoring Project (VTDEC). This database provided data for water column secchi depth, TP, TSS and vertical temperature profiles.

VTANR staff was given an opportunity to review and comment on the proposed values. Based on their review, VTANR Staff recommended that for areas where there was a significant separation between the NY route studied in the Marine Route Survey Report from the proposed VT route (i.e., the deepest portion of the lake), VTANR staff recommended that the constituent values reported in the NY Marine Route Survey be doubled for this study to be conservative. This adjustment was included in development of the final model inputs.

3.3 Constituent Resuspension

The cable laying operation represents a moving resuspension source along the cable route that will increase the particulate and dissolved components in the water column on a temporary basis. This resuspension source is assigned (on and off) along the cable route in each model segment based on the length of time that the cable installation occurs in a specific segment. For example, if a model segment is 15 meters long (i.e., size of the fine mesh elements) and the installation speed is 1.4 miles/day or 1.6 meters /minute, the resuspension source will be active for 9.6 minutes until the source moves to the next model segment. The resuspension source is assigned into the bottom model layer, which is set as approximately 2-3 meters deep for the jet-plow installation area north of Crown Point. For the area south of Crown Point where shear-plow installation is proposed, an approximately 0.6 meter thick bottom model layer was employed to reflect the reduced sediment resuspension associated with the shear-plow installation method.

3.3.1 Constituent Concentrations

The sediment data for the five representative locations where water quality modeling was completed is presented in Table 4. There are 46 sediment sampling locations at approximately two mile intervals along the cable route. Additional Lake Champlain sediment data was reviewed by Dr. Pat Manley (Manley, 2014b) from recent studies. The results of this review indicated median particle diameters (d50) for the Lake Champlain sediments that ranged from 4-12 µm, which compared very favorably to the d50 data obtained from the 2010 cable route survey. All of the sediment PCB data available in sediment samples were reported as non-detect (ND) and, therefore, water quality impacts associated with PCB resuspension is not expected.

Table 4. Lake Champlain Sediment Characteristics					
Parameter	**MP6**	**MP20**	**MP50**	**MP68**	**MP83**
Porosity (%)	89.5	89.5	89.5	89.5	76.0
Specific Gravity	2.745	2.626	2.641	2.659	2.708
d50 (µm)	11.8	3.9	1.4	1.3	1.0
PCB (mg/kg)	ND	ND	ND	ND	ND
Arsenic (mg/kg)	3.21	6.64	9.94	6.48	4.67
Cadmium (mg/kg)	0.073	0.445	0.317	0.297	0.333
Copper (mg/kg)	8.94	30.7	28.7	28.6	25.3
Lead (mg/kg)	2.91	14.8	12.4	13.4	16.0
Nickel (mg/kg)	10.7	46.0	44.2	47.8	44.8
Zinc (mg/kg)	29.4	115.0	110.0	121.0	119.0
Silver (mg/kg)	0.08	0.40	0.01	0.01	0.01
Mercury (mg/kg)	0.177	0.284	0.118	0.049	0.072
DP (mg/L)	2.19	2.19	1.28	2.10	2.89
PP (mg/g)	1.82	1.82	2.37	2.70	1.30

In order to calculate the TSS concentration at a specific location for calculating the sediment resuspension source, porosity and specific gravity data are used in the equation below:

$$TSS = (1 - \varphi) \times \rho_S \times 1000$$

where: *TSS* – total suspended solids (g/m^3 or mg/L);

φ – porosity (dimensionless); and

ρ_S – density of solids (kg/m^3) or 1000 x specific gravity.

As the VWQS are based on the dissolved form of the metals, reported sorbed metals concentrations (see Table 4) were converted to dissolved concentrations using metal specific partition coefficients. The partition coefficient is the ratio of the sorbed concentration to the dissolved concentration and is represented by the following equation.

$$K_d = \frac{C_S}{C_D}$$

where: K_d – partition coefficient (L/kg);

C_S – sorbed concentration (mg/kg); and

C_D – dissolved concentration (mg/L).

Table 5 presents the partition coefficients used to convert the sorbed metals data to dissolved concentrations.

Table 5. Metals Partition Coefficients

Metals	Log Partition Coefficient (L/kg)
Arsenic	2.5
Cadmium	3.6
Copper	4.2
Lead	5.1
Nickel	4.0
Zinc	3.7
Silver	3.6
Mercury	4.9

EPA, 2005. Partition Coefficients for Metals in Surface Water, Soil and Waste. EPA/600/R-05/074. July 2005.

In order to analyze TP concentrations, the sediment sorbed phosphorus data was converted to particulate phosphorus (PP) by multiplying the sorbed phosphorus concentration by the sediment TSS concentration, which was calculated using the above formula. Table 6 presents the dissolved metals concentrations at the five representative locations that were used to calculate the sediment resuspension source in the water quality model. It should be noted that the existing sediment dissolved metals concentrations are all less than the applicable acute and chronic VWQS. Therefore, all dissolved metals concentrations in the overlying water column due to the cable installation and resuspension will also be less than the VWQS.

Table 6. Lake Champlain Sediment Concentrations

Parameter	MP6	MP20	MP50	MP68	MP83
Arsenic (µg/L)*	10.2	21.0	31.4	20.5	14.8
Cadmium (µg/L)*	0.018	0.112	0.080	0.075	0.084
Copper (µg/L)*	0.56	1.94	1.81	1.81	1.60
Lead (µg/L)*	0.023	0.118	0.098	0.106	0.127
Nickel (µg/L)*	1.07	4.60	4.42	4.78	4.48
Zinc (µg/L)*	5.87	22.9	21.9	24.1	23.7
Silver (µg/L)*	0.020	0.100	0.003	0.003	0.003
Mercury (µg/L)*	0.002	0.004	0.001	0.001	0.001
DP (mg/L)	2.19	2.19	1.28	2.10	2.89
PP (mg/L)	525	502	657	754	845

* - Dissolved metal concentration

3.3.2 Resuspension Calculation

This resuspension source is calculated using the cross-sectional area of the installation trench, the cable installation speed and the sediment concentration. The flow rate associated with the cable installation is calculated as:

$$Q = A_T \times U_P$$

where: Q – flow rate associated with installation (m^3/s);

A_T – cross-sectional area of the trench (m^2); and

U_P – plow speed (m/s).

The plow speed for both the jet-plow and shear-plow installation methods is 1.4 mi/d or 0.026 m/s. The cross sectional area for the jet-plow and shear plow was assumed to be 1.2 m^2 and 0.25 m^2, respectively, based on the expected burial depth and a conservative estimate of the width of the trenches. The flow associated with the installation is therefore 0.030 m^3/s for the jet-plow and 0.0065 m^3/s for the shear-plow.

The resuspension source is then calculated using a sediment concentration as:

$$W_R = Q \times C \times R$$

where: W_R – resuspension source (kg/s);

C – sediment concentration (kg/m^3); and

R – release fraction.

3.3.2.1 Release Fraction

A key component of the water quality model assessment is what fraction of the trench sediments are resuspended during cable laying operations (i.e., release fraction). In practice, the total volume of the trench sediments is not completely introduced into the water column and the typical modeling approach is to assume that a certain fraction remains in the trench (or conversely that a certain fraction is released into the overlying water column). As part of this effort, readily available information was reviewed in order to determine what sediment release fraction should be used.

A review of previous water quality modeling efforts that assessed jet-plow cable installations and received regulatory review and approval was completed. Table 7 presents the jet-plow release fractions used in these modeling efforts.

Table 7. Jet-Plow Release Fraction from Other Modeling Studies

Modeling Study	Waterbody	Release Fraction Used
Bayonne Energy Center[1]	Upper NY Bay and Gowanus Bay	0.25 (0.03 for clamshell dredging installation)
Poseidon Project[2]	Raritan Bay and NY Bight	0.25
Roberts Bank Installation[3]	Roberts Bank, Strait of Georgia (British Columbia, Canada)	0.25-0.30

1 - *Results from Modeling of Sediment Dispersion during Installation of the Proposed Bayonne Energy Center Submarine Cable* (10/2008)

2 - *Modeling of Sediment Dispersion during Installation of the Submarine Cable for the Poseidon Project* (9/18/2013)

3 - Jiang, J., D.B. Fissel and K. Borg, 2007. *Sediment Plume and Deposition Modeling of Removal and Installation Underwater Electrical Cables on Roberts Bank, Strait of Georgia, British Columbia, Canada (Presented at ECM10 2007 ASCE Conference)*

Additionally, reports prepared to estimate the release fraction associated with jet-plow installation, based on observations and other calculation methods were reviewed and are discussed below.

- Bohlen Report (*Attachment 4C – Preliminary Sediment Transport Analysis.* In *Northport NY to Norwalk CT 138kV Submarine Cable Replacement Project – Application to the NYSPSC for a Certificate of Environmental Compatibility and Public Need, LIPA*; 10/2001)

  This report is frequently referenced as the justification for use of a 30% jet-plow release fraction. Dr. Bohlen reviewed available video imaging provided by cameras mounted on operating jet-plow equipment and concluded that the majority of the sediments displaced by the jetting process settle rapidly into and along the trench following passage of the jet-plow. He estimated that sediment loss was 30% of the trench volume and that there was significant coverage of the placed cable along with a slight residual depression in bottom contours along the cable route.

- Nexans Sediment Disturbance Description (Document o*btained during Neptune Cable Project by HDR from the installer*; 2002)

  This study reviewed video recordings and, based on observations that the majority of the sediment settled back into the trench, estimated that 50-90% of the trench sediment will remain in the trench (i.e., a 10-50% release fraction) depending on ambient current and sediment conditions. A 30% release fraction for jet-plow installation was estimated in this study. This document was in part based on the Bohlen Report and its estimated release fraction for jet-plow installation.

- Resuspension of Sediment by the ITG Jet Plow during Submarine Cable Installation (Paper obtained from Neptune Cable Project online File Summary; 2002)

  This document is the most quantitative approach taken to estimate the sediment release fraction associated with jet-plow cable installation. The report presents calculations involving estimated trench volume (with and without surface collapse of sediment trench walls) and fluidized volume (sum of original trench volume and water volume required to fluidize the sediment in the trench). Based on the difference between these two volumes, the authors estimated release fractions for different trench assumptions ranging from 10-35% depending on the sediment water content (with higher release rates associated with higher sediment water content).

Many of the modeling efforts for similar projects that have undergone regulatory review and gained regulatory approval have used a jet-plow release fraction of between 25% and 30%. In addition, previously completed studies suggest that 30% is a reasonable value, with one quantitative study suggesting a range of 10-35%. Therefore, this modeling effort used a jet-plow release fraction of 30%.

The release fraction for the shear-plow installation was assigned as 2%. The lower value was assumed based on the much lower sediment resuspension associated with this installation technique because fluidizing of the trench sediments does not occur. That is, the trench sediments are opened in place for cable installation using a physical plow method, not a water jet, which results in significantly less sediment resuspension.

3.3.3 Settling Velocity

As solids introduced into the water column will settle, a settling rate is required in the model for properly assessing the distribution of TSS and PP. The sediment core median particle diameter data (d50), sediment specific gravity and Stokes Law were used to calculate the settling rate along the cable route. The calculated solids settling rate varied from 0.08 and 29.6 m/d with the higher rates in the northern lake (between MPs 1 and 12) and lower rates in the middle and southern parts of the lake. The median settling rate for the entire lake was calculated as 0.4 m/d.

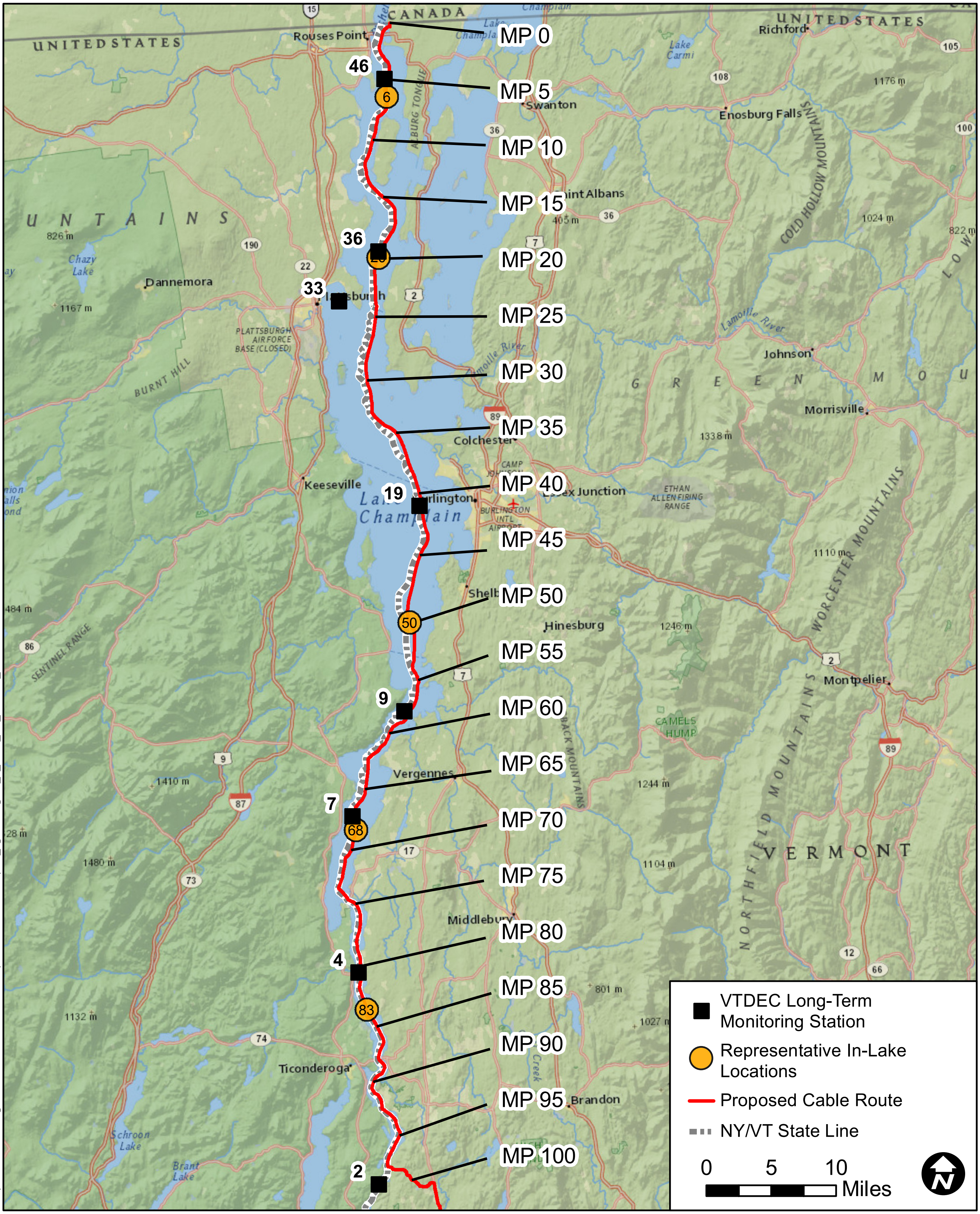
The use of Stokes Law calculated settling rates is very conservative in that this calculation does not account for the flocculation of cohesive fine grained sediments (silts and clays) that is observed to occur in lake environments. Lake Champlain sediments along the cable route consist of cohesive fine grained silts and clays. These fine grained sediments flocculate into larger effective diameter flocs that can settle faster than individual particles.

Theoretical relationships between sediment concentration and settling rates have been developed and can be used to estimate settling rates for flocs in addition to modeling studies where the floc settling rate was determined based on calibration to observed data (Chao, X. and Y. Jia, 2011;Delft, 2005). In addition, field and laboratory measurement have been completed relating settling rates to floc size (Manning, A.J. et al., 2010; Fathi-Moghadam, M. et al., 2011; Manning, A.J. et al., 2011; Maa, J.P. and J. Kwon, 2007; Manning, A.J. and D.H. Schoellhamer, 2013). Based on these studies of measured floc settling rates, the minimum settling velocity measured was approximately 0.1 mm/s or 8.6 m/d.

In order to account for the flocculation of the cohesive fine grained silts and clays present in Lake Champlain along the cable route, a minimum settling velocity of 0.1 mm/s (8.6 m/d) will be used. That is, if the Stokes Law calculated settling rate is less than 0.1 mm/s it will be set equal to 0.1 mm/s (8.6 m/d).

3.4 Simulation Period

The model is run for a summer period (July/August) for the jet-plow installation area (north of Crown Point, MP6, MP20, MP50, and MP68) and for a fall period (September) for the shear-plow installation area (south of Crown Point, MP83). It is not anticipated that model results for these time periods would be significantly different for cable installation model results at other times of the year.



New England Clean Power Link
VTDEC Long-Term Monitoring Station Locations

Figure 4

December 01, 2014

4 Model Results

The Lake Champlain water quality model results for TSS, TP, DP and the eight metals (arsenic, cadmium, copper, lead, nickel, zinc, silver and mercury) are presented in a number of different graphical formats and tables in the next sections. These model results are based on the model setup and various model inputs described in Section 3 and reflect concentration increases due to the cable installation (i.e., the increase above background levels for any given parameter). The model concentration increases were compared to applicable VWQS or targets. In addition, the model maximum concentrations at the five representative locations were also presented as a function of time to present the relative time duration of water quality concentration increases associated with the cable installation.

It should be noted again that the jet-plow installation method is proposed to be used north of Crown Point (MP6, MP20, MP50 and MP68); and the shear-plow installation method used south of Crown Point (MP83). The less intrusive shear-plow method results in reduced disturbance of the trench sediments and, therefore, the model results reflect this difference in the installation method. In addition, at water depths greater than 150 feet the cable will be placed on the bottom of the lake and create minimal disturbance of sediments. Therefore, model results for MP50 (water depth of 305 feet) using the jet-plow installation method will be a very conservative estimate of water quality changes at this representative location.

4.1 TSS

The calculated TSS concentrations are based on the porosity and specific gravity data along the cable route. In addition, the model-calculated bottom current speeds and assigned settling rates affect the temporal, magnitude and spatial distribution of TSS along the cable route. The model output is presented at the five representative locations along the cable route (MP6, 20, 50, 68 and 83) as spatial maps in the horizontal and vertical directions along with concentration time-series at these five locations. This model output information was used to assess water quality changes as a result of the cable installation.

4.1.1 TSS Spatial and Vertical Distributions

Figures 5-9 present the model calculated TSS distributions in the horizontal and vertical directions for the five representative locations along the cable route. These figures present the horizontal TSS distribution in the bottom layer (left panel) along with 200 foot offset distances on either side of the cable route (vertical gray lines) and lateral transect (horizontal gray line) that corresponds to the vertical TSS distribution shown in the right panel. The gray circle noted in the vertical distributions indicates the location for which time-series TSS model output is presented in Figures 10-12. The horizontal and vertical concentration distributions are presented at the time when the installation is at the noted representative location and reflect the maximum concentrations at these locations.

The horizontal TSS distributions at the five representative locations indicate that the highest concentrations occur around the point of installation and then decrease rapidly as distance from the installation increases. At a lateral distance of 50-100 feet from the installation point, the maximum resuspended TSS concentration increases are less than 100 mg/L and at 200 feet from the point of installation the TSS concentration increases are less than 3 mg/L above background TSS levels observed in Lake Champlain. Although there is much variability in the background TSS levels in the lake, the average lake TSS is 2.6 mg/L (ranging from 0.1-177 mg/L) based on the VTDEC long-term monitoring data from 1992-2005 at Stations 2, 4, 7, 9, 19, 33, 36 and 46.

In the vertical direction, increased TSS concentrations are limited to the bottom one to three layers of the model (about the bottom 2-3 meters of the water column at MPs 6, 20, 50 and 68; and the bottom 1 meter of the water column at MP83). Above these depths from the bottom, the model calculated TSS concentration increases are less than 3 mg/L above background levels observed in the lake.

At all five of the representative locations, the model calculated TSS concentration increases due to the cable installation are less than 3 mg/L above background lake TSS levels at 200 feet from the point of installation and within one to three meters of the lake bottom. These five representative locations were selected to be indicative of the TSS increases along the entire cable route due to the similar sediment characteristics and bottom lake currents.

4.1.2 TSS Time-Series

Figures 10-12 present the model calculated TSS concentration increases versus time for the five representative locations in order to provide duration information for the increased TSS concentrations during cable installation. These figures present the model calculated TSS concentration increases in the bottom model layer (layer 1, solid black line) as noted in the vertical distribution figures as well as the second model layer up from the bottom (layer 2, dashed black line).

At MP6, MP20, MP50 and MP68, the model calculated peak TSS concentration increases ranged from about 1,200-1,700 mg/L and then rapidly decreased to less than 100 mg/L in about 20-60 minutes depending on the representative location. At MP83, the model calculated peak TSS concentration increase was about 35 mg/L, which reflects the use of the shear-plow installation method south of Crown Point.

At all five representative locations, the calculated TSS concentration increases reach a peak concentration at the point of installation and then experience a rapid decrease. TSS concentration increases of 100 mg/L occur in the first hour while increases less than 3 mg/L above background TSS levels are achieved in the first one to four hours depending on the representative location.

4.2 Phosphorus

The calculated phosphorus concentration increases (PP and DP) are largely based on the sediment concentrations for phosphorus obtained in previous sampling events. In addition, the model calculated bottom current speeds and assigned settling rates (for PP) affect the temporal, magnitude and spatial distribution of TP along the cable route. Presentation of TP is a sum of the model- calculated PP and DP. The model output is presented at the five representative locations along the cable route (MPs 6, 20, 50, 68 and 83) as spatial maps in the horizontal and vertical directions along with concentration increase time-series at these same five locations using the same formats as used for TSS. This model output information was used to assess water quality changes as result of the cable installation.

4.2.1 Phosphorus Impact on Algal Growth

Algal (phytoplankton) growth is a function of ambient nutrient, light and temperature conditions as well as the effects of residence time. Excluding the effects of light and temperature, typically one nutrient serves at the limiting factor which controls the growth of algae. The limiting nutrient can be estimated based on comparing algal nutrient stoichiometry (i.e., the relative nutrient composition of algae, sometimes referred to as the Redfield ratios) to ambient data and also by comparing ambient concentrations to minimum levels that reduce algal growth. In freshwater lakes, phosphorus is usually the limiting nutrient that controls algal growth and, therefore, improving lake water quality typically focuses on phosphorus controls.

The influence of nutrients on algal growth is generally seen over the longer term (i.e., seasonal or annual) rather than a short term (i.e., hours or days). As such, nutrient standards are usually expressed as seasonal or annual averages. In Lake Champlain, the Lake Champlain Phosphorus Management Task Force report (1993) indicated that TP standards in the lake be applied as “summer or annual mean values in central, open-water regions of each lake segment” (VTANR and NYSDEC, 2002), which is how the TP water quality standards have been implemented in Vermont (i.e., annual mean). From this perspective, the short term increases in TP levels in the lake (i.e., hours or days) should not significantly impact phosphorus and algal levels in the lake as long as they do not materially affect the annual mean TP concentrations.

4.2.1.1 Lake Champlain Phosphorus Standards

In order to interpret the model phosphorus results, the Lake Champlain ambient phosphorus levels and VWQS are used. Table 8 presents historical ambient lake TP data at different monitoring stations as an overall average from 1992 to 2013 and as a range of annual averages over this same period. Location information and the associated lake segment TP water quality standards are also provided. The average TP concentration for each of the five stations ranged from 0.012-0.05 mg/L, with annual averages ranging from 0.008-0.061 mg/L. In these lake segments, the VWQS for TP range from 0.010-0.054 mg/L.

Table 8. Lake Champlain Ambient TP Levels			
Long-Term Station	**Lake Segment**	**Annual Mean TP Standard (mg/L)[1]**	**TP Data (mg/L)[2]**
46 (MP6)	Isle La Motte	0.014	0.016 (0.012-0.021)
36 (MP20)	Isle La Motte	0.014	0.012 (0.009-0.018)
33	Cumberland Bay	0.014	0.013 (0.011-0.020)
19	Main Lake	0.010	0.012 (0.008-0.016)
9 (MP50)	Otter Creek	0.014	0.015 (0.010-0.019)
7 (MP68)	Port Henry	0.014	0.015 (0.010-0.021)
4 (MP83)	South Lake A	0.025	0.034 (0.024-0.047)
2	South Lake B	0.054	0.050 (0.037-0.061)

1 – TP standard applied as an annual mean in the euphotic zone (euphotic zone is depth to 1% light depth)
2 – Long-term data average from 1992-2013. Values in parenthesis are range in annual averages.

4.2.1.2 Secchi Depth Data, Euphotic Zone and Mixed Layer

As noted in Table 9, the VWQS values "shall be achieved as the annual mean total phosphorus concentration in the photosynthetic depth (euphotic) zone in central, open water areas of each lake segment". The photosynthetic depth or euphotic zone is typically defined as the water depth to the 1% light level. The 1% light level can be calculated using a light extinction coefficient, which can be estimated from secchi depth data. The following equations are used to calculate the light extinction coefficient and 1% light depth or euphotic zone.

$$K_e = \frac{1.7}{H_S}$$

$$\frac{I}{I_0}(0.01) = e^{-K_e H} \quad or \quad H_{1\%} = \frac{\ln(0.01)}{-K_e} = \frac{4.605}{K_e}$$

where: K_e – light extinction coefficient (1/m);

H_S – secchi depth (m);

I – light level at depth H;

I_0 – light level at the surface; and

$H_{1\%}$ - 1% light depth (m).

Available secchi depth data were obtained from the VTDEC long-term monitoring program from 1992-2013 at a number of stations along the cable route and are presented in Figure 13 (top panel) as the mean (filled circle) and range. The secchi depth average ranges from 1.6 meters in the southern lake (Station 4) to 5.2 meters in the northern lake (Station 36). Converting these average secchi depths to a 1% light depth using the equations above results in a euphotic depth range from 2.5-14.0 meters. The euphotic depth (or 1% light depth) is presented in the bottom panel as the green line and circles, with average water depth being shown as a black line, along the cable route. The lateral transects for the five representative mileposts are also shown. This analysis indicates that the euphotic zone encompasses the entire water depth at northern (MP 0.5 to 14) and southern (MP 72 to 98) sections of the route. At the intermediate route segment (MP 14-72), the euphotic zone does not reach the bottom and, therefore, the TP standard does not apply below this depth.

For the northern and southern representative locations (MP6 and MP83), the euphotic depth constitutes the entire water column and, therefore, model calculated phosphorus increases will include considerations of the spatial (horizontal and vertical) distribution of TP and DP along with the time-series of calculated concentrations due to the cable installation. Because the dissolved form of phosphorus (PO_4 or orthophosphate) is more readily available for phytoplankton (algal) growth, the DP model calculated concentrations will also be assessed as it relates to potential water quality impacts in the lake.

Although the calculated short term phosphorus increases associated with the cable installation at MP20, MP50 and MP68 will occur in water depths deeper than the euphotic zone, the surface mixed layer can be deeper than the euphotic zone depth. The depth of the surface mixed layer represents the location of the thermocline, which is a thin layer with rapid temperature changes and relatively well mixed layers above (epilimnion) and below (hypolimnion). The thermocline also represents a barrier that restricts vertical movement of constituents in lakes. For example, the thermocline restricts movement of well oxygenated surface layer water into the deeper bottom layer water; and also restricts movement of higher bottom layer phosphorus levels into the surface mixed layer.

For the purposes of understanding potential impacts within the surface mixed layer, this report also assesses the potential concentration increase of TP in the surface mixed layer. Vertical temperature profile data from the VTDEC long-term monitoring program from 2009-2013 were reviewed at stations 7, 9, 19 and 36 to estimate the depth of the surface mixed layer. These stations represent the deeper parts of the lake, where the euphotic depth ranges from 10-15 meters. The surface mixed layer depth was estimated based on where the largest vertical change in temperature occurred (>2ºC/m) and ranged from about 5-35 meters with the deepest depths ranging from 20-35 meters. Both the euphotic and surface mixed layer depths will be used to assess the potential phosphorus impacts associated with the cable installation.

4.2.2 Phosphorous Spatial and Vertical Distributions

Figures 14-18 present the model calculated temporary TP increase distributions in the horizontal and vertical directions for the five representative locations along the cable route. As with the TSS representations, the figures present the horizontal TP distributions in the bottom layer (left panel) as well as the location of 200 foot offset distances on either side of the cable route and the lateral transect (horizontal gray line) that corresponds to the vertical TSS distribution shown in the right panel. The circle in the vertical distributions indicates the location for which the time-series model output is presented in Figures 19-23.

The horizontal TP distributions indicate that the highest temporary concentration increases occur at the point of installation and then decrease rapidly as distance from the installation increases. At a lateral distance of 50-150 feet from the installation point, the temporary resuspended maximum TP concentration increases are less than 0.01 mg/L above background annual mean TP levels observed in Lake Champlain (0.01-0.06 mg/L) as presented in Table 9.

In the vertical direction, the model calculated temporary TP concentration increases are limited to the bottom 1-3 layers of the model (about the bottom 2-3 meters of the water column at MPs 6, 20, 50 and 68; and the bottom 1 meter of the water column at MP83). Above these depths from the bottom, the model calculated temporary TP concentration increases are less than 0.01 mg/L above background annual mean TP levels observed in the lake.

At all five of the representative locations, the model calculated temporary TP concentration increases due to the cable installation are less than 0.01 mg/L above background annual mean lake TP levels at 200 feet from the point of installation and within 1-3 meters of the lake bottom. These five representative locations were selected to be indicative of the TP increases along the entire cable route due to the similar sediment characteristics and bottom lake currents.

Because dissolved phosphorus (DP) is readily available for phytoplankton (algal) growth and a more important parameter to consider from a water quality perspective, similar spatial and vertical graphics are presented for DP in Figure 24-28. These figures indicate that maximum temporary DP increases are less than 0.025 mg/L at all locations at the five representative locations along the cable route.

4.2.3 Phosphorous Time-Series

Figures 19-23 present the model calculated temporary TP and DP concentration increases versus time for the five representative locations to provide duration information for the increased concentrations during cable installation. The top panel presents the model calculated temporary TP concentration increases in the bottom model layer (layer 1, solid black line) as noted in the vertical distribution figures; and the second model layer up from the bottom (layer 2, dashed black line). The bottom panel presents the model calculated DP concentration increases in the same format.

At MP6, MP20, MP50 and MP68, the model calculated temporary peak TP concentration increases ranged from about 2.3-4.1 mg/L and then rapidly decreased to less than 0.01 mg/L above background levels in about one to four hours. At MP83, the temporary peak TP concentration increase was about 0.045 mg/L and then rapidly decreased to background levels in less than 30 minutes, reflecting the use of the shear-plow installation method south of Crown Point. At all five representative locations, temporary DP concentration increases reach a peak concentration at the point of installation and then decrease rapidly. The peak temporary DP concentration increases (which are a more available form of phosphorus for algal growth) ranged from 0.001-0.022 mg/L, but these fell to less than 0.01 mg/L above background levels within one to three hours. Although there is much variability in the background TP and DP levels in the lake, the average annual mean lake TP is 0.020 mg/L (ranging from 0.01-0.06 mg/L) and the average lake DP is 0.011 (ranging from 0.002-0.068 mg/L) based on the VTDEC long-term monitoring data from 1992-2013 at Stations 2, 4, 7, 9, 19, 33, 36 and 46.

4.2.4 Summary of Potential Phosphorus Impacts

At all five representative locations, TP concentration increases reach a temporary peak concentration at the point of installation and then decrease rapidly. The time to reach 0.01 mg/L above background TP and DP concentrations is on the order of one to four hours. The model results indicate modest temporary increases in TP and DP over a relatively small spatial area in both the horizontal and vertical directions. TP increases were greater than DP due to the addition of the PP component, but due to the settling rate of PP represented only a short term increase (i.e., within one to four hours).

In order to provide a context for these values, an assessment of the total mass resuspended during cable installation was compared to total annual external phosphorous inputs. External TP loads to Lake Champlain as presented in the Lake Champlain Basin Program report titled *Lake Champlain Phosphorus Concentrations and Loading Rates, 1990-2008* (Smeltzer, E., F. Dunlap and M. Simoneau, 2009) are presented in Table 9 for two-year periods from 1991-2008. The external TP loads to Lake Champlain ranged from 580-1,220 metric tons/year (580,000-1,220,000 kg/yr). Since the particulate fraction of phosphorus (PP) resuspended during cable installation settles back to the sediment on the order of hours and does not significantly contribute to concentrations in the lake, the total mass of DP used as model input over the entire cable route during installation of 60 kg or 0.06 metric tons (mt) was used for comparison to the external TP inputs. Based on this information, the cable installation represents less than 0.01% of the total external phosphorus input to Lake Champlain. It should be noted, however, that the cable installation does not represent a new source to the lake but rather the re-introduction of existing sediment sources into the water column on a short term basis.

Table 9. External TP Inputs to Lake Champlain			
Year Range	External TP Input (mt/yr)[1]		
	Point Source	Nonpoint Source[3]	Total[2]
1991-1992	200	590	790
1993-1994	200	570	770
1995-1996	89	731	820
1997-1998	88	1132	1220
1999-2000	87	748	835
2001-2002	72	508	580
2003-2004	65	795	860
2005-2006	59	886	945
2007-2008	51	954	1005

1 – 1 mt/yr = 1,000 kg/yr
2 – Estimated from Figure 10 of Loading Report
3 – Calculated from Total and Point Source Inputs

Another method of assessing the potential phosphorus impact associated with the cable installation is to estimate the increase in DP levels in the upper layers of the lake. The surface area of the lake excluding the northeast arm (Missisquoi Bay, St. Albans Bay, Malletts Bay) and the southern part beyond MP97, combined with the estimated thickness of the euphotic and surface mixed layer depth, were used to calculate a lake volume into which the previously calculated DP mass (60 kg) could be mixed. Table 10 presents the results of these calculations and indicates that the potential temporary DP increase is less than 0.009 µg/L (or less than 0.1% of existing DP levels in the lake). This analysis could be considered as conservative because it assumes that the DP mass re-introduced from the sediments into the bottom of the lake can completely transfer into the surface layer of the lake (euphotic zone or surface mixed layer) considering that the thermocline represents a barrier to vertical mass transport in the lake. This level of DP resuspension represents a *de minimis* temporary increase in overall DP levels in the Lake.

Table 10. Potential DP Increase		
Parameter	**Euphotic Zone**	**Surface Mixed Layer**
Depth (m)	10-15	20-35
Volume (m^3)	6.4-9.3E09	12.0-18.5E09
DP Increase (µg/L)	0.006-0.009	0.003-0.005
Ambient DP (µg/L)	Surface – 10.4 Bottom – 9.62	

4.3 Metals

The model calculated metals concentration increases are largely based on the sediment concentrations obtained in previous sampling events. As discussed in Section 3.3.1, existing sediment dissolved metals concentrations along the length of the cable route (i.e., at the five representative locations) are all less than the VWQS acute and chronic values, so that any resuspension of these metals into the water column will be compliant with these standards. Because the metals concentrations are all less than the applicable VWQS, only the time-series figures for metals will be presented.

4.3.1 Metals Time-Series

Figures 29-43 present the model calculated metals concentration increases versus time for the five representative locations to provide duration information for the increased metals concentrations during cable installation. These figures present the calculated metals concentration increases in the bottom model layer (layer 1, solid black line) as noted in the vertical distribution figures; and the second model layer up from the bottom (layer 2, dashed black line). All of the calculated metals concentration increases are less than applicable acute and chronic VWQS, and, therefore, water quality impacts associated with the eight metals (arsenic, cadmium, copper, lead, nickel, zinc, silver and mercury) due to the installation of the cable in Lake Champlain are expected to be in compliance with VWQS. In addition, the concentration increases are all less than method detection limits (MDLs) for these metals and are not measureable.

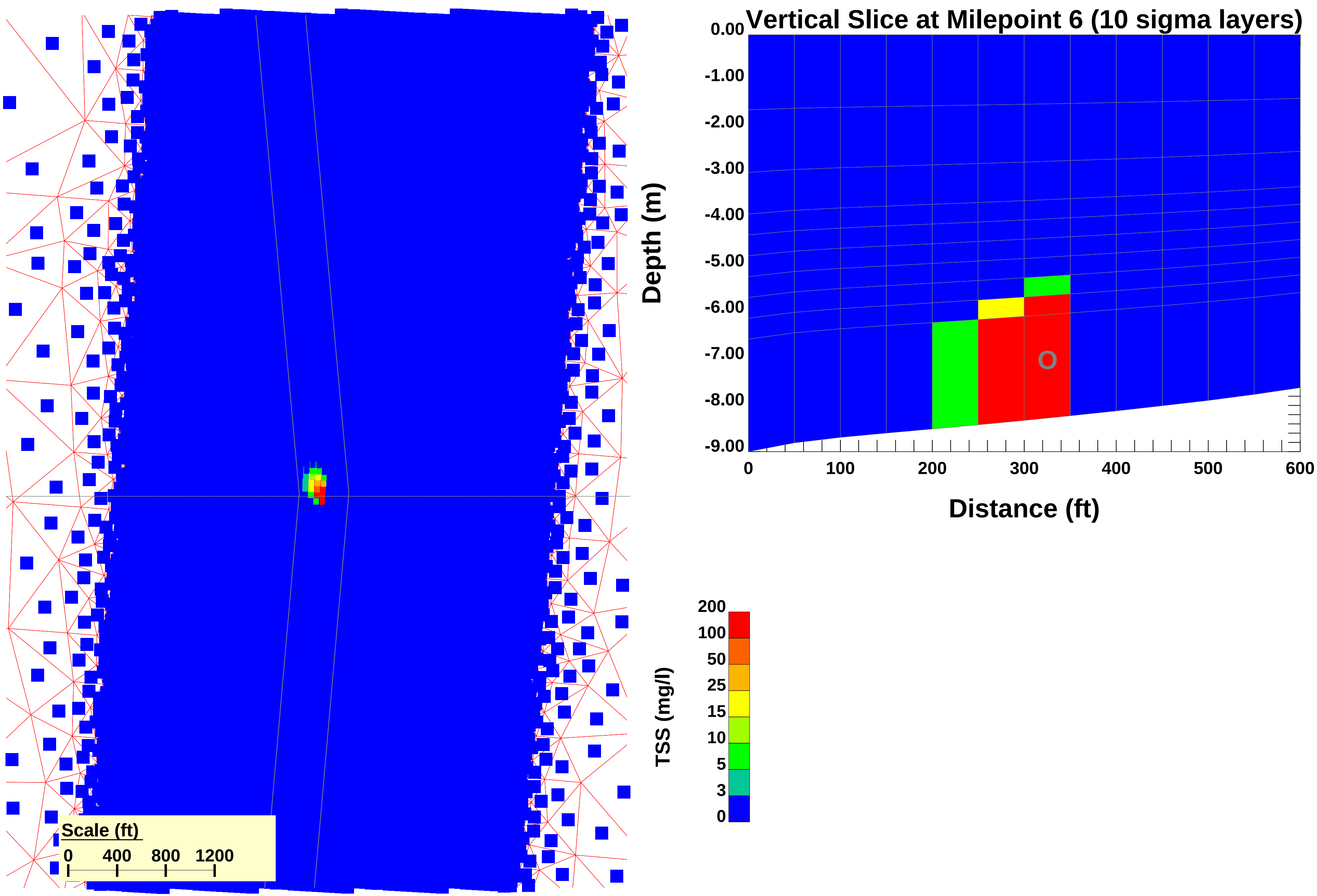


Figure 5. Lake Champlain Water Quality Model Calculated TSS at MP6

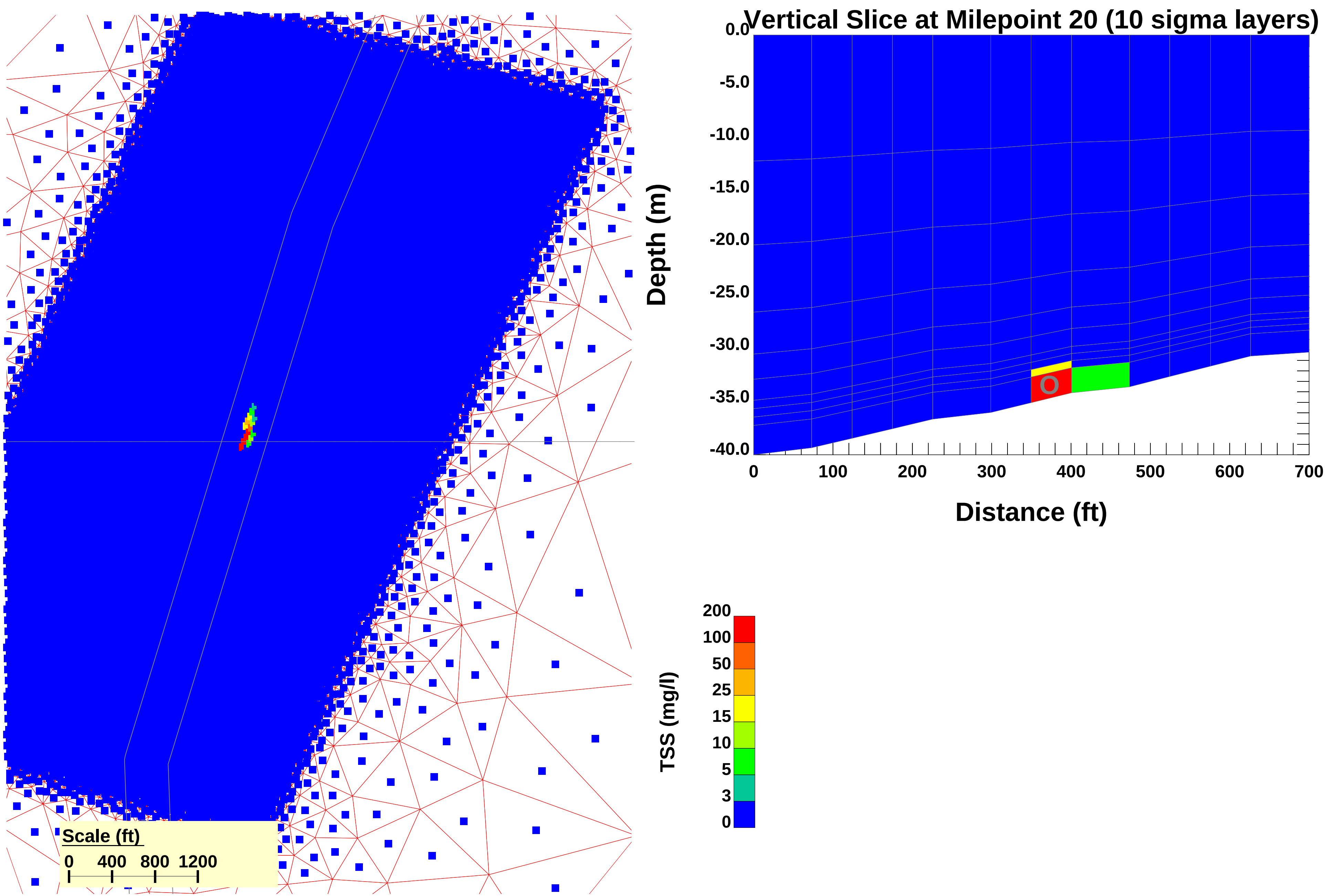


Figure 6. Lake Champlain Water Quality Model Calculated TSS at MP20

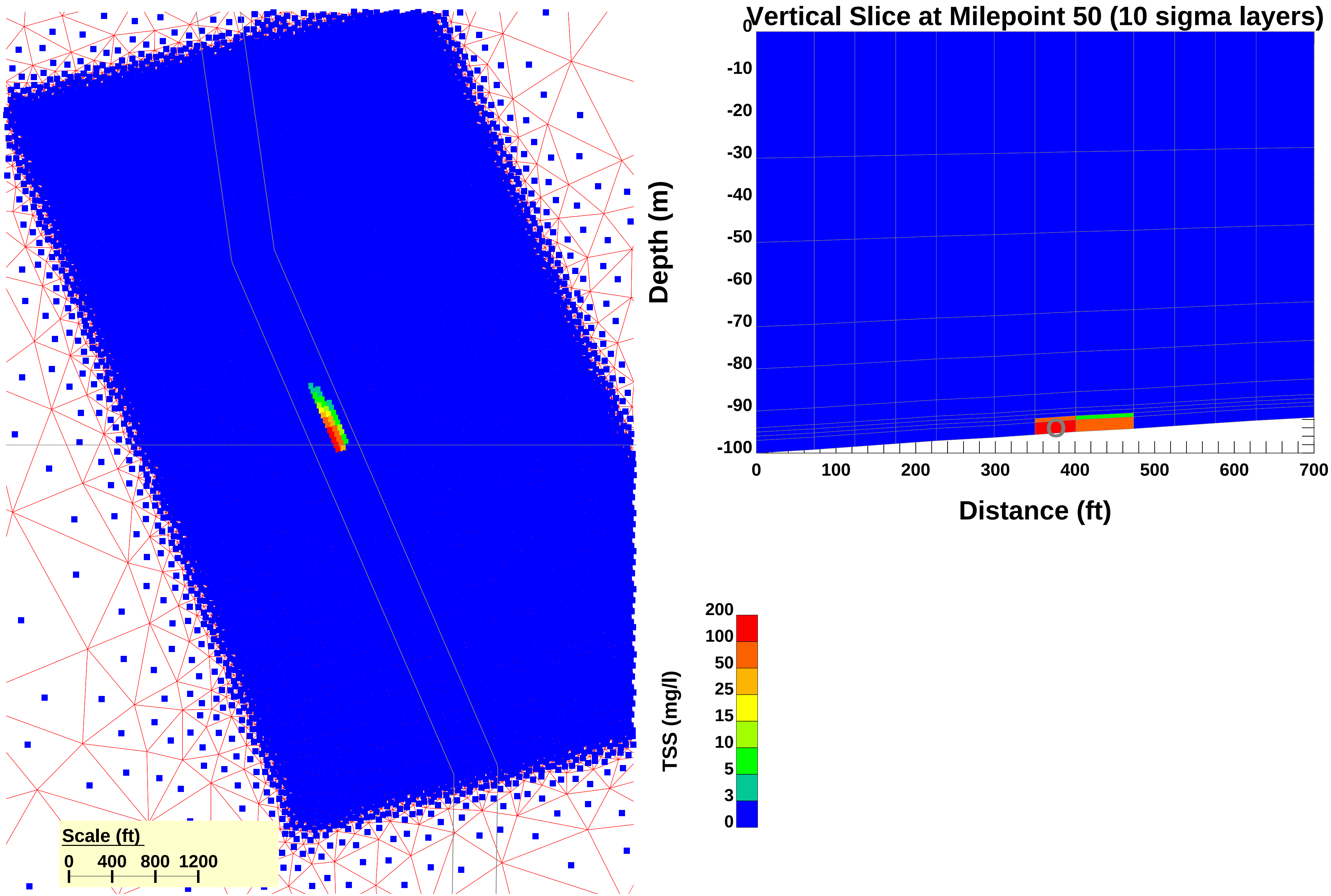


Figure 7. Lake Champlain Water Quality Model Calculated TSS at MP50

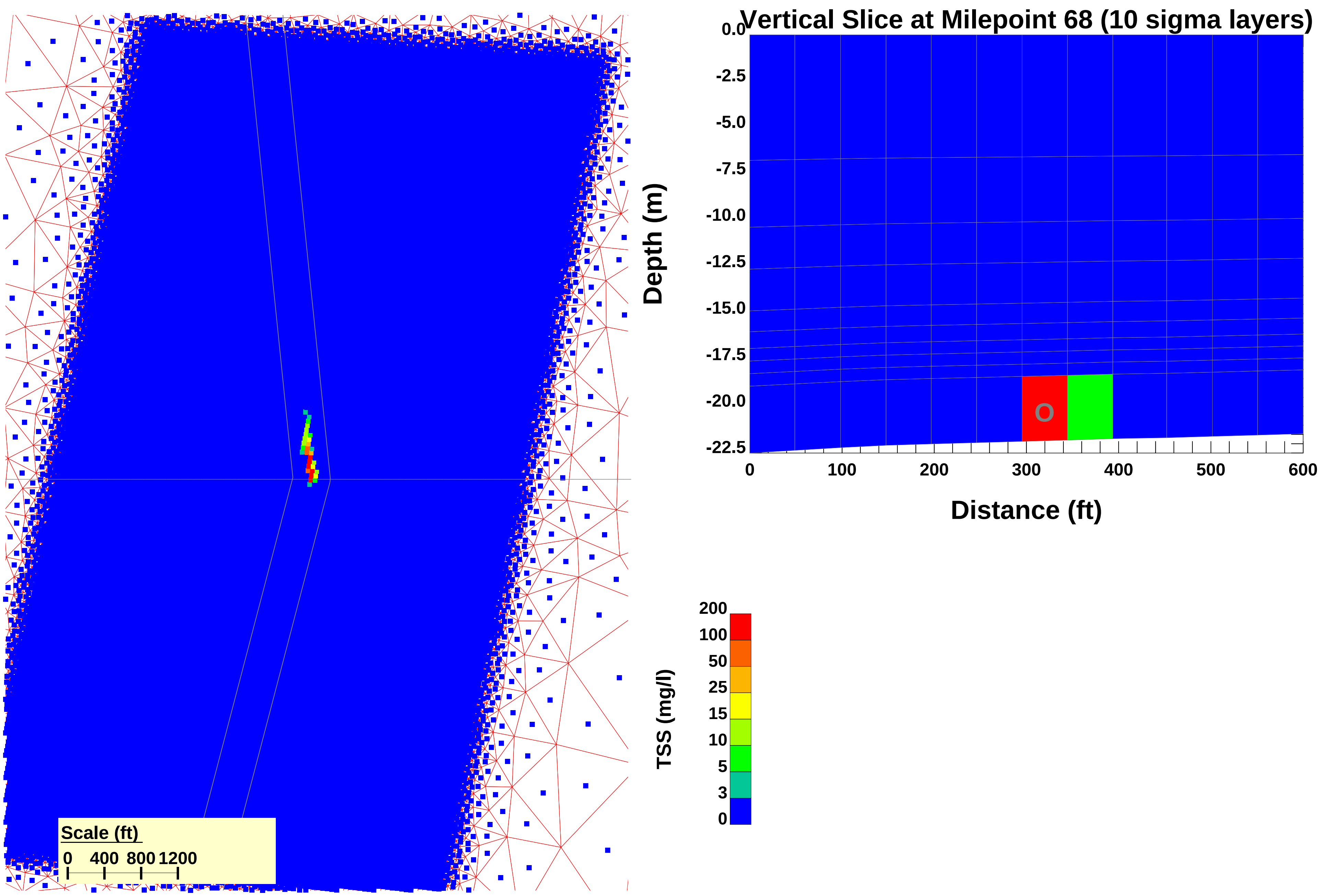


Figure 8. Lake Champlain Water Quality Model Calculated TSS at MP68

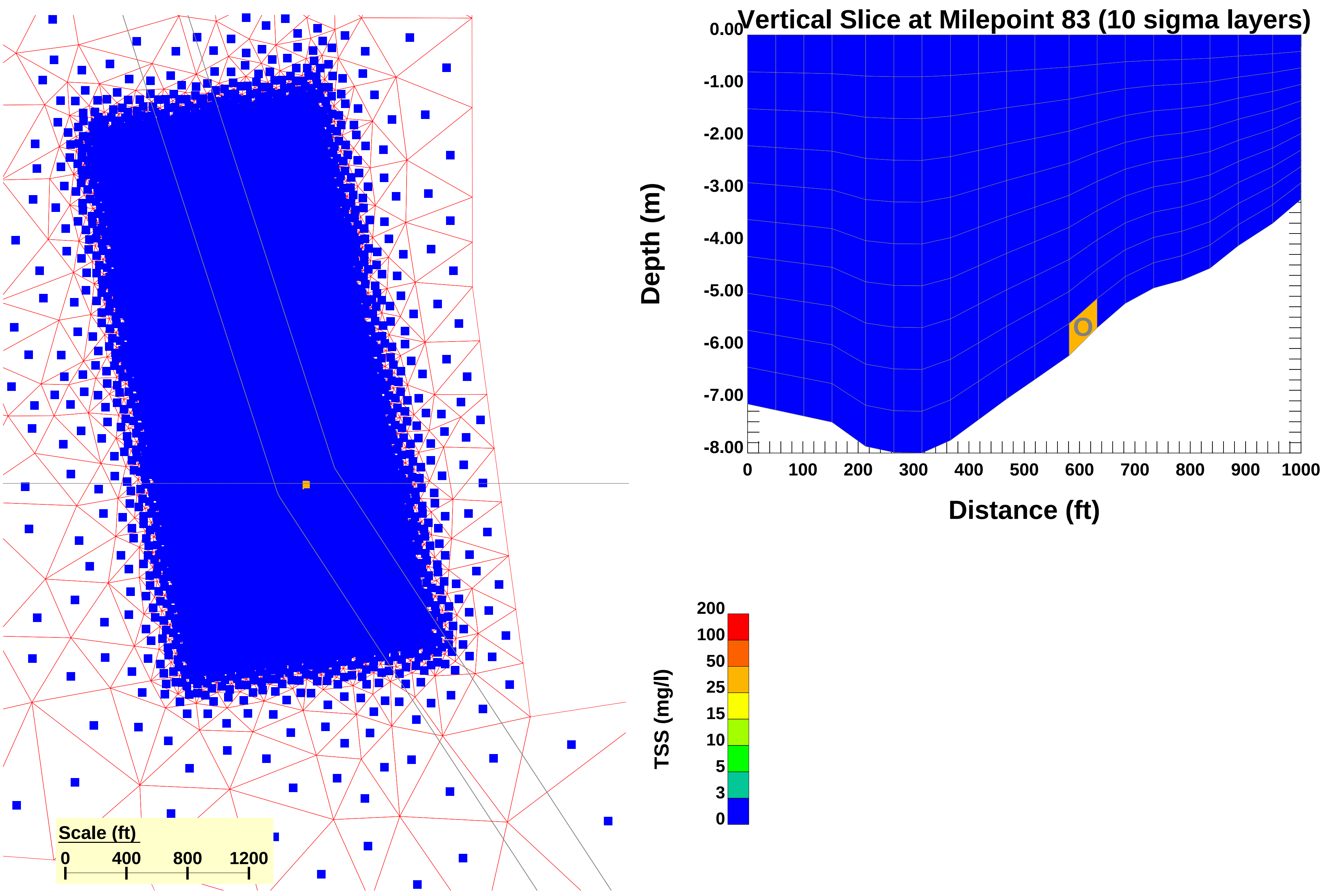


Figure 9. Lake Champlain Water Quality Model Calculated TSS at MP83

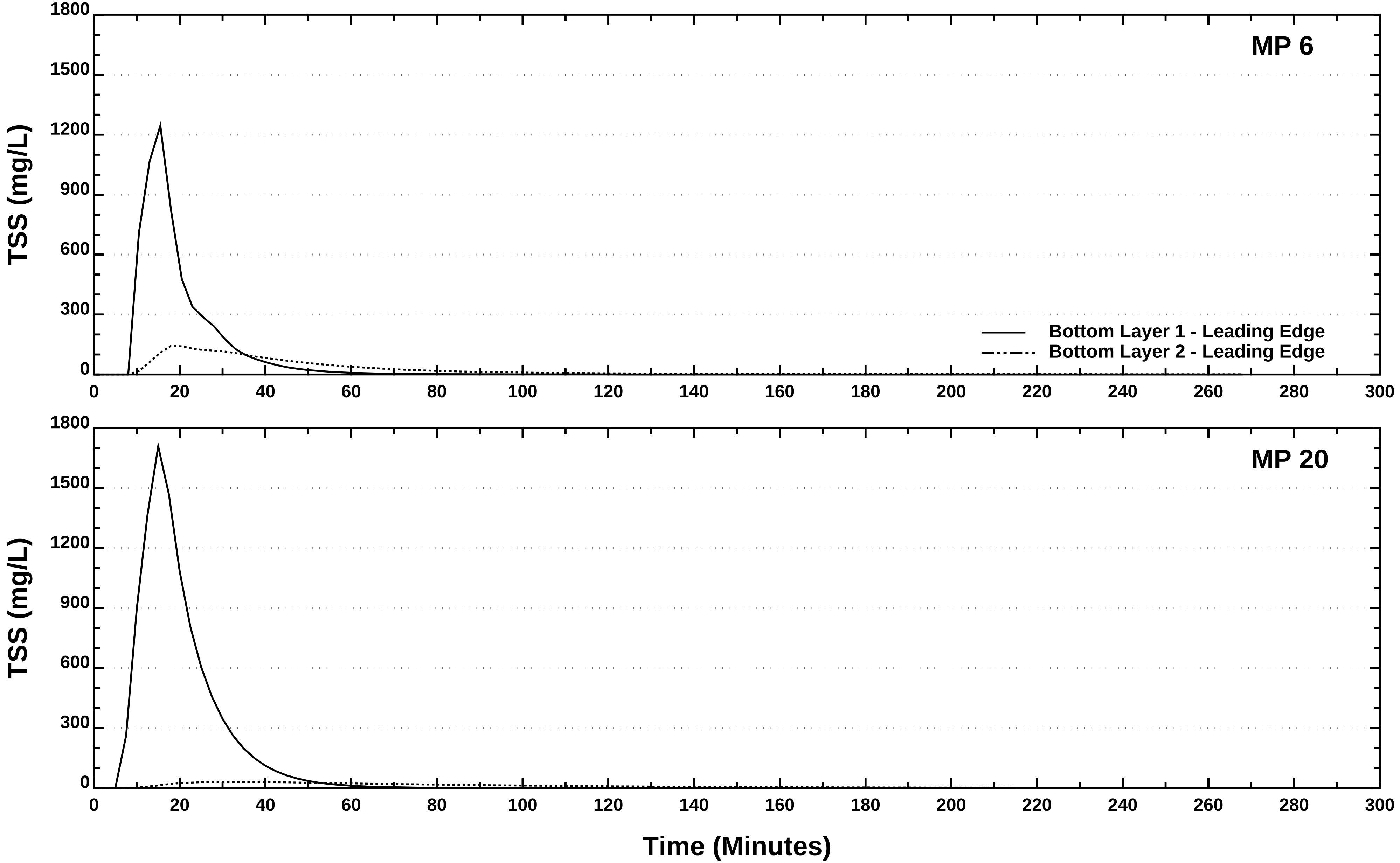


Figure 10. Lake Champlain Model Computed Concentrations - MP 6 and MP 20

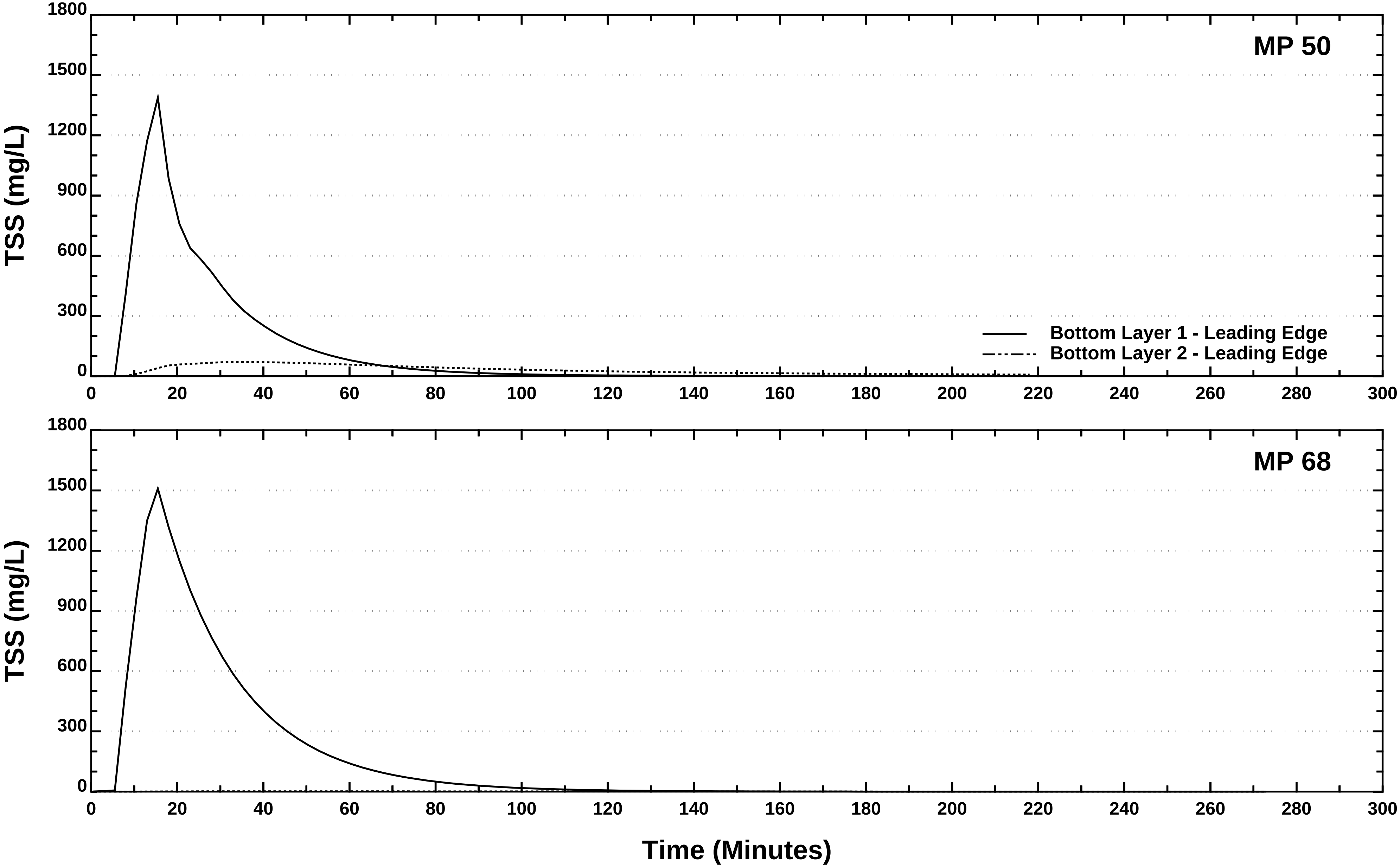


Figure 11. Lake Champlain Model Computed Concentrations - MP 50 and MP 68

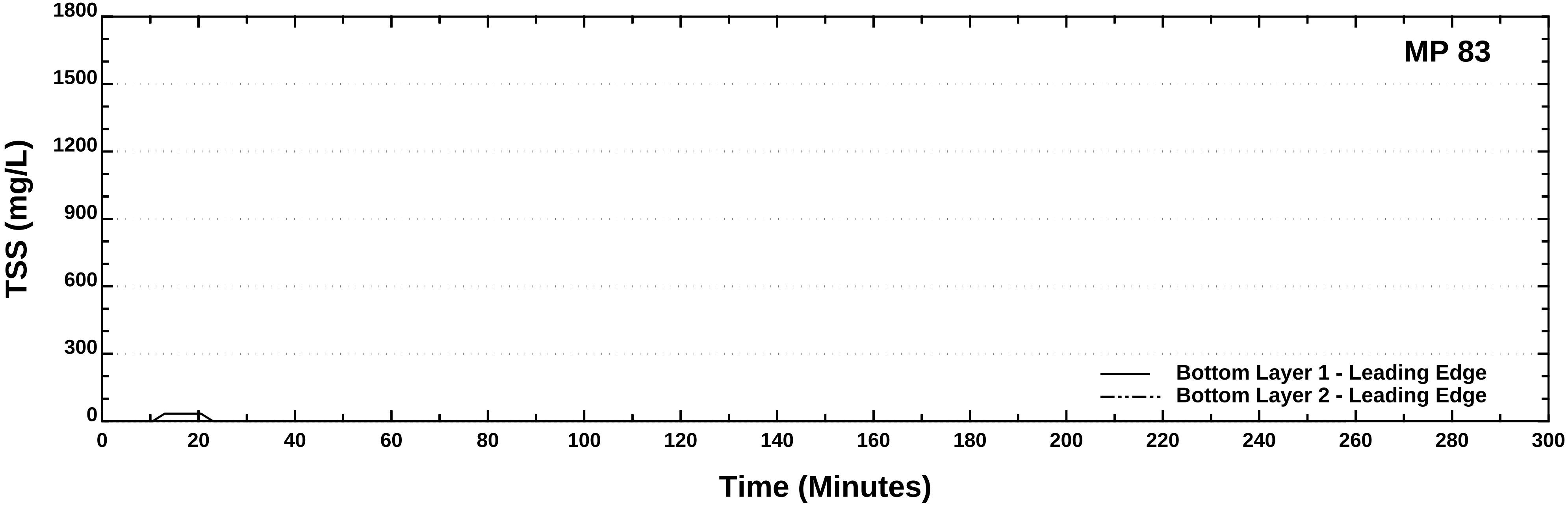


Figure 12. Lake Champlain Model Computed Concentrations - MP 83

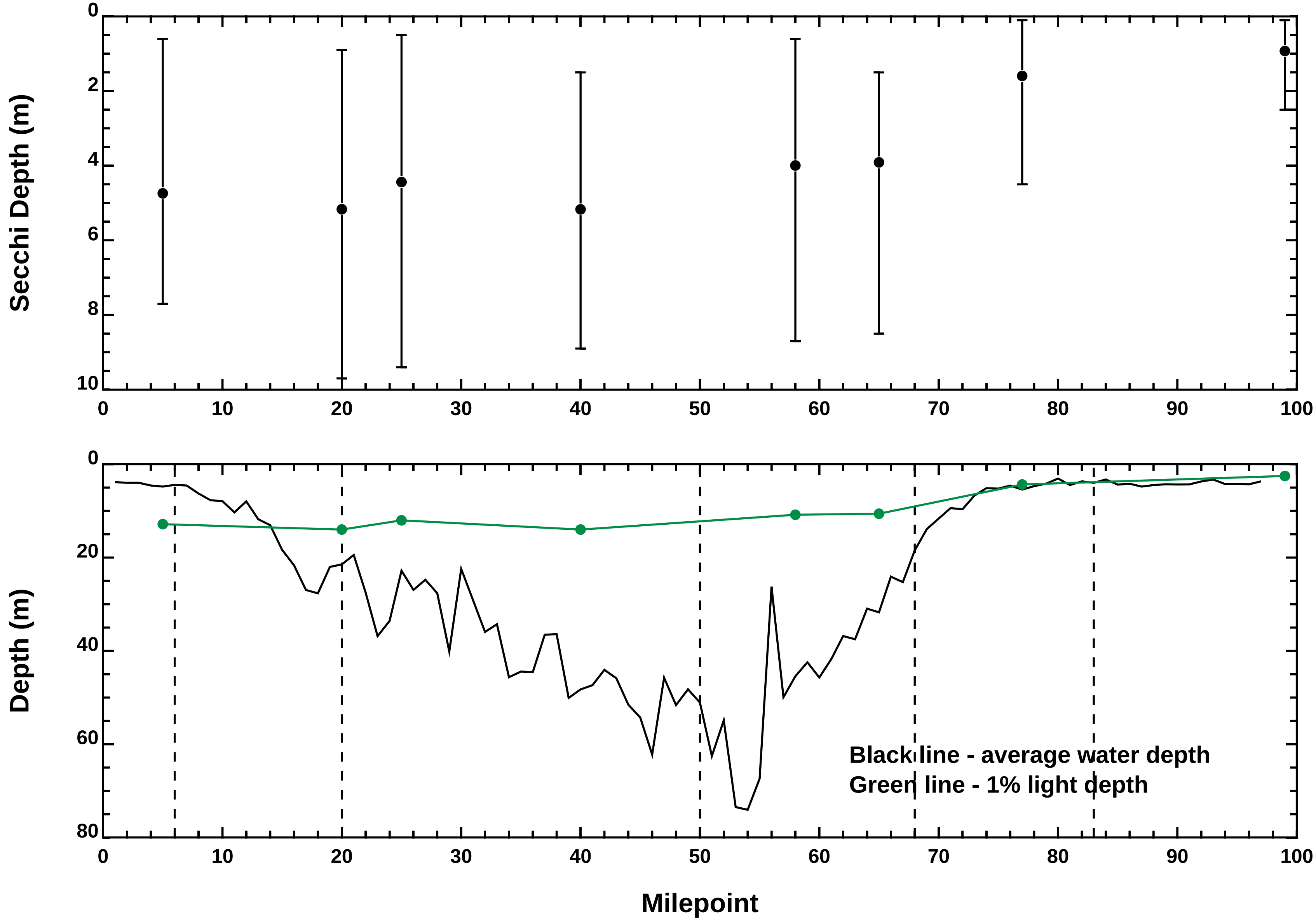


Figure 13. VTDEC Lake Champlain Long-Term Secchi Depth Data and Calculated 1% Light Depth

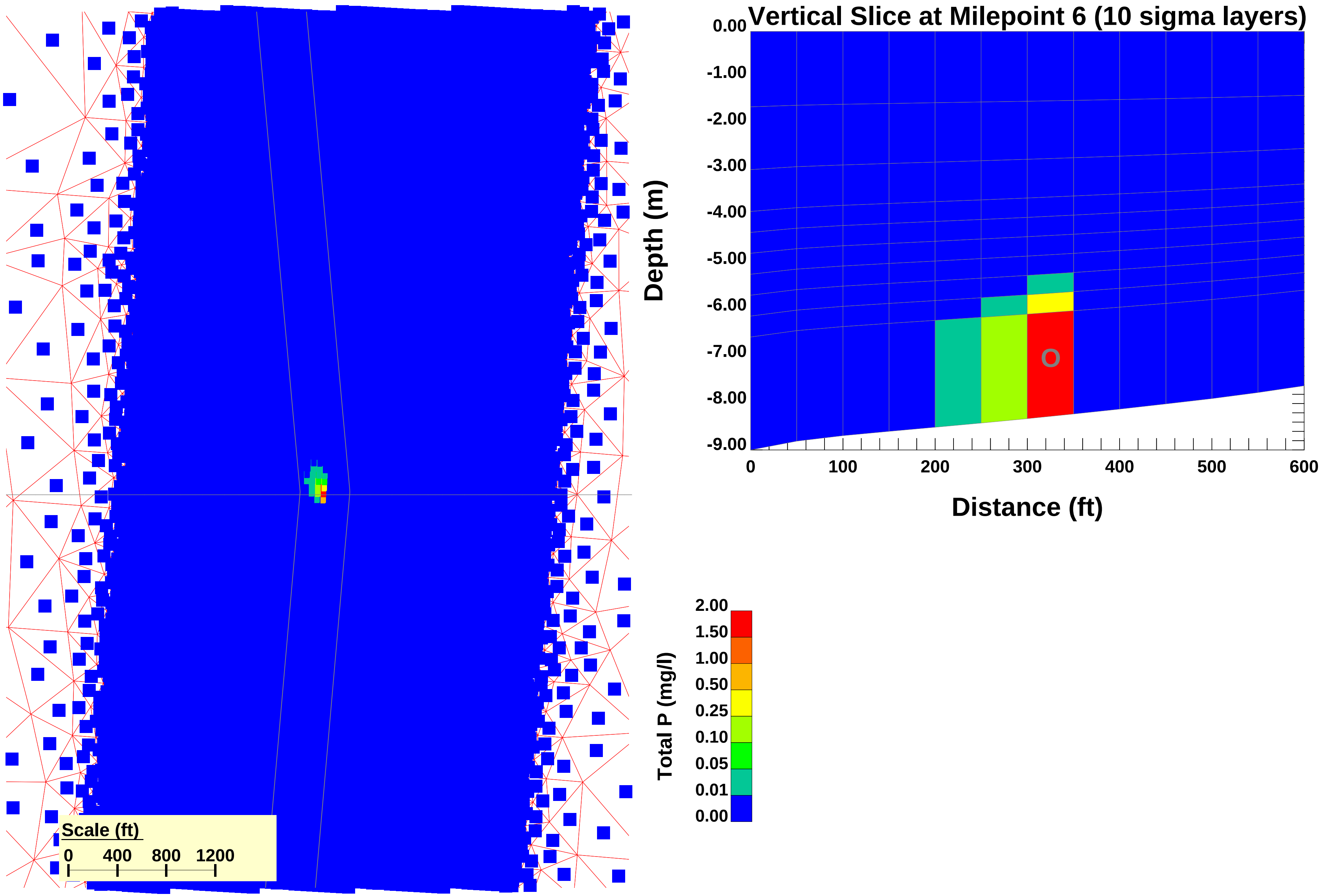


Figure 14. Lake Champlain Water Quality Model Calculated TP at MP6

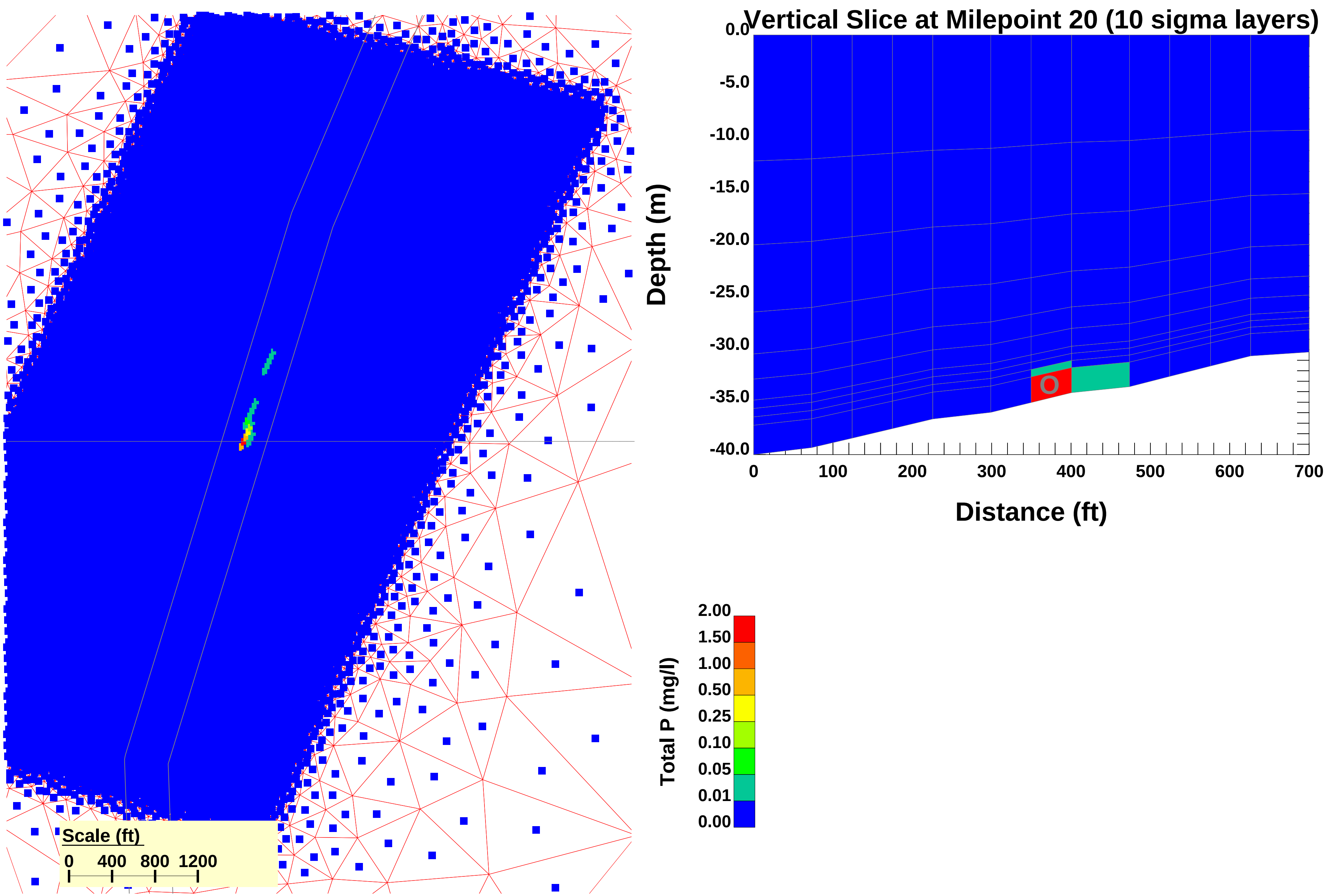


Figure 15. Lake Champlain Water Quality Model Calculated TP at MP20

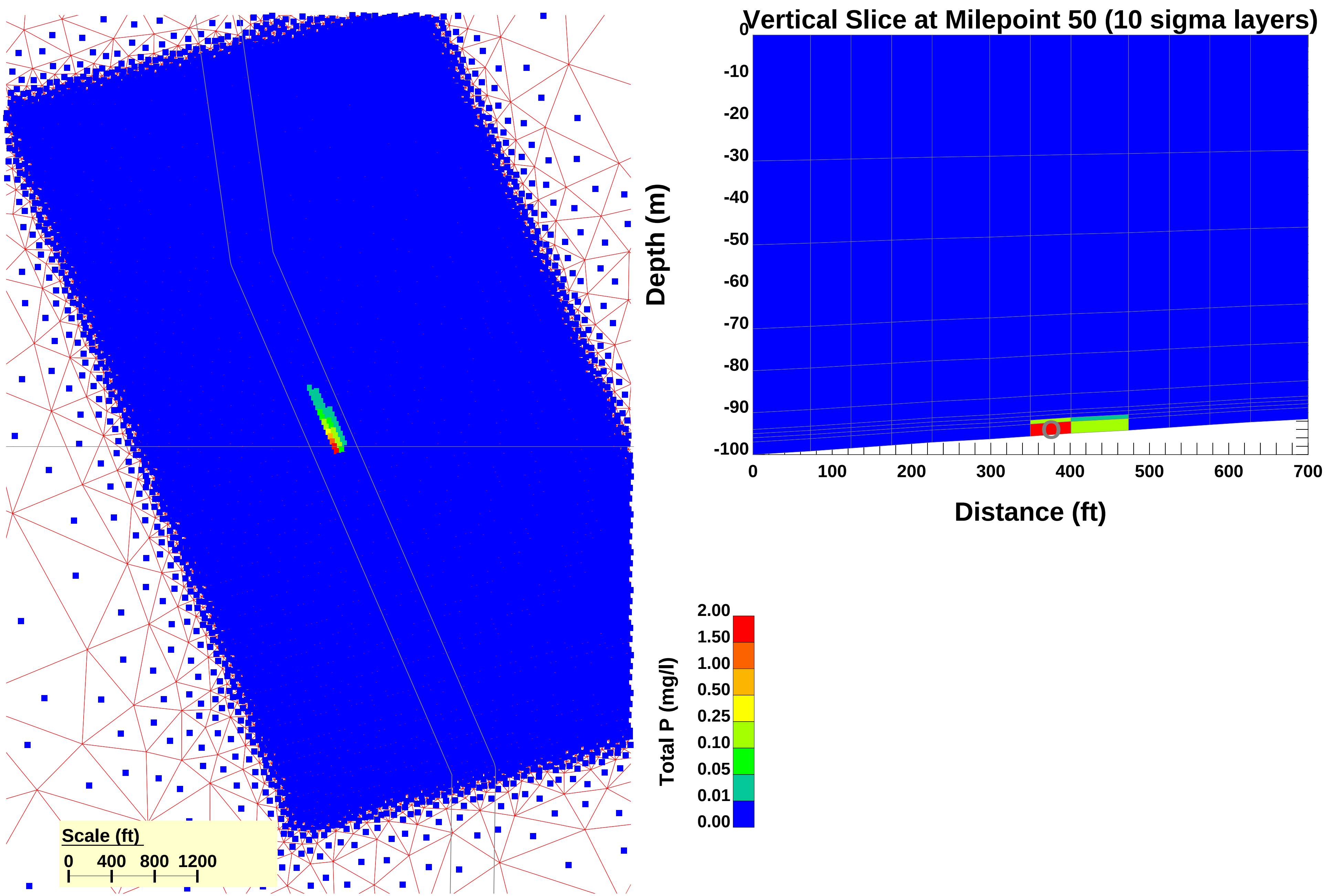


Figure 16. Lake Champlain Water Quality Model Calculated TP at MP50

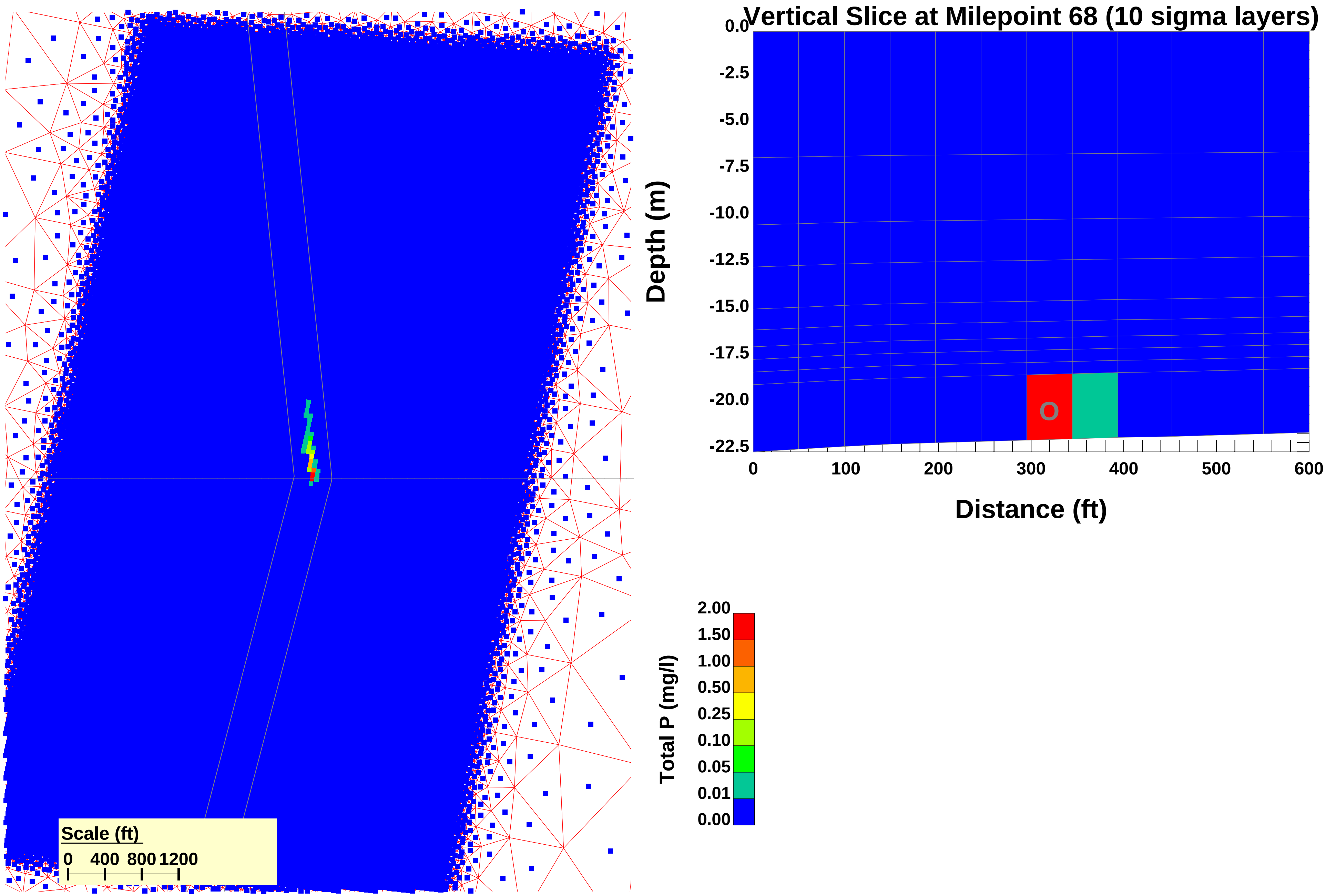


Figure 17. Lake Champlain Water Quality Model Calculated TP at MP68

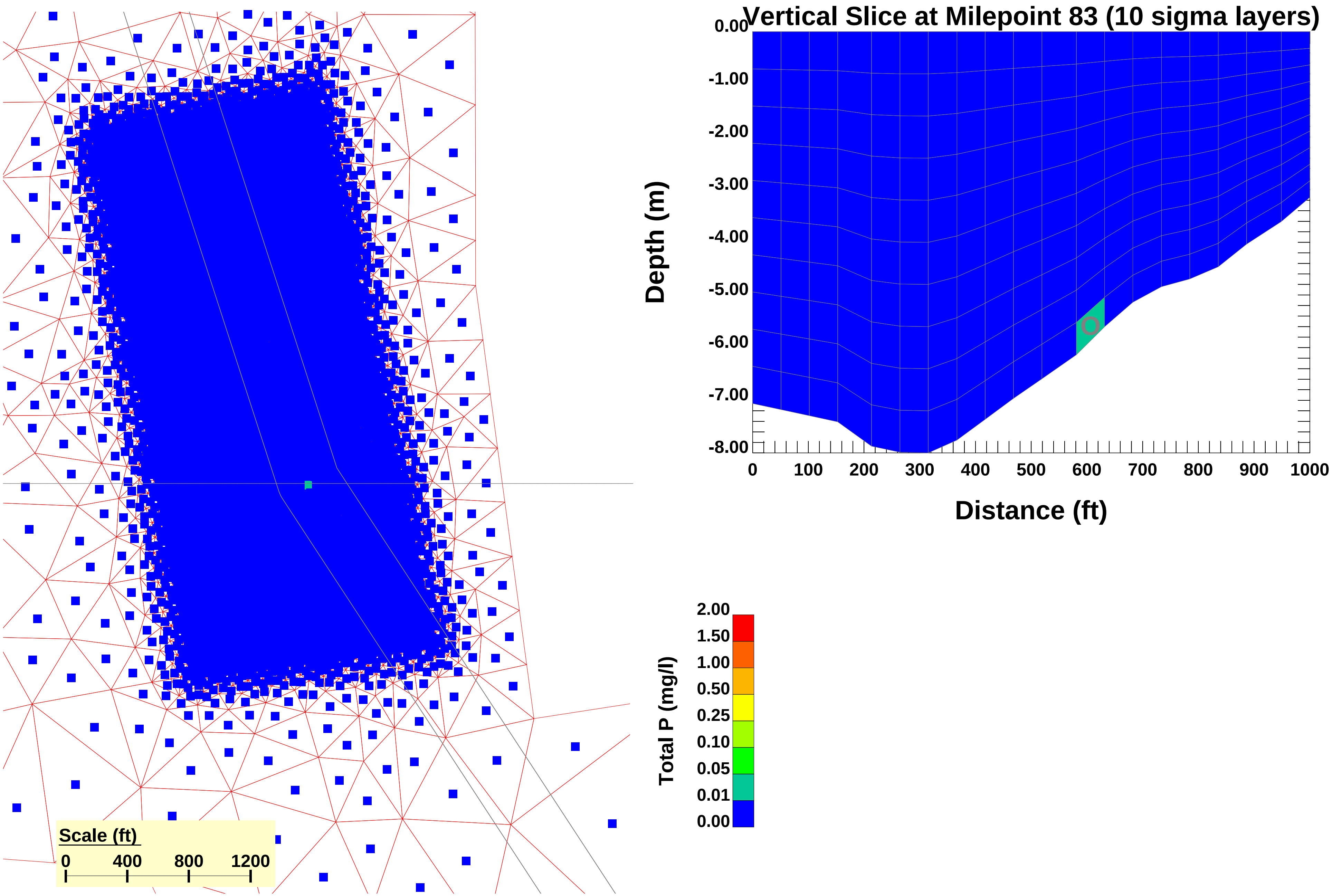


Figure 18. Lake Champlain Water Quality Model Calculated TP at MP83

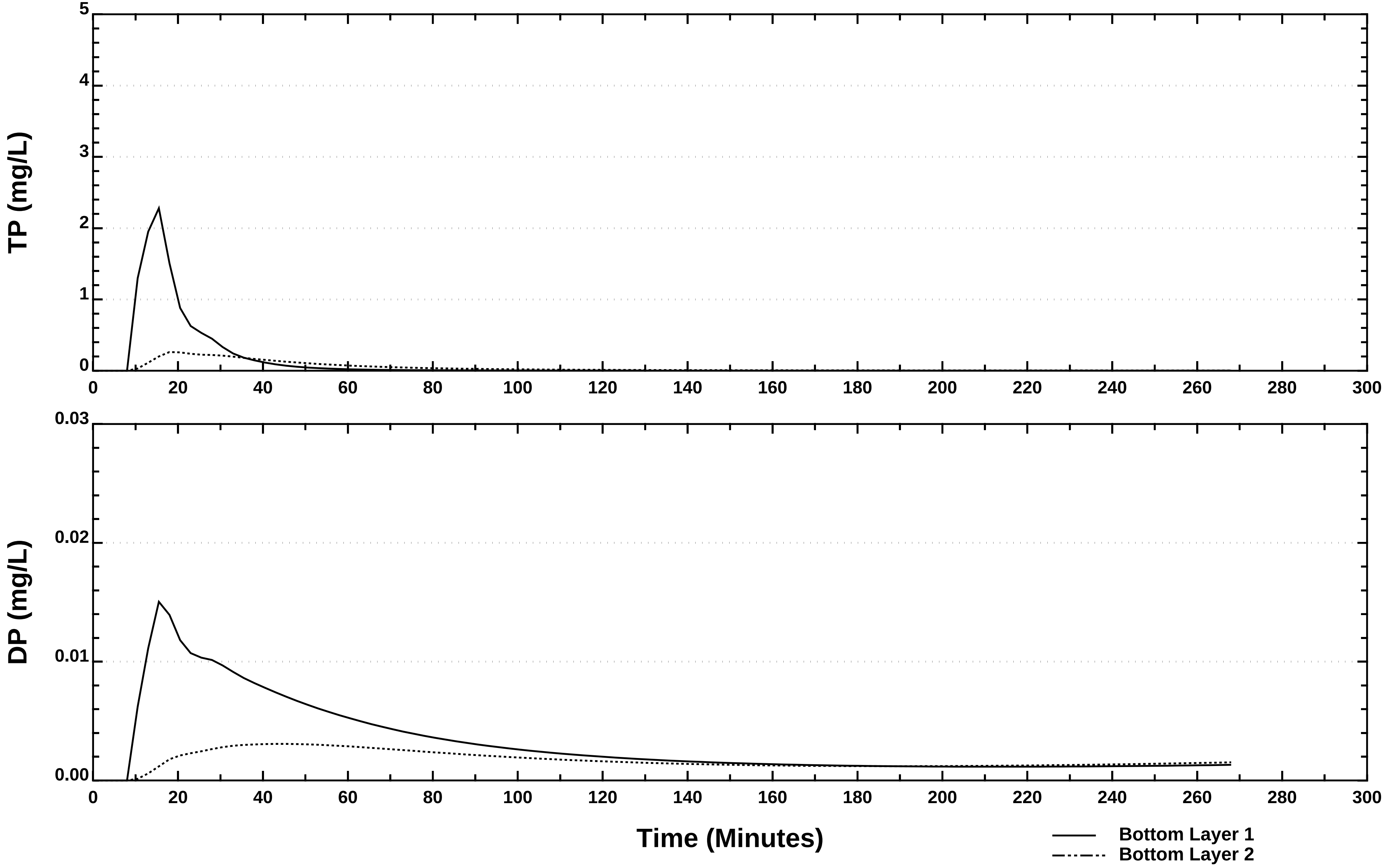


Figure 19. Lake Champlain Model Computed Concentrations - MP 6

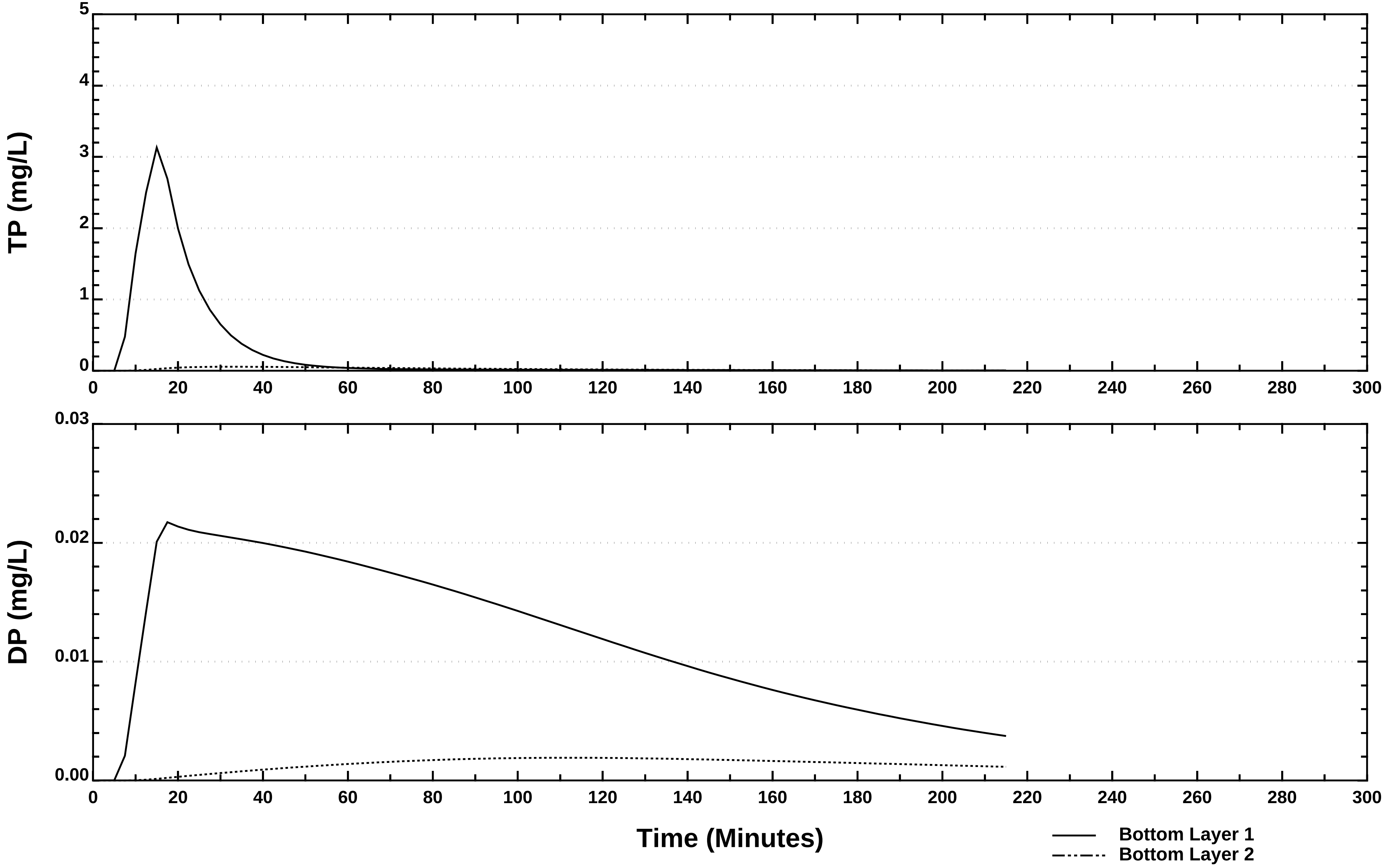


Figure 20. Lake Champlain Model Computed Concentrations - MP 20

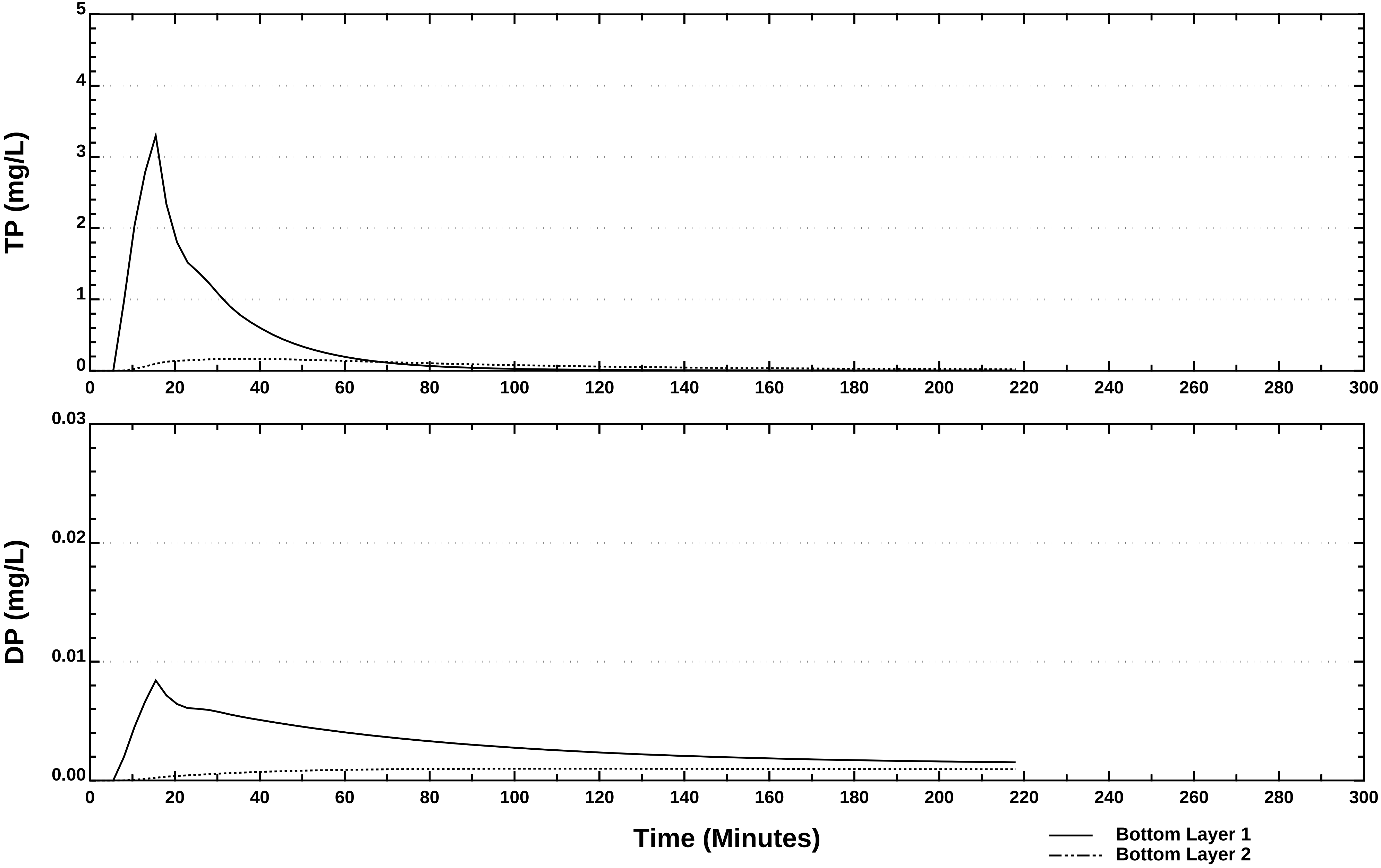


Figure 21. Lake Champlain Model Computed Concentrations - MP 50

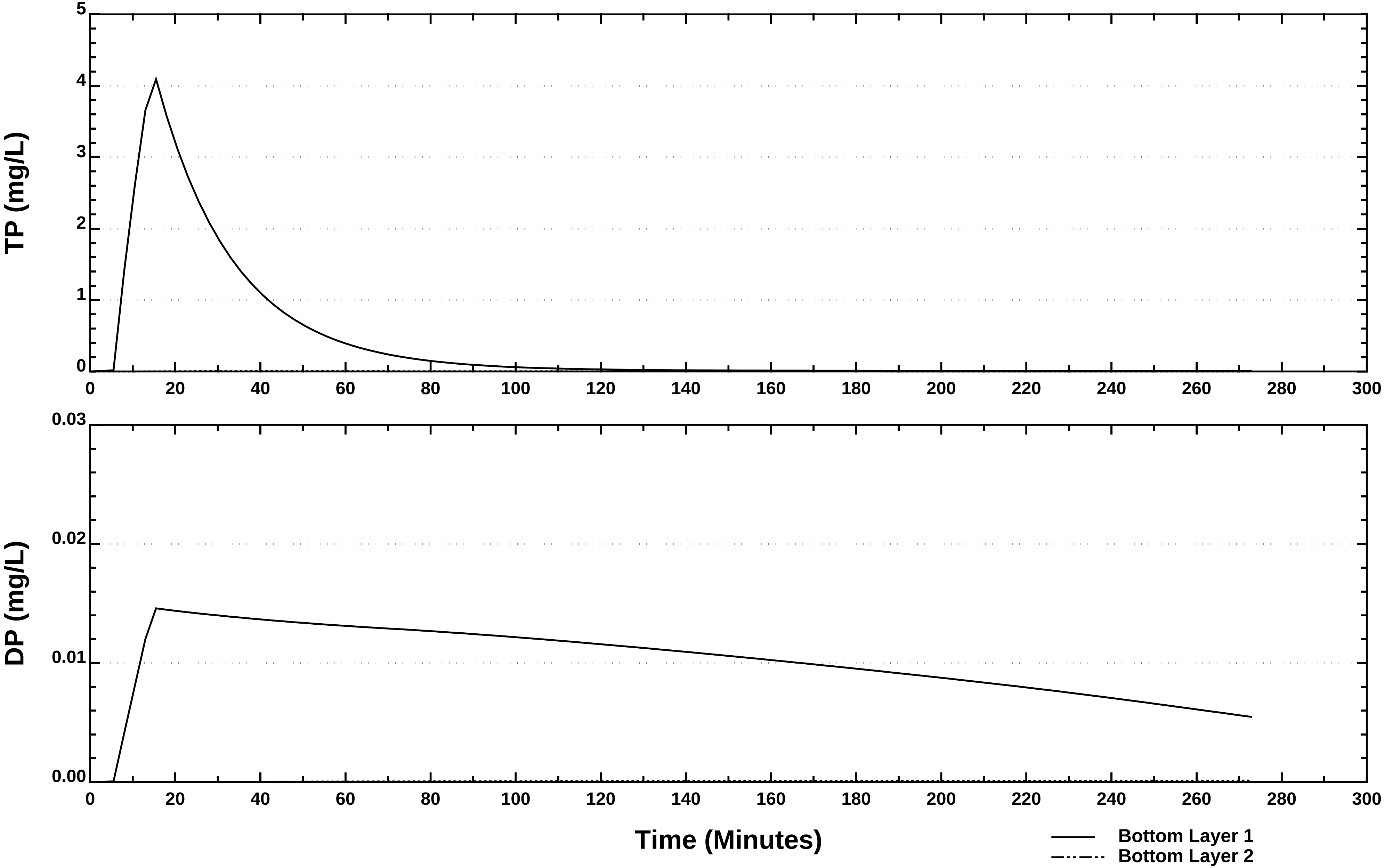


Figure 22. Lake Champlain Model Computed Concentrations - MP 68

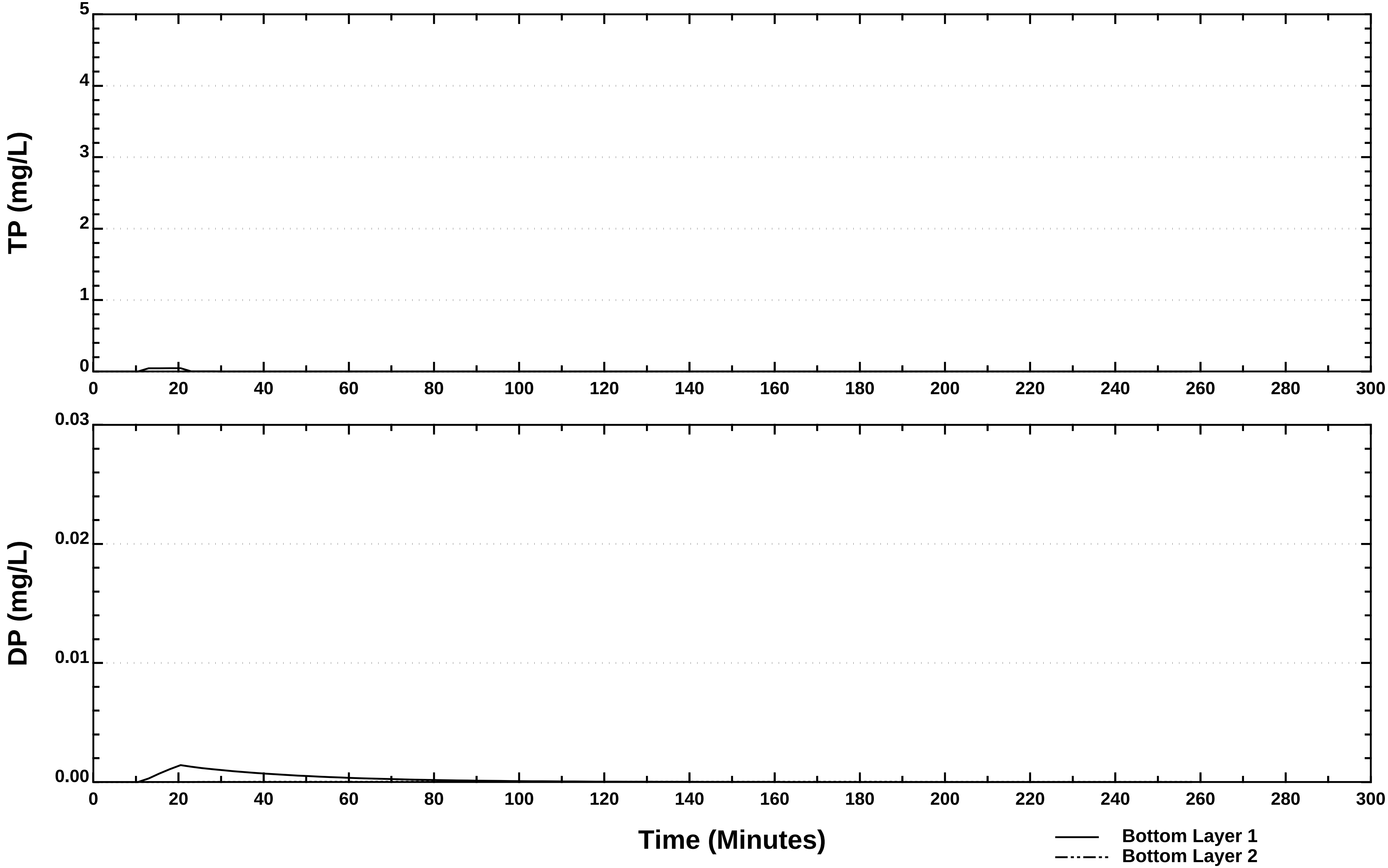


Figure 23. Lake Champlain Model Computed Concentrations - MP 83

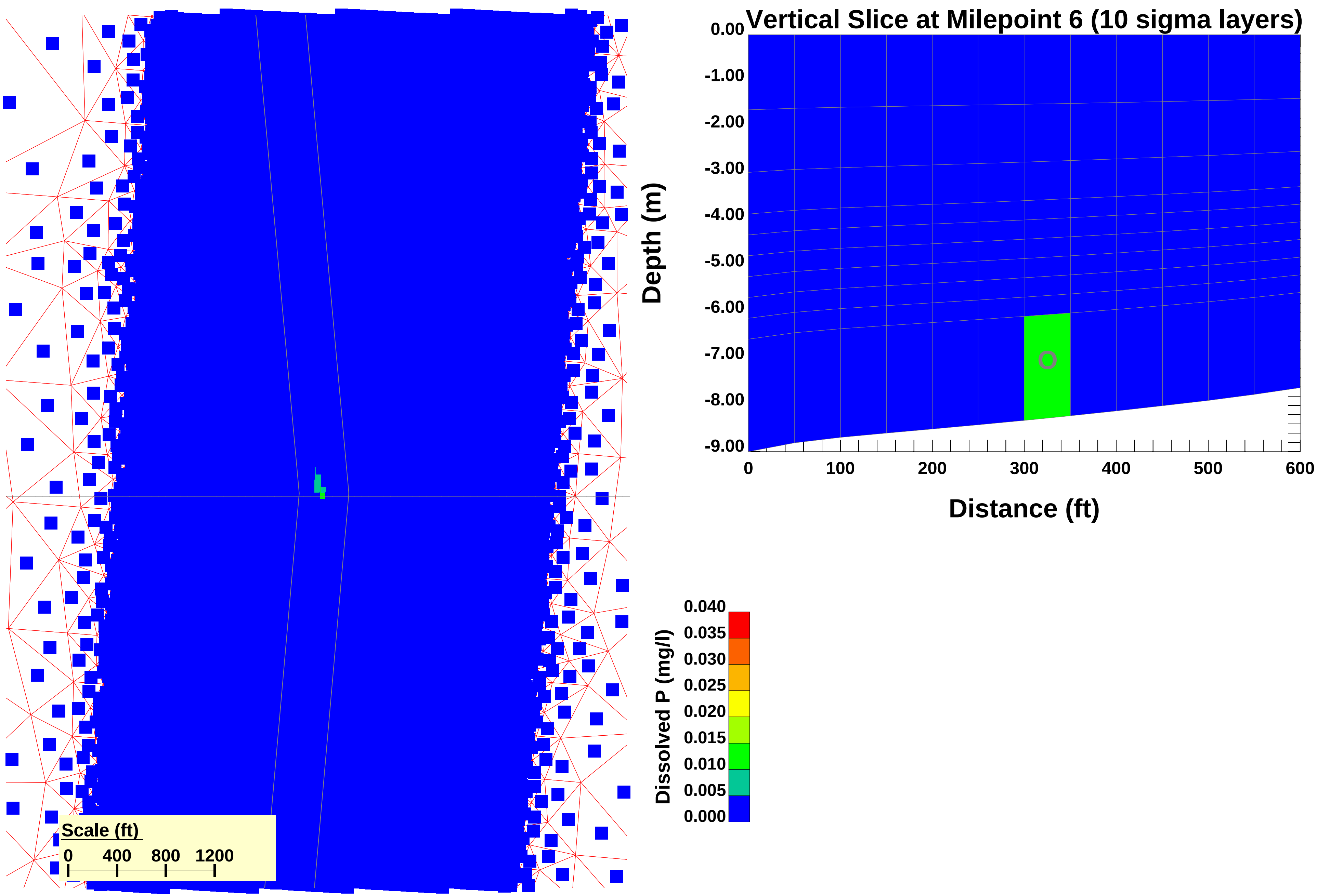


Figure 24. Lake Champlain Water Quality Model Calculated DP at MP6

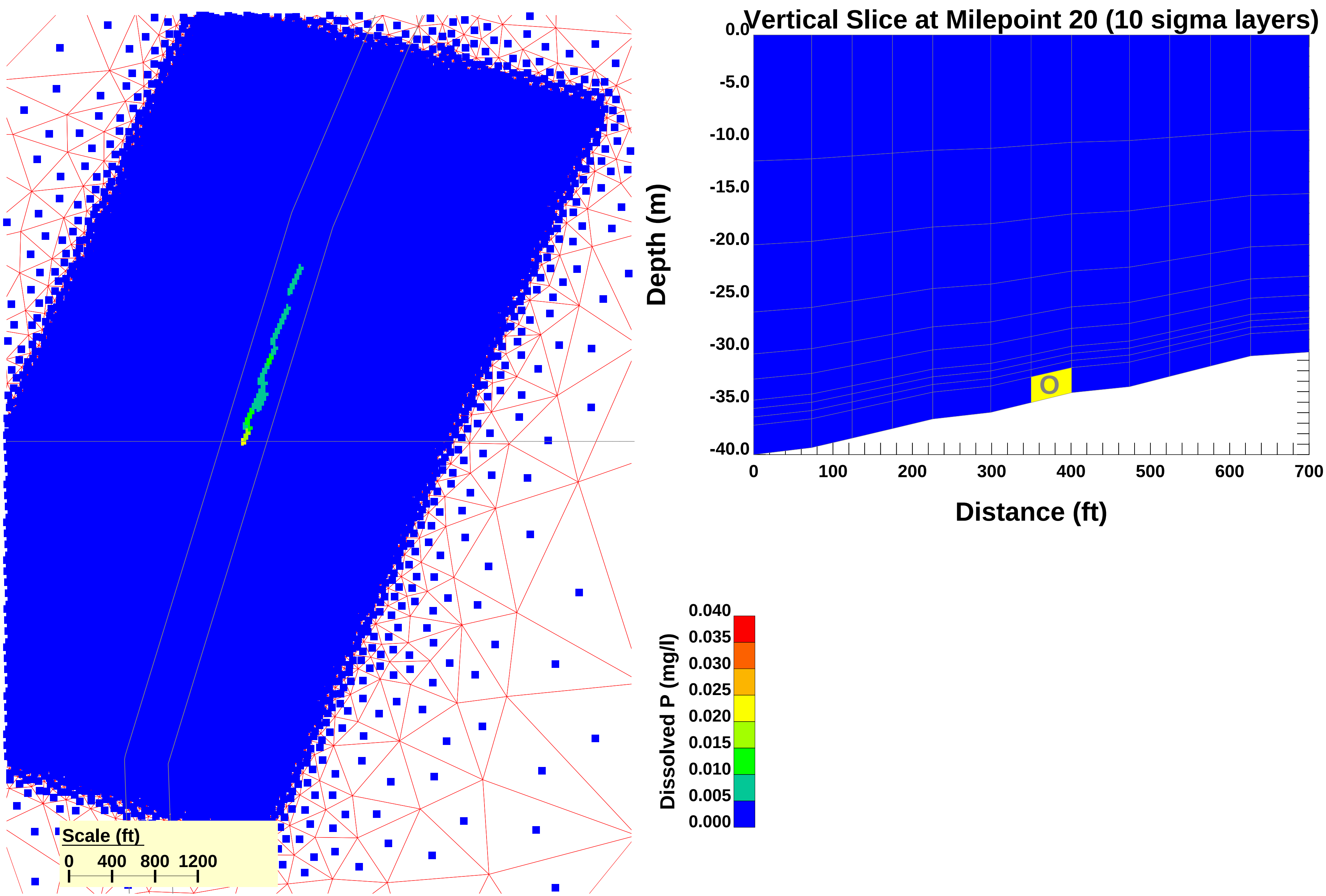


Figure 25. Lake Champlain Water Quality Model Calculated DP at MP20

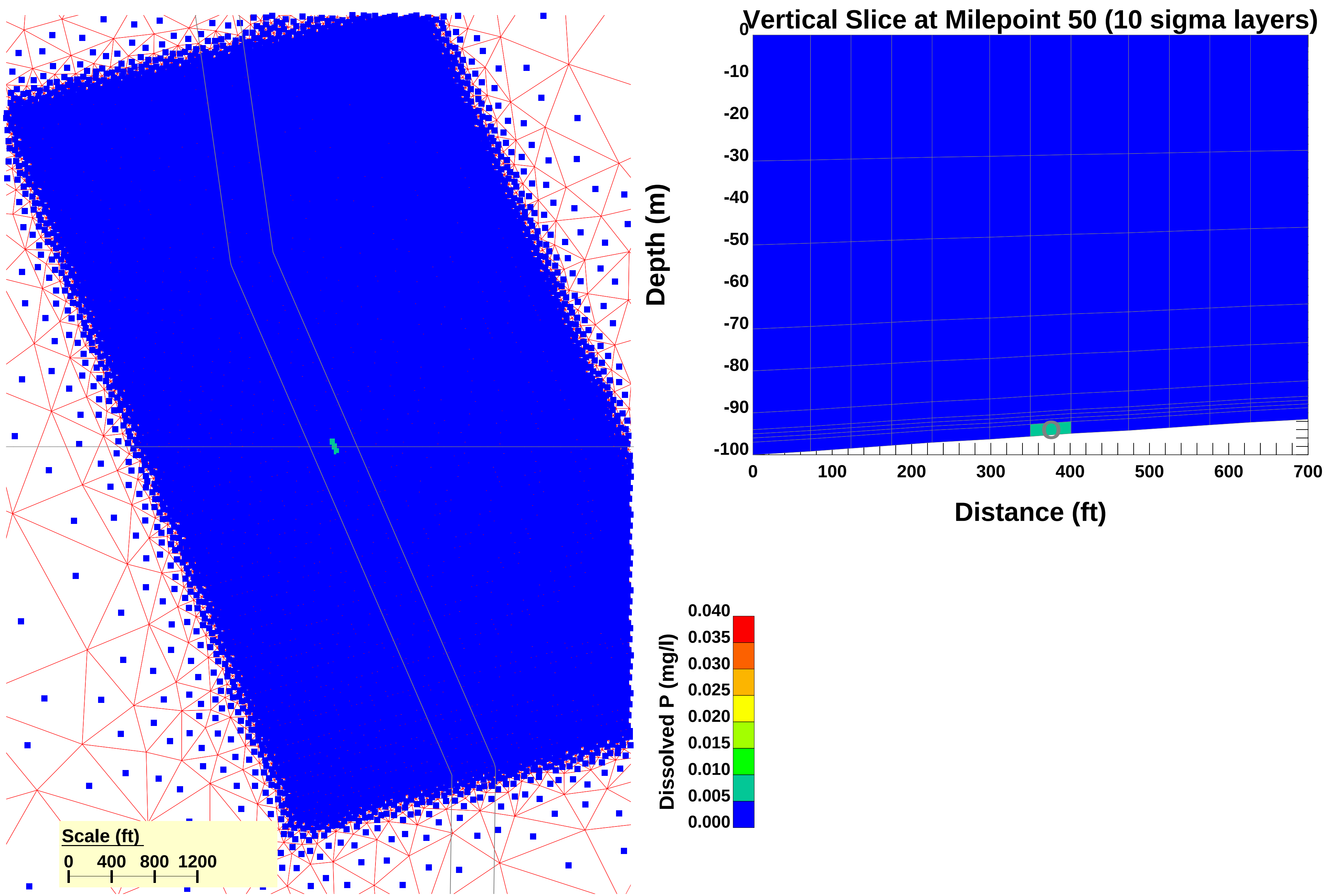


Figure 26. Lake Champlain Water Quality Model Calculated DP at MP50

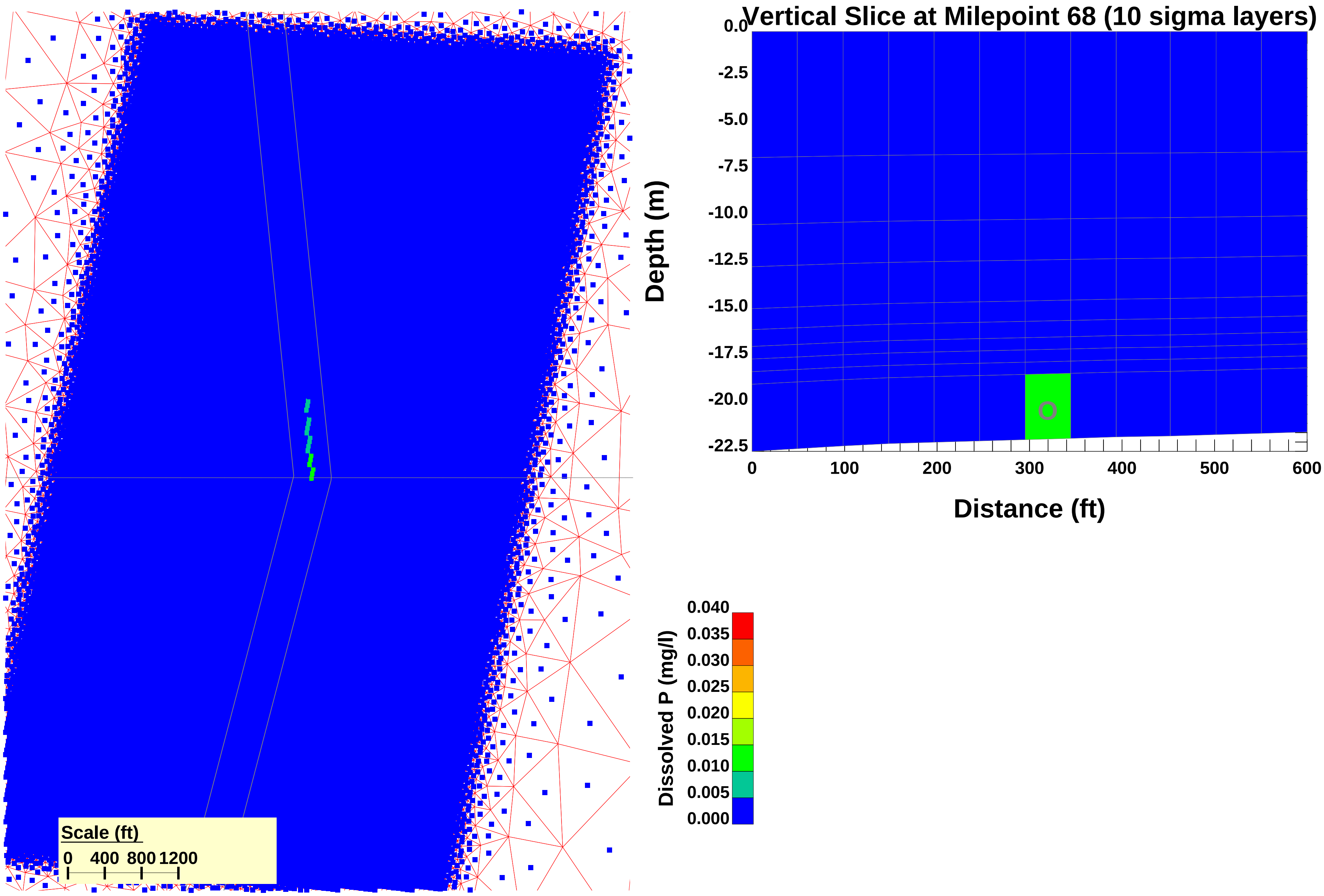


Figure 27. Lake Champlain Water Quality Model Calculated DP at MP68

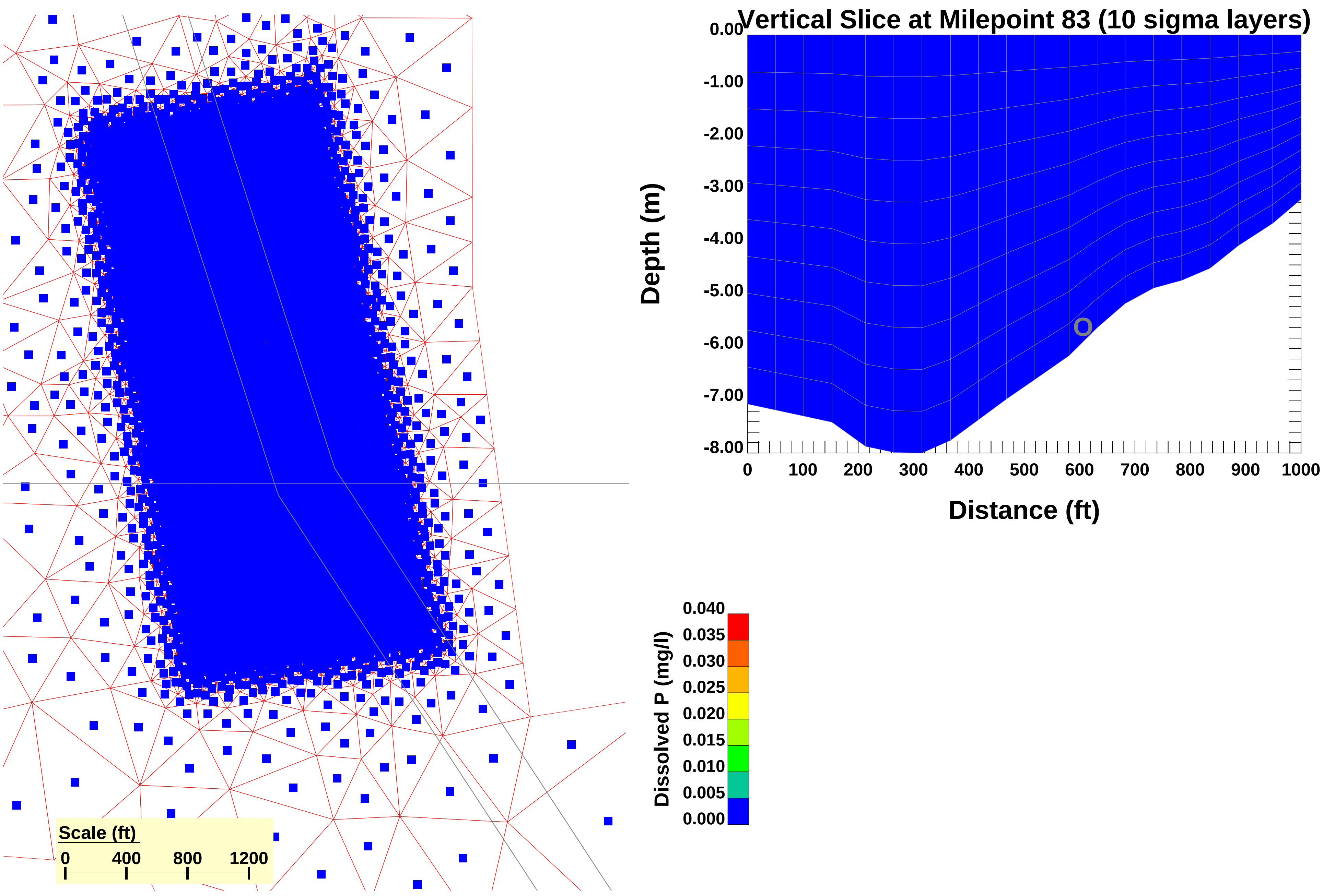


Figure 28. Lake Champlain Water Quality Model Calculated DP at MP83

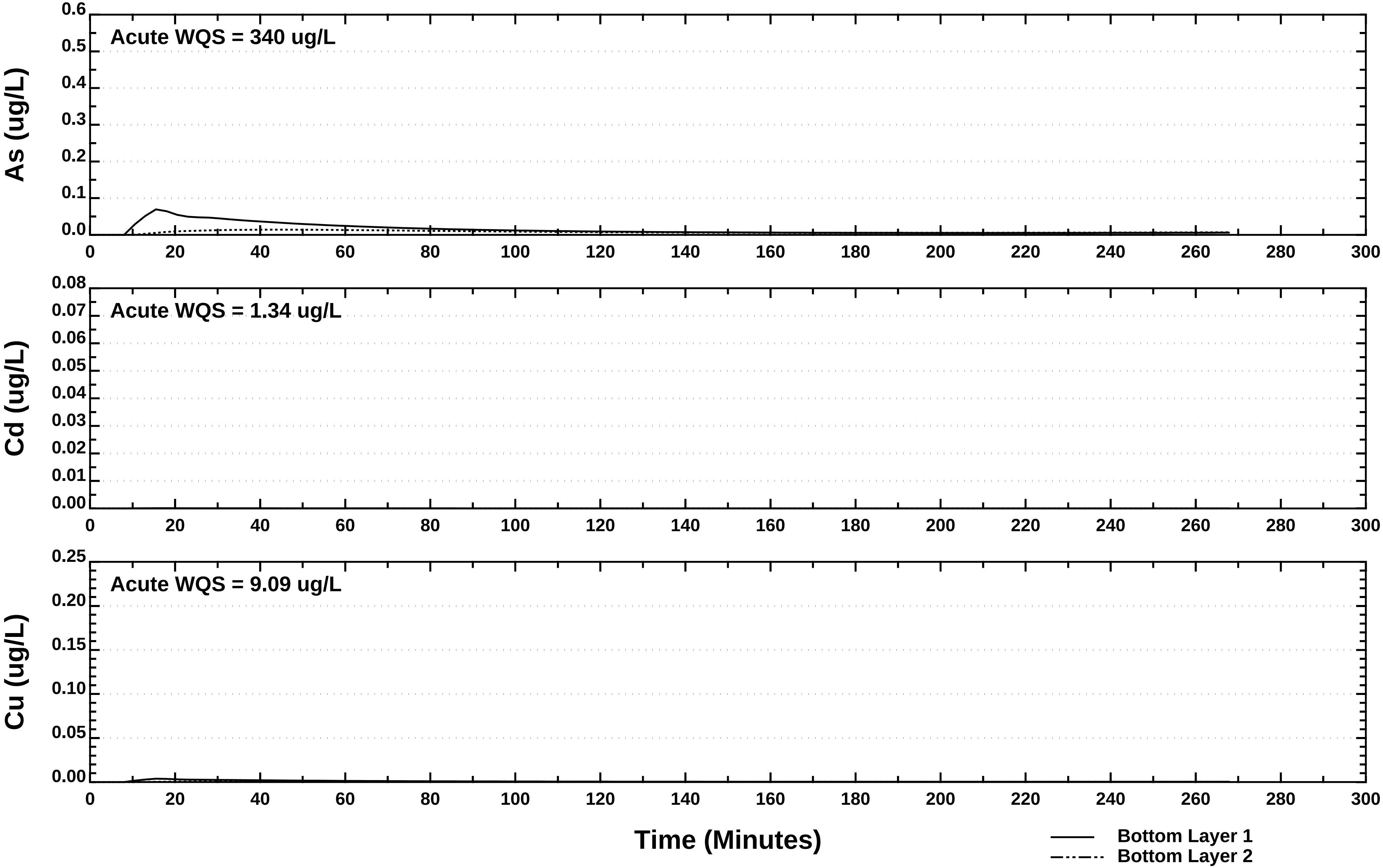


Figure 29. Lake Champlain Model Computed Concentrations - MP 6

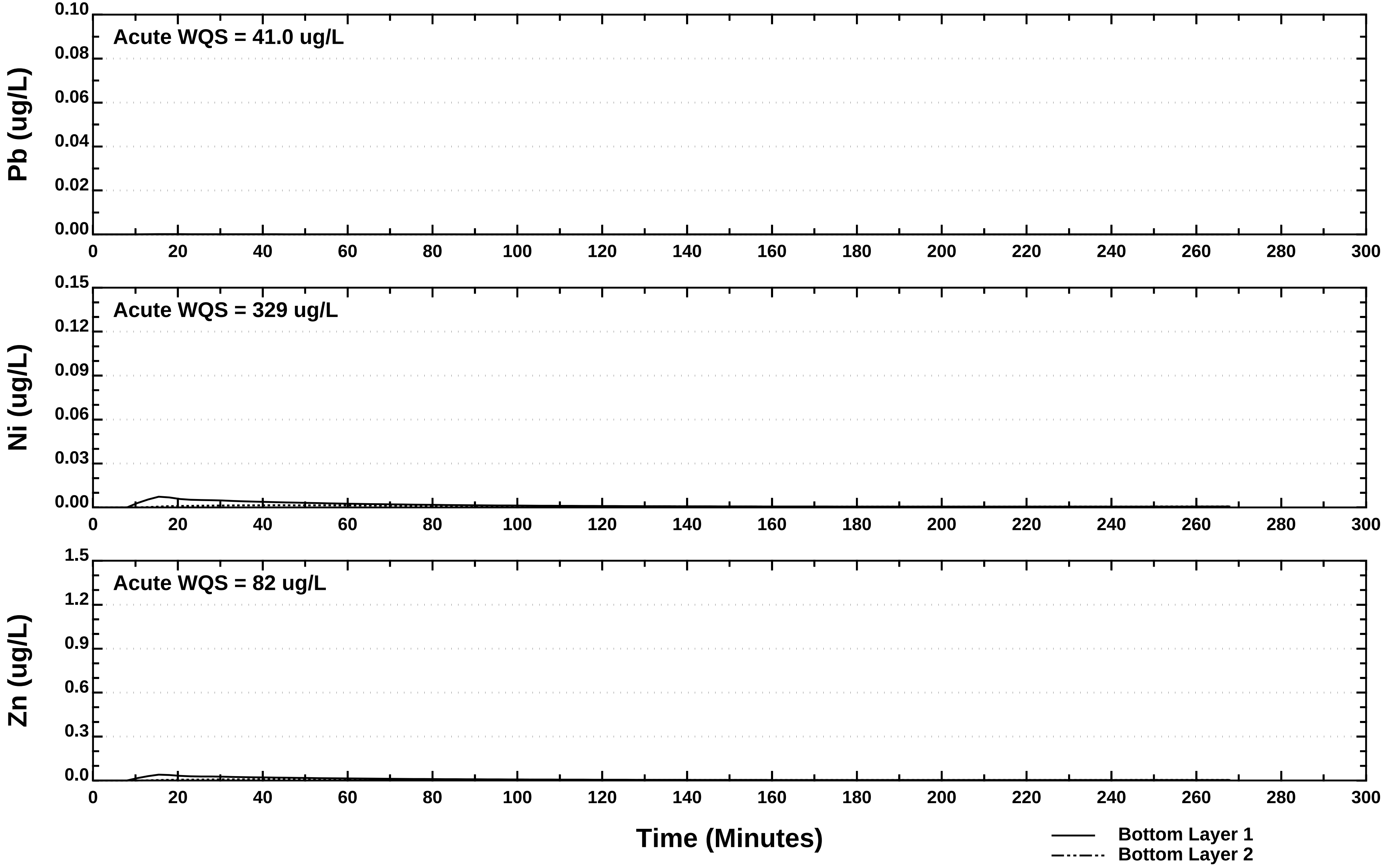


Figure 30. Lake Champlain Model Computed Concentrations - MP 6

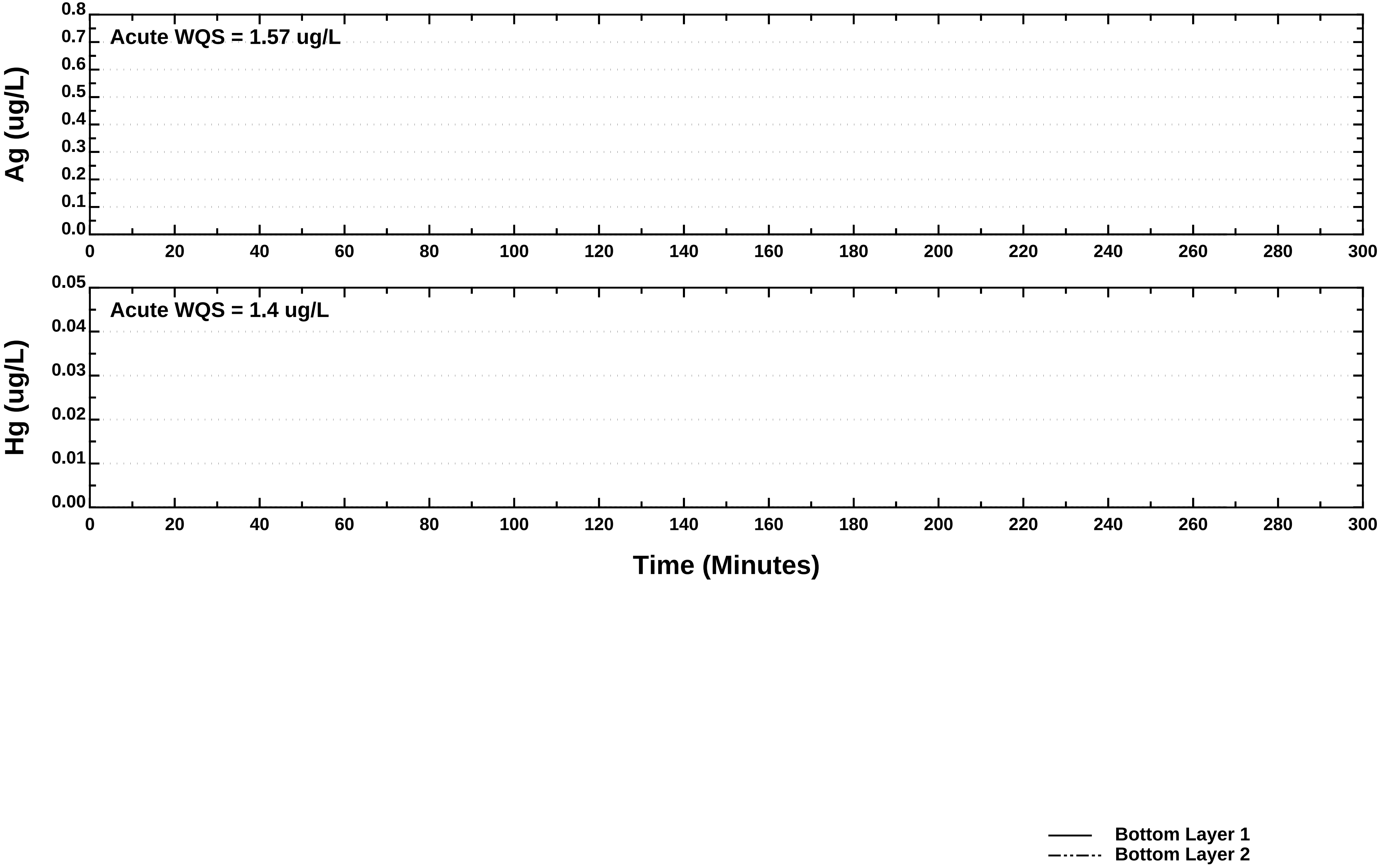


Figure 31. Lake Champlain Model Computed Concentrations - MP 6

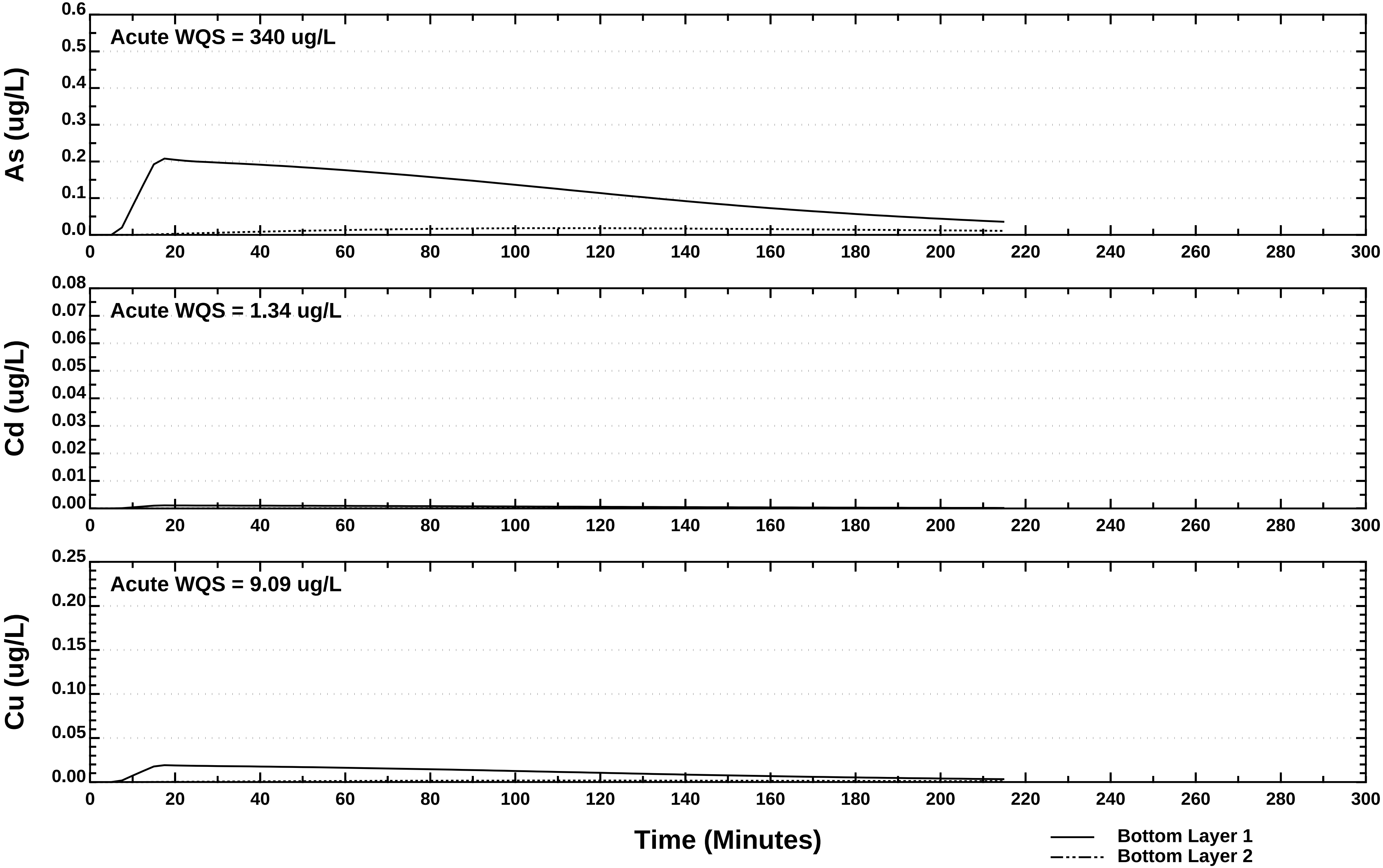


Figure 32. Lake Champlain Model Computed Concentrations - MP 20

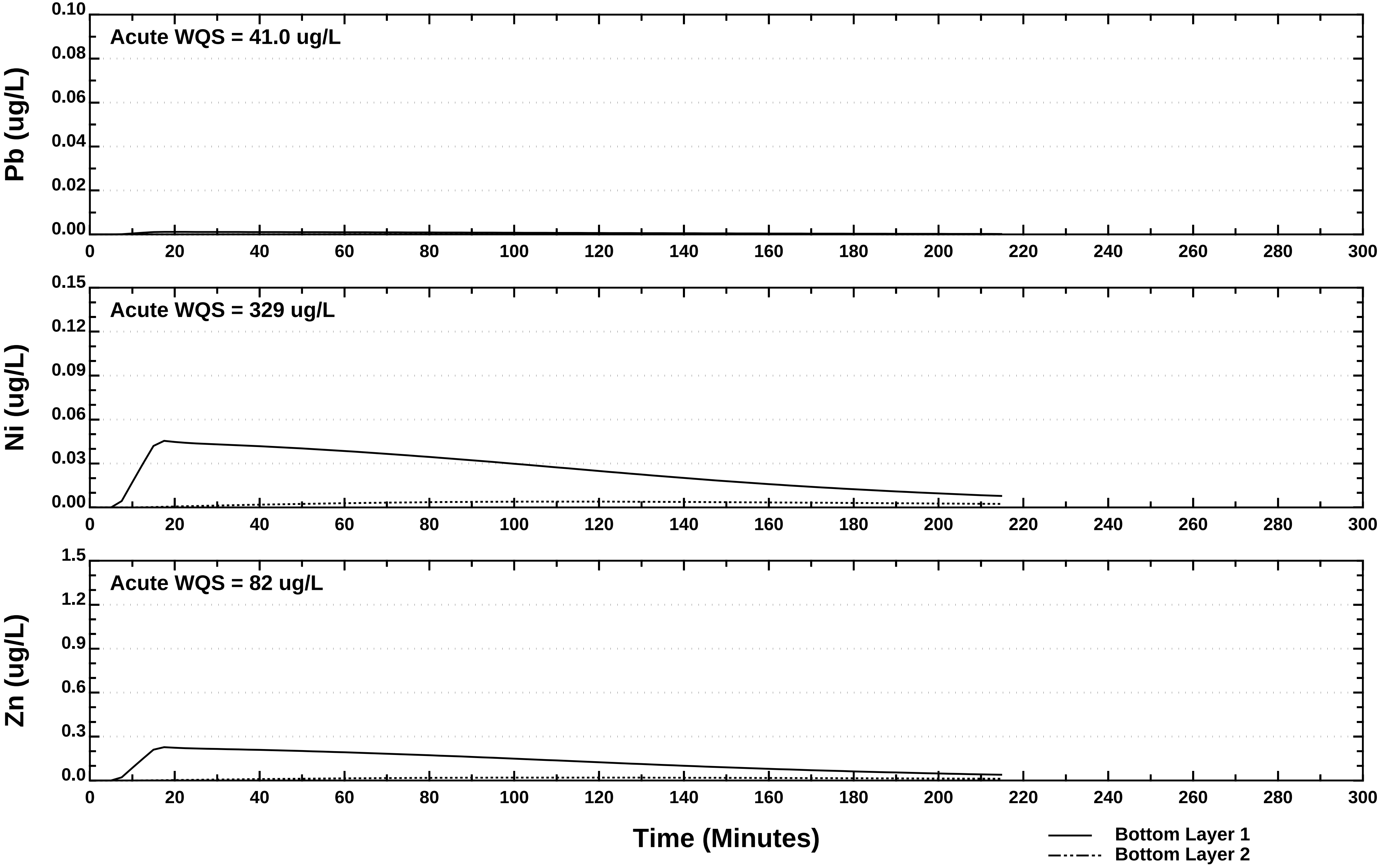


Figure 33. Lake Champlain Model Computed Concentrations - MP 20

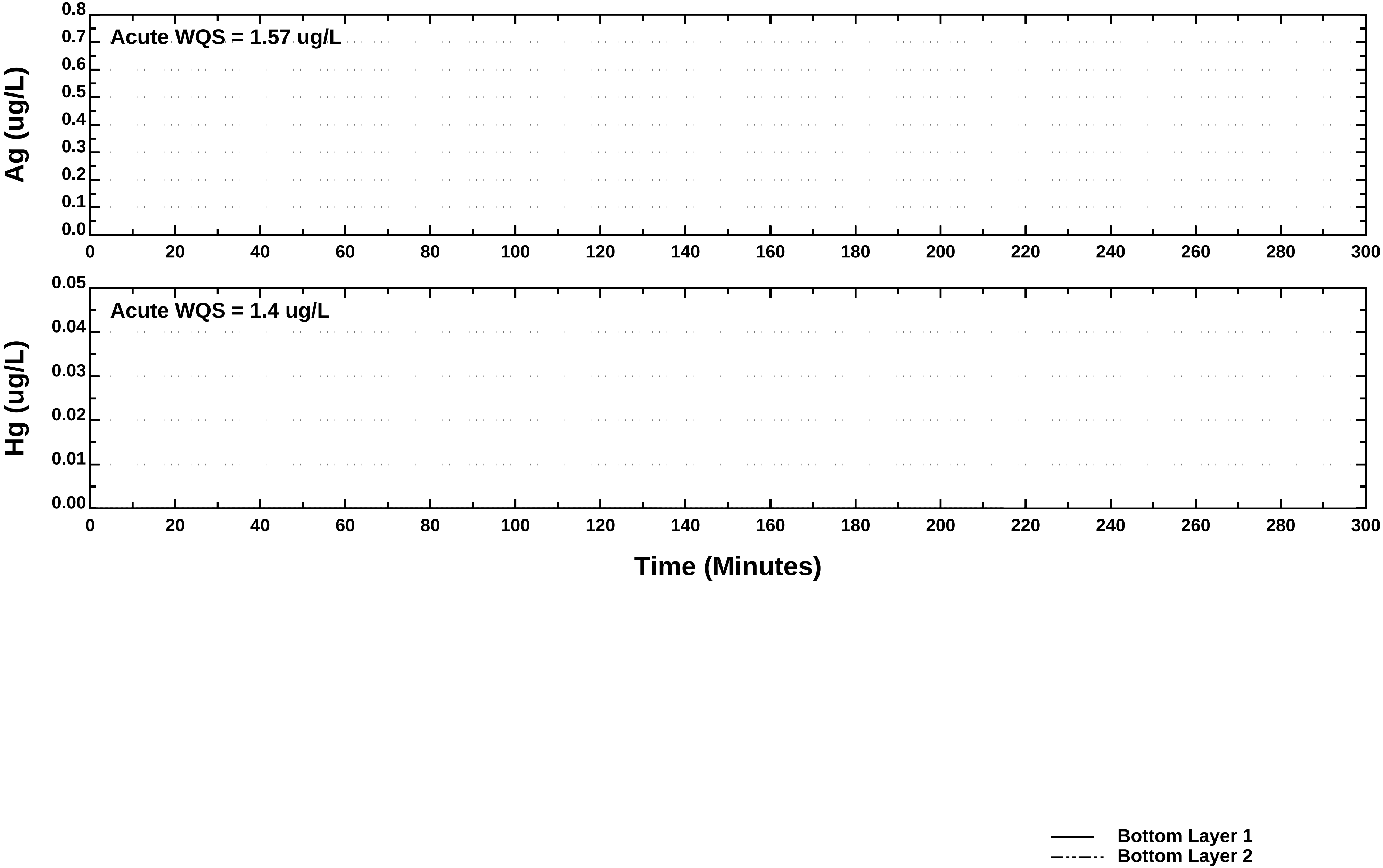


Figure 34. Lake Champlain Model Computed Concentrations - MP 20

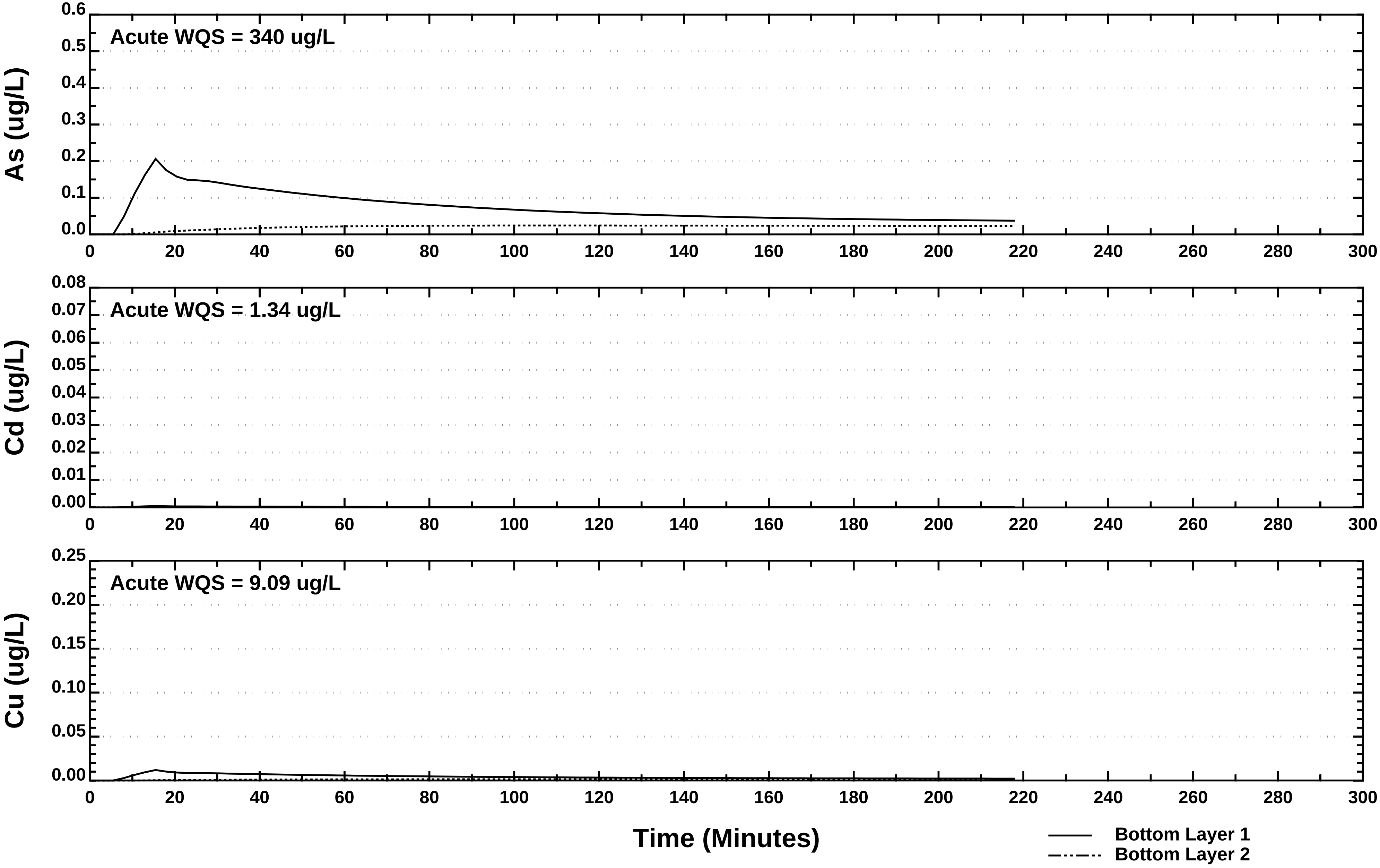


Figure 35. Lake Champlain Model Computed Concentrations - MP 50

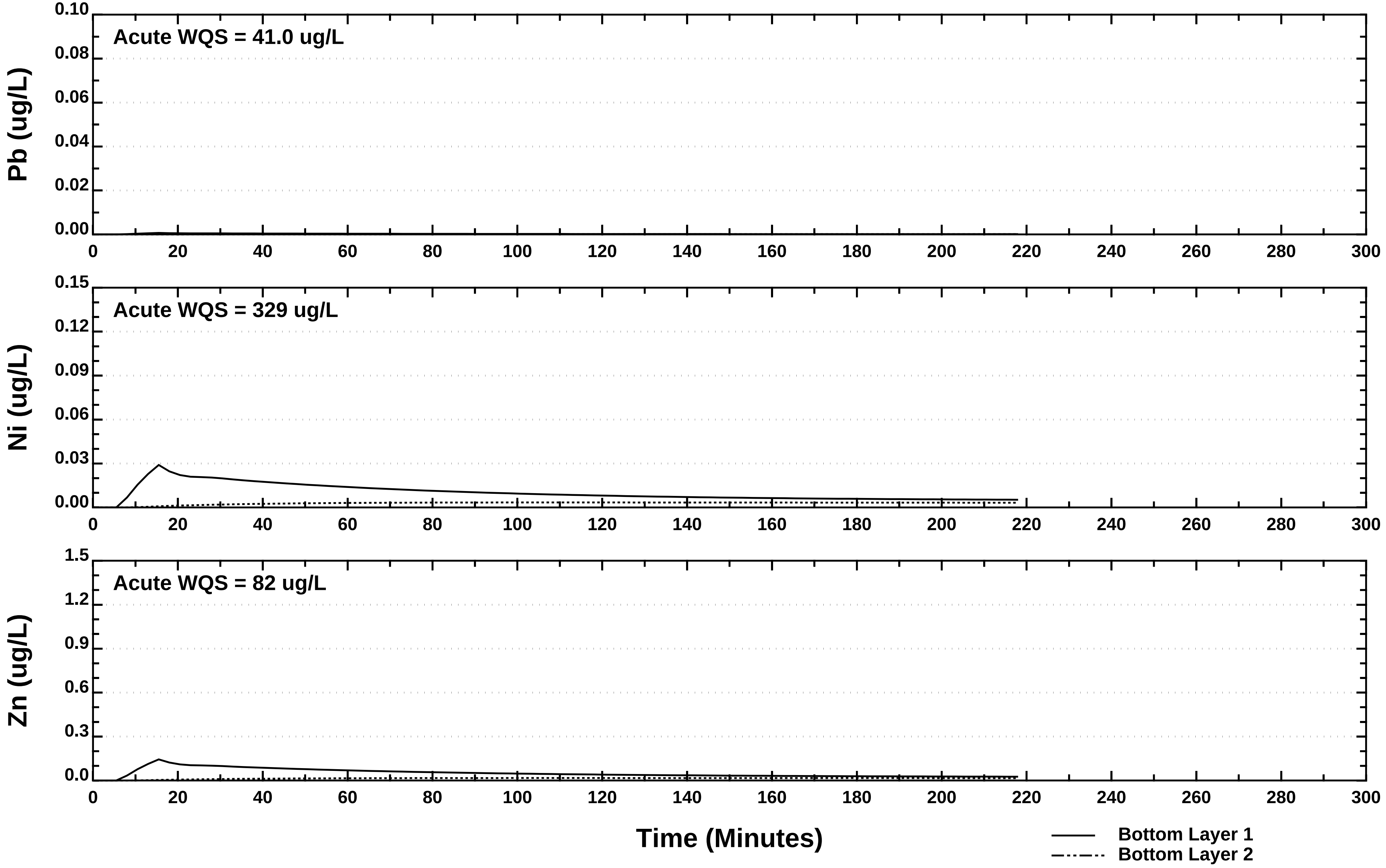


Figure 36. Lake Champlain Model Computed Concentrations - MP 50

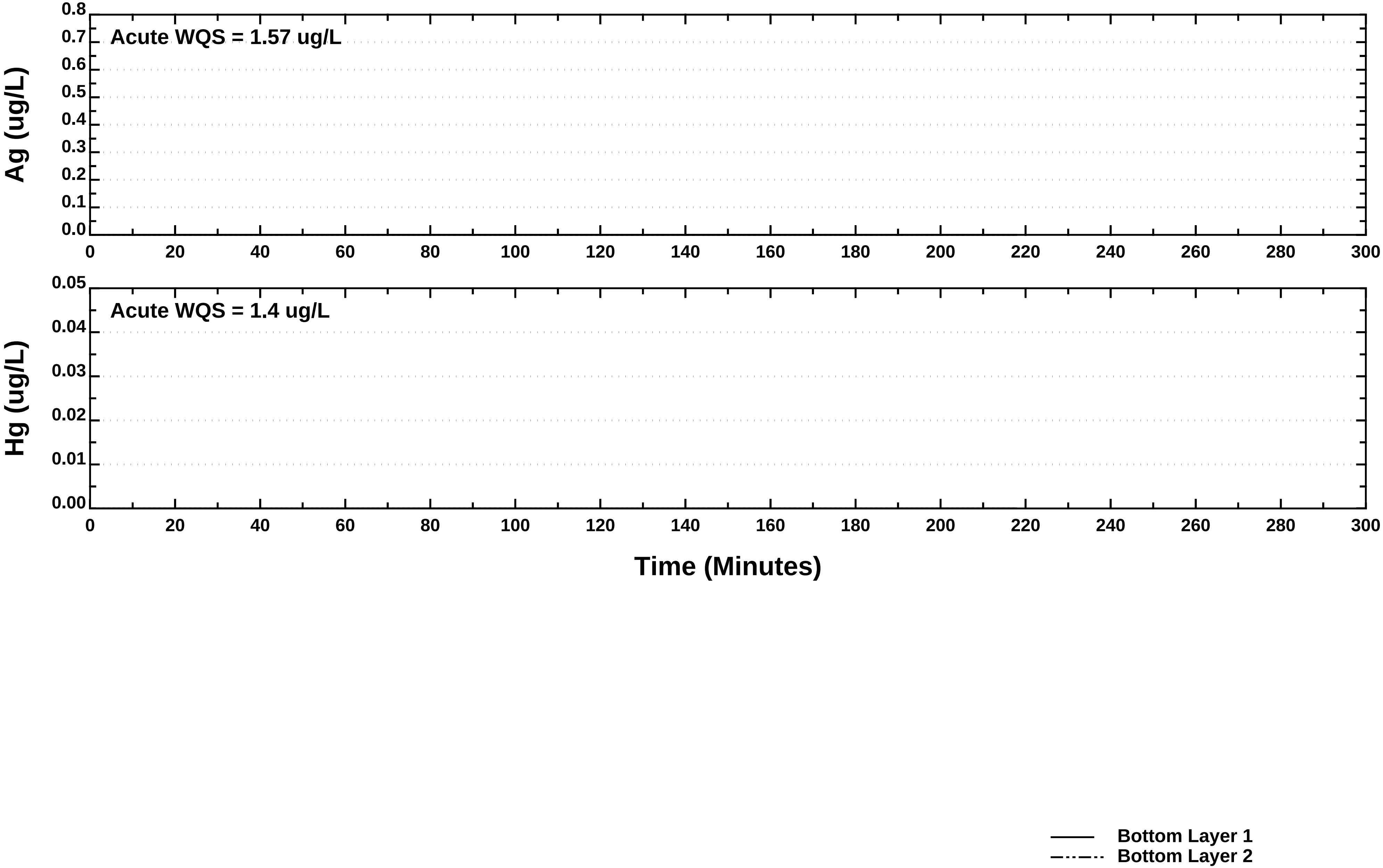


Figure 37. Lake Champlain Model Computed Concentrations - MP 50

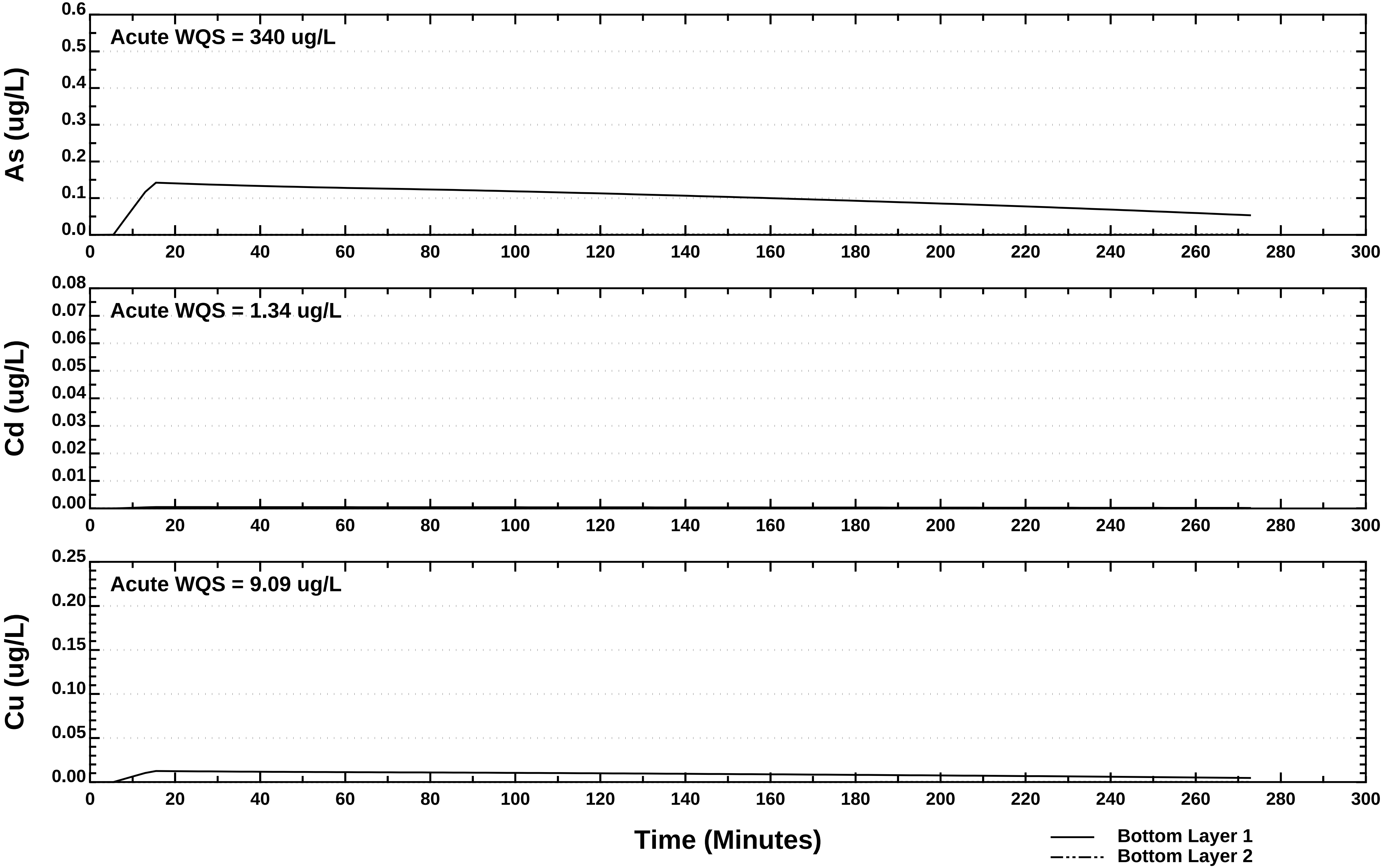


Figure 38. Lake Champlain Model Computed Concentrations - MP 68

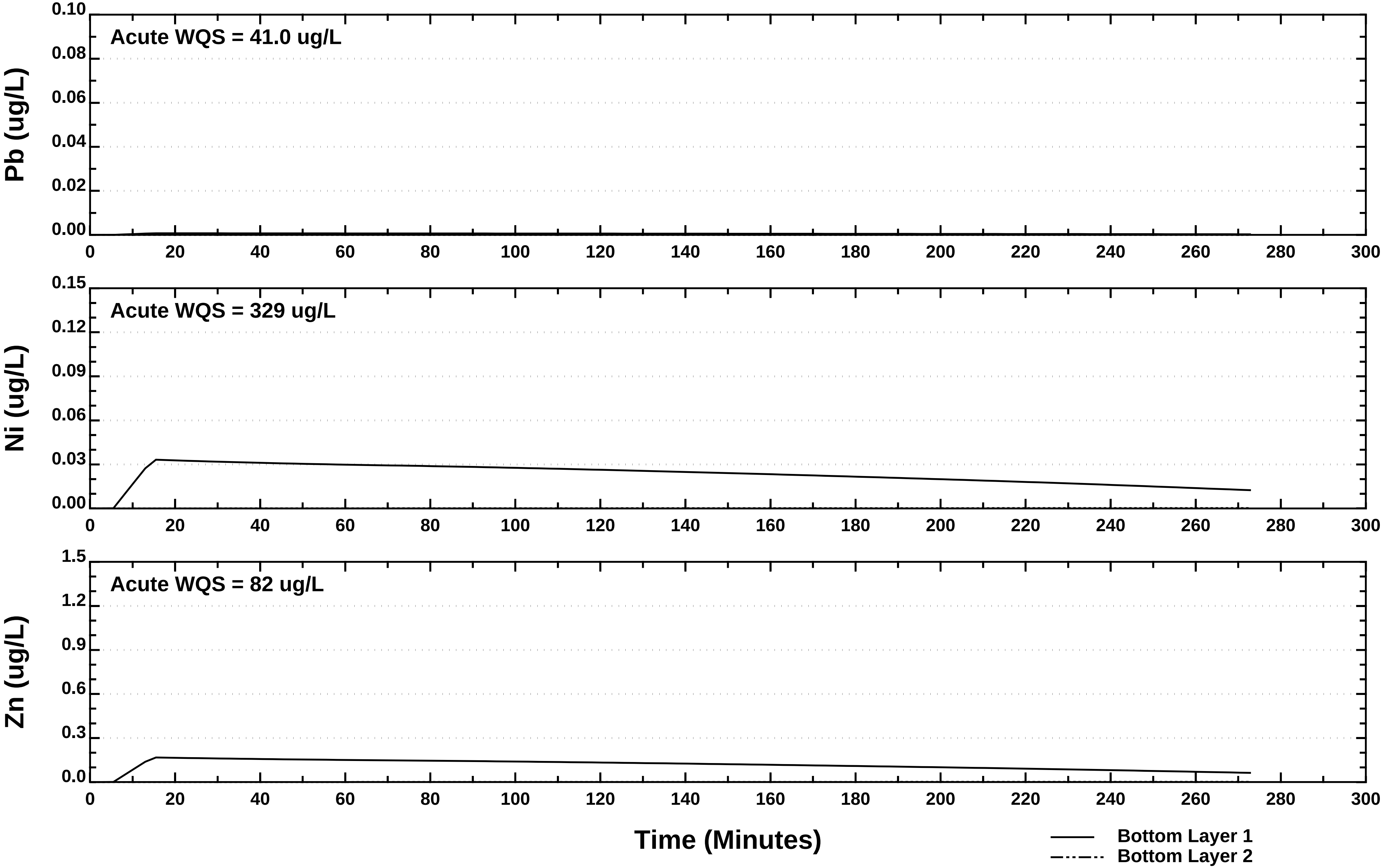


Figure 39. Lake Champlain Model Computed Concentrations - MP 68

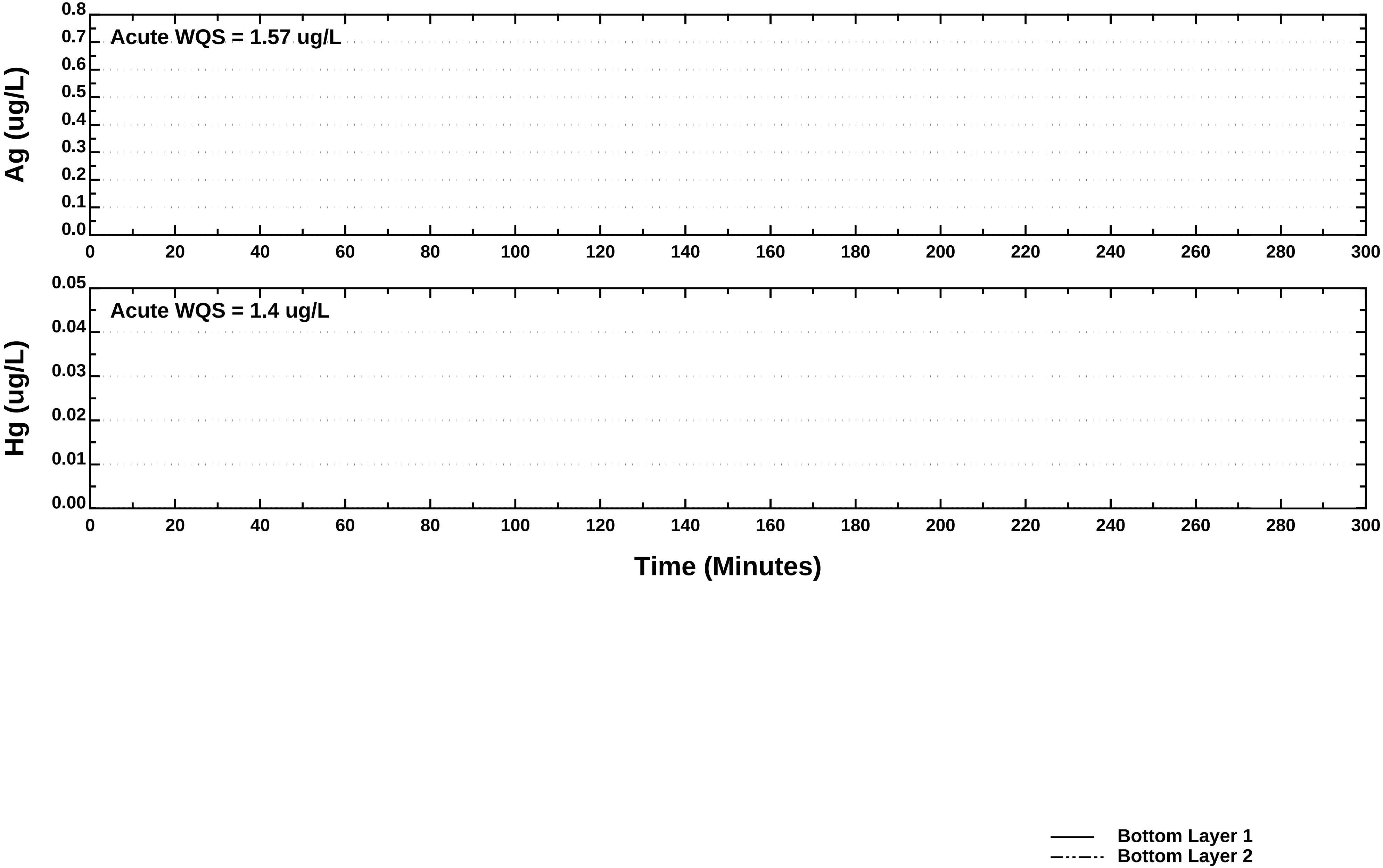


Figure 40. Lake Champlain Model Computed Concentrations - MP 68

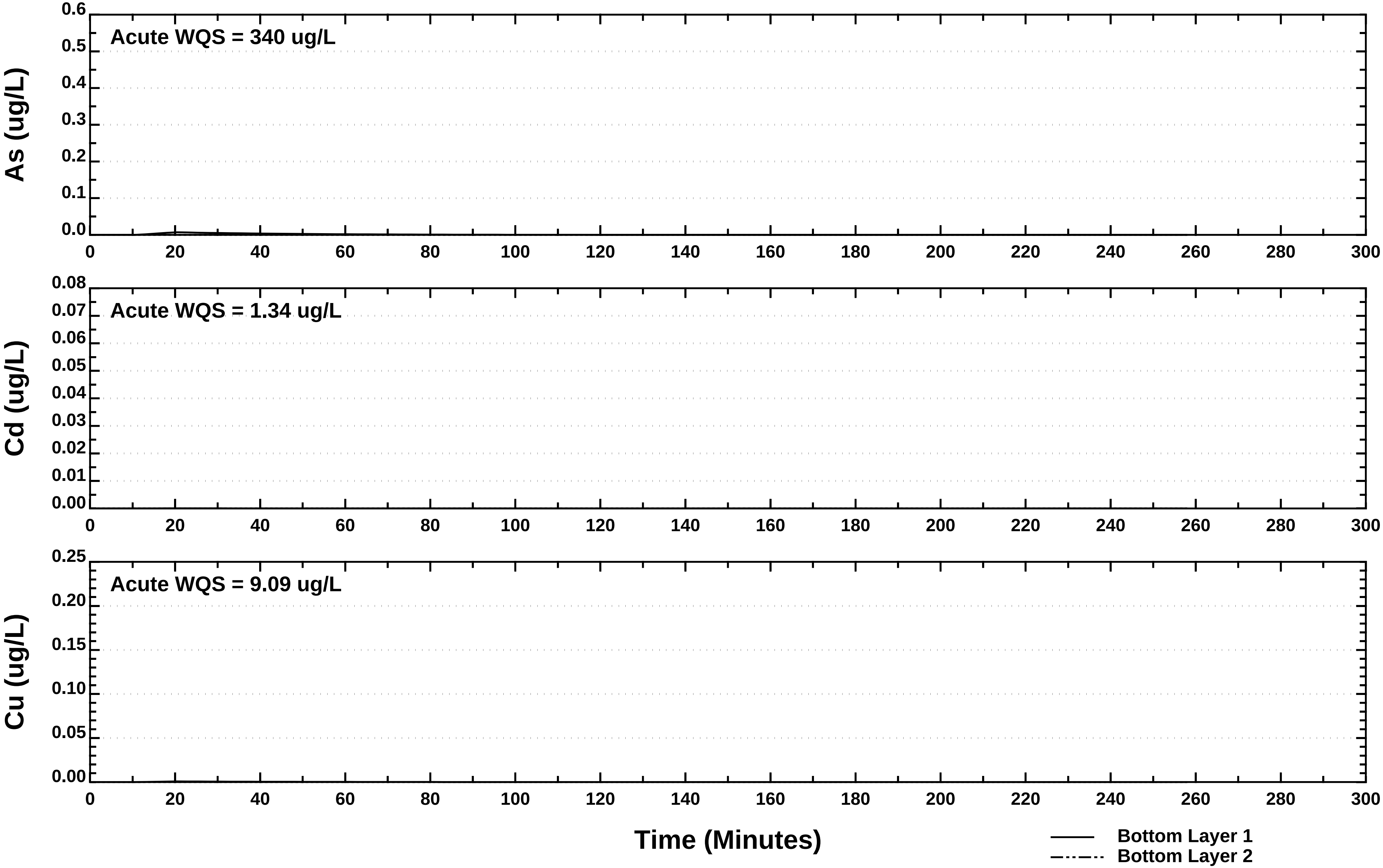


Figure 41. Lake Champlain Model Computed Concentrations - MP 83

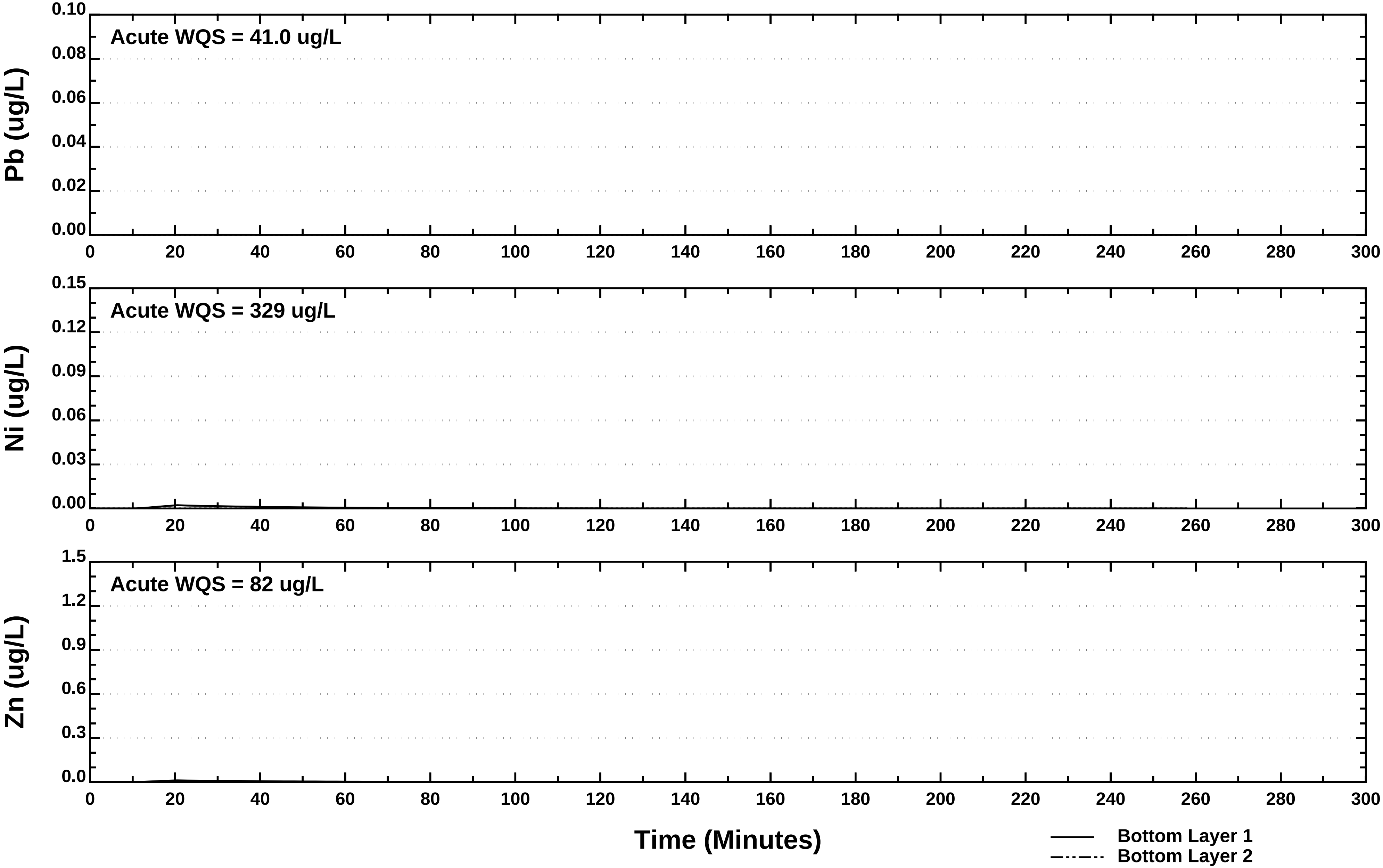


Figure 42. Lake Champlain Model Computed Concentrations - MP 83

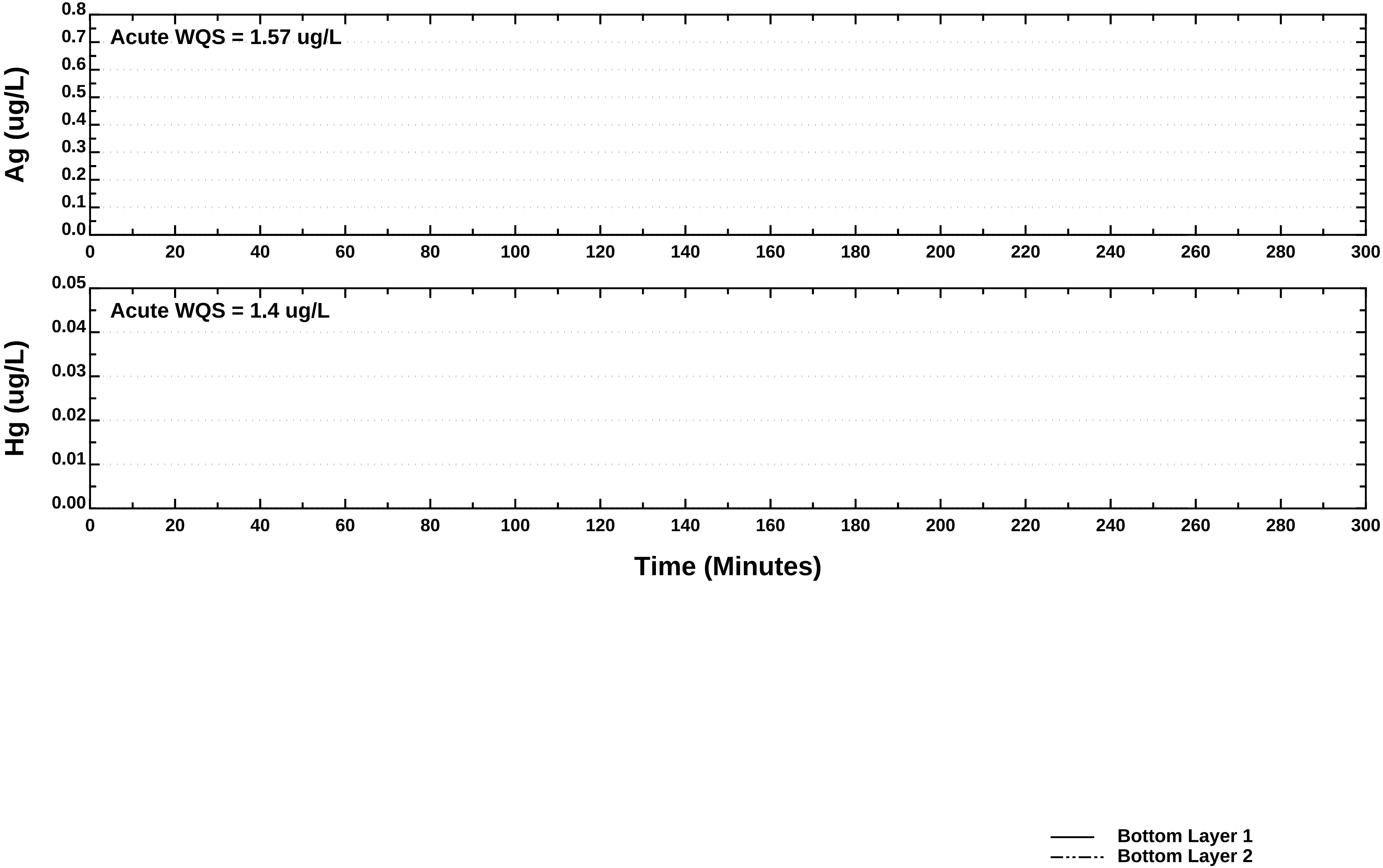


Figure 43. Lake Champlain Model Computed Concentrations - MP 83

5 Conclusions

A water quality model of Lake Champlain was developed to assess the potential water quality impacts associated with the resuspension of lake sediments during NECPL cable installation. These potential water quality impacts are associated with the re-introduction of existing sediments during cable installation and do not represent a new source to the lake. The water quality modeling was completed to show the concentration increases associated with the cable installation at five representative locations for the following parameters: TSS; TP; DP; arsenic; cadmium; copper; lead; nickel; zinc; silver; and mercury.

The results from the water quality modeling have shown that minimal water quality impacts are associated with the cable installation in Lake Champlain. Specific conclusions reached from the water quality modeling are presented below.

- At all five of the representative locations, the model calculated TSS concentration increases due to the cable installation are less than 3 mg/L above observed background lake TSS levels at 200 feet from the point of installation and within one to three meters of the lake bottom. The model calculated TSS concentration increases reach a temporary peak concentration at the point of installation and then decrease rapidly. The time to reach a TSS concentration increase of 100 mg/L is on the order of one hour and to reach 3 mg/L above background TSS levels is on the order of one to four hours.

- At all five of the representative locations, the model calculated temporary TP and DP concentration increases due to the cable installation are less than 0.01 mg/L above observed background lake TP and DP levels at 200 feet from the point of installation and within one to three meters of the lake bottom. The model calculated temporary TP and DP concentration increases reach a peak concentration at the point of installation and then decrease rapidly. The time to reach 0.01 mg/L above background TP and DP concentrations is on the order of one to four hours.

- The DP mass re-introduced during cable installation represents less than 0.01% of the total external annual phosphorus inputs based on loadings rates from 1991-2008. It should be noted that the cable installation does not represent a new source to the lake but rather represents the re-introduction of existing sediment sources into the water column on a short term basis.

- The potential DP increase in both the euphotic zone and surface mixed layer along the cable route (i.e., excluding the northeast arm (Missisquoi Bay, St. Albans Bay, Malletts Bay) and the southern part beyond MP97) is less than 0.009 µg/L (or less than 0.1% of existing DP levels in the lake). This analysis could be considered conservative because it assumes that the DP mass re-introduced from the sediments into the bottom of the lake can completely transfer into the surface layer of the lake considering that the thermocline represents a barrier to vertical mass transport in the lake.

- All model calculated dissolved metals concentration increases are less than the associated MDLs and much less than applicable acute and chronic dissolved VWQS. Therefore, water quality impacts associated with the eight metals (arsenic, cadmium, copper, lead, nickel, zinc, silver and mercury) due to the installation of the cable in Lake Champlain are expected to be in compliance with applicable VWQS.

- All of the sediment PCB data available have been reported as below the MDL and, therefore, water quality impacts associated with PCB resuspension is not expected.

- Overall, the water quality impact assessment completed is conservative in nature due to the following assumptions used in the water quality modeling:

    - At depths greater than 150 feet the cable will be installed by placing the cable on the bottom of the lake without the use of either a jet-plow or shear-plow installation method, which results in minimal disturbance of the lake sediments and represents approximately 43% of the cable route. This portion of the cable route (43% of the overall length) was analyzed using the jet-plow installation method, which significantly over estimates the resuspension source and, therefore, represents a conservative assessment of potential water quality impacts in Lake Champlain.

    - After review and comment by VTANR staff on the sediment concentration data to be used in the modeling, the VTANR recommended doubling the sediment concentrations in the deeper areas of the lake to reflect the significant separation between the NY route studied in the Marine Route Survey Report and the proposed VT route. This increase in the sediment concentrations and the associated resuspension source represents a conservative assumption included in the water quality modeling.

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