Lake Champlain Long-Term Water Quality and Biological Monitoring Program

Program Description

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Program Background and Purpose

The Lake Champlain Long-Term Water Quality and Biological Monitoring Program began in 1992 and has continued each year since then. The project is conducted by the Vermont Department of Environmental Conservation (DEC) and the New York State DEC, with funding provided by the Lake Champlain Basin Program and the two states.

The current monitoring program grew from the Lake Champlain Diagnostic-Feasibility Study conducted by Vermont DEC and New York State DEC (1997). The Diagnostic-Feasibility Study focused primarily on the measurement of phosphorus and chloride concentrations in the lake and its tributaries to support a phosphorus loading budget and mass balance model for Lake Champlain. The Diagnostic-Feasibility Study also provided vertical water column profile data on several other water quality measurements at deep-water stations. The present long-term monitoring project continued sampling a subset of the lake and tributary station network that was established for the previous Lake Champlain Diagnostic-Feasibility Study, and extended the program to include a broader range of chemical and biological measurements.

The purposes, scope, and methods for the current monitoring project are described in annual work and quality assurance project plans, approved by the U.S. Environmental Protection Agency. One of the original purposes of the program was to provide a current limnological survey of Lake Champlain, including a data set that would support the development of hydrodynamic, eutrophication, and food web models for the lake (e.g., Applied Science Associates, Inc.1996, Levine *et al.*1997, HydroQual, Inc. 1995). The primary purpose of the project was redefined in 1995 to be the detection of long-term environmental change in the lake, and the sampling program was modified to more efficiently serve this purpose. The list of sampling variables was narrowed to include those lake and tributary constituents judged by the Lake Champlain Basin Program Technical Advisory Committee to be the most meaningful for assessing the long-term effects of management actions and other changes in the environment. Optimum sampling frequencies were determined from a statistical power analysis. The power analysis was conducted to ensure that sample sizes would be adequate, but not excessive, for the purpose of statistically documenting the anticipated magnitude of water quality changes in the lake and its tributaries over time.

The Technical Advisory Committee of the Lake Champlain Basin Program reviewed the program again in 2006-2007 and began to incorporate the concept of “ecological indicators” into the work plan. Criteria for these indicators require that they be ecologically and socially relevant, measurable, statistically sound, and interpretable (Watzin *et al.* 2005). Changes to the monitoring program were implemented to more closely align sampling parameters and methodology with ecological indicators to provide quantifiable measures of overall ecosystem health. This is an on-going process and the sampling program will continue to incorporate elements of the ecological indicators program over the next several years.

The project data are stored in a computerized database and are freely available on request and on the Internet to researchers, management agencies, consultants, students, and the general public. The purpose of this report is to describe the project methods and document the database for users of the data.

Sampling and Analytical Methods

Detailed descriptions of the field sampling and analytical methods and quality assurance procedures can be found in the annual Work and Quality Assurance Project Plan (New York State DEC and Vermont DEC 2007). A brief summary of methods is provided here.

The sampling station network includes the core set of 15 lake stations and 21 tributary stations shown in Figure 1 and listed in Table 1. The tributary stations are located as near to the river mouths as possible on rivers which have continuous flow gages operated by the U.S. Geological Survey (USGS) or the Quebec Ministry of Sustainable Development, Environment, and Parks (MDDEP). These lake and tributary stations have been sampled consistently during the entire monitoring period since 1992, with the exception of lake stations 9 and 16 which were added in 2001, and station 51 which was added in 2006. The sampling station on Rock River was added in 2007, and sites on Stevens Brook and Jewett Brook were added late in 2008. Other lake stations listed in Vermont DEC and New York State DEC (1997) have been sampled during short-term surveys for a limited number of water quality measurements.

The 15 core lake stations are sampled for most chemical tests using Kemmerer or Van Dorn water bottle devices, with discrete depth samples combined to form vertical water column composites. The lake stations are sampled approximately biweekly from May to early November each year. When thermal stratification exists, composite samples (composed of 2-3 discrete-depth samples) are obtained from both the epilimnion and hypolimnion layers. Temperature and dissolved oxygen concentrations are measured in vertical profile at discrete depths at the deeper stations. Chlorophyll-a is sampled as a vertically integrated composite of the photic zone, defined as twice the Secchi disk depth.

Quantitative biological sampling in the lake for phytoplankton, zooplankton, and mysids is conducted concurrently with the water quality sampling. Beginning in 2006, net phytoplankton and zooplankton have been sampled biweekly. Mysids are sampled monthly, six months per year. Zooplankton and mysid samples are analyzed at the Lake Champlain Research Institute (SUNY-Plattsburgh) under contract with the New York State DEC. Beginning in 2006, phytoplankton samples have been analyzed by the Vermont DEC.

Close-interval, *in situ* vertical profiles for temperature, dissolved oxygen, pH, specific conductance, total dissolved solids, turbidity, and reduction-oxidation potential are obtained at some sites in the lake using a multi-probe sonde unit. Since 2006, close-interval profiles have been collected for temperature, dissolved oxygen, pH, and specific conductance during most site visits using a multi-probe sonde unit (Hydrolab, Inc.1991, 2006).

Tributary samples are obtained from bridges using depth and velocity-integrating sampling devices. An effort is made to obtain up to 20 samples per year at each tributary site, including as high a proportion of samples as possible during high flow conditions in order to improve the precision of tributary annual mass loading estimates (Vermont DEC and New York State DEC 1997). Beginning in 2006, four additional collections during base flow conditions were added to the workplan.

A list of the tests sampled in the lake and the tributaries and the current chemical analytical methods is given in Table 2. During the period of this program, chemical analyses have been conducted by the Vermont DEC Laboratory, the New York State Department of Health Laboratory, and other private contracted laboratories in New York. In some cases, samples were split in the field and analyzed concurrently at laboratories in both states. Currently, all samples

are analyzed at the Vermont DEC Laboratory only. Care should be taken by data users when combining results of samples analyzed at different laboratories. A previous analysis of paired samples (Vermont DEC and New York State DEC 1998) revealed small but statistically significant differences between the results obtained by the different laboratories for many of the tests. The laboratory where each sample was analyzed (VT or NY) is recorded in the project database.

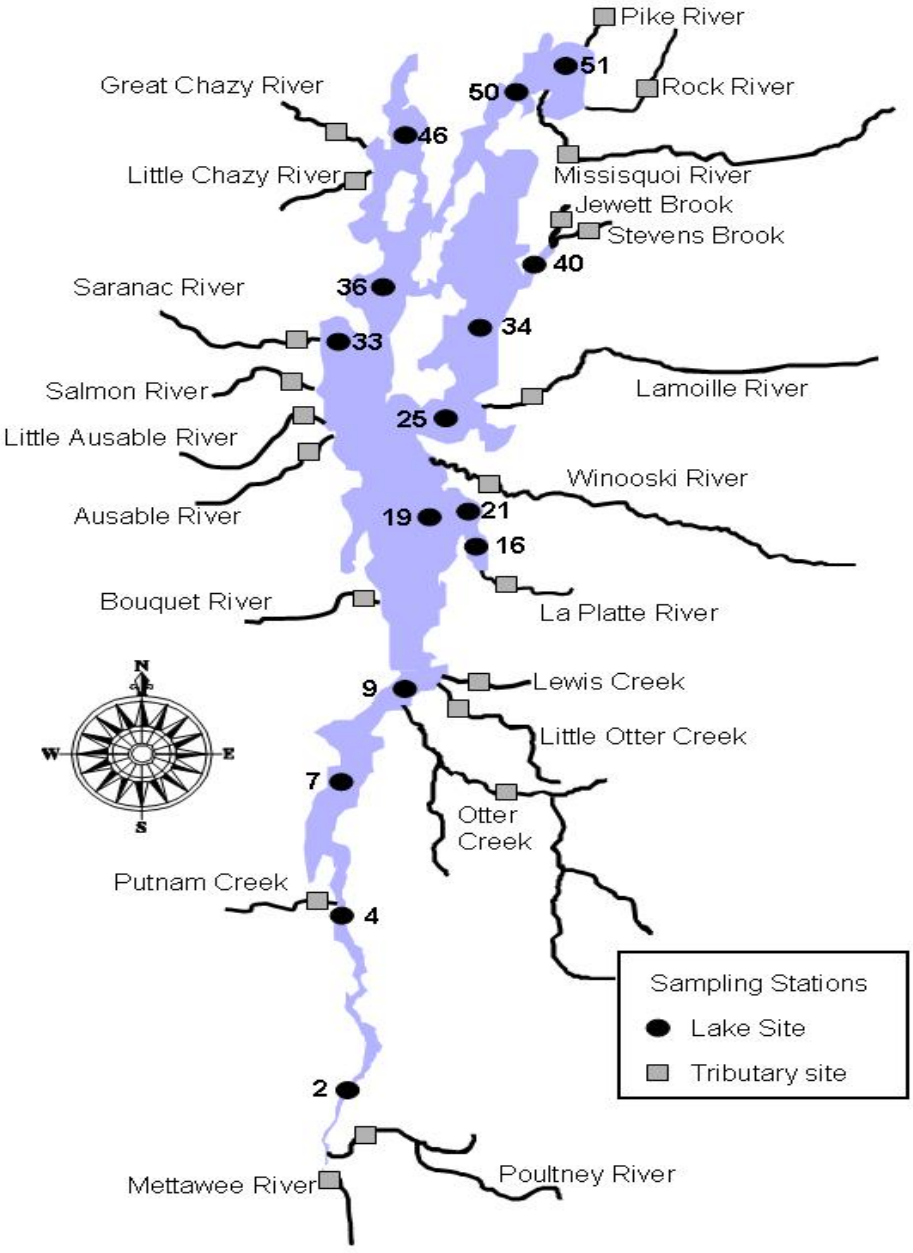

Figure 1. Lake and tributary sampling sites.

Table 1. List of lake and tributary sampling stations and their locations. The station codes used in the database for the tributary stations are given in parentheses.

Lake Station	Latitude N	Longitude W	Tributary Station	Latitude N	Longitude W
2	43° 42.89'	73° 22.98'	Winooski (WINO01)	44° 31.52'	73° 15.41'
4	43° 57.10'	73° 24.47'	Otter (OTTE01)	44° 09.94'	73° 15.40'
7[1]	44° 07.56'	73° 24.77'	Missisquoi (MISS01)	44° 55.23'	73° 07.63'
9	44° 14.53'	73° 19.75'	Lamoille (LAMO01)	44° 37.96'	73° 10.39'
16[1]	44° 25.55'	73° 13.92'	Poultney (POUL01)	43° 34.24'	73° 23.53'
19	44° 28.26'	73° 17.95'	Pike (PIKE01)	45° 07.38'	73° 04.18'
21	44° 28.49'	73° 13.90'	Lewis (LEWI01)	44° 14.80'	73° 14.77'
25	44° 34.92'	73° 16.87'	Little Otter (LOTT01)	44° 12.24'	73° 15.11'
33	44° 42.07'	73° 25.09'	LaPlatte (LAPL01)	44° 22.21'	73° 13.01'
34	44° 42.49'	73° 13.61'	Saranac (SARA01)	44° 41.52'	73° 27.19'
36	44° 45.37'	73° 21.30'	Ausable (AUSA01)	44° 33.63'	73° 26.95'
40	44° 47.12'	73° 09.73'	Mettawee (METT01)	43° 33.33'	73° 24.10'
46	44° 56.90'	73° 20.40'	Great Chazy (GCHA01)	44° 58.81'	73° 25.96'
50	45° 00.80'	73° 10.43'	Bouquet (BOUQ01)	44° 21.84'	73° 23.41'
51[2]	45° 02.50'	73° 07.78'	Little Ausable (LAUS01)	44° 35.65'	73° 29.79'
			Salmon (SALM01)	44° 38.40'	73° 29.70'
			Putnam (PUTN01)	43° 57.35'	73° 25.99'
			Little Chazy (LCHA01)	44° 54.12'	73° 24.88'
			Rock River (ROCK02)[3]	44° 59.49'	73° 04.22'
			Stevens Brook (STEV01)[4]	44° 50.95	73° 07.15’
			Jewett Brook (JEWE02)[4]	44° 51.37’	73° 09.06’

[1] Added in 2001.
[2] Added in 2006.
[3] Added in 2007.
[4] Added in 2008.

Table 2. List of current analytical methods for tests included in the project database.

Measurement	Test Code	Reporting Units	Method Reference[3]	Method Number
Total Phosphorus	TP	µg/L	APHA (1998)	4500-P H
Dissolved Phosphorus	DP	µg/L	APHA (1998)	4500-P H
Ortho-Phosphorus[1]	OP	µg/L	USEPA (1983)	365.1
Chloride	TCl	mg/L	APHA (1998)	4500-Cl G
Dissolved Silica[2, 4]	DSi	mg/L	APHA (1998)	4500-SiO_2 F
Alkalinity	Alk	mg/L	APHA (1998)	2320-B
Total Nitrogen	TN	mg/L	APHA (1998)	4500-N C
Total Kjeldahl Nitrogen[1]	TKN	mg/L	USEPA (1983)	351.2
Total Nitrate/Nitrite Nitrogen[1]	TNOX	mg/L	USEPA (1983)	353.2
Total Ammonia Nitrogen[1]	TNH3	mg/L	USEPA (1983)	350.1
Total Suspended Solids[5]	TSS	mg/L	APHA (1998)	2540-D
Total Organic Carbon[1]	TOC	mg/L	USEPA (1983)	415.2
Dissolved Organic Carbon[1]	DOC	mg/L	USEPA (1983)	415.2
Dissolved Inorganic Carbon[1,2]	DIC	mg/L	APHA (1995)	4500-CO_2
Calcium, Magnesium, Sodium, Potassium, Iron[4]	Ca, Mg, Na, K, Fe	mg/L (µg/L for Fe)	USEPA (1992) USEPA (1994)	3010-A 6020-A
Lead[1]	Pb	µg/L	USEPA (1983)	239.2
Dissolved Oxygen[2]	DO	mg/L	APHA (1998) Hydrolab (1991, 2006)	4500-OC
Chlorophyll-a[2]	Chl-a	mg/L	USEPA (1997)	445.0
Temperature	Temp	°C	VT DEC (2006) YSI (1998) Hydrolab (1991)	1.1.2
Conductivity	Cond	µS/cm	VT DEC (2006) YSI (1998) Hydrolab (1991)	1.6.2
pH	pH		VT DEC (2006) YSI (1998) Hydrolab (1991)	1.5.5
Secchi Disk Depth[2]	Secchi	m	VT DEC (2006)	1.2.1
Net phytoplankton, total density	NP_Tot_den	cells/L	APHA 2005	10200 F 2a
Net phytoplankton, total biovolume	NP_Tot_bio	$\mu m^3/L$	Wetzel and Likens 2000 Hillebrand et al 1999	
Net phytoplankton, Cyanobacteria density	NP_Cya_den	cells/L	APHA 2005	10200 F 2a
Net phytoplankton, Cyanobacteria biovolume	NP_Cya_bio	$\mu m^3/L$	Wetzel and Likens 2000 Hillebrand et al 1999	
Net phytoplankton, Chlorophyta density	NP_Chl_den	cells/L	APHA 2005	10200 F 2a

Net phytoplankton, Chlorophyta biovolume	NP_Chl_bio	$\mu m^3/L$	Wetzel and Likens 2000 Hillebrand et al 1999	
Net phytoplankton, Chrysophyta density	NP_Chr_den	cells/L	APHA 2005	10200 F 2a
Net phytoplankton, Chrysophyta biovolume	NP_Chr_bio	$\mu m^3/L$	Wetzel and Likens 2000 Hillebrand et al 1999	
Net phytoplankton, Pyrrophyta density	NP_Pyr_den	cells/L	APHA 2005	10200 F 2a
Net phytoplankton, Pyrrophyta biovolume	NP_Pyr_bio	$\mu m^3/L$	Wetzel and Likens 2000 Hillebrand et al 1999	
Net zooplankton, total density	NZ_Tot_den	organisms/m^3	APHA 1998	10200 G
Net zooplankton, Cladoceran density	NZ_Cla_den	organisms/m^3	APHA 1998	10200 G
Net zooplankton, Copepod density	NZ_Cop_den	organisms/m^3	APHA 1998	10200 G
Net zooplankton, Rotifer density	NZ_Rot_den	organisms/m^3	APHA 1998	10200 G

[1] No longer included in the sampling program.
[2] Not currently sampled in the tributaries. Chlorophyll-a was sampled in tributaries from 1995-2005.
[3] APHA = American Public Health Association
USEPA = U.S. Environmental Protection Agency
VT DEC = Vermont Department of Environmental Conservation
YSI = Yellow Springs Instrument, Corp.
[4] Sampled on five year cycle after 2005; next sampling occurs in 2010.
[5] Not sampled in the lake after 2005.

Project Database

The project database is maintained by the Vermont DEC on its computer network using the commercial database program Microsoft® Access 2003 in conjunction with a SQL® server. Daily tape backup is provided, and copies of backup files are archived in separate locations. The SQL Server's robust security features are used to prevent editing or deletion of the original data by users other than the authorized database administrators. Copies of the current database are also available at the New York State DEC.

In 2008, a major reorganization of the database was initiated to improve the database design and replace three Microsoft Access® databases with a single SQL Server database. The use of the SQL Server database improves query performance and allows the use of the T-SQL database language to create more advanced queries. The data tables were normalized to conform to relational database requirements and new tables were added to store plankton data. The SQL Server database was made accessible from both the internal Vermont DEC Access front-end databases and the public web server Lake Champlain Monitoring Program application, which resulted in the elimination of multiple and duplicative Access databases. A single database improves the efficiency of storing and updating data and improves the accuracy of the data as additions and changes are made only in one database. SQL Server Views were created to increase the speed and functionality of the Lake Champlain Monitoring web application.

Database integrity is enforced in several ways. Primary keys are defined to uniquely identify each record in the database and prevent duplication. The primary keys are composed of multiple fields that uniquely identify each sample (e.g., field id, station, date). Foreign keys and check constraints on fields are used to ensure that only valid data are entered.

The database is updated annually within a few months of the end of the field season. Data are freely available to other government agencies, researchers, consultants, students, and the general public. Water chemistry data and plankton summaries can be downloaded via the Internet (http://www.anr.state.vt.us/dec/waterq/lakes/htm/lp_longterm.htm). Other electronic formats or paper copies are available upon request.

Chemistry results for both tributary and lake samples are maintained in a single table, named 'ChemistryData,' distinguished by waterbody type, station name, field accession number, visit date, collection method, and analysis type. The analytical results for each water quality sample are contained in database fields with names corresponding to the test codes indicated in Table 2. Each chemical test field in the database has an associated remark field in which "less than" or "greater than" signs are entered where necessary for results below or above analytical detection limits. Additional database codes are noted in Table 3.

The tributary stations were sampled during 1990-1992 for total phosphorus, dissolved phosphorus, and chloride by the Lake Champlain Diagnostic-Feasibility Study (Vermont DEC and New York State DEC 1997) using the same sampling and analytical methods employed by the current long-term monitoring program. These earlier tributary data have been added to the project database.

Plankton data are housed in two tables. The first, 'PlanktonData,' contains the original count data distinguished by plankton type (phytoplankton, zooplankton), station name, field accession number, species name, visit date, sample type, and result type. The second, 'PlanktonStats,' contains data aggregated by major taxonomic group. During phytoplankton analysis, organisms

are frequently observed outside of the designated counting boundaries. These are noted as "present but not counted" and are not quantified or incorporated into summary statistics. The data available for download from the web interface include phytoplankton cell densities and biovolumes, and zooplankton densities, grouped by major taxonomic category. Counts by individual taxa will eventually be added to the web page, but are currently available only by request.

Additional tables store tributary flow data, multiprobe data, wastewater treatment facility data, plankton taxonomic information, and station location coordinates. These data are not available through the web page but can be obtained by request.

Table 3. Additional database codes.

Data Table	**Data heading**	**Data code**	**Description**
Chemistry	WaterbodyType	Trib Lake	Tributary Lake
	CollectionMethod	ComSediSamp Kemmerer Thermister Secchi Hose CompEpi CompHypo CompUnstra	Depth/flow integrated sampler Kemmerer Thermister Secchi disk Integrated sample by hose Epilimnion composite by Kemmerer Hypolimnion composite by Kemmerer Unstratified composite by Kemmerer
	Depth		Sample depth (m)
	Stratum	E H P U	Epilimnion Hypolimnion Profile Unstratified (effective 2009, 'com' is no longer noted in the database)
	QA	A D	Field sample Field duplicate sample
	Lab	NY VT	Location (state) of lab responsible for analysis
Plankton	PlanktonType	Phyto Zoo	Phytoplankton Zooplankton
	Depth		Integrated net tow or hose collection depth (m)
	QA	A D DC QCC	Field sample Field duplicate sample Laboratory duplicate count (phyto. only) Repeat Aliquot count (phyto. only)
	SampleType	Net tow, 63µm Net tow, 153µm	Plankton net, 63µm mesh, 13cm diameter Plankton net, 153µm mesh, 30cm diameter
	ResultType	Biovolume Cell density Colony density Organism density	Biovolume Number of cells (phytoplankton only) Number of Colonies (phytoplankton only) Number of individuals (zooplankton only)
	IsPresentNotCounted	1	Taxon present in sample outside of counting boundaries (phytoplankton only)

Flow rates in the monitored tributaries are continuously measured by the USGS or the Quebec MDDEP. A list of the downstream-most flow gages on these tributaries is given in Table 4. The flow data can be used with the water quality sampling results to estimate mass loading rates, and for other purposes. The historical daily flow data for many of the USGS gages are available at the following website: http://waterdata.usgs.gov/nwis

Table 4. List of U.S. Geological Survey (USGS) and Quebec Ministry of Sustainable Development, Environment, and Parks (MDDEP) stream flow gages on monitored tributaries.

Tributary	**Gage Location**	**State**	**Reference No.**	**Agency**
Ausable	Au Sable Forks	NY	4275500	USGS
Bouquet	Willsboro	NY	4276500	USGS
Great Chazy	Perry Mills	NY	4271500	USGS
Little Ausable	Valcour	NY	4273800	USGS
Little Chazy	Chazy	NY	4271815	USGS
Mettawee	Middle Granville	NY	4280450	USGS
Putnam	Crown Point Center	NY	4276842	USGS
Salmon	S. Plattsburgh	NY	4273700	USGS
Saranac	Plattsburgh	NY	4273500	USGS
Pike	Bedford	QC	030420	MDDEP
Pike[1]	Notre-Dame-de-Stanbridge	QC	030424	MDDEP
Lamoille	E. Georgia	VT	4292500	USGS
LaPlatte	Shelburne Falls	VT	4282795	USGS
Lewis	N. Ferrisburg	VT	4282780	USGS
Little Otter	Ferrisburg	VT	4282650	USGS
Missisquoi	Swanton	VT	4294000	USGS
New Haven[2]	Brooksville	VT	4282525	USGS
Otter	Middlebury	VT	4282500	USGS
Poultney	Fair Haven	VT	4280000	USGS
Winooski	Essex Jct.	VT	4290500	USGS
Rock[1]	St. Armand	QC	030425	MDDEP
Stevens[3]	St. Albans	VT	4292770	USGS
Jewett[4]	St, Albans	VT	4292810	USGS

[1]New gages on the Pike and Rock were installed by Quebec MDDEP in 2002.
[2]The New Haven River is a tributary to the Otter Creek that is not directly sampled by the project, but is included in the gage network to supplement the hydrologic coverage for the Otter Creek watershed.
[3]New gage on Stevens Brook was installed by USGS in 2005.
[4]New gage on the Jewett Brook was installed by USGS in 2008.

Accessing the Data

The project website (http://www.anr.state.vt.us/dec/waterq/lakes/htm/lp_longterm.htm) provides the ability for data users to selectively view the original data for specific sampling stations, time periods, and analytical tests using simple, interactive query forms. Beginning in 2009, users have a choice to view a webpage or download the data as an EXCEL® spreadsheet. They also may choose to download only the current year's data for all stations and dates, or all data available for a particular station. The program's webpage includes links to the necessary metadata descriptions needed to properly interpret the data summaries, including the project quality assurance plan, this project description, and a summary of field and analytical methodology used over the life of the project.

Simple summary figures have been prepared for each parameter currently sampled. Data are presented on the website as box plots of the median, 10^{th}, 25^{th}, 75^{th} and 90^{th} percentiles for each station for the entire sampling period. Lake data are presented as both annual and cumulative summaries of unstratified and epilimnetic samples. Tributary data are presented as cumulative summaries only. Figures are updated annually after the new data are reviewed and added to the database.

References

American Public Health Association. 1995. Standard methods for the examination of water and wastewater. 19th ed. Washington, D.C.

American Public Health Association. 1998. Standard methods for the examination of water and wastewater. 20th ed. Washington, D.C.

Applied Science Associates, Inc. 1996. Hydrodynamic and water quality modeling of Lake Champlain. Lake Champlain Basin Program Tech. Rep. No. 19. Grand Isle, VT.

Hydrolab, Inc. 1991. (Revision B, 1997). Operations and maintenance manual for Hydrolab Surveyor III and IV. Austin, TX.

Hydrolab, Inc. 2006. Hydrolab Instruction Sheet, Hach LDO™ Sensor. Loveland, CO

HydroQual, Inc. 1995. Benthic phosphorus cycling in Lake Champlain: Results of an integrated field sampling/water quality modeling study. Part A: Water quality modeling. Lake Champlain Basin Program Tech. Rep. No. 34A. Grand Isle, VT.

Levine, S.N., M. Borchardt, M. Braner, A. Shambaugh, and S. Spencer. 1997. Lower trophic level interactions in the pelagic food web of Lake Champlain. Lake Champlain Basin Program Tech. Rep. No. 30. Grand Isle, VT.

New York State Department of Environmental Conservation and Vermont Department of Environmental Conservation. 2007. Long-term water quality and biological monitoring project for Lake Champlain. Work quality assurance project plan. Prep. for Lake Champlain Basin Program. Grand Isle, VT.

U.S. Environmental Protection Agency. 1983. Methods for chemical analysis of water and wastes. EPA-600/4-79-020.

U. S. Environmental Protection Agency. 1992. Test methods for evaluating solid wastes. EPA SW-846 (Rev.1). Office of Research and Development. Washington, D.C.

U.S. Environmental Protection Agency. 1994. Test methods for evaluating solid wastes. EPA SW-846 (Rev. 0). Office of Research and Development, Washington, D.C.

U.S. Environmental Protection Agency. 1997. In Vitro Determination of chlorophyll a and pheophytin in marine and freshwater algae by fluorescence. Revision 1.2. Washington, D.C.

Vermont Department of Environmental Conservation. 2006. Field methods manual. Waterbury.

Vermont Department of Environmental Conservation and New York State Department of Environmental Conservation. 1997. A phosphorus budget, model, and load reduction strategy for Lake Champlain. Lake Champlain Diagnostic-Feasibility Study final report. Waterbury, VT and Albany, NY.

Vermont Department of Environmental Conservation and New York State Department of Environmental Conservation. 1998. Long-term water quality and biological monitoring project for Lake Champlain. Cumulative report for project years 1992-1996. Lake Champlain Basin Program Tech. Rep. No. 26. Grand Isle, VT.

Watzin, M.C., R.L. Smyth, E.A. Cassell, W.C. Hession, R.E. Manning, and D. Wang. 2005. Ecosystem Indicators and an Environmental Score Card for the Lake Champlain Basin Program. Lake Champlain Basin Program Tech. Rep. No. 46. Grand Isle, VT. 192 p.

Yellow Springs Instrument Corp. 1998. Operations manual for YSI model 63. Yellow Springs, OH.