PART FOUR: SURFACE WATER MONITORING & ASSESSMENTS

A) Current Surface Water Quality Monitoring Program

The following section is a description of the Water Quality Division's (WQD) current ambient monitoring program that is comprised of numerous discrete projects. The WQD's monitoring efforts are classified herein as physical/chemical, biomonitoring, volunteer and other. Within each of these classes, monitoring projects are further described as core, or long-term projects; diagnostic studies, which identify the causes of particular water quality problems; and special studies, which provide information and data on specific water quality issues. Other projects coordinated by close partners of the WQD are also included in this listing.

1) Physical and chemical monitoring

Core Programs

The Spring Phosphorus Program collects spring overturn nutrient and physical and chemical data on Vermont lakes and ponds that are 20 acres in size or larger. Parameters include total phosphorus, total nitrogen, alkalinity, calcium, magnesium, hardness, Secchi disk transparency, and multi-probe profiles (temperature, dissolved oxygen, conductivity and pH). Since 1977, 236 lakes have been monitored in conjunction with this program. Forty-eight lakes have 10 or more years of data and 18 of these have 15 years or more. The Spring Phosphorus Database contains over 1,700 records.

The Lake Assessment Program is designed to rapidly assess the extent to which lakes meet designated uses and to gather information to focus lake management and protection efforts. The sampling intensity for assessment lakes varies with the degree to which impairment is evident or must be documented. In general, lakes are circumnavigated and detailed assessment observations are made regarding in-lake and shoreline conditions with respect to designated uses and threats to water quality. Detailed notes are made regarding the extent and species composition of the macrophyte community. Sampling is performed for total phosphorus, alkalinity, Secchi disk transparency, and multi-probe profiling. Additional sampling may be performed as necessary to determine compliance with Vermont Water Quality Standards. Since 1989, close to 280 comprehensive assessments and 60 cursory assessments have been performed.

The River Assessment Program is designed to assess the extent to which rivers and streams support designated uses to focus management and protection efforts. Rivers and streams in the basins of focus are visited to look for obvious sources of pollution from the land or indicators of problems or threats in the water such as sedimentation, heavy algae growth, or water with unnatural color or odor. The Ambient Biomonitoring Program (described below) provides most of the information used to determine a waterbody's aquatic life use support and compliance with Vermont Water Quality Standards. Temperature, nutrients, pH, conductivity and alkalinity are parameters commonly measured concurrently with the biological sampling.

The Water Level Monitoring Program monitors lake surface elevations to establish mean water levels for a variety of purposes, most notably to determine the jurisdictional boundary of the State's lakes and ponds under the shoreland encroachment permit program and Vermont's Public Trust Doctrine.

The Lake Champlain Long-Term Monitoring Program surveys the quality of Lake Champlain waters on a biweekly basis from May to November at 13 locations throughout the lake. Eighteen major tributaries are sampled on an event basis as well. The program's large physico-chemical parameter list includes: species of phosphorus, nitrogen and organic carbon; chlorophyll-a; base cations; alkalinity; total suspended solids; dissolved oxygen; conductivity; and pH. As of April 2003, this program had assembled a database comprising 6,366 lake and 4,282 tributary sampling events. The reader is referred to Part Six of this report, the section entitled Lake Champlain Phosphorus TMDL, for information concerning the Lake Champlain Clean and Clear Initiative.

The Long-Term Monitoring (LTM) Acid Lakes Program collects chemical and biological data on lakes located in low alkalinity regions to determine the effects of acid deposition on Vermont's lakes. Initially, nearly 200 lakes statewide were surveyed during the winters of 1980 through 1982 to identify the acid sensitive areas of the state. Eleven lakes selected from these areas are now included in the LTM and are sampled at least eight times every year for 16 chemical parameters related to acidification. These data are used to classify lakes according to their acidification status, evaluate spatial and temporal variability in measured parameters, track changes in acidification status over time as related to reductions in atmospheric emissions of acid precursors (e.g., oxides of sulfur and nitrogen), and evaluate impacts of acidification on aquatic communities. As of April 2003, the LTM data archive comprised 1,857 in-lake and 405 lake-outlet sampling records. This project contributed data to a seminal article describing long-term acidification trends across northeast North America, which was published in the journal Nature in 2000.

The Stream Geomorphic Assessment Program collects geomorphologic data on streams throughout the state to assess stream geomorphic condition and develop regime relations for Vermont's streams. Geomorphic assessments enable the prediction of expected rates of river adjustment and an evaluation of the effects of various land and river management practices on geomorphic condition and physical habitat quality. Regime relations guide stream protection, management, and restoration projects and assist in the establishment of Vermont-specific physical criteria for water quality classification and use attainment determinations. Parameters measured include channel dimension (cross section), pattern (meander geometry), longitudinal profile, channel substrate conditions, structure and composition of riparian vegetation, and floodplain and valley morphology. Geomorphic assessment protocols have been developed and promoted by the Agency of Natural Resources. Geomorphic assessments are done according to different levels of complexity. The map on the following page illustrates the location and level of completed or ongoing stream geomorphic assessment efforts.

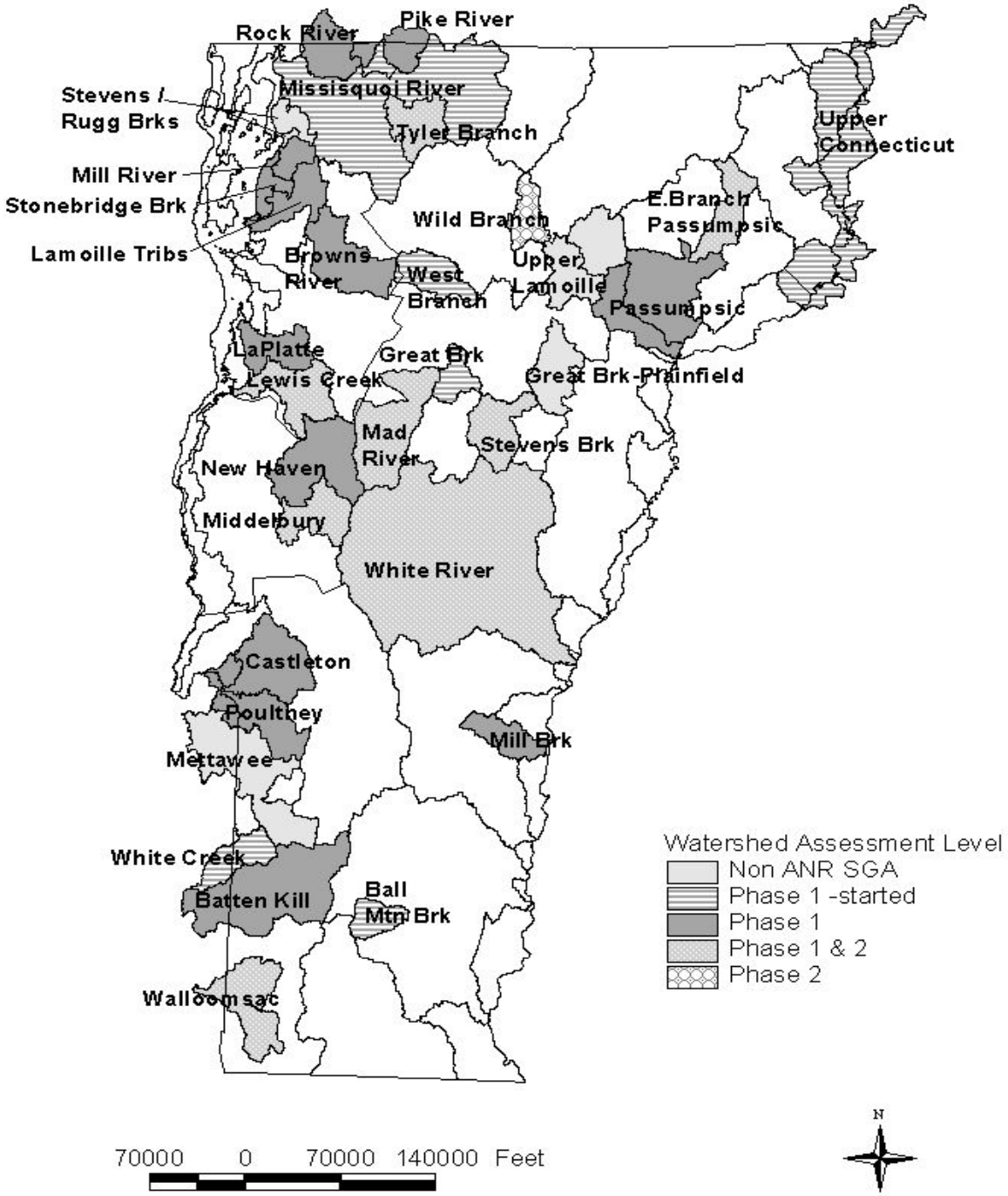


Figure 4.A.1. Location & Level of Stream Geomorphic Assessments (April 2004).

Lake Diagnostic Studies
Diagnostic studies are typically aimed at identifying the cause of eutrophication in Vermont lakes. Over the past 20 years, Vermont has performed numerous such monitoring studies, and the results of these studies have led to remediation steps. Lakes on which diagnostic studies have been performed include Harveys Lake (Barnet), Lake Morey (Fairlee), Lake Iroquois (Hinesburg), Fairfield Pond (Fairfield), Lake Parker (Glover), Lake Carmi (Franklin), and Lake Champlain. Presently, the DEC is investigating the possible initiation of a new diagnostic study for Ticklenaked Pond, a nutrient-impaired lake in Ryegate.

A wide variety of parameters are sampled in conjunction with lake diagnostic studies, and the actual tests performed are specific to the project. Standard eutrophication parameters (total phosphorus, Secchi disk transparency, and dissolved oxygen) are always measured. Other parameters taken from sediments and the water column can be measured as needed.

Special Studies
Special studies are those performed to gain more information about a particular environmental issue of importance to DEC. There are four special studies noted below.

The EPA-sponsored **REMAP Assessment of Mercury** in Sediments, Waters and Biota of Vermont and New Hampshire Lakes Project is a three-year effort to identify lake types occurring in the two states that have elevated levels of mercury in fish and upper trophic level biota. The parameter list for this integrated collaborative monitoring project is large, and includes standard limnological measurements and mercury in total and methyl phases in sediment, water, and biota. There is also a paleolimnological component that has determined the extent to which atmospherically deposited mercury has entered lakes in the study set. Two peer-reviewed journal articles have been produced from this study that was completed in 2003.

The Best Management Practices Effectiveness Demonstration Project is a long term stream monitoring effort (1999–2007) designed to assess the efficacy of best management practices in controlling pollutants in nonpoint source runoff in tributaries of Lake Champlain.[1] This cooperative DEC-USGS project differs from the project described immediately above in that it uses an upstream-downstream approach to pinpoint reductions in pollutant runoff attributable to specific installed Best Management Practices. The project is being carried out simultaneously on one agricultural and one urban stream in the Lake Champlain basin (Little Otter Creek and Englesby Brook, respectively). Sampling is focused on nutrients and sediment and sampling is conducted monthly and during storm events. Minor BMP structures were installed during 2002 in both watersheds. Larger implementation projects are scheduled for 2004.

In conjunction with the **Paleolimnology of Vermont Lakes Project**, DEC is collaborating with the University of Vermont to develop a set of indicators of present and historical trophic status

[1] During 1994-2001, a similar study was conducted known as **the Lake Champlain Agricultural Best Management Practices Monitoring Project.** This comparative observational study was carried out to evaluate the efficacy of both low- and high-intensity reach specific BMP implementation strategies related to livestock grazing. Parameters measured included total phosphorus, total and Kjeldahl nitrogen, total suspended solids and *E. coli* along with biological assessments. Even though the project has been completed and results published, biological assessments conducted by DEC are continuing.

based on the paleolimnology of carbon and nitrogen stable isotopes ($\delta^{13}C$ and $\delta^{15}N$). Using cores from the sediments of several lakes, DEC is working to identify the extent to which the present trophic condition in these lakes deviates from the historic background. Such information is instrumental in understanding the extent to which productivity (and thus phosphorus) has been elevated since the lake watersheds were first cleared in the early 1800's.

2) Biological monitoring

Core Programs

The **Ambient Biomonitoring Program** was established in 1982 to 1) monitor long-term trends in water quality as revealed by changes in ambient aquatic biological communities over time; 2) evaluate potential impacts on aquatic biological communities from permitted direct and indirect discharges, ACT 250 (10 V.S.A. 151) projects, nonpoint sources, and spills; and 3) establish a reference database to facilitate the generation of Vermont-specific biological criteria for water quality classification and use attainment determinations. Since 1985, DEC has used standardized methods for sampling fish and macroinvertebrate communities, evaluating physical habitat, processing samples, and analyzing and evaluating data. The program has led to the development of two Vermont-specific fish community Indexes of Biotic Integrity (IBI) and several macroinvertebrate metrics. Guidelines have been developed to determine water quality standards attainment using both macroinvertebrate community biological integrity metrics and the IBI. Approximately 75 sites per year are assessed using fish and/or macroinvertebrate assemblages. Alkalinity, pH, conductivity, temperature and such measurements as substrate composition, embeddedness, canopy cover, percent and type of periphyton cover, and approximate velocity are routinely monitored. From 1985 to April 2003, well over 1,700 stream assessments were completed using macroinvertebrate and/or fish from 1229 stream reaches.

The Aquatic Macrophyte Monitoring Program collects baseline information on aquatic plant communities in Vermont lakes by conducting descriptive surveys using a pre-established plant cover scale. This program has been active since the late 1970's, and information is available from 177 discrete surveys.

The WQD conducts numerous **Aquatic Nuisance Species Searches and Surveys** each year to search for new populations and monitor existing populations of nuisance aquatic species, primarily Eurasian watermilfoil (*Myriophyllum spicatum*), water chestnut (*Trapa natans)*, zebra mussels (*Dreissena polymorpha*), and the wetland invasive purple loosestrife (*Lythrum salicaria*).

One interesting component of these aquatic nuisance species efforts is the Lake Champlain Zebra Mussel Monitoring Program. For this effort, 13 in-lake and 12 shoreline stations in Lake Champlain are monitored for larval and settler zebra mussel presence and density every two weeks from April through November. In addition, adult zebra mussel surveys are performed at selected shoreline locations during late summer. Notably, this is the only such zebra mussel monitoring project of it's kind in the United States. As of April 2003, there were 2,220 veliger records and 1,013 settler records within this program's nine years of data records.

Special Studies

The Biodiversity Monitoring Program evaluates the status of selected biological species and communities in Vermont. Specific activities include 1) distribution surveys of aquatic plant, fish and macroinvertebrate species listed by the Vermont Endangered Species Committee as rare, threatened, endangered, or of special concern; 2) distribution surveys of communities having species considered likely candidates for future listing (e.g., snails); and 3) monitoring of biological communities or community types, the diversity of which is threatened (e.g., Lake Champlain mussel and cobble/shale macroinvertebrate communities threatened by zebra mussels). Data are used to describe species distribution, identify species/communities at risk, and develop management plans for the protection of identified species/communities.

The Lake Bioassessment Project was initiated in 1995 to begin developing biological criteria for Vermont lakes. This monitoring effort was launched as a cooperative project with the State of New Hampshire. The goal of the project is to develop numeric measurements of the phytoplankton, macrophyte, and macroinvertebrate communities in reference lakes for use in assessing aquatic life use attainment in lakes. Consistent protocols have been developed to measure these biological assemblages, and to date, 12 New Hampshire and 41 Vermont lakes have been included in the project. Statistically-validated multimetric indices have been developed for the phytoplankton and macroinvertebrate communities. To date, data describing macrophyte commbnities have proven insufficiently precise to develop macrophyte criteria.

The **Vermont Wetlands Bioassessment Project** is a coordinated effort between the DEC and the Vermont Department of Fish and Wildlife's Nongame and Natural Heritage Program to document and understand the biological and physical characteristics associated with seasonal pools (vernal pools) and northern white cedar swamps in Vermont. Since 1999, the project has collected biological, physical and chemical data from 28 seasonal pools throughout the state. Information collected on the invertebrates, amphibians, algae, and plants associated with seasonal pools has been used to assess and monitor the ecological health of seasonal pools in Vermont. This project was completed in 2002 and efforts at using these data to develop vernal pool biocriteria have seen limited success. DEC plans to modify this project for 2004 by adopting protocols and sampling strategies consistent with the Lake Bioassessment Project, to include more rigorous procedures for monitoring marginal wetland macrophytes.

The Lake Champlain Long-Term Monitoring Program described above also includes biological sampling, which is primarily aimed at assessing phytoplankton, zooplankton, and macroinvertebrate communities. Data from this element of the project resides in the New York State Natural History Museum with copies available only in spreadsheet form in Vermont. These data have been underanalyzed and underutilized as of this writing, but should provide a baseline for evaluating changes in ecosystem structure given implementation of the Lake Champlain TMDL for phosphorus.

The Northern Leopard Frog Surveys in the Lake Champlain Basin Project was initiated in response to reports of malformed frogs in the Lake Champlain basin in Vermont in the summer of 1996. Malformed frogs were reported from 12 sites in five counties within the Lake Champlain basin. Systematic field surveys were initiated in 1997, targeting the northern leopard frog (*Rana pipiens*). These surveys recorded the frequency and morphological characteristics of

gross abnormalities among newly metamorphosed northern leopard frog populations at 20 sites within the Lake Champlain basin. With subsequent support through the USEPA REMAP program, DEC has examined over 6,000 northern leopard frogs since 1996, and external malformations have been detected in 7.5% of the frogs examined. Data characterizing the gross abnormalities and describing the frequency and occurrence of abnormalities within northern leopard frog populations continues to be gathered at 10 established sites within the Lake Champlain basin. All findings are reported to the North American Reporting Center for Amphibian Malformations (http://www.npwrc.usgs.gov/narcam/). DEC also continues to collaborate with the National Institute of Environmental Health and Sciences, the National Wildlife Health Center, and other researchers, providing environmental samples and specimens to help further malformed frog investigations.

Other Biological Monitoring Projects either ongoing or conducted on a periodic basis include:

- monitoring nontarget impacts to aquatic biota in lakes chemically treated with the aquatic herbicide Sonar® (fluridone) to control Eurasian watermilfoil infestations;
- monitoring the effects on both target and nontarget organisms of copper sulfate treatments to small recreational lakes and water supply reservoirs; and
- monitoring impacts to nontarget fish and macroinvertebrates in rivers treated with lampricide (TFM) to control sea lamprey (*Petromyzon marinus*) in Lake Champlain..

The Fish Contaminant Monitoring Program is managed by the WQD and performed in cooperation with the Vermont Department of Fish and Wildlife and the Vermont Department of Health. Edible tissue from game fish acquired throughout the state is analyzed for mercury and other contaminants. These data are then used to set and subsequently refine fish consumption advisories issued by the Vermont Department of Health.

3) Volunteer monitoring

Citizen groups have become increasingly involved in monitoring, education, protection, and restoration projects in Vermont. DEC provides assistance and training to volunteers whenever possible. Watershed and lake associations are presently active on numerous rivers and lakes in the state. In fact, there are over 100 such associations statewide. DEC has developed a directory listing various watershed associations and their activities in "Current Programs of Vermont Watershed Associations – 2002," with a lake association addendum listing active lake groups.

Core programs

The Vermont Lay Monitoring Program equips and trains local lake users to measure the nutrient enrichment of lakes by collecting water quality data following a rigorously documented and quality assured methodology. This citizen monitoring program is based on trophic parameters and monitors approximately 40 inland lakes and 25 Lake Champlain stations per year. All Lake Champlain stations and many inland lakes in the program are sampled for chlorophyll-a, total phosphorus, and Secchi disk transparency. Other lakes are sampled only for Secchi disk transparency. All sampling occurs on a weekly basis during the summer. Since the development of the Lay Monitoring Program in 1979, data has been generated on 84 lakes and 36 Lake Champlain stations. Seventy-two inland lakes and 30 Lake Champlain stations have five or more years of full season data. In addition to their standard monitoring, Vermont's

citizen lake monitors also assist in the ANS Watchers Program (see below), and in collecting data for the Lake Bioassessment Project.

The Citizen Lake and Watershed Survey Program provides survey sheets and technical training to volunteers, lake and watershed associations, and other interested groups to enable them to perform screening level assessments to identify potential nonpoint sources of pollution to lakes by conducting in-lake, lakeshore, and lake watershed surveys.

The Aquatic Nuisance Species (ANS) Watchers Program trains citizen volunteers to monitor for the presence of invasive nonnative aquatic species. The program is currently focusing on monitoring for Eurasian watermilfoil, water chestnut, and zebra mussels. There are presently 110 ANS Watchers throughout Vermont.

The Volunteer Acid Precipitation Monitoring Program was initiated in 1980 to monitor changes in precipitation chemistry. Dedicated volunteers at six sites around Vermont (Holland, Morrisville, Mt. Mansfield, St. Albans, St. Johnsbury, and Underhill) collect precipitation samples on an event basis. The volume and pH of each storm event is recorded. Additional parameters such as conductivity and wind direction are recorded at individual stations. The data are used to assess spatial and temporal variability in the pH of bulk precipitation and assess changes in the pH of bulk precipitation over time and as related to reductions in atmospheric emissions of acid precursors (e.g., oxides of sulfur and nitrogen).

Other volunteer initiatives

The Water Quality Division collaborates with the LaRosa Laboratory (described below) on a novel program to assist citizen monitoring groups statewide. Beginning in 2003, the Water Quality Division and LaRosa Laboratory began issuing analytical services grants to volunteer organizations, based on a competitive proposal process. The project was very successful in 2003. Eleven projects were supported. These projects ranged in scope from small, single-lake studies to large, multi-year and multi-parameter watershed assessment initiatives. In 2003, the program produced in excess of 1,800 viable, quality-assured data records across Vermont.

4) Monitoring partnerships

Federal

The US Army Corps of Engineers (ACOE) manages several flood control reservoirs in Vermont. These are monitored routinely for flow and stage, and periodically for a variety of physico-chemical constituents. ACOE reservoirs with designated swimming beaches are also monitored for *E. coli* regularly during the swimming season. ACOE reports on it's monitoring activities annually, and shares these reports with WQD. ACOE sampling results are used in conjunction with Integrated Assessment reporting.

The US Environmental Protection Agency (EPA) coordinates regional water quality monitoring projects of a variety of types. In recent years, projects which WQD has been involved include the REMAP New England Wadeable Streams Project and the National Study of Chemical Residues in Fish. EPA was also the principal sponsor of the REMAP Assessment of Mercury in Waters, Sediments and Biota of Vermont and New Hampshire Lakes project. WQD

plans to participate in the upcoming REMAP New England Lakes Project. Results of these studies are used for a variety of purposes in addition to Integrated Assessment reporting.

The US Fish and Wildlife Service (FWS) sponsors projects across New England dealing with toxic contamination of aquatic biota. WQD has collaborated with FWS on several projects, and data are freely shared. In addition, FWS co-sponsored toe REMAP mercury project discussed above.

The US Geological Survey (USGS) operates a network of gauging stations on Vermont waters, which are supported by a cooperative agreement with DEC. This gauging network provides water flow data that are critical for numerous applications, both within and outside of DEC. USGS also coordinates several water quality studies throughout Vermont in a variety of disciplines, and the results and data are commonly shared with DEC for numerous uses including permitting and integrated Assessment reporting.

State

The Vermont Department of Forests, Parks, and Recreations operates a comprehensive beach monitoring program for all of it's public use beaches on State Park lands. Twenty-nine beaches are monitored on a weekly basis following established protocols. Swim advisories are posted based on results of the testing, when *E. coli* sample values exceed the Vermont standard for Class B waters of 77 *E. coli* /100ml. These data are openly shared with DEC. They are used for assessments as well as for identifying beaches subject to chronic, controllable bacterial contamination.

The Vermont Department of Health (DOH) operates a program whereby appointed Town Health Officers are trained to collect water quality samples at designated beaches. This program is suitable for small municipalities with informally-used swim beaches. Data reported back to Town Health Officers from the DOH laboratory take the form "safe for swimming," or "violates Vermont's standard unsafe for swimming." These data are not reported not tracked as numeric results. Town Health Officers commonly use these data to post warnings at swim beaches. Owing to resource constraints, samples collected in conjunction with that program cannot follow the strict quality assurance procedures required by DEC and the Department of Forests, Parks and Recreation in their *E. coli* monitoring projects. As such, this program provides useful and preliminary screening information to determine where swim beach water quality may need further assessment.

The Vermont Monitoring Cooperative (VMC) is a collaborative organization in which scientists collect and pool information and data for the purpose of improving our understanding, protection, and management of Vermont's forested ecosystems. Participating cooperators from government, academic and private sectors, conduct research projects on a variety of topics including forest health, air quality and meteorology, wildlife, aquatic systems and others. The VMC helps make the data and results from these projects available to other scientists, educators, resource managers and the general public. The VMC was initiated in 1990 as a state, university, and federal partnership, with a one-hundred year envisioned lifespan. The centerpiece of the VMC is the data library and card catalogue system that allow data to be shared, archived, and accessed by scientists and other interested parties via the VMC website. The data archive

contains data and ancillary textual material from over 100 projects, and is geographically referenced.

Academic

DEC maintains ties with several academic institutions interested in water quality monitoring. A partial list of these include Dartmouth College, Middlebury College, the University of Vermont, and member schools of the Vermont State College System. Collectively, these institutions carry out numerous projects and resultant data are commonly used by DEC for assessment purposes. The University of Vermont also carries out several larger-scale research and monitoring projects cooperatively with or of significant interest to DEC. A non-inclusive list of University of Vermont projects includes paired assessments of geomorphic and macroinvertebrate biometrics on streams, research into natural background levels and strategies to mitigate *E. coli* in Vermont waters, assessment of cyanotoxins in Lake Champlain and elsewhere, impacts of non-native species on aquatic food webs.

Local

The Addison County Collaborative (ACC) is a volunteer-based consortium of local volunteer organizations that monitor waters in several watersheds in Addison County. The ACC has monitored approximately 45 sites across four watersheds for *E. coli* and eutrophication-related parameters. ACC provides data and summary reports to DEC on an annual basis for assessment purposes. These data are also being used to assist in development of the Otter Creek and Lower Direct Champlain Basin Plans. The ACC received a LaRosa Laboratory services grant in 2003. This organization plans to launch a new monitoring project, in partnership with DEC, during 2004, to assist in the development of nutrient criteria.

The White River Partnership (WRP) is a private, non-profit organization dedicated to helping local communities balance the long-term cultural, economic and environmental health of the watershed through active citizen participation. The WRP has established a monitoring program for the watershed using several volunteer "stream-teams." Activities include geomorphic assessment, priority site mapping, and water quality sampling for a variety of constituents including temperature, turbidity, conductivity, and *E. coli*. WRP's volunteer monitors generate quality-assured data that are used to identify priority reaches for protection or remediation. DEC is periodically provided data summaries for use in implementation of the DEC-prepared White River Basin Plan, for assessment purposes, and in other joint special studies.

The West River Watershed Alliance (WRWA) is another watershed group dedicated to similar goals as the ACC and WRP but whose focus is on the waters in the West River watershed. The Alliance has re-established a monitoring program in the West River watershed that for many years was run by the Bonnyvale Environmental Education Center (BEEC). BEEC data were provided annually to DEC for assessment purposes for many years. The WRA also received a LaRosa laboratory services grant in 2003.

The City of Burlington and Town of Colchester collectively monitor several heavily-used swimming beaches, by measuring *E. coli* on a regular basis. These data are made publicly in near real-time via the “Burlington Eco-Info” website (www.burlingtonecoinfo.net).

The Watershed Alliance of the University of Vermont and **River Network** have been active in promoting surface water quality monitoring for elementary and high schools throughout Vermont. Such monitoring is valuable from an educational and student/community involvement standpoint. When monitoring results are shared with DEC, the information can be considered during assessment reporting.

The Friends of the Mad River (FMR) is a non-profit organization sharing similar goals to the above noted groups. The FMR has undertaken a number of planning and implementation projects along with a long-standing water quality monitoring program which includes *E. coli* and a number of other parameters. DEC is periodically provided data for use in assessment reporting.

B) Assessment Methodology

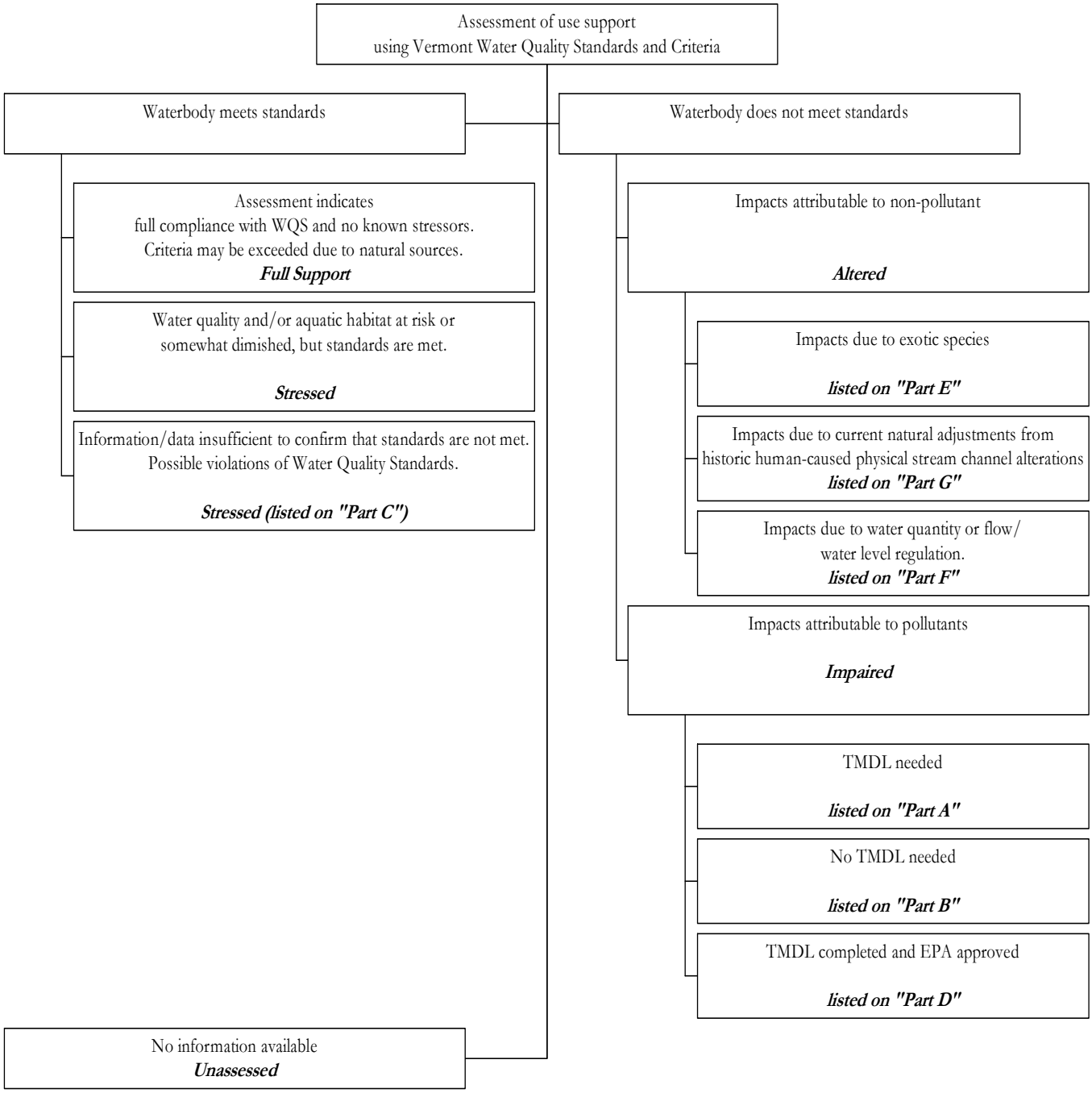
The following section describes the manner in which the WQD regularly gathers data and other information to make informed decisions about the status, integrity or condition of surface waters.

The collection, analysis and evaluation of water quality monitoring data and other information represent the assessment of a water's condition. The assessment of a water is most accurate when judgements about the water's condition are made using chemical, physical and/or biological data of known reliability collected through monitoring. While not as definitive as data collected though monitoring, an assessment of a water's condition can also take into account field observations or other qualitative information.

The Vermont Water Quality Standards, periodically revised and promulgated by the Vermont Water Resources Board, provide the basis used by DEC in determining the condition of surface waters including whether the water meets (attains) or does not meet (exceeds or violates) certain criteria. The assessment of a water's condition within the context of the Water Quality Standards requires consideration of the water's classification and management type, a variety of designated or existing uses, and a series of criteria which can be numerical or narrative. The outcome of an assessment conducted by the DEC is to categorize Vermont's surface waters as either "full support," "stressed," "altered," or "impaired." Waters determined to be "impaired" or "altered," and certain "stressed" waters are presented for water quality management purposes on one or more listings. Over time, DEC is gradually reducing the number of waters characterized as "unassessed." The organizational chart appearing on the following page illustrates the major components of DEC's surface water assessment and listing process.

The reader is referred to Appendix C for the entire 2004 Assessment and Listing Methodology.

Chart Depicting Organization of Vermont's Water Quality Assessment & Listing Methodology.



C) Rivers & Streams Water Quality Assessment (Statewide)

Three basin assessment reports were completed and a fourth was essentially completed in the last two years since the 2002 305b Report. A report for Basin 13 (the Lower Connecticut River watershed) was completed in April 2002; a report for Basin 1 (the Battenkill, Walloomsac, Hoosic watershed) was completed in August 2002; and a report for Basin 12 (the Deerfield River watershed) was completed in March 2003. Each completed assessment report noted above and those completed previously are available from DEC on request. Basin 5 (the Northern Lake Champlain watershed) is undergoing final revisions at the time of this writing. The data and information gathered prior to production of these reports are incorporated into the rivers and streams and lakes and ponds discussions and reporting numbers which follow below.

1) Assessment of use support

The assessment of Vermont's statewide river and stream surface water quality and aquatic habitat conditions has been updated from the 2002 305b statewide assessment with water quality information and data from waters monitored and assessed during the last two years. There is a substantial difference, however, between the use support determinations in this statewide assessment summary and those of past 305b reports. As described above and in the appendix containing the Assessment Methodology, miles of river or stream are placed in one of four categories by designated use – full support, stressed, altered or impaired. This categorization differs from the categories of full support, full support/threatened, partial support, and non-support used in all earlier 305b assessment reports. This biennial report contains rivers and streams that have been re-assigned to the new categories to the extent possible. However, the current assessment categories do not directly equate to the former categories and there are a number of waters where the data and information are too old to permit a decision about the proper assessment category for the river or stream miles. The assessment category of these rivers and streams will be determined as Vermont DEC gets to them in the assessment rotation. *The numbers given below in use support categories as well as the miles of rivers and streams affected by different causes and sources need to be considered as transitional until a complete re-assignment and re-assessment has been done.*

Determination of use support is based on data and information from biological monitoring, chemical monitoring, physical assessments, modeling results, and known sources of problems such as channelization work, combined sewer overflows (CSOs), or flow fluctuations, non-singular incidences of fish kills or spills.

According to EPA, Vermont has approximately 7,100 miles of perennial rivers and streams. Of the approximate 5,464 river and stream miles assessed for this report, overall approximately 88% of those miles are in compliance with the state's water quality standards and support designated uses, and 12% do not meet water quality standards or do not fully support the designated uses.

Table 4.C.1 below is a summary of the number of miles of rivers and streams throughout Vermont which support or do not support the water quality standards or designated uses of the waters. For each river use or value that is assessed, the miles of river or stream fully supported, stressed, altered, or impaired are determined. For example, river miles that are supported for aquatic biota have macroinvertebrate and fish communities in good to excellent health based on a

number of metrics for each community. River miles that are supported for swimming have no known high levels of *E. coli*, a bacteria that is used as an indicator for pathogens. Overall use support, expressed as proportion of miles meeting/not meeting uses, by waterbody, is shown in Figure 4.C.1 on the following page.

The number of miles in each support category are provided for six uses or values: aquatic biota and/or habitat, contact recreation (swimming, tubing), secondary contact recreation (boating, fishing), aesthetics, fish consumption, and drinking water supply. The use called "overall" reflects the miles for which one or more of the uses are fully supported, stressed, altered, or impaired. The fish consumption use is not factored into the "overall" category because all miles of river and stream are at least stressed for fish consumption due to a statewide fish consumption advisory. If taken into account in "overall", this status would mask the extent of other stresses.

Table 4.C.1. Statewide Overall & Individual Use Support Summary (miles) for Rivers & Streams.

Designated Use	Full support	Stressed	Altered	Impaired	Total assessed
Overall	4003	848	317	311	5479
Aquatic biota/habitat	4099	836	317	227	5479
Contact recreation	4734	455	8	151	5348
Secondary contact recreation	4509	645	141	70	5365
Aesthetics	4461	692	171	149	5473
Drinking water supply	244	16	10	9	279
Fish consumption	0	5870	0	53	5923

2) Summary of Causes and Sources

A cause is a pollutant or condition that results in a water quality or aquatic habitat impairment, alteration or stress; a source is the origin of the cause and can be a facility, a land use, or an activity. The sources are subdivided into point and nonpoint, and a nonpoint source is defined as any pollutant not discharged directly from the end of a pipe. Tables 4.C.2 and 4.C.3 summarize the miles of rivers and streams affected by various causes and sources, respectively.

Because a stretch of river or stream may be affected by more than one cause or source, the same mileage may be tallied in several places in Tables 4.C.2 and 4.C.3. For this reason, the two columns on each table are not additive because the total would overestimate the total number of miles affected by all causes and sources in Vermont. The purpose of these summaries is to give natural resource managers and the public an idea of the relative size of the impact from different pollutants or conditions on Vermont's waters and from which land uses or activities they may originate.

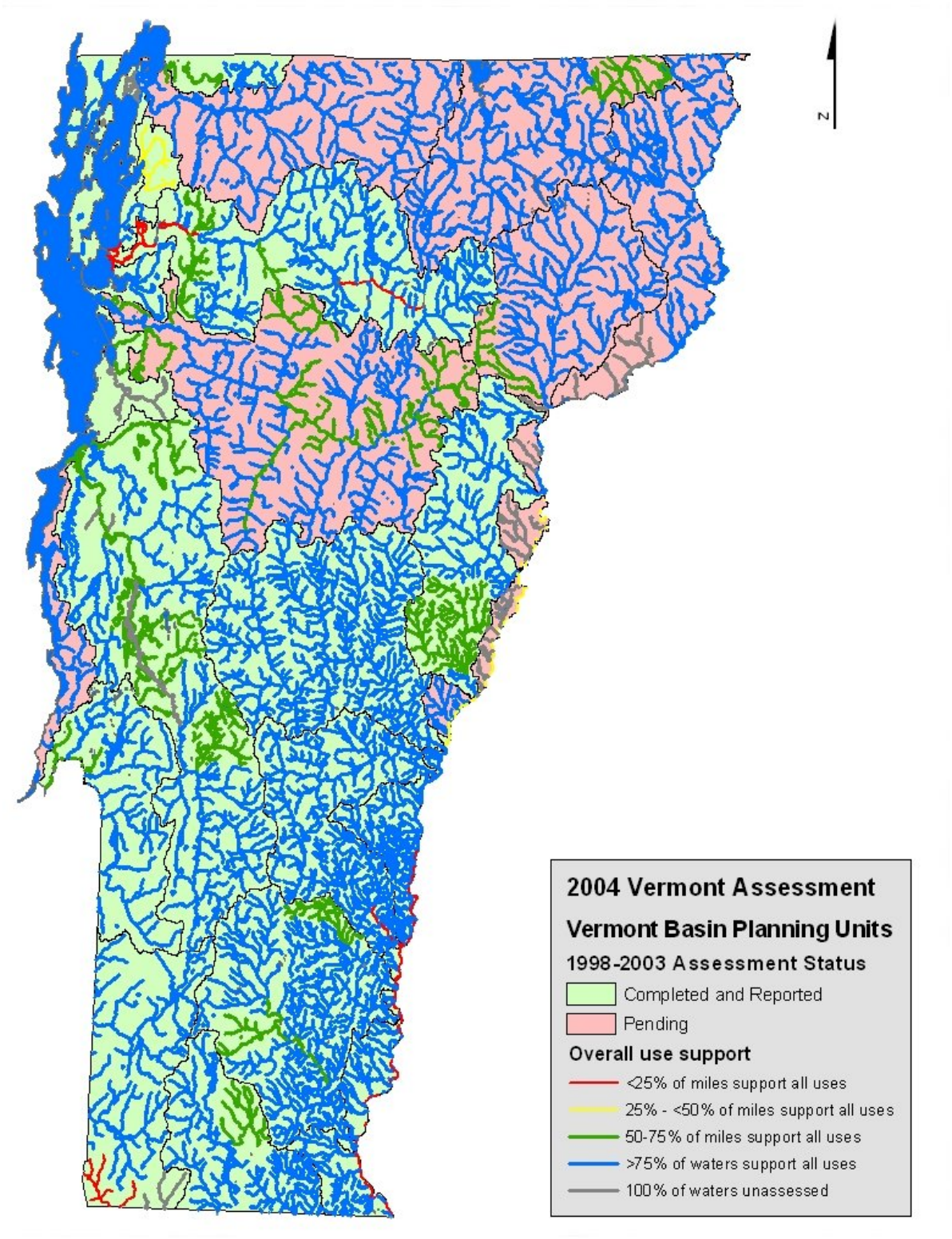


Figure 4.C.1. Overall Use Support for Rivers and Streams.

Causes

Sedimentation/siltation is the largest cause of stresses and impairments to river or stream water quality or aquatic habitat in Vermont. Sedimentation/siltation has long been the leading pollutant of our flowing waters. Unnatural levels of sediment alter or destroy macroinvertebrate habitat and fish spawning areas, fill in swimming holes, and cause the river or stream channel to become unstable. Sedimentation results in approximately 333 miles of river and stream not meeting standards and stresses another 700 miles based on the information available at this time.

The second largest documented cause of impacts and impairments is flow alteration. This problem affects about 264 miles and stresses another 67 miles.

The cause affecting the third largest number of miles in terms of pollutants or conditions is nutrient loading to waters. Nutrients contribute to 225 miles of river and stream not meeting standards and to over 440 stressed river or stream miles.
Physical habitat alterations affect the fourth largest number of miles of river and stream causing 195 miles of not full support and stressing another 433 miles.

The other substantial causes identified include: pathogens affecting about 140 miles and stressing over 260 miles; thermal modifications affecting 126 miles and stressing over 475 miles (the second largest stressor identified); turbidity affecting 130 miles and stressing 138 miles; and metals affecting about 90 miles and stressing another 150 miles.

Past assessments have generally had similar results in terms of which pollutants or conditions have the most impact on water quality or aquatic habitat. Sedimentation was the most extensive cause of pollution in the 2000, 1998 and 1996 305b assessments. The eight most significant causes of river and stream impairments, alterations, or stresses are given in Table 4.C.2 below.

Table 4.C.2. Total River and Stream Miles Affected by Cause Category.

Cause of impairment, alteration, or stress	Magnitude (miles)	
	Not meeting standards	Meeting standards but stressed
Sedimentation	333.0	721.0
Flow alterations	264.0	67.1
Nutrients	224.7	449.2
Physical habitat alterations	194.9	433.5
Pathogens	141.7	261.3
Thermal modifications	126.0	478.4
Turbidity	130.2	138.2
Metals	91.0	151.6

Sources

The four sources of pollution identified as having the greatest impacts or causing the greatest stresses on miles of river and stream are flow alteration from hydroelectric facilities, snowmaking water withdrawals and other sources; streambank erosion; agricultural land uses and activities; and removal of riparian vegetation. In some situations, all three latter sources could be interrelated and affecting one given stretch of river and stream at the same time.

Flow fluctuations or reductions alter about 284 miles and stress another 60 miles. The number of miles attributed to flow modification as a source are less than in the 2002 305b assessment cycle due to licenses issued at hydroelectric facilities and snowmaking withdrawal changes. Federal Energy Regulatory Commission (FERC) licenses have been issued for the Vergennes, Middlebury Lower and Weybridge hydroelectric projects on the Otter Creek. The Fifteen Mile Falls Project on the Connecticut River has been licensed now as well and so the waters involved (many miles of river and impoundment) comply with the Vermont and New Hampshire Water Quality Standards. The Clyde River Project also has a new FERC license and so the streamflows in this watershed (a portion of the Clyde River itself, Echo Lake outlet stream, and Seymour Lake outlet stream) have been improved as well. Killington snowmaking water withdrawals are now complying with the water quality standards on the portions of the Ottauquechee River and two tributaries.

Streambank erosion has been identified as the cause of about 247 miles of impact and 587 miles of stresses. Streambank erosion is described as a source in and of itself, but this 'source' results from other 'sources' such as riparian vegetation removal and channel instability.

Agricultural land uses and activities have an impact on 187 miles and stress another 524 miles of river or stream. As mentioned above, the interrelationship between agricultural activities, riparian vegetation loss, streambank erosion, and channel instability as sources makes the attribution of miles stressed, altered, or impaired to each of these sources an imprecise task. The relative contribution of each source should be the focus.

Approximately 154 miles of impact and 526 miles of stress have been attributed to the removal of riparian vegetation. Removal of riparian vegetation continues to be a growing problem in the state. Individual residential and commercial landowners, farmers, town road crews and the Agency of Transportation all encroach on the riparian zone with their activities and the result is the loss of the trees and shrubs protecting rivers and riverbanks. Flooding and channel instability also result in loss of riparian vegetation, but the loss of riparian vegetation also increases a stream's vulnerability to channel changes in an unstable system.

Atmospheric deposition is primarily responsible for mercury and acidified conditions in Vermont's surface waters. While these conditions are most exacerbated in lake systems, stream biological communities do exhibit quantifiable impacts, particularly due to acidification. Atmospheric deposition has an impact on 106 miles of river and stream and stress about 17 miles.

Urban/developed land runoff, road and bridge runoff, and land development are three other separately identified sources of impairments and stresses that are also interrelated.

Urban/developed land as a source includes runoff from any urban, suburban, village or other developed areas. Developed land changes the amount and timing of runoff reaching rivers and streams and the runoff contains many pollutants including sediment, metals, nutrients and organic compounds. Most of the road/bridge runoff water quality problems come from gravel town roads that drain toward streams and discharge silt to them. Runoff from bridges over streams goes directly into streams. Road runoff also goes to slopes adjacent to the bridge abutments, which causes the slopes to erode to the streams. In addition, highway maintenance often includes washing pollutants off bridges into adjacent rivers and streams. Land development includes clearing, grading, excavation and filling, done in many cases with no or improperly maintained erosion control devices.

Land development has an effect on 83 miles and stresses about 62. Urban/developed land runoff affects about 80 miles of river and stream and stresses about 129 miles as determined in this assessment. Road and bridge runoff contributes to 44 miles of impairment and over 180 miles of stressed conditions

Other sources specifically tracked include: channel instability, upstream impoundments, onsite wastewater systems, hazardous waste sites, and resource extraction among others.

Table 4.C.3. Total Miles of Rivers & Streams Affected by Source Category.

Source of impairment	Magnitude (miles)	
	Not Meeting Standards	Meeting standards but stressed
Flow modification	283.7	60.0
Streambank erosion	246.9	586.9
Agriculture	187.4	523.9
Removal of riparian vegetation	154.5	526.1
Atmospheric deposition	106.2	17.0
Land development	82.6	62.1
Urban/developed land runoff	80.1	128.6
Channel instability	64.6	147.9

D) Lakes & Ponds Water Quality Assessment (Statewide)

1) Assessment of use support for inland lakes

A statewide summary of inland lake use support is provided in Table 4.D.1. Inland lakes are considered all waters within the borders of the State, except for all eleven segments of Lake Champlain. Moore and Comerford Reservoirs, Lake Memphremagog, and Wallace Pond are transboundary waters that are reported as “inland lakes.” Overall, 35,908 inland lake acres

support uses, and 19,434 acres do not support uses. Proportionally, aesthetics use is most highly supported in inland lakes (88% of acres), followed by swimming (87%) and drinking water supply. Although all waters are impacted by mercury pollution and are subject to consumption advisories, Vermont's assessment methodology indicates the need for waterbody-specific tissue data to indicate non-support of fish consumption. Accordingly, when assessed following the methodology, 85% of inland lake acres support fish consumption use. However, based on research conducted specifically in Vermont, all waters are subject to atmospheric mercury contamination, and many waters have the potential be impaired for fish consumption, were data available to support such assessments. The reader is referred to Section 4.D.5 for a comprehensive discussion of mercury impacts in Vermont, including a probability-based estimate of the proportion of lakes that are not likely to support fish consumption use.

Table 4.D.1. Acres of Vermont Inland Lakes Supporting or Not Supporting Uses.

Use	Full Support	Stressed	Total Meeting WQS	Altered	Impaired	Total Not Meeting WQS	Not Assessed
Overall Uses	15026	20882	35908	8874	9910	19434	162
Aesthetics	37517	11180	48697	4216	2529	6645	162
Agricultural Water Supply	-	-	-	-	-	-	53492
Aquatic Life Use Support	22614	16933	39547	8916	6979	15795	162
Drinking Water Supply	1268	0	1268	0	123	123	123
Fish Consumption	41054	5966	47020	0	8115	8115	369
Secondary Contact Uses	36721	9380	46101	5719	2559	8178	1225

Note: All Vermont waters are subject to contamination by atmospheric mercury.

Overall use support, expressed as proportion of lake/pond acres supporting/not supporting uses, by assessed waterbody, is shown in Figure 4.D.1 on the following page.

2) Summary of causes and sources for inland lakes

The causes and sources of impairments, alterations, and stresses to Vermont lakes are shown simultaneously in Table 4.D.2 beginning on the next page. In spite of the small amount of lake-specific fish tissue monitoring data available, metals and mercury remain the greatest cause of impairment to Vermont lakes, causing 8,115 inland lake acres not to meet fish consumption uses. This is due to the fact that mercury (Hg) contamination is quite elevated in fish tissues of the component reservoirs within the Fifteen Mile Falls (Connecticut River near St. Johnsbury, VT – Littleton, NH) and Deerfield River hydroelectric projects. Atmospheric deposition is the most important source of Hg to Vermont's landscape and, accordingly, is listed as the most important source category. Flow alteration is the second most important cause of alterations to aquatic life and other uses in Vermont, resulting in loss of use to 7,773 acres, due largely to hydromodification. Lake acidification, caused by low pH, it the third most prevalent cause of impairment and the source of this low pH is atmospheric deposition of acid precursors, along with natural factors such as low catchment buffering capacity. In Vermont, 4,420 lake acres are impaired by cultural acidification and an additional 6,883 acres are stressed. A TMDL addressing acid deposition to 30 Vermont lakes was issued by DEC during the reporting period.

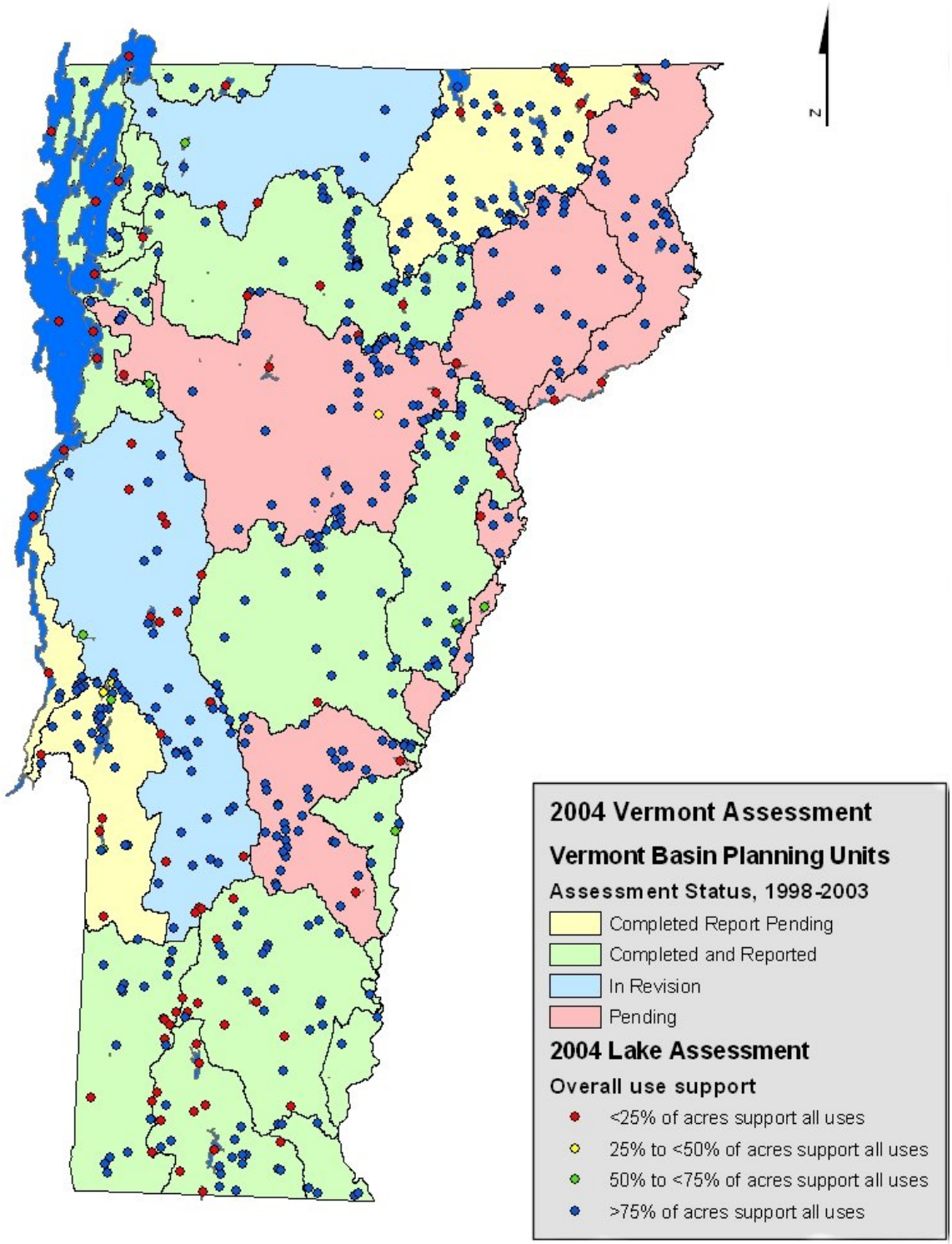


Figure 4.D.1. Overall Use Support for Lakes and Ponds.

Phosphorus and nutrients the fourth most important cause of impairment, limiting or precluding uses on 2,515 lake acres and stressing approximately additional 4,900 acres. Siltation is tracked separately from phosphorus, but is the result of similar sources. Siltation impairs 1,833 acres and stresses an additional 3,365. Several sources simultaneously account for nutrients, phosphorus, and siltation, including agricultural, silvicultural, and developed land, road runoff, unstable streams, and residential property management. Finally, non-native species (largely the Eurasian milfoil *Myriophyllum spicatum*) alter several uses and is spread by recreational lake uses. Non-native species currently alter 1,697 acres and stress an additional 5,182 acres.

Table 4.D.2. Causes & Sources of Impacts to Inland Vermont Lakes.
Causes and sources are ranked in decreasing order of total acreage impaired/altered.
(Note: listed causes and sources are not linked)

Cause of impact	Magnitude of **Cause**		**Source** of impact	Magnitude of **Source**	
	Not meeting WQS	Use stressed		Not meeting WQS	Use stressed
0500 Metals	8115	0	8100 Atmospheric deposition	16178	5702
0560 Mercury	8115	0	7400 Flow regulation/modification	9785	4884
1500 Flow alteration	7773	4813	7000 Hydromodification	7773	4859
1000 pH	4420	6883	8600 Natural sources	4420	7774
2210 Noxious aquatic plants - algae	2537	3294	1000 Agriculture	2413	2277
0900 Nutrients	2515	4926	1100 Nonirrigated crop production	2378	858
0910 Phosphorus	2515	4951	9070 Inspecified nonpoint source	2151	841
1100 Siltation	1831	3365	1800 Animal holding/management area	1926	796
2600 Exotic Species	1697	5182	1400 Pasture grazing-riparian and/or upland	1908	967
1200 Organic enrichment - DO	1187	1150	7900 Marinas and recreational boating	1797	5211
2200 Noxious aquatic plants - native	554	1405	7910 In-water releases	1734	5235
2400 Total Toxics	1		7550 Habitat modification	612	446
0000 Cause unknown	0	7	7700 Streambank modification/destabilization	612	472
0800 Other inorganics	0	6	0200 Municipal point sources	521	
1300 Salinity - TDS - chlorides	0	9	0400 Combined sewer overflow	470	
1700 Pathogens	0	808	6000 Land disposal	452	456
2300 Filling and draining	0	49	6400 Industrial land treatment	452	446
2500 Turbidity	0	51	3000 Construction	200	3342
			3200 Land development	200	3322
			7600 Removal of riparian vegetation	85	1131

Cause of impact	Magnitude of **Cause**		**Source** of impact	Magnitude of **Source**	
	Not meeting WQS	Use stressed		Not meeting WQS	Use stressed
			8530 Internal nutrient cycling (lakes)	54	72
			8300 Highway maintenance and runoff	51	3186
			2000 Silviculture	35	1393
			2100 Harvesting, restoration, residue management	35	1098
			4000 Urban runoff/storm sewers	1	1115
			0100 Industrial point sources	0	17
			1410 Pasture grazing-riparian	0	5
			2300 Logging road construction/maintenance	0	20
			3100 Highway/road/bridge construction	0	4
			4300 Other urban runoff	0	148
			4500 Highway/road bridge runoff	0	166
			4600 Erosion and sedimentation	0	3
			5000 Resource extraction	0	21
			5100 Surface mining	0	21
			6300 Landfills	0	14
			6500 Onsite wastewater systems (septic tanks)	0	54
			7300 Dam construction	0	37
			8520 Debris and bottom deposits	0	20
			8700 Recreational and tourism activities (not boating)	0	105
			9000 Source unknown	0	1026

3) Assessment of use support for Lake Champlain

A summary of Lake Champlain use support is provided in Table 4.D.3. In Lake Champlain, due to the combined effects of trace metal contamination, nutrient accumulation and non-native species, none of Lake Champlain's 174,175 acres fully support all designated uses. Proportionally, aquatic life use is most highly supported (88% of Champlain waters), followed by secondary contact (83%). Due to phosphorus concentrations in excess of Vermont Water Quality Standards in most areas of the lake, only 23% of Lake Champlain fully supports

swimming uses, and only 20% supports aesthetics. No acres support fish consumption use due to mercury and polychlorinated biphenyls (abbreviated as PCBs) in fish tissue.

Table 4.D.3. Lake Champlain Acres Supporting or Not Supporting Uses.

Use	Full Support	Stressed	Total Meeting WQS	Altered	Impaired	Total Not Meeting WQS	Not Assessed
Overall Uses	0	0	0	13201	174175	174175	0
Aesthetics	35290	0	35290	11394	132053	138885	0
Aquatic Life Use Support	152672	0	152672	21503	5388	21503	0
Drinking Water Supply	121872	0	121872	15673	0	12904	0
Fish Consumption	0	0	0	0	174175	174175	0
Secondary Contact Uses	144300	0	144300	12994	0	29875	0
Swimming Uses	39271	0	39271	15595	132063	134904	0

Note: all segments of Lake Champlain are considered impaired for fish consumption use due to fish tissue mercury data which show elevated Hg concentrations for various fish species, in all sections of the lake.

4) Summary of causes and sources for Lake Champlain

The causes and sources of impairments, alterations, and stresses to Lake Champlain are shown simultaneously in Table 4.D.4 below. Mercury is the greatest cause of impairment to Lake Champlain, precluding fish consumption use on the entire lake for a subset of Vermont's citizens. Priority organics (PCBs) also impair fish consumption use on the majority of Lake Champlain acres. Atmospheric deposition is the most important source of mercury to Vermont's landscape and is listed as the most important source of mercury to Lake Champlain. The source of PCBs in lake trout was identified in 1994 as a residual "dump" of PCBs in the vicinity of the Wilcox Dock in Plattsburg Bay, New York. The PCB source and contaminated sediments were cleaned up in the late 1990s by the New York State Department of Environmental Conservation.

Nutrients, phosphorus, and associated algal growth impair 132,053 acres of Lake Champlain, and related siltation contributes to that impairment, by stressing uses on 5,388 acres. Unspecified nonpoint sources of nutrients are the largest source of the nutrient pollution, although a suite of sources also contribute nutrients to Lake Champlain, as discussed above (Section 4.D.2). Urban runoff, including stormwater, is also an important nutrient and sediment source in certain segments of Lake Champlain. During the reporting period, a comprehensive TMDL for phosphorus was finalized for Lake Champlain. The Lake Champlain TMDL is the centerpiece of Vermont Governor Douglas' *Clean and Clear Water Action Plan*, which is beginning to be implemented as of this writing. Exotic species are a significant problem in Lake Champlain, impairing several uses on 21,503 acres. In Lake Champlain, there is a mix of Eurasian milfoil, water chestnut (*Trapa natans*) and zebra mussel (*Dreissena polymorpha*) infestations which all impact aquatic life, aesthetics, swimming, boating, and drinking water uses.

Table 4.D.4. Causes & Sources of Impacts to Lake Champlain (acres).
Causes and sources are ranked in decreasing order of total area impaired/altered.
(Note: listed causes and sources are not linked)

Cause of impact	Magnitude of **Cause**		**Source** of impact	Magnitude of **Source**	
	Not meeting WQS	Use stressed		Not meeting WQS	Use stressed
0500 Metals	174175		8100 Atmospheric deposition	174175	
0560 Mercury	174175		9070 VT-unspecified nonpoint source	132053	
0300 Priority organics	163678		0200 Municipal point sources	73869	
0900 Nutrients	132053		1000 Agriculture	31859	
0910 Phosphorus	132053		7910 In-water releases	24803	
2210 Noxious aquatic plants - algae	132053		7900 Marinas and recreational boating	21503	
2600 Exotic Species	21503		0100 Industrial point sources	21362	
1700 Pathogens	19	222	4000 Urban runoff/storm sewers	13744	
1100 Siltation	0	5388	3000 Construction	13725	
2200 Noxious aquatic plants - native	0	500	8300 Highway maintenance and runoff	13725	
			8600 Natural sources	5388	6
			9000 Source unknown	0	216

5) Probabilistic statewide assessment of mercury contamination in lakes

The material presented in the following section summarizes technical findings from a large study of mercury contamination in Vermont and New Hampshire lakes that was undertaken by DEC and other partners during the period 1998-2002 and reported in 2003. This project was supported by EPA Region 1 and EPA's Office of Research and Development, under the Regional Environmental Monitoring and Assessment Program (REMAP). Comprehensive results of the study are available online as reported by Kamman et al. (2003)[2] at www.vtwaterquality.org/lakesremap.htm. Results of the study have also been published in the journals *Atmospheric Environment*[3] and *Environmental Toxicology and Chemistry*[4] and are in–press in several additional manuscripts to publish in the journal Ecotoxicology in 2005. In this Integrated Report, a summary of the raw data findings from the project is presented in Tables 4.D.5.a-c and in Figure 4.D.5. Findings from a suite of detailed statistical analyses are provided in Section 5.e. The statistical analyses are outside the scope of this report, but summary tabular data are provided for readers who have an interest in the dataset developed by the project.

[2]Kamman, N.C., C.T. Driscoll, R. Estabrook, D.C. Evers, and E. Miller. 2003. Biogeochemistry of Mercury in Vermont and New Hampshire Lakes-An Assessment of Mercury in Waters, Sediments and Biota of Vermont and New Hampshire Lakes. Vermont Department of Environmental Conservation. Waterbury VT USA.
[3] Kamman and Engstrom, 2002. Current and historical fluxes of Hg to VT and NH lakes inferred from 210Pb-dated sediment cores. *Atmos. Environ*. 36: 1599-1609
[4] Kamman *et al*., 2004. Assessment of mercury in waters, sediments, and biota of New Hampshire and Vermont lakes sampled using a geographically randomized design. *Env. Tox. Chem*. 23:5

a) VT-NH probabilistic assessment of mercury (Hg) and other chemical parameters in waters.
Water chemistry results are summarized by lake strata (epilimnion and hypolimnion, denoted as "EPI" and "HYP" in Table 4.D.5.a), and are presented based on geographically weighted data. Statistics based on weighted datapoints provide statistically unbiased estimates of all measured parameters for the population of lakes in Vermont and New Hampshire. Water chemistry results for aqueous parameters are presented below by lake strata in Table 4.D.5.a.

Table 4.D.5.a. Summary of Water Chemistry Data Based on Weighted Sampling Results for Vermont & New Hampshire Lakes.

Parameter	Lake strata	Count	Mean	95% lower C.L.	95% upper C. L.
Acid Neut. Capacity	EPI	127	19.1	17.1	21.1
Acid Neut. Capacity	HYP	75	24.1	21.2	27.0
CL^-_mg/l	EPI	129	8.09	7.46	8.72
CL^-_mg/l	HYP	80	7.84	6.93	8.76
Diss. Color PtCo units	EPI	90	27.10	24.46	29.74
Diss. Color PtCo units	HYP	55	41.24	36.11	46.38
DOC mg/l	EPI	130	4.31	4.18	4.44
DOC mg/l	HYP	80	3.91	3.75	4.07
Total mercury (HgT)_ng/l	EPI	129	1.78	1.68	1.88
HgT_ng/l	HYP	68	11.52	10.62	12.41
Methylmercury (MeHg)_ng/l	EPI	129	0.299	0.281	0.318
MeHg_ng/l	HYP	68	0.829	0.738	0.921
NO_X_mg/l	EPI	128	0.03	0.03	0.04
NO_X_mg/l	HYP	80	0.04	0.04	0.04
SO4_mg/l	EPI	129	4.11	4.03	4.19
SO4_mg/l	HYP	80	3.96	3.82	4.10
Sulfide_mg/l	EPI	44	0.12	0.09	0.14
Sulfide_mg/l	HYP	72	0.13	0.12	0.15
Total Color PtCo units	EPI	127	39.75	37.48	42.01
Total Color PtCo units	HYP	78	65.94	61.15	70.73

b) VT-NH probabilistic assessment of Hg and other chemistry parameters in sediments.
Sediment chemistry summary statistics are presented using geographically weighted data, for percent solids and loss on ignition, total mercury (HgT), methylmercury (meHg), and percent of HgT as meHg. These statistics are presented in Table 4.D.5.b below.

Table 4.D.5.b. Summary of Sediment Chemistry Data Based on Weighted Sampling Results for Vermont and New Hampshire Lakes.

Parameter	Count	Mean	St. error	95% lower C.L.	95% upper C. L.
Sediment HgT - ug/g	129	0.24	0.00	0.23	0.25
Sediment meHG - ug/g	78	0.004	0.0001	0.004	0.004
Sediment meHG, % of HgT	78	1.713	0.054	1.607	1.818
Solid content %	129	8.35	0.19	7.97	8.72
Loss on ignition %	129	32.17	0.39	31.40	32.95

c) VT-NH probabilistic assessment of mercury and other chemistry parameters in biota.
Summary statistics are presented for: HgT in yellow perch fillets, bulk macrozooplankton (≥ 201 μ) and avian piscivore blood, feathers, and eggs; HgT and meHg in prey-sized (≤15cm) yellow perch composites; and, physical characteristics of tissue samples. Summary statistics are provided in Table 4.D.5.c.

Table 4.D.5.c. Summary of Sediment Chemistry Data Based on Weighted Sampling Results for Vermont and New Hampshire Lakes.

Parameter	Count	Mean	95% lower C.L.	95% upper C. L.
Filet Length_cm	278	20.6	20.4	20.8
Filet Weight_g	278	114.59	110.69	118.49
Fish Age	232	4.6	4.5	4.7
Yellow Perch Fillet HgT_ug/g ww	278	0.239	0.232	0.246
Yellow Perch Prey weight_ g	45	80.99	76.35	85.62
Yellow Perch Prey HgT ug/g w.w.	45	0.098	0.092	0.103
Yellow Perch Prey meHg ug/g w.w.	30	0.0914	0.0846	0.0983
Zooplankton % Solid	41	0.24	0.22	0.26
Zooplankton HgT ug/g d.w.	38	0.432	0.387	0.478
Zooplankton HgT ug/g w.w.	38	0.091	0.082	0.101
Loon blood HgT ppm w.w.	18	1.356	1.184	1.528
Loon egg HgT ppm w.w.	15	0.762	0.699	0.825
Kingfisher blood HgT ppm w.w.	10	0.759	0.623	0.895

Note: Zooplankton HgT values are given as both dry and wet weight to facilitate comparison to other biological matrices.

*d) Probabilistic assessment of mercury risk to common loon (*Gavia immer*) across northern New England.*

Tissue samples acquired from common loons permit assessment of the overall risk to loons posed by mercury bioaccumulation. Risk characterizations were derived using either adult or juvenile blood, or abandoned eggs. The type of sample acquired was determined in the field based on availability and opportunity. Risk attributions followed the protocols of Evers et al. (2000)[5]. Based on these characterizations, samples collected from lake in this study were evaluated by state, and in relation to loon tissues acquired from the Maine REMAP study lakes (MEDEP, 1995)[6]. Results are provided in Figure 4.D.5.

Fifty percent of loons from Vermont study lakes and 70% of loons from NH study lakes have sufficient mercury in their tissues so as to pose a moderate or greater risk to the animals themselves. In Maine, the proportion is 78%. The total percentage of birds at high or extra high

[5] Evers, D. C., C. DeSorbo, and L. Savoy. 2000. Assessing the impacts of methylmercury on piscivorous wildlife as indicated by the Common Loon, 1998-99. Maine Dept. Environ. Protection, Augusta, Maine).
[6] Maine Department of Environmental Protection. 1995. Fish tissue contamination in Maine lakes, data report. Regional environmental monitoring and assessment program (REMAP). Augusta, Maine, USA.

risk increases from 20% in Vermont to 27% in Maine. A geographic gradient is apparent in these data with a clear increase from west to east. This is consistent with the findings of Evers, et al. (2000).

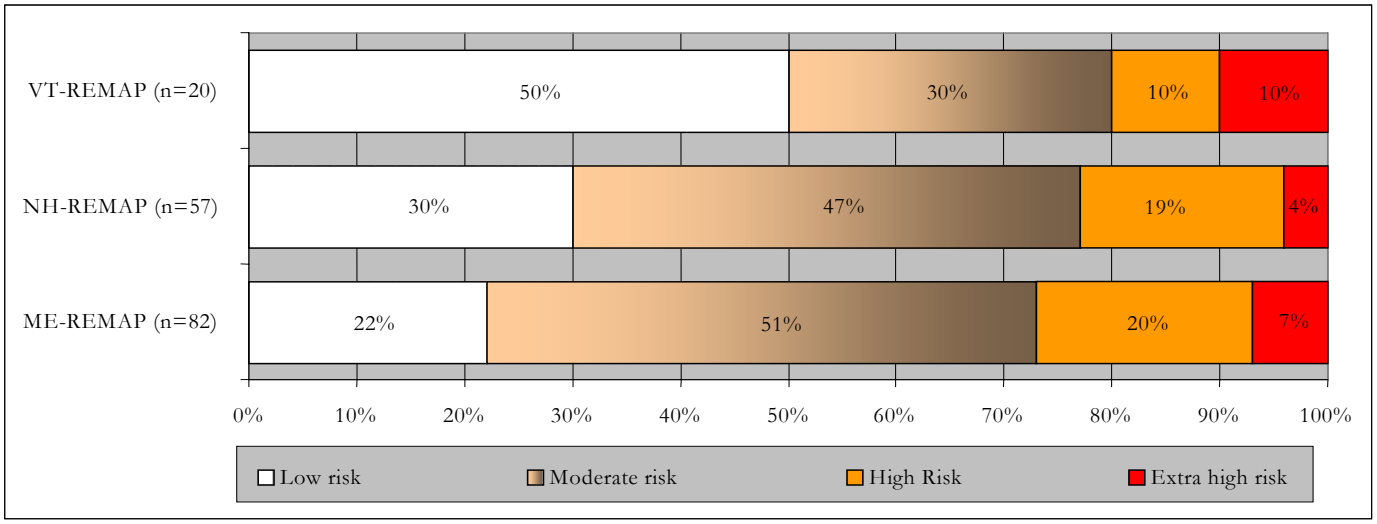


Figure 4.D.5. Mercury risk to breeding Common Loons (*Gavia immer*), based on adult and juvenile blood and egg Hg levels.

Evers (2003)[7] further indicates that these proportions are sufficient so as to threaten entire loon populations. The present hypothesis regarding population-level impacts to loons is that chronic mercury exposure impacts to loons is reducing the ability of loon pairs to successfully produce chicks, owing to impacts to individual birds within the parent pair (Evers, personal comm.). Individual-level impacts include reduced ability to acquire food for chicks, and reduced ability to defend nesting territories from predators and other loons. However, in the field, observations regarding loon nesting habits from citizen monitoring groups show continuing increases in overall numbers of nesting loon pairs. While these two phenomena seem at odds, they are in fact consistent, when the effect of the male loon "buffer population" is accounted for. The "buffer population" is that group of male birds (typically juvenile or sub-adult, lone birds) which are available to fill in for a nesting male bird, if that bird is unable to successfully defend it's territory, or is lost due to disease or other factors. It is the decline in the "buffer population" which is cause for concern. Declines in actual nesting loon pair and reared chicks are expected to accompany further reductions in the buffer population.

e) Summary of REMAP project data analyses

In the following paragraphs, results of detailed statistical analyses using the REMAP project data are excerpted from Kamman et al. (2003).

[7] Evers, D.C.. 2003 in prep. Development of a wildlife criterion value to protect against methylmercury exposure to piscivorous wildlife in Maine. Maine Dept. Environ. Protection, Augusta, Maine.

"Yellow perch fillet mean HgT concentrations for the present study lakes are most accurately estimated using age as a covariate. The overall VT-NH average yellow perch fillet HgT concentration, adjusted to an age 4.6 year fish, is 0.225 $\mu g\ g^{-1}$ w.w.

"Reviewed geographically, the raw data on mercury in waters, sediments, and biota indicate that New Hampshire lakes have elevated epilimnetic meHg, and hypolimnetic HgT and meHg. Concentrations of hypolimnetic meHg are highest in southern NH. There is a 'hotspot' in yellow perch fillet HgT (age-adjusted means) in southwestern NH. The same hotspot is reflected in sediment meHg concentrations, and may reflect a localized Hg source.

"Cumulative frequency diagrams based on weighted individual lake mean observations show the distribution of mercury in water, sediment, and biota across the region, as well as by state. Based on these diagrams, approximately 25% of lakes across the region possess yellow perch which violate the EPA criterion of 0.3 $\mu g\ g^{-1}$ w.w. meHg in fish tissues. Significant differences between hypolimnetic HgT and meHg, prey and fillet tissue HgT, and zooplankton HgT are apparent between the states, with New Hampshire displaying generally higher overall values. Comparisons are available from the Maine REMAP project, which indicate that while sediment HgT concentrations in Maine are lower than in the Vermont-New Hampshire region, yellow perch tissue concentrations are generally consistent with those of New Hampshire lakes.

"A formal statistical evaluation of the role of trophic status on Hg in waters, sediments, and biota indicated that: 1) epilimnetic HgT and meHg was elevated in both eutrophic and dystrophic lakes; 2) yellow perch fillet HgT are greatest in dystrophic lakes, and lowest in eutrophic lakes; and, 3) in general, dystrophic lakes can be expected to have HgT fillet concentrations that are 0.218 $\mu g\ g^{-1}$ w.w. greater than in all other lake types. These findings support the hypothesis that mercury is biodiluted in lakes with significant algal production.

"Mean log-bioconcentration factors range from a low of 4.37 for concentration from hypolimnetic HgT to yellow perch fillets, to a high of 6.94 from epilimnetic meHg to loon blood. The bioconcentration factors calculated from this studies' data re consistent with those published elsewhere in the literature.

"Numerous water chemistry parameters show significant ($p<0.05$) correlations to a variety of mercury measurements, in both waters and sediments. Data reduction techniques such as principal components analysis are useful to reduce the variability in the dataset, and show how covariance among parameters influences mercury in the study lakes. Such an analysis showed that while HgT and meHg concentrations are higher both in more acidic lakes and more eutrophic lakes, tissue HgT only becomes enhanced in lakes of increased acidity. Sediment HgT increases with increasing lake acidity, and decreases with increasing productivity. This is either the result of bloom dilution and subsequent accumulation to the broad trophic webs characteristic of eutrophic lakes, or related to the reduced ability of algal-derived DOC to bind mercury relative to the higher molecular-weight allocthonous DOC characteristic of acidic lake watersheds.

"Land use characteristics also influence Hg in the present study lakes. As is characteristic of numerous studies, meHg and tissue HgT is elevated in lakes with larger forested and wetland areas. Age-adjusted perch fillet mean HgT is reduced in developed watersheds. Sediment HgT decreases with increasing agricultural area and increased watershed building count."

Of specific interest from a fish consumption use assessment standpoint are the following statistical modeling results describing the likelihood that fish tissues of all Vermont-New

Hampshire lakes, and of any individual Vermont or New Hampshire lake, would exceed the 2001 USEPA §304(a) water quality criterion of 0.3 $\mu g\ g^{-1}$ methylmercury in fish tissue:

"Statistical models were developed to predict whether a lake would attain or violate the 0.3 $\mu g\ g^{-1}$ w.w fish tissue meHg criterion, with only a 13% likelihood of misclassifying an individual lake. Application of this model to lakes across the Vermont-New Hampshire region indicated that 40.2% of lakes would violate the criterion (54% in NH, 25% in VT). Evaluation of model performance using the independently derived Maine REMAP dataset produced mixed results, which were poor when performance was evaluated using Maine yellow perch data, but better when Maine smallmouth and largemouth bass data were used. This can be explained by several factors, and does not indicate that the model is overly flawed for use in the Vermont-New Hampshire region. Overall, the statistical models capture those factors which the present study indicates are important in estimating whether lakes will have fish tissues in excess of the EPA criterion. Lacking a more detailed, mechanistic model, the statistical model can be used to select lakes outside of the REMAP study set for future sampling, both to verify model performance, and to refine fish tissue advisories."

E) Wetlands Assessment (Statewide)

Background

Vermont wetlands are significant resources that contribute to the economic, cultural, and physical well being of its residents. Wetlands provide numerous ecological functions and social values, including habitat for fish and wildlife, recreational and educational opportunities, habitat for threatened and endangered species, temporary storage of flood waters, and they aid in the maintenance of water supply and quality. However, these resources have been significantly affected by human land and water use activities.

The primary function of the Vermont Wetlands Program within DEC is to administer the Vermont Wetland Rules, which regulate most palustrine wetlands that have been mapped on the Vermont Significant Wetland Inventory maps, and therefore have a higher level of protection than unmapped wetlands. The Wetlands Program also provides comment on Act 250 applications that involve wetland issues and conducts pre-Act 250 determinations to assist potential developers in meeting the requirements of the Act. Wetlands Program staff provide comment and advice to other state agencies and they are called upon as wetland experts wherever testimony is deemed appropriate. DEC reviews projects that involve wetland filling under Section 401 of the Clean Water Act based on compliance with the Vermont Water Quality Standards and other applicable provisions of State law. On January 23, 1996, the Vermont Water Quality Standards included the statement that the Standards shall apply to "all waters of the United States," as defined in 40 C.F.R. §122.2 (1995). This wording, therefore, includes wetlands as being part of "all water..." with respect to having met the goals of the Water Quality Standards.

Extent of Wetland Resources

The Vermont Agency of Natural Resources digitized all the National Wetland Inventory (NWI) maps for the state. For Vermont, a total of 232,000 acres of palustrine wetlands are depicted on the maps. These wetland areas are considered significant and are designated as Class Two wetlands under the Vermont Wetland Rules. Wetland inventories conducted in selected towns around Vermont indicate there are considerably more acres of wetland than identified by the

NWI project. A comparison of NRCS mapped hydric soils versus Class Two wetlands in the Lamoille River Watershed found that hydric soils covered approximately 3% more of the landscape than VSWI mapped wetlands, bringing total coverage of total wetland acreage in the watershed to 7%. The wetlands that do not appear on the NWI maps are considered Class Three by the Vermont Wetland Rules. Extrapolating the soil information in the Lamoille Watershed to the rest of the state indicates there may be approximately 90,000 acres of Class Three wetlands in Vermont. Class One wetlands are considered exceptional or irreplaceable in their contribution of Vermont's natural heritage and are therefore are afforded the highest level of protection under the Vermont Wetland Rules. In order for a wetland to be given Class One status, it must be petitioned for reclassification through the Water Resources Board. Four wetland complexes, totaling 2,138 acres, have been evaluated and given the status of Class One since 1990. Dorset Marsh in Dorset is a 200 acre wetland complex that was successfully petitioned to Class One by the Dorset Citizens for Responsible Growth in 1991, and was also given a 100 foot buffer zone. The North Shore Wetland in Burlington is a 15 acre wetland complex on Lake Champlain that was petitioned by the Vermont Natural Resources Council (VNRC) and given Class One status and a 300 foot buffer zone in 2000. Tinmouth Channel in Tinmouth was reclassified to Class One in 2001. This 1,473 acre wetland complex was petitioned by VNRC, and in addition to Class One status, now contains a buffer zone that is 300 feet on the North End, and 100 feet on the southern end. The Lake Bomoseen Wetland was successfully petitioned to Class One by VNRC in 2003. This 450 acre wetland complex in Hubbarton was given a 100 foot buffer in most places, but retained a 50-foot buffer zone in one heavily developed area.

Wetland Loss

A recent analysis of all completed projects reviewed by DEC shows that there has been a total of 330 acres of documented wetland loss and 491 acres of documented wetland impairment over the period between 1990 and 2002 (see Table 4.E.1 below). The analysis was based on the Wetland Program's database that tracks wetland losses associated with projects reviewed by the program. Only Class 3 wetlands under review for 401 Water Quality Certification, Act 250 or voluntary review are included in this table.

These figures do not represent all wetland impacts as they are based only on summaries of projects that have been completed for each year. There is a certain lag phase between when a project is started and completed. The year in the table listed above represents the year a project was started, but not necessarily completed. It is likely that many of the projects which have not been completed are larger projects and may represent substantial areas of wetland impacts. Also, it is clear there are many wetland alterations still occurring that are not reported to DEC and are not included in this database.

Table 4.E.1. Acres of Wetland Loss & Impairment 1990 through 2002.[8]

	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02
# of Completed Projects	474	483	559	455	394	379	324	371	362	340	374	398	389
Acres of Wetland Loss													
Class One & Two Wetlands	21.6	18.6	14.3	26.3	9.0	20.4	7.6	7.3	3.8	6.7	11.8	7.8	2.2
Class Three Wetlands	27.0	15.0	12.8	19.0	16.8	32.0	13.0	7.8	2.7	6.0	12.9	4.3	3.2
Acres of Wetland Impair.													
Class One & Two Wetlands	115.5	45.4	114.5	26.7	30.3	25.8	13.3	4.2	3.0	17.8	21.1	6.5	8.0
Class Three Wetlands	6.3	12.9	16.4	6.5	19.7	3.8	9.0	1.6	0	0.5	7.6	2.3	8.0

The database analysis also shows that there were over 588 acres of wetlands saved during the 1990-2002 period. This was achieved by encouraging developers to move their projects out of wetlands or to reconfigure them so as to have little or no impact on wetlands.

Wetlands Protection Mechanisms

On October 15, 1997, the State of Vermont and the US Army Corps of Engineers issued the State General Permit for projects in waters of the United States that occur in Vermont. Under this program, any fill under 3,000 square feet (except in Class Two wetlands, or special wetlands, or wetlands adjacent to international bodies of water, or in the towns of Athens, Brookline, Grafton, Newfane, Putney, Rockingham, or Townshend) do not have to report their fill activity to either the Corps of Engineers or the State of Vermont. Fills between 3,000 square feet and 43,560 square feet (between 0.068 and 1 acre) are reviewed by an interdisciplinary team. The Vermont Water Quality Standards are the basis for review of projects under Section 401 Water Quality Certification. The Vermont Water Quality Standards do not specifically address wetlands. The Standards address discharges to open water and impacts to surface water which are used by the Wetlands program to evaluate wetland impacts. DEC works closely with the US Army Corps of Engineer's Vermont Field Office staff on many projects.

A Conditional Use Determination (CUD) is used to allow reasonable development in and around Class One and Two wetlands while protecting the functions and values of this natural resource. CUDs are issued by the Vermont Wetlands Program only when it is determined that undue adverse impacts will not result from a proposed project.

Geographically, Chittenden County is the area of the state with the highest acreage of wetland alteration (refer to Figure 4.E.1). Chittenden County remains the area of the state with the largest number of Department site visits and the largest area of wetland loss.

[8] Figures are based on the projects that have been completed. (Source: Wetlands Office Database).

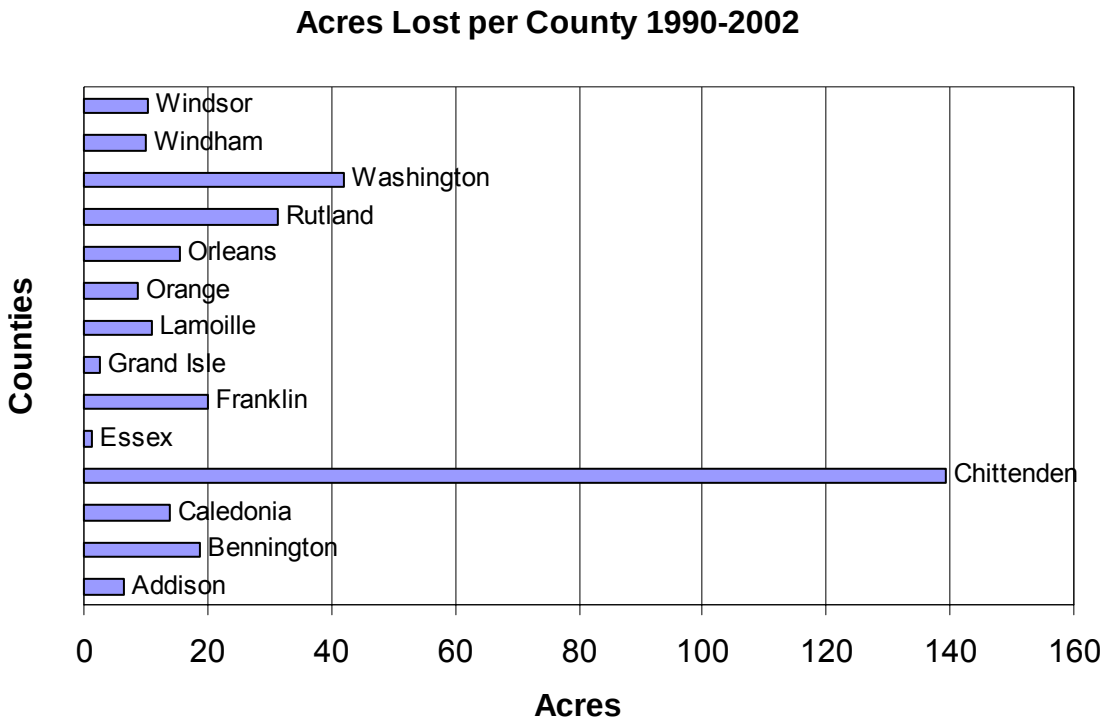


Figure 4.E.1. Wetland loss (in acres) by county 1990 – 2002.

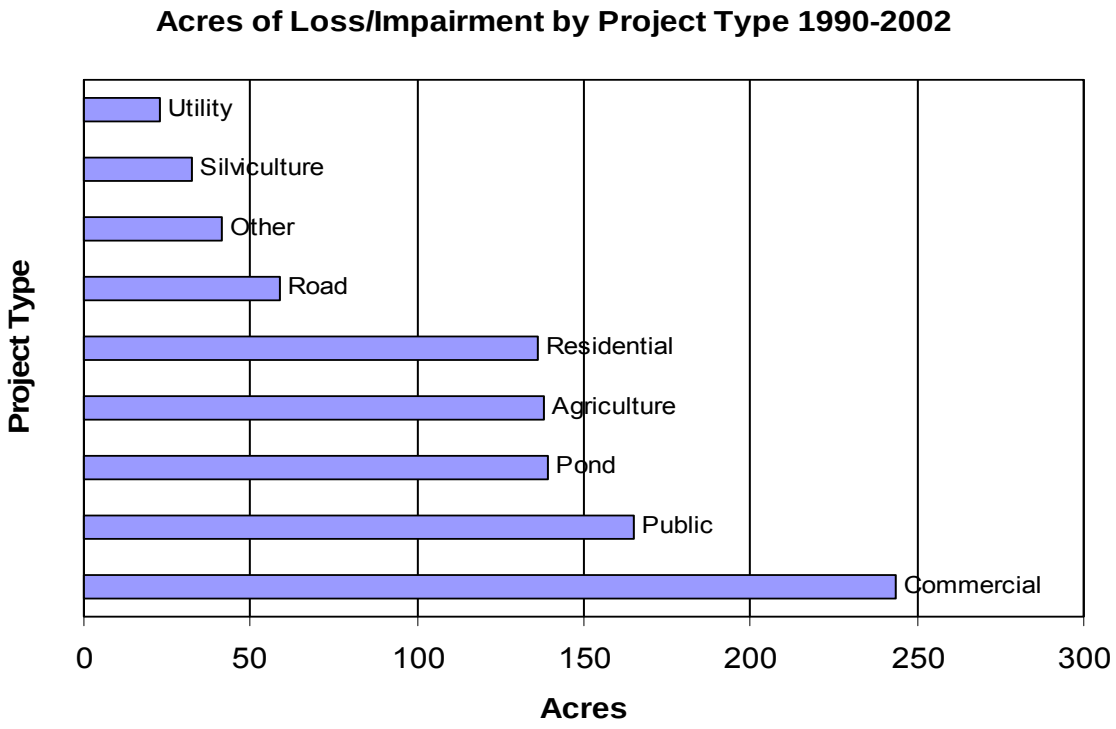


Figure 4.E.2 Wetland loss & impairment by project type (1990 – 2002).

For projects completed during the 1990-2002 period, DEC's database shows that of the project types, public projects (165 acres) and commercial/industrial development (243 acres) resulted in the greatest area of wetland loss and impairment (refer to Figure 4.E.2 above). Residential, agricultural, and pond related projects all resulted in 136 to 139 acres of wetland impact and impairment. Commercial/industrial development, residential development and road construction generally result in mostly wetland loss with small areas of wetland impairment.

Figure 4.E.3 below shows the area of wetland loss and impairment over the period from 1990 to 2002 based on the functions identified to be present in each altered wetland. A particular wetland, where an alteration occurred, may provide one or many of the ten functions and values listed, the documented area of alteration for that wetland is included in the totals for each function and value provided by that wetland. The surface water quality protection and wildlife habitat functions were the most frequently occurring functions in altered wetlands.

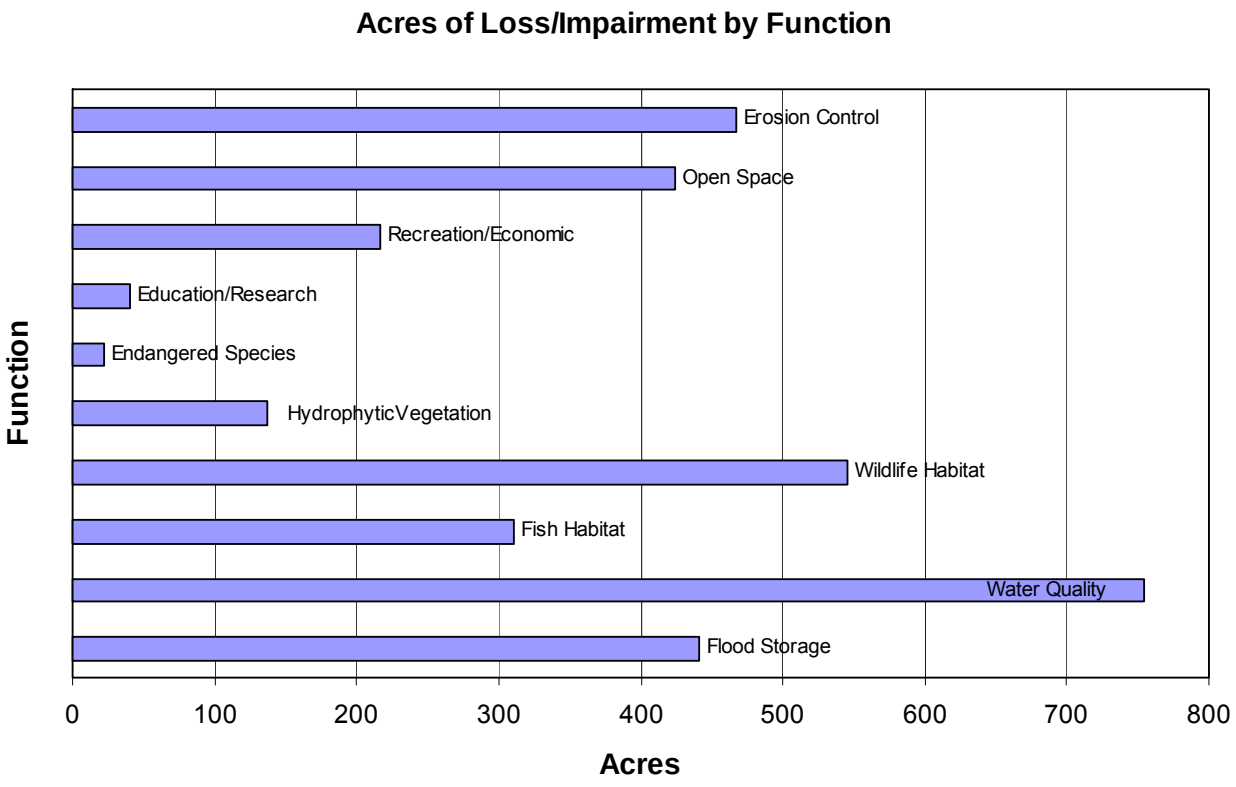


Figure 4.E.3 Wetland loss in relation to wetland function (1990 – 2002).

Table 4.E.4 below, shows the percentage of projects reviewed by the Vermont Wetlands Program by wetland type. As shrub swamps are the most common wetland type, this type has the highest percentage of reviewed project. Emergent marsh and forested wetlands have the next highest percentage of projects.

Table 4.E.4. Percentage of Projects by NWI Wetland Type.

NWI Wetland Type	Wetland Type Description	Percentage of Projects
PEM	Palustrine – emergent	16.3
PFO/PEM	Palustrine - forested/emergent	1.1
PFO/PSS	Palustrine - forested/scrub-shrub	7.7
PFO1	Palustrine - forested (broad leaved deciduous)	16.6
PFO2	Palustrine - forested (needle leaved deciduous)	0.5
PFO4	Palustrine - forested (needle leaved evergreen)	4.2
PFO5	Palustrine - forested (dead)	0.5
POW	Palustrine - open water	13.5
POW/PEM	Palustrine - open water/emergent	1.2
POW/PFO	Palustrine - open water/forested	0.4
POW/PSS	Palustrine - open water/scrub-shrub	0.5
PSS/PEM	Palustrine - scrub-shrub/emergent	18.1
PSS1	Palustrine - scrub-shrub (broad leaved deciduous)	19.1
PSS3	Palustrine - scrub-shrub (broad leaved evergreen)	0.5

In 1998, DEC began carrying out a wetland biomonitoring pilot project, a collaborative effort ion with the Vermont Fish and Wildlife Nongame and Natural Heritage Program. The focus of the project was to determine biological indicators of the ecological health of vernal pools and northern white cedar swamps. The initial task was to describe the reference condition for both wetland types and to examine a subset of disturbed sites. The assemblages that were studied included macroinvertebrates, amphibians, and algae for vernal pools and birds and plants for cedar swamps. The project also included study of the 150 meters (492 feet) around vernal pools to characterize the surrounding upland.

Data for the biomonitoring project was collected over two field seasons (1999 and 2000). After data analysis, a report was completed in June 2003. The project demonstrated methods that can be successfully employed for future wetland monitoring, but failed to detect indicators or metrics that could be used to assess wetland health. There was a great deal of variability in the vernal pools from year to year and season to season, both within pools and among pools, that may have

masked any significant relationships between vernal pool disturbance and potential metrics. The northern white cedar swamps appear to be robust wetlands that are not suitable for traditional bioassessment methods used for aquatic systems. However, the Nature Conservancy's method of community characterization is more suitable for this and other forested wetlands. Future work will focus on integrating wetland monitoring with on-going stream and lake bioassessments.

The Wetlands Office has again sponsored work on bio-control of purple loosestrife *(Lythrum salicaria)*, a non-native invasive plant species. The goal of the program is to reduce purple loosestrife in Vermont by ninety percent. To accomplish this goal, the program's work has been divided into three main aspects: biological control, documentation of purple loosestrife populations, and education and outreach. Since 1996, approximately 318,979 beetles have been released at 127 sites throughout Vermont for biological control purposes. In 2003, approximately 72,203 beetles were released on 178.25 acres of purple loosestrife infested land. An ongoing monitoring program was also initiated and has enlisted the help of the Vermont Agency of Transportation. Through education and outreach, the program strives to help prevent the intentional spread of purple loosestrife by informing the community of the consequences of this invasive species.

The Vermont Wetlands Program has actively participated in voluntary wetland restoration efforts with NRCS, EPA, the Army Corps of Engineers, Ducks Unlimited, Vermont Fish and Wildlife Department, and the Vermont Waterfowl Stamp Advisory Committee. Past projects have been located along Otter Creek, in Whiting Swamp, West Rutland Marsh, and along Lower Otter Creek. Several meetings were held to determine the restoration and management plan for the 356 acre Pomainville Farm located in Pittsford. Ground work will start in the spring of 2004 and restoration efforts will be monitored by the Wetlands Program. The Zelazny site (located directly across Otter Creek from the Pomainville site) will offer an opportunity to restore an additional 69 acres of previously drained wetlands. This will be accomplished through various partners and USDA's Wetland Reserve Program.

Education is an important approach in dealing with issues related to beaver populations in Vermont. In 2001, the Vermont Wetlands Program developed an Educational Plan with the Water Resources Board. In 2002, DEC in conjunction with the Vermont Department of Fish and Wildlife published *Best Management Practices for Resolving Human-Beaver Conflicts in Vermont*. Also in 2002 and in collaboration with the Natural Resources Conservation Service, EPA and the Army Corps of Engineers, the Vermont Wetlands Program undertook an outreach program specifically targeting Vermont's agricultural community. In 2003, the Vermont Wetlands Program held a training workshop for environmental consultants who work on wetlands in Vermont.