Connecticut Department of Energy & Environmental Protection

Ambient Water Quality Monitoring Program Strategy 2015-2024

Connecticut Department of
ENERGY & ENVIRONMENTAL PROTECTION

Bureau of Water Protection and Land Reuse
Planning and Standards Division
79 Elm Street
Hartford, CT 06106

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Two quotes from notable people who have retired from the Department exemplify the backbone of this monitoring strategy. That is, the importance of biological monitoring and data management cannot be over emphasized in order for a monitoring and assessment program to be successful.

We thank them for their guidance and know they are enjoying their retirement.

"Trying to run a water quality management program without biological monitoring information is like trying to drive a car at night without the headlights on. And if you <u>do</u> *monitor but don't look at the data, it's like driving the car with the headlights on but with your eyes closed."*

Lee Dunbar, former Assistant Director, Planning & Standards Division

"The database upgrade should be highest priority... If this project fails you might as well send everybody home."

Ernest Pizzuto, former Supervising Environmental Analyst, Monitoring and Assessment Program

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Executive Summary

Connecticut's Ambient Water Monitoring Program Strategy describes the scope and objectives to implement ambient surface water monitoring activities on inland waters of Connecticut. It is intended to provide an adaptive framework for the Connecticut Department of Energy and Environmental Protection's Monitoring and Assessment Program for a period of ten years, 2015-2024, as well as meet the requirements of Section 106(e)1 of the Federal Clean Water Act. The plan follows the 10 elements of a state water monitoring and assessment program recommended by United States Environmental Protection Agency (USEPA).

This strategy provides a scope, description (***Element 1-Monitoring Program Strategy***) and program objectives (***Element 2-Monitoring Program Objectives***) to monitor and assess the surface waters in Connecticut to meet federal and state needs. To accomplish the program monitoring objectives, this strategy will employ a combination of targeted and probabilistic monitoring designs (***Element 3 – Monitoring Design***). This approach will provide answers to waterbody specific questions essential to the Department's water resource management activities and also provide the comprehensive assessment capability required by the USEPA.

The ***Core and Supplemental Water Quality Indicators (Element 4)*** section describes the water quality indicators that will be monitored to meet the objectives of this Monitoring Strategy. Sections on ***Quality Assurance (Element 5)***, ***Data Management (Element 6)***, ***Data Analysis and Assessment (Element 7)***, and ***Reporting (Element 8)*** are described in detail to support the objectives of this Monitoring Strategy. The section on ***Programmatic Evaluation (Element 9)*** includes a summary of the Critical Elements Review by external experts as well as recommendations for future work if resources allow for program expansion. Finally, a section of ***General Support and Infrastructure Planning (Element 10)*** describes the current program support and infrastructure with projected program needs within the next 10 years.

Element 1- Monitoring Program Strategy

This Ambient Water Quality Monitoring Program Strategy describes the scope and objectives to implement ambient surface water monitoring activities on inland waters of Connecticut. It is intended to serve as guide for the Connecticut Department of Energy and Environmental Protection (DEEP) Monitoring and Assessment Program for a period of ten years, 2015-2024.

The Federal Clean Water Act (CWA) Sections: 106, 319, 314, 303, 305(b) and the Connecticut General Statutes (Sections: 22a-424(e), 22a-426(d)) provide the regulatory context and mandate for the Department's Water Monitoring and Assessment Program (WMAP). This comprehensive monitoring and assessment plan was developed pursuant to guidance issued by the United States Environmental Protection Agency (USEPA) under Section 106 of the CWA (USEPA 2003). USEPA's guidance document recommends that state plans contain ten basic program elements to meet the monitoring requirements of the CWA. These ten program elements serve as the section headings in Connecticut's Ambient Water Quality Monitoring Program Strategy (Table 1).

Table 1. The 10 elements of a state water monitoring and assessment program recommended by USEPA (USEPA 2003).

Element	Monitoring Strategy Section Heading	Page in this Monitoring Strategy
1	Monitoring Program Strategy	1
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This strategy provides an update of previous documents that formed work plans in the past for the DEEP's WMAP and focuses on Connecticut's Inland Waters. For Long Island Sound, the COAST Institute of Marine Sciences Research Center has formed the foundation of monitoring in Long Island Sound under the Long Island Sound Study (CIMSRC 1994).

DEEP conducts a Long Island Sound Water Quality Monitoring Program on behalf of the Long Island Sound Study estuary program. From October to May, water quality is monitored by collecting samples once a month from 17 sites by staff aboard the Department's Research Vessel. Bi-weekly hypoxia surveys start in mid-June and end in September with up to 48 stations being sampled during each survey.

The Long Island Sound Study's committees and work groups help to implement the Comprehensive Conservation and Management Plan (CCMP) for Long Island Sound which is undergoing a major revision that is expected to be completed in 2015. Together these committees and work groups (Table 2) represent the Long Island Sound Study Management Conference, a partnership of federal, state, interstate, and local agencies, universities, environmental groups, industry and the public. The Management Conference was convened in March 1988 following the Congressional designation of Long Island Sound as an Estuary of National Significance at the requests of Connecticut and New York. Since the management strategy and monitoring requirements for Long Island Sound are well documented in the CCMP (Table 3), this Monitoring Strategy focuses primarily on Connecticut's inland waters.

Like management of Long Island Sound waters, other state-wide planning documents (CTDEP 1999, CTDEP 2005) have preceded this document and have formed the foundation for the current monitoring program for Inland Waters. This strategy updates the DEEP's 2005 Connecticut Comprehensive Ambient Water Quality Monitoring Strategy (CTDEP 2005). The WMAP recognizes this strategy must be adaptive to changing environmental standards, emerging environmental issues, staff and funding resource constraints, improved analytical methods, as well as input from our collaborators and Connecticut's citizens. It is intended to provide an adaptive framework for monitoring activities, to discuss emerging issues within this framework, and identify areas for program growth and projected programmatic needs.

Table 2. Long Island Sound Study (LISS) committees and work groups to implement the Comprehensive Conservation and Management Plan for Long Island Sound. More information can be found on the Long Island Sound Study webpage [1].

Group	Responsibility
Policy Committee	Overall responsibility for LISS, including approval of goals and the Comprehensive Conservation and Management Plan
Executive Steering Committee	Provides upper-level management engagement in the LISS process and provides direction to the Management Committee on LISS programs and budgets.
Management Committee	Develops goals, approves work plan, and budgets and oversees projects.
Citizens Advisory Committee	Communicates citizen concerns about the Sound and the Study to the management committee, provide advice on public education activities, and build a constituency to support the implementation of the Management Plan
Science and Technical Advisory Committee	Advises the Management Committee on science and technical aspects of LISS's goals
State/EPA TMDL Workgroup	To develop fair and equitable allocations (both wasteload and load allocations) consistent with Clean Water Act and the Total Maximum Daily Load (TMDL) completed in 2000.
Habitat Restoration Workgroup	Planning, coordinating and implementing restoration of the twelve priority habitat types adopted by the Policy Committee in 1998
Nonpoint Source Pollution and Watersheds Work Group	Focuses on activities that have the potential to mitigate nonpoint source pollution (stormwater runoff) and support watershed management.
Sentinel Monitoring for Climate Change Work Group	Assists in designing and developing a dynamic climate change monitoring program for the ecosystems of the Long Island Sound and its coastal ecoregions.
Stewardship Work Group	Identifies sites of significant biological, scientific, and recreational value throughout Long Island Sound, and is charged with developing a strategy for recognizing these sites and coordinating efforts to protect or enhance them.

[1] http://longislandsoundstudy.net/about/committees/

Table 3. Major elements of the monitoring program under the Comprehensive Conservation and Management Plan for Long Island Sound.

Monitoring Activity	Responsible party	Reference
Open water quality monitoring, including temperature, salinity, dissolved nitrogen, nutrients, and pH, phytoplankton and zooplankton.	CTDEEP	CTDEEP LISWQMP
Marine fisheries survey	CTDEEP	CT DEEP
CT Bureau of Aquaculture & Laboratory Services and the NYSDEC's Shellfish Safety Section monitor shellfish beds in accordance with the U.S. Food and Drug Administration's National Shellfish Sanitation Program	CTDOAG NYSDEC	Bureau of Aquaculture & Laboratory Services NYSDEC
Buoy-based time-series monitoring of wave, weather, and water quality data	UCONN Department of Marine Science	UCONN-LISICOS
National Coastal Condition Assessment of water quality, sediment quality, biota, habitat, and ecosystem integrity.	USEPA	NCCA
Waters at 240 swimming beaches are monitored by local health departments and other agencies to test the water for microorganisms and reduce the risk of swimmer-related illness.	USEPA CTDPH CTDEEP Town Health Departments	US EPA CTDPH CTDEEP
Harbor Water Quality Survey provides data on fecal coliform and enterococcus pathogens in the Upper East River and Western Long Island Sound that have been monitored by the DEP as well as data for water quality indicators such as dissolved oxygen levels and concentrations of microscopic plants and animals.	NYSDEC	
Narrows and Western LIS Basin water quality monitoring	Interstate Environmental Commission (IEC)	IEC
Fall line monitoring to characterize nutrient loading to LIS	USGS	USGS
Streamflow and water quality monitoring to assess water quality trends and loads at tributaries to LIS	USGS	USGS
Inland monitoring at tributaries to LIS under section 305(b) Clean Water Act	CTDEEP	CTDEEP
Sentinel Monitoring for Climate Change, including an overall strategy and pilot monitoring projects	Sentinel Monitoring for Climate Change work group	LISS

Element 2-Monitoring Program Objectives

Monitoring program objectives that serve DEEP's water resource management programs as well as requirements of the CWA are outlined in this section.

Objective 1: Monitor and assess the surface waters of the State of Connecticut to:

(a) assess trends of surface waters;
(b) establish water quality standards attainment;
(c) identify high quality surface waters;
(d) identify impaired surface waters;
(e) identify causes and sources of water quality impairments;
(f) provide data to establish the science to review and revise water management and regulatory programs, if necessary;
(g) evaluate the effectiveness of current water quality programs and policies, and;
(h) identify emerging water quality problems to provide better water management policies and effectively manage these new contaminants.

Objective 2: Communicate monitoring information to the public and resource agencies by:

(a) collaborating with other DEEP programs (e.g. Non-point Source Program, TMDL Program, Permitting Programs, Inland and Marine Fisheries), other state agencies (e.g. Department of Agriculture, Department of Public Health), federal partners (e.g. USEPA, United States Geological Survey, United States Fish and Wildlife Service), universities, non-governmental organizations (e.g. Nature Conservancy) to optimize resources;
(b) encouraging citizen volunteer monitoring groups by providing technical support by maintaining the volunteer monitoring coordinator position;
(c) evaluating opportunities to expand the Volunteer Monitoring Program;
(d) turning raw data into information by providing analysis and summary reports of monitoring data on the Department's website and websites of collaborators, and;
(e) updating water quality assessments every 2-years (i.e. 305(b) CWA).

Objective 3: Maintain an electronic database to

(a) upload monitoring data to USEPA's STORET Data Warehouse via the Water Quality Exchange (WQX);
(b) provide timely monitoring information to the research community and the public;
(c) provide timely information to inform the Department's water quality policy decisions, and;
(d) support objectives 1 and 2.

Element 3-Monitoring Design

The Water Quality Monitoring Program Strategy uses a combination of targeted monitoring and probabilistic monitoring designs to meet the objectives of this strategy. Targeted monitoring is designed to answer specific questions regarding status and trends, identification of healthy and impaired waters, pollution control effectiveness, damage assessment, wasteload allocations, and stressor identification at predetermined locations. This type of monitoring generates information that is waterbody specific and is an essential component of Connecticut's water resource management activities.

Probabilistic monitoring incorporates a statistical design whereby sampling locations are chosen randomly. These monitoring designs are useful to characterize and assess the waters of the state and to meet requirements of the CWA. Since the resources are lacking to sample "everywhere all the time", probabilistic monitoring can be used to characterize the state's surface waters. For example, probabilistic sampling designs can help answer questions such as, "What percent of the streams in Connecticut are healthy and what percent are impaired for aquatic life?"

Targeted Monitoring

Rotating Basin Framework

A five-year Rotating Basin Monitoring Framework was developed and implemented in 1996 following existing CWA Section 106 and 305(b) guidance (CTDEP 1999). The Rotating Basin approach uses eight major drainage basins – Pawcatuck, Southeast Coast, Thames, Connecticut, South Central Coast, Housatonic, Southwest Coast, and Hudson - as a hydrological framework to organize monitoring and assessment work and facilitates statewide coverage of WMAP activities (Figure 1). The major basins were delineated by interpreting the contour elevation lines from the United States Geological Survey (USGS) quadrangle maps at the 1:24,000 map scale (Nosal 1997). The Connecticut, Thames, and Housatonic Basins are the three largest basins that represent 77.1% of total watershed area in Connecticut.

Rotating Basin Assessment Units- Major Basins in Connecticut

Major Basin Name (Number)	USGS HUC-8	Sampling Year	Percent of Watershed Area in CT
Pawcatuck (1000)	01090005	2019,2024	1.2
Southeast Coast (2000)	01100003	2019,2024	3.2
Thames (3000)	01100001 01100002 01100003	2019,2024	23.4
Connecticut (4000)	01080205 01080207	2017,2022	28.9
South Central Coast (5000)	01100004	2018,2023	10.3
Housatonic (6000)	01100005	2016,2021	24.8
Southwest Coast (7000)	01100006	2018,2023	7.8
Hudson (8000)	02030101	2016,2021	0.4

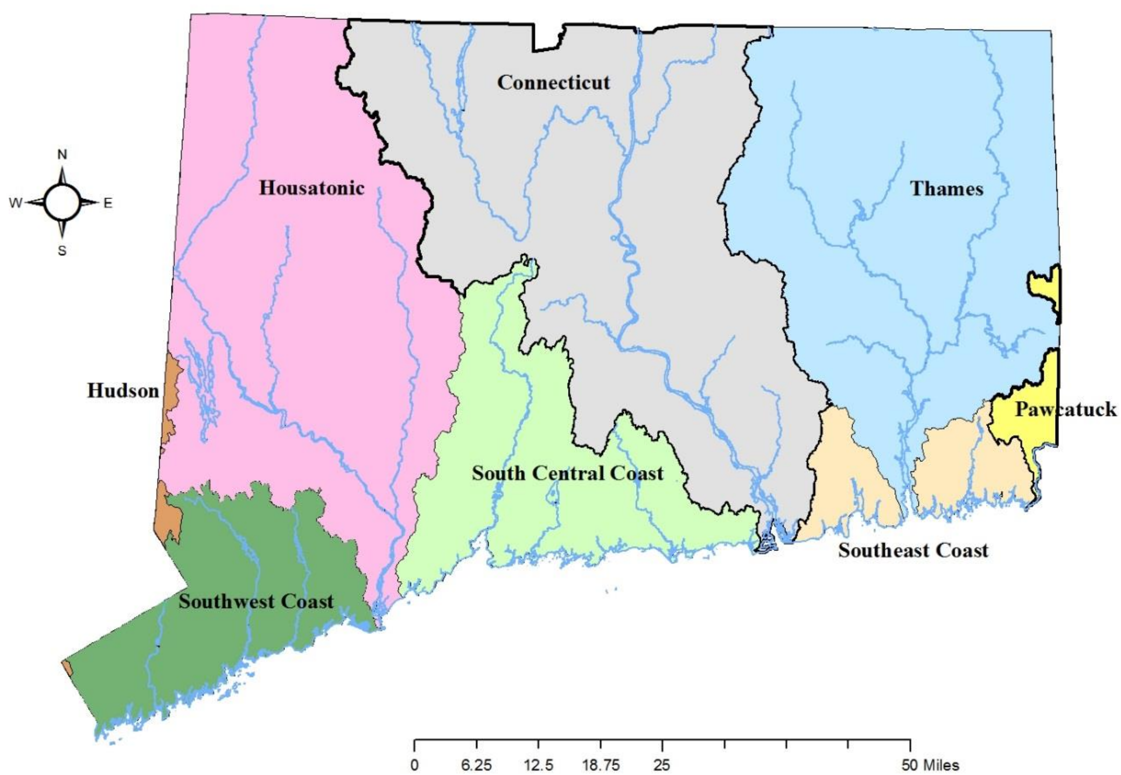

Figure 1. Major drainage basins in Connecticut used for planning monitoring and assessment activities under the Rotating Basin framework from 2015-2024.

Major river basins are roughly equivalent, but not identical to USGS eight digit Hydrologic Unit Codes (Seaber et al 1987) and are further sub divided into three categories of sub basins. In order of decreasing size, these are regional, sub regional, and local basins. The number of drainage basin units at each level of scale is listed below -

Major basins	8
Regional basins	45
Sub regional basins	336
Local basins	2,893.

The Rotating Basin Framework helps to organize and communicate mid-term monitoring goals that meet the objectives of the Monitoring Strategy (Figure 2). In addition, the Rotating Basin approach allows for identification of spatial coverage and gaps in monitoring data, provides a predictable schedule that can enhance collaboration with other programs, and ensures statewide coverage of surface waters for assessment with the goal of completing all eight major basins every 5 years. Ultimately the goals and objectives of this Monitoring Strategy are implemented through completing annual work plans. These annual work plans provide an opportunity for other programs to request monitoring assistance and allows the work load to be prioritized to accomplish the objectives of this Monitoring Strategy.

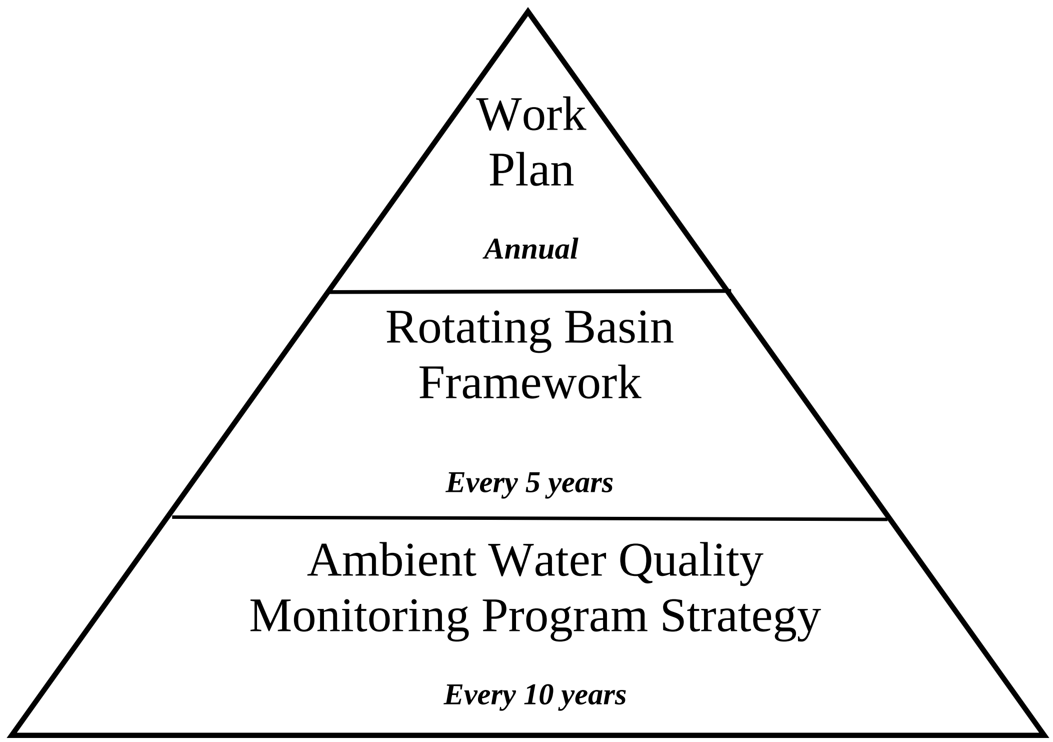

Figure 2. Monitoring and Assessment Program planning pyramid showing long-term planning implemented through the Ambient Water Quality Monitoring Program Strategy, mid- term planning through the Rotating Basin Framework, and implementation of the Water Quality Monitoring Program Strategy through an annual Work Plan.

Probabilistic Monitoring

Probabilistic or statistically based monitoring designs can be used to answer questions regarding designated use impairment status on a statewide, regional or national scale for discreet resource categories within the various sample populations (e.g. rivers and streams, lakes, estuaries, and wetlands). This type of information is used by WMAP and USEPA primarily to fulfill reporting requirements under the CWA.

DEEP has participated in the USEPA's National Aquatic Resource Surveys (NARS) since the beginning of the program in 2006. NARS surveys are "statistically-representative surveys of aquatic resources…that are designed to yield unbiased estimates of the condition of a whole resource". These surveys are scheduled by water resource type (e.g. lakes, rivers and streams, coastal resources, and wetlands) and provide nationally consistent, scientifically-defensible assessments of our nation's waters.

In addition to contributing to the NARS, the WMAP has completed probabilistic surveys to characterize designated use support in wadeable streams for aquatic life and recreation for Connecticut. The probabilistic surveys in Connecticut provide a scientifically defensible status of Connecticut's waters and can be used to track conditions over time and report the status of waters to Connecticut's citizens. A Generalized Random Tessellation Stratified (GRTS) survey design (Stevens and Olsen 2004) was provided to DEEP from USEPA and implemented with a target population of streams based on the National Hydrography Dataset at the 1:24,000 scale. The WMAP has incorporated a probabilistic sampling design into aquatic life use assessments such that a reassessment of the overall condition of the state's waters can be achieved every 5 years within the Rotating Basing Framework.

Element 4-Core and Supplemental Water Quality Indicators

The Connecticut Water Quality Standards Regulations (WQS) are promulgated under Sections 22a-426-1 to 22a-426-9 of the Regulations of Connecticut State Agencies and are the foundation of water quality management in Connecticut. The WQS influence selection of appropriate environmental indicators, and establish the narrative and numeric criteria to support existing and designated uses (DEEP 2013).

Designated uses, water quality classifications, and environmental indicators used to determine designated use-support are presented in Table 4. A more detailed discussion of assessment criteria and use-support thresholds can be found in the *Connecticut Consolidated Assessment and Listing Methodology (CALM) for 305(b) and 303(d) Reporting* which is presented in Chapter 1 of the 2014 State of Connecticut Integrated Water Quality Report. The CALM is updated as necessary as assessment methods and scientific knowledge changes.

For some designated uses, other state departments have the primary responsibility to manage the resources in Connecticut. Monitoring and assessment of shellfishing resources is the responsibility of the Connecticut Department of Agriculture, Bureau of Aquaculture and Laboratory Services. The Connecticut Department of Public Health and the water supply utilities share responsibility for monitoring and assessment of public water supplies. In these cases, WMAP coordinates with these Departments to incorporate their information into use support assessments which as detailed in the CALM document.

A Core Element Summary Report For Inland Water for the 5-year rotation 2006-2010 is useful to gain a more in-depth understanding of the effort and breadth of the WMAP program (DEEP 2011). For example, between 2006 and 2010, more than 25,000 samples were collected generating over 1.2 million data points to support DEEP water monitoring objectives. In the Core Element Report, data have been summarized and presented in maps, tables, and statistical summaries such as bar charts, line charts, pie charts and box plots to inform the public of DEEP monitoring efforts. For some categories of data, summaries include more detail such as a brief description of each parameter, the water quality criterion (if applicable), and implications to water quality in Connecticut.

Table 4. Clean Water Act (CWA) designated use, Connecticut Water Quality Standard (WQS) designated uses for surface waters for applicable class of surface water.

CWA Designated Use	Connecticut WQS Designated Use	Surface Water Class	Functional Definition
Primary Contact Recreation	Recreation	AA, A, B, SA, SB	Swimming, water skiing, surfing or other full body contact activities.
Secondary Contact Recreation	Recreation	AA, A, B, SA, SB	Boating, canoeing, kayaking, fishing, aesthetic appreciation or other activities that do not require full body contact.
Aquatic Life Use Support	Habitat for fish and other aquatic life and wildlife.	AA, A, B, SA, SB	Waters suitable for the protection, maintenance and propagation of a viable community of aquatic life and associated wildlife.
Fish Consumption	Not specified as a use, but implicit in "Habitat for fish and other..."	AA, A, B, SA, SB	Waters supporting fish that do not contain concentrations of contaminants, which would limit consumption to protect human health and wildlife.
Shellfishing [2]	Shellfish harvesting for direct human consumption where authorized.	SA	Waters from which shellfish can be harvested and consumed directly without depuration or relay. Waters may be conditionally approved.
Shellfishing [2]	Commercial shellfish harvesting where authorized.	SB	Waters supporting commercial shellfish harvesting for transfer to a depuration plant or relay (transplant) to approved areas for purification prior to human consumption (may be conditionally approved); also support seed oyster harvesting
Public Water Supply [3]	Existing or proposed drinking water supplies.	AA	Waters presently used for public drinking water supply or officially designated as potential public water supply.
Aesthetics	Not a designated use but included in narrative criteria.	AA, A, B, SA, SB	Appearance, odor or other characteristics of water, which impact human senses, are acceptable.

[2] Monitoring and assessment are conducted by the Connecticut Department of Agriculture, Bureau of Aquaculture and Laboratory Services

[3] Monitoring and assessment are conducted by the Connecticut Department. of Public Health and public water supply utilities

Biological Monitoring in Rivers and Streams

A comprehensive list of core and supplemental water quality indicators was identified and categorized by the Interagency Task Force on Monitoring Water Quality (ITFM 1995). Yoder (1997) further discussed and described three main indicator categories in the context of their roles in adequate state watershed monitoring and assessment programs as follows:

- *Stressor indicators* - measures of activities, which have the potential to impact the environment (e.g. pollutant loadings, land use characteristics, habitat changes).
- *Exposure indicators* - measures of change in environmental variables that suggest a degree of exposure to a stressor expressed in magnitude or duration (e.g. water column or sediment pollutant concentrations, toxicity response levels, habitat quality indices, biomarkers).
- *Response indicator*s - composite measure or expression of an integrated or cumulative response by a biological community to exposure and stress (e.g. biological community indices, aquatic community structure metrics, or status of an index species).

Both documents make a strong case for the use of response indicators to evaluate aquatic life use-support (ALUS) and caution against the inappropriate substitution of stressor and exposure indicators for that purpose.

The WMAP strongly believes that the stressor / exposure / response paradigm is the appropriate model for managing aquatic systems and have adopted biological community structure measures (response indicators) as our core indicators for ALUS in rivers and streams (Table 5). Biological monitoring integrates the effects of stressors over time and thus provides a good measure of their aggregate impact. This means that biological communities reflect overall ecological integrity (i.e., chemical, physical, and biological integrity) and therefore directly assess the status of a waterbody relative to meeting CWA goals (Barbour et al 1999).

Table 5. Stressor, exposure, and response indicators used by the Water Monitoring and Assessment Program.

Use	**Response**	**Exposure**	**Stressor**
Aquatic Life	-Aquatic Macrophytes -Fish Community -Diatom Community -Macroinvertebrate Community -Lake Trophic Indices -Fish Kills	-Chlorophyll a -Dissolved Oxygen -pH -Chemical Pollutants (e.g. nutrients, heavy metals) -Water Clarity -Water Temperature -Fish Tissue Contaminants: (e.g. mercury, PCBs, pesticides)	-Land Cover Models -Point Source Discharges -Pollutant Loading Models -Stream Flow -Habitat
Recreation	-Algae Blooms -Aquatic Macrophytes -Odor and Appearance	-Indicator Bacteria -Total Nitrogen -Total Phosphorus -Water Transparency	-Land Cover Models -Known Threats to Public Health
Public Water Supply	-Odor and Appearance	-Indicator Bacteria -Toxic Chemicals at intake structures	-Known Threats to Public Health
Shellfishing	-Shellfish Kills	-Indicator Bacteria	-Point Source Discharges

The WMAP has sampled macroinvertebrate communities in wadeable river and stream segments beginning in the 1970’s and has gained decades of experience using biological monitoring for assessments of Connecticut’s waters (Figure 3). Today, macroinvertebrates continue to be an important component of the biological monitoring program. This experience and historical perspective of biological monitoring in Connecticut is a core strength of the WMAP.

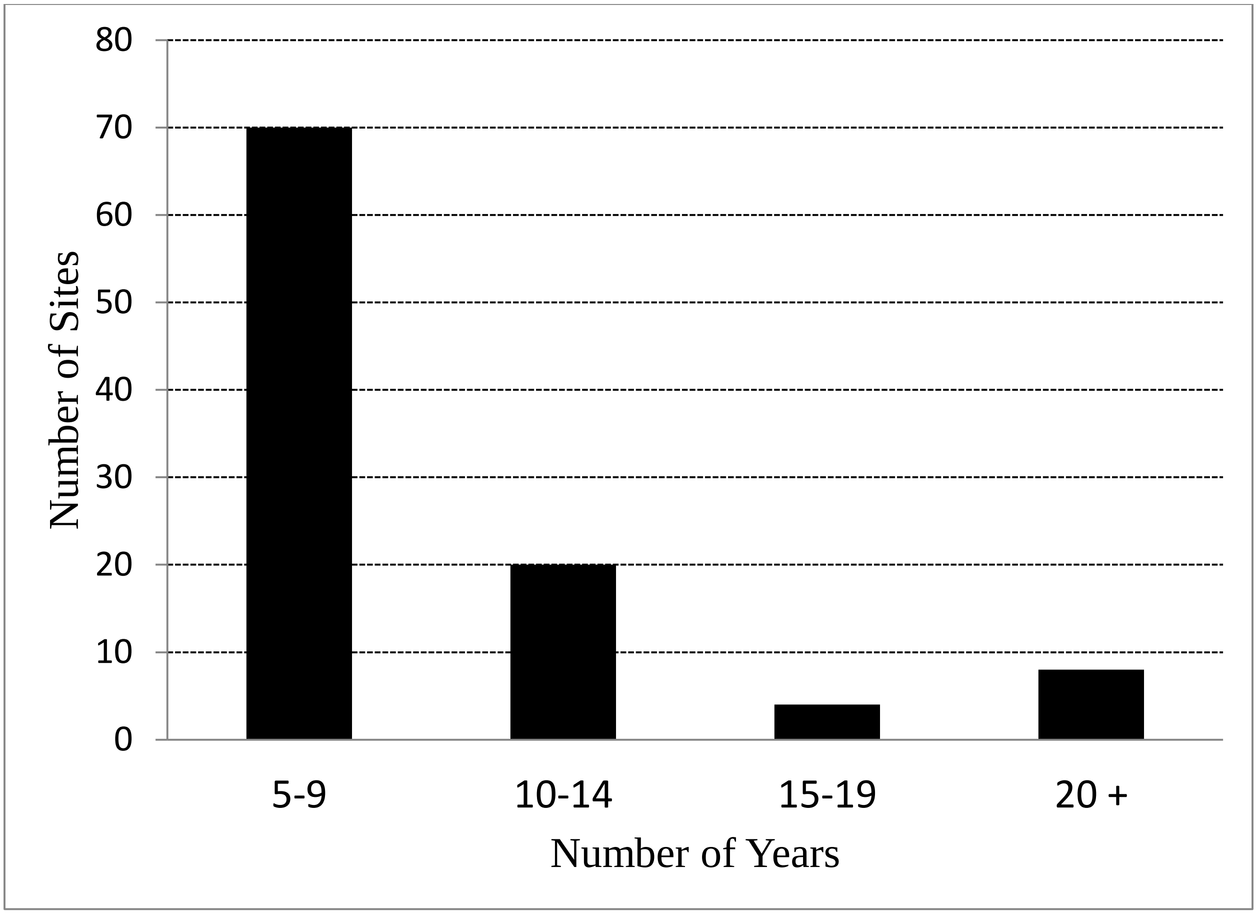

Figure 3. The period of record in years for long-term biological monitoring sites in Connecticut.

Many of these long-term sites have been identified as an important Stream Sampling Network for determining trends. For example, there are 23 Sentinel Sites in the Stream Sampling Network (Appendix 1) which are minimally disturbed stream locations that are scheduled to be sampled annually under this Monitoring Strategy (Figure 4). The remaining sites in the Stream Sampling Network are scheduled to be sampled at least 2 times per 5 years (per Rotating Basin) as staff resources allow. Collectively, these Stream Sampling Network sites were chosen to provide statewide coverage, represent the range of watershed sizes in Connecticut, and the range of disturbance conditions in the state. Percent impervious land cover in the watershed was used as a surrogate measure for disturbance with streams classified as - least disturbed (< 4% impervious cover), moderately disturbed (4.1-11.99% impervious cover), or impacted (> 12% impervious cover).

The Stream Sampling Network is also useful for monitoring long term trends in water quality for important regional issues such as climate change. For example, recently some of Connecticut's least disturbed long term monitoring locations were incorporated into the [Regional Monitoring Networks](#) (RMNs) to Detect Climate Change Effects in Stream Ecosystems Project. These data can be used to detect temporal trends in important components for stream ecosystems over a large region. Biological monitoring at these sites such as those identified in Figure 4 should continue to be high priority and should be sampled annually for macroinvertebrates and every 3-5 years for fish.

Long-term Biological Monitoring Locations in Connecticut

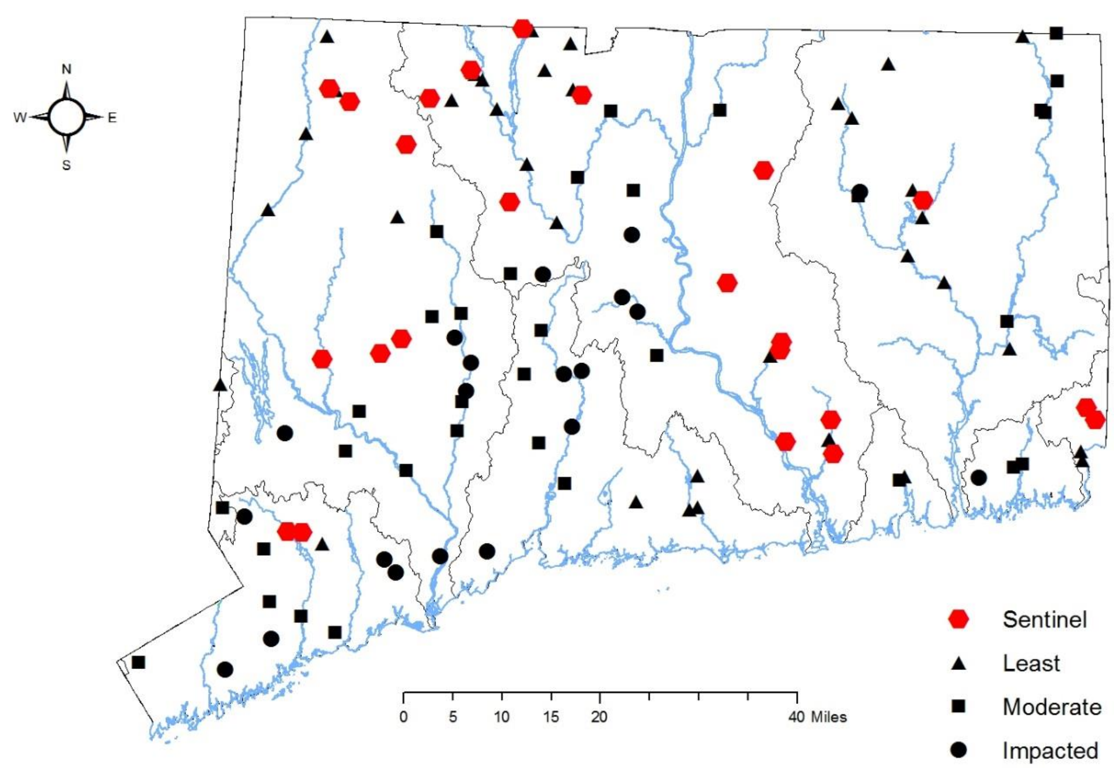

Figure 4. Network of long-term biological monitoring sites in Connecticut. Sentinel sites are scheduled for biological monitoring annually and least, moderate, and impacted sites are scheduled to be sampled 2 times per every Rotating Basin.

The scientific validity and strength of water quality assessments is strengthened by obtaining data on more than one biological community. Beginning in 1999, significant investment was made to formalize the macroinvertebrate community assessment process beyond the Rapid Bioassessment Protocols (Pflafkin et al 1989). With the assistance of USEPA, the WMAP completed a project to develop assessment tools in the form of a macroinvertebrate multimetric index (MMI) as well as a method to assign a macroinvertebrate taxa list to Biological Condition Gradient tiers (Gerritsen and Jessup 2007). Also beginning around 1999, a long-term project was initiated to develop an assessment methodology for fish communities to provide a second biological community for stream and river assessments. After several years of data collection and analysis, fish community assessment tools in the form of MMIs (Kanno et al 2010) and BCGs (Stamp and Gerritsen 2013) were developed and incorporated into stream health assessments. Fish community sampling is now fully integrated the Stream Sampling Network. The MMI and BCG assessment techniques has led to program growth and an increase in the miles of assessed rivers and streams from 2006 to 2014 (Figure 5).

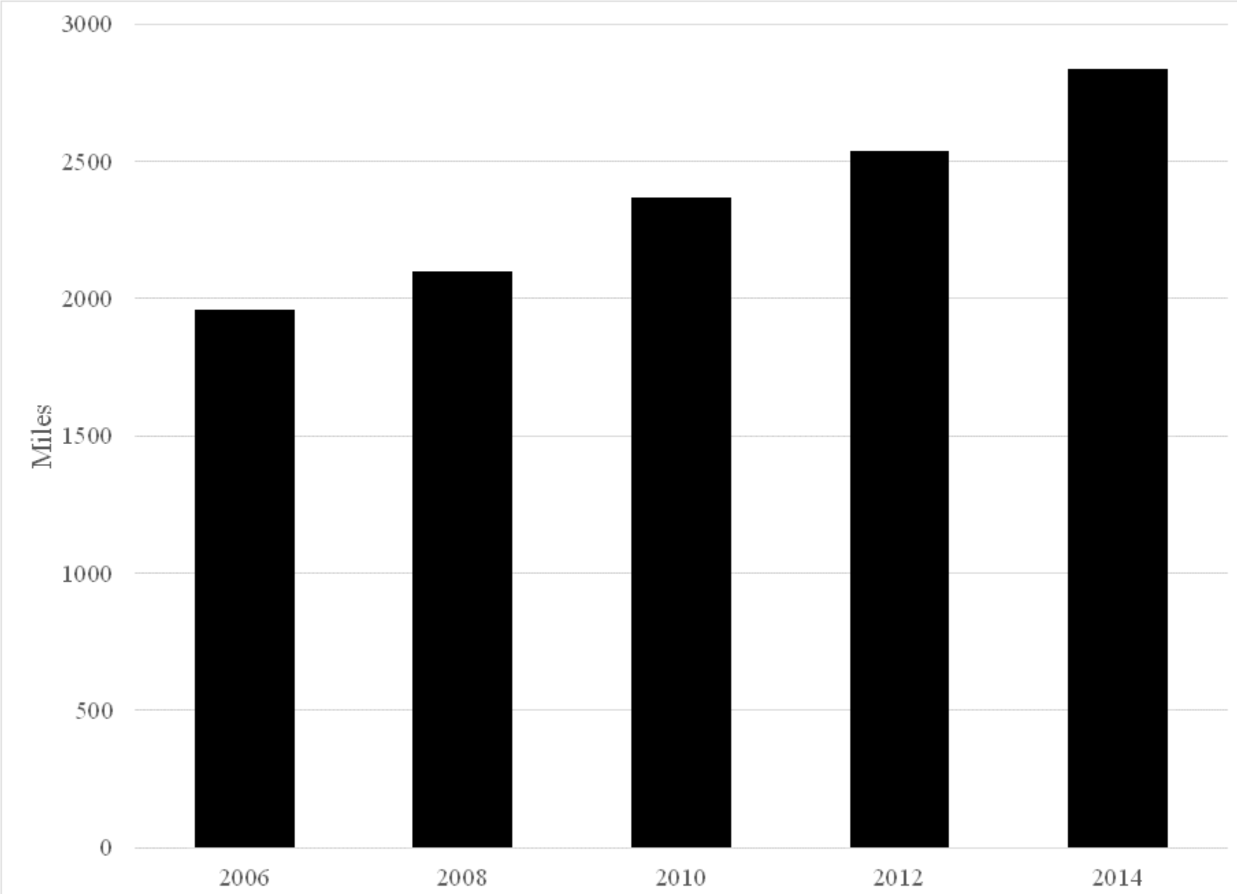

Figure 5. Assessed stream and river miles from 2006-2014.

The WMAP is currently evaluating a third biological community using diatoms to support stream and river assessments as well as nutrient management strategies in Connecticut. A pilot project to monitor periphyton was initiated during a statewide survey of wadeable streams from 2002–2004. Analysis of these data showed promising results (e.g. Smucker et al 2013) and WMAP continues to incorporate this work into annual work plans. A five year project is underway (Becker 2012) to evaluate diatoms as a water quality assessment tool as well as to characterize the ability to use the diatom community to support nutrient management in Connecticut's wadeable streams (Becker 2014). Additional information and project goals are outlined in Section 9, Programmatic Evaluation, of this document.

Physical/Chemical Monitoring

Conventional and toxic pollutant levels in water and sediment (i.e. exposure indicators) are used as supplemental indicators for ambient assessment of ALUS. Exposure indicators may serve as core indicators for special purposes such as monitoring for impaired waters assessments or remediation projects. Typically, chemical monitoring in streams is conducted in conjunction with site visits for biological monitoring. Routine chemical monitoring consists of surface water grab samples that are analyzed for the following parameters: alkalinity, ammonia, calcium, chloride, hardness, nitrate, nitrite, orthophosphate, pH, total Kjeldahl nitrogen, total organic carbon, total phosphorus, total silica, total suspended solids, total solids, and turbidity.

Certain projects may require additional chemical analysis be performed. DEEP uses two laboratories for analysis of chemical data –the Katherine A. Kelley State Public Health Laboratory and the Center for Environmental Sciences and Engineering at the University of Connecticut. Higher frequency chemical monitoring is conducted at the cooperative network of water quality stations maintained by USGS.

Cooperative USGS water quality monitoring network

In addition to water chemistry samples collected during DEEP biological monitoring activities, DEEP and the USGS New England Water Science Center - Connecticut Office maintain a cooperative fixed station water quality network at 33 stations in Connecticut (Table 6). Water quality samples are collected at these stations and analyzed for nutrients, major ions, trace elements, total organic carbon, and indicator bacteria at a frequency ranging from quarterly to monthly. Some stations are part of a national network and have additional sampling to meet the project objectives. For example, the Norwalk River at Winnipauk (Site Number 01209710) and Connecticut River at Thompsonville, CT (Site Number 01184000) are part of the National Water-Quality Assessment Program. Parameters such as pesticides, glyphosate, and suspended sediment are added to the suite of parameters listed above and sample frequency in increased for those stations included in the national network of sites.

The 33- station water quality monitoring network and the USGS stream flow gage network, are critical to maintain as it is the primary source of water chemistry monitoring and stream flow data with sufficient sampling frequency, data quality, and period of record to perform trend analysis (e.g. Columbo and Trench 2002; Mullaney 2004; Mullaney and Schwarz 2013;Trench et al 2012). Stream flow information is critical to providing pollutant load estimates, trend analysis, and many other water management needs including support for stream flow regulations and flooding, and water supply needs. Funding contributions from DEEP for the cooperative monitoring/stream flow network is provided by a line item in the state budget.

Water Temperature Monitoring

Water temperature is an important variable that influences aquatic communities. Hourly water temperature data have been collected by the WMAP in cooperation with the Inland Fisheries Division using water temperature probes since 1998. Site locations are selected annually in cooperation with the Inland Fisheries Division and other DEEP Programs in order to maximize effort and minimize site overlap. Site locations are detailed in annual work plans.

The spatially dense temperature network supports many objectives in this Strategy. These data are critical to informing the aquatic life assessment process in streams since water temperature is such an important driver of fish communities (Beauchene et al 2014) and other aquatic communities in Connecticut. In addition, these data can be used to assess the water temperature water quality criteria, since this has been an area highlighted for evaluation in recent WQS triennial review process.

Finally, these data can be used to collaborate with partners from a broader geographical area to pool data and resources to gain a better understanding of how water temperature affects aquatic life. WMAP has participated in several regional water temperature meetings to further water temperature science in the region - Stream Temperature Data and Modeling Meeting I and Stream Temperature Data and Modeling Meeting II .The Spatial Hydro-Ecological Decision Support (SHEDS) is one example of a data storage module, coupled with models, and a decision support system that can inform environmental decisions in Connecticut and broader. These examples of regional collaboration and using data to support the SHEDS web system are consistent with the Objective 2(d) of this Monitoring Strategy to communicate monitoring information to the public and resource agencies by of turning raw data into information.

Table 6. United States Geological Survey water quality monitoring stations in Connecticut rivers and streams.

Site Number	Site Name	Longitude	Latitude
01119375	WILLIMANTIC R AT MERROW, CT	-72.3101	41.8354
01120800	NATCHAUG R AT CHAPLIN CT	-72.1181	41.8009
01122610	SHETUCKET R AT SOUTH WINDHAM, CT	-72.1659	41.6823
011230695	SHETUCKET RIVER AT TAFTVILLE, CT	-72.0462	41.5700
01124000	QUINEBAUG RIVER AT QUINEBAUG, CT	-71.9556	42.0223
01125100	FRENCH R AT N GROSVENORDALE, CT	-71.9005	41.9785
01125520	QUINEBAUG RIVER AT COTTON BRIDGE ROAD NR POMFRET, CT	-71.9240	41.8584
01127000	QUINEBAUG RIVER AT JEWETT CITY, CT	-71.9841	41.5975
01127500	YANTIC RIVER AT YANTIC, CT	-72.1215	41.5587
01184000	CONNECTICUT RIVER AT THOMPSONVILLE, CT	-72.6054	41.9873
01184490	BROAD BROOK AT BROAD BROOK, CT	-72.5497	41.9139
01188000	BUNNELL (BURLINGTON) BR NR BURLINGTON, CT	-72.9648	41.7862
01188090	FARMINGTON RIVER AT UNIONVILLE, CT	-72.8870	41.7555
01189030	PEQUABUCK R AT FARMINGTON, CT	-72.8398	41.7168
01189995	FARMINGTON RIVER AT TARIFFVILLE, CT	-72.7594	41.9083
01192050	HOCKANUM R AT ROCKVILLE, CT	-72.4862	41.8659
01192500	HOCKANUM RIVER NEAR EAST HARTFORD, CT	-72.5873	41.7832
01192704	MATTABESSET RIVER AT ROUTE 372 AT EAST BERLIN	-72.7151	41.6082
01193500	SALMON RIVER NEAR EAST HAMPTON, CT	-72.4493	41.5523
01195100	INDIAN RIVER NEAR CLINTON, CT	-72.5310	41.3062
01196500	QUINNIPIAC RIVER AT WALLINGFORD, CT	-72.8413	41.4503
01196530	QUINNIPIAC R AT NORTH HAVEN, CT	-72.8715	41.3901
01200600	HOUSATONIC R NR NEW MILFORD, CT	-73.4496	41.5931
01201487	STILL RIVER AT ROUTE 7 AT BROOKFIELD CENTER, CT	-73.4032	41.4658
01203000	SHEPAUG R NR ROXBURY, CT	-73.3298	41.5498
01205500	HOUSATONIC RIVER AT STEVENSON, CT	-73.1666	41.3838
01208049	NAUGATUCK RIVER NR WATERVILLE,CT	-73.0579	41.6154
01208500	NAUGATUCK RIVER AT BEACON FALLS, CT	-73.0623	41.4423
01208736	NAUGATUCK R AT ANSONIA, CT	-73.0793	41.3307
01208873	ROOSTER RIVER AT FAIRFIELD, CT	-73.2190	41.1798
01208950	SASCO BROOK NEAR SOUTHPORT, CT	-73.3059	41.1529
01208990	SAUGATUCK RIVER NEAR REDDING, CT	-73.3951	41.2945
01209710	NORWALK RIVER AT WINNIPAUK,CT	-73.4262	41.1354

This program generates over 1.3 million data points per year and has generated data management challenges related to quality assurance and data storage. The WMAP has been using a MS Access database to manage the information but have reached the storage capacity of this type of database. Efforts are underway to develop a database that can accommodate these water temperature data.

Healthy Watersheds in Connecticut

DEEP strives to meet the objective of the CWA "to restore and maintain the chemical, physical, and biological integrity of the nation's waters." An important step in achieving this objective is to develop a method to classify healthy waters and then identify the location of these watersheds in Connecticut. This effort is in line with USEPA's Healthy Watersheds Initiative, which recognizes that identification of healthy watersheds or healthy components of watersheds is an important component of a monitoring program.

Connecticut's Healthy Watershed Initiative is an important component of the 2015-2025 Monitoring Strategy and builds on previous work from 2005-2014. From 2006 to 2014, the miles of monitored healthy waters (i.e. fully supporting aquatic life use) has increased from 584 miles to 1,550 miles (Figure 6) due to a variety of WMAP projects and efforts, including stream flow classifications and land cover studies. This work can help provide the scientific support for Water Quality Standards policy such as anti-degradation in the future.

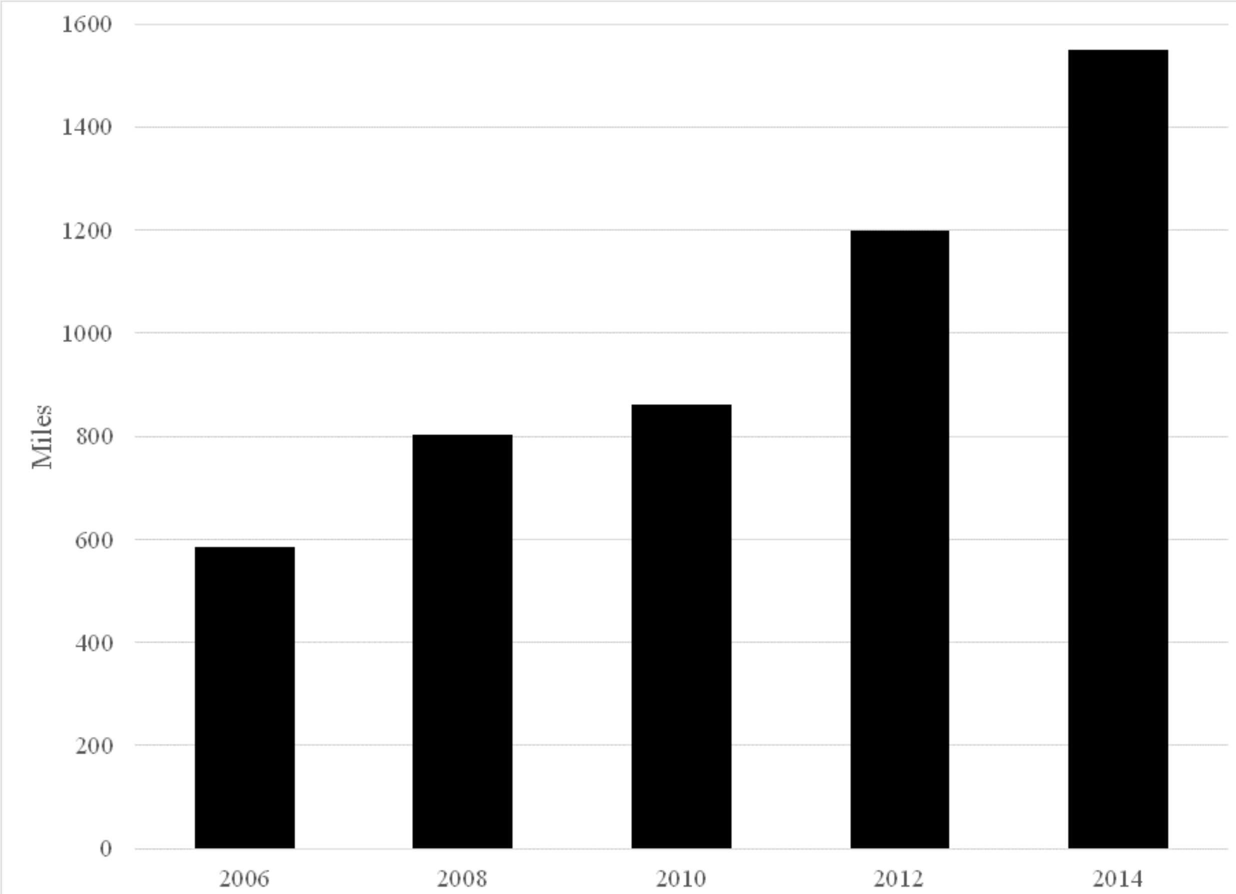

Figure 6. Healthy stream and river miles monitored from 2006-2014.

<u>Building Blocks of Connecticut's Healthy Watershed Initiative</u>

Stream Flow Classifications

Natural hydrology (e.g., flow regime, lake water levels) that supports aquatic species and habitat is critical to maintaining healthy watersheds (Poff et al 1997, USEPA 2011). Simply put, no water means no aquatic life or water related recreational opportunities.

In 2005 the Connecticut General Assembly passed Public Act 05-142 which required the DEEP to work with the State Department of Public Health and stakeholders to update standards for maintaining minimum stream flows in rivers and streams. The Act required these standards to balance the various uses of water by providing for river and stream ecology, wildlife and recreation, while providing for the needs and requirements of public health, flood control, industry, public utilities, water supply, public safety, agriculture and other lawful uses of water.

After six years collaborating with workgroups consisting of stakeholders representing the water industry, municipalities, non-governmental organizations, universities, and state/federal agencies, the Stream Flow Standards and Regulations were finalized on December 12, 2011. These Stream Flow Standards and Regulations give the Department the authority to develop stream flow classes using factors indicative of the degree of human alteration of natural stream flow, environmental flow needs and existing and future needs for public water supply. For the first time, Connecticut will have a stream flow classification system (Table 7) to identify the degree of alteration of stream flow from a natural hydrograph. Stream flow classifications for the Thames River, Pawcatuck River, and Southeast Coastal Basins have been completed (Figure 7) and it is expected that the entire state will be classified by 2018.

When the stream flow classifications are completed, they be used to identify minimally altered streams in terms of stream hydrology. In addition, tools developed to support stream flow regulation development such as Connecticut StreamStats can be helpful to inform future strategies to identify healthy streams in Connecticut. StreamStats is a web based GIS application that provides drainage basin characteristics and statistics for use in water resources planning and management.

Table 7. Stream flow classes, stream condition, and narrative standard for each stream flow class adopted under the Stream Flow Standards and Regulations.

Stream flow Class	Stream Condition	Narrative Standard
1	Free Flowing Stream	Maintain stream flow and water levels to support and maintain habitat conditions supportive of an aquatic, biological community characteristic typically of free-flowing stream systems
2	Minimally Altered	Maintain stream flow and water levels to support and maintain habitat conditions supportive of an aquatic, biological community characteristic minimally altered from that of typically of free-flowing stream systems
3	Moderately Altered	Maintain stream flow and water levels to support and maintain habitat conditions supportive of an aquatic, biological community characteristic moderately altered from that of typically of free-flowing stream systems
4	Altered	Exhibit substantially altered stream flow conditions caused by human activities to provide for societal needs

Land Cover Studies

There have been several land cover studies conducted over the last Monitoring Strategy cycle that support healthy watersheds work in Connecticut. The Department has developed conceptual models relating impervious land cover and stream health for waters impaired by stormwater (Bellucci 2007). This work has led to the development of the first Impervious Cover TMDL in the nation and the implementing of plans to clean up waterbodies with stormwater impairments at the local level (Arnold et al 2010).

In 2007, with funding from USEPA Region 1, DEEP initiated a study to identify least disturbed watershed in Connecticut based on stringent screening criteria using Geographic Information Systems. Land use characteristics (natural land cover > 80%, impervious land cover < 4%), water quantity stress (no known diversions), habitat fragmentation (no large dams and no dams of any type within 1.6 km of stream reach), and no fish stocking were used to select least disturbed streams. Details of the selection methodology are in Bellucci et al (2011). The macroinvertebrate and fish communities and chemical characteristics were described for 30 least disturbed streams in Connecticut. Ninety percent of the least disturbed streams sampled contained Brook Trout, *Salvelinus fontinalis*, a sentinel fish species for small, least disturbed streams in Connecticut. These streams also contained many sensitive macroinvertebrate taxa, some of which are only known to occur in least disturbed small stream in Connecticut. This work forms the basis of an initial healthy waters list and has been incorporated into DEEP's Nonpoint Source Management Program Plan (DEEP, 2014b). Identification of least disturbed watersheds and lakes in the Nonpoint Source Management Program Plan (DEEP 2014b) supports eligibility for grant funding for healthy watershed work for these waters.

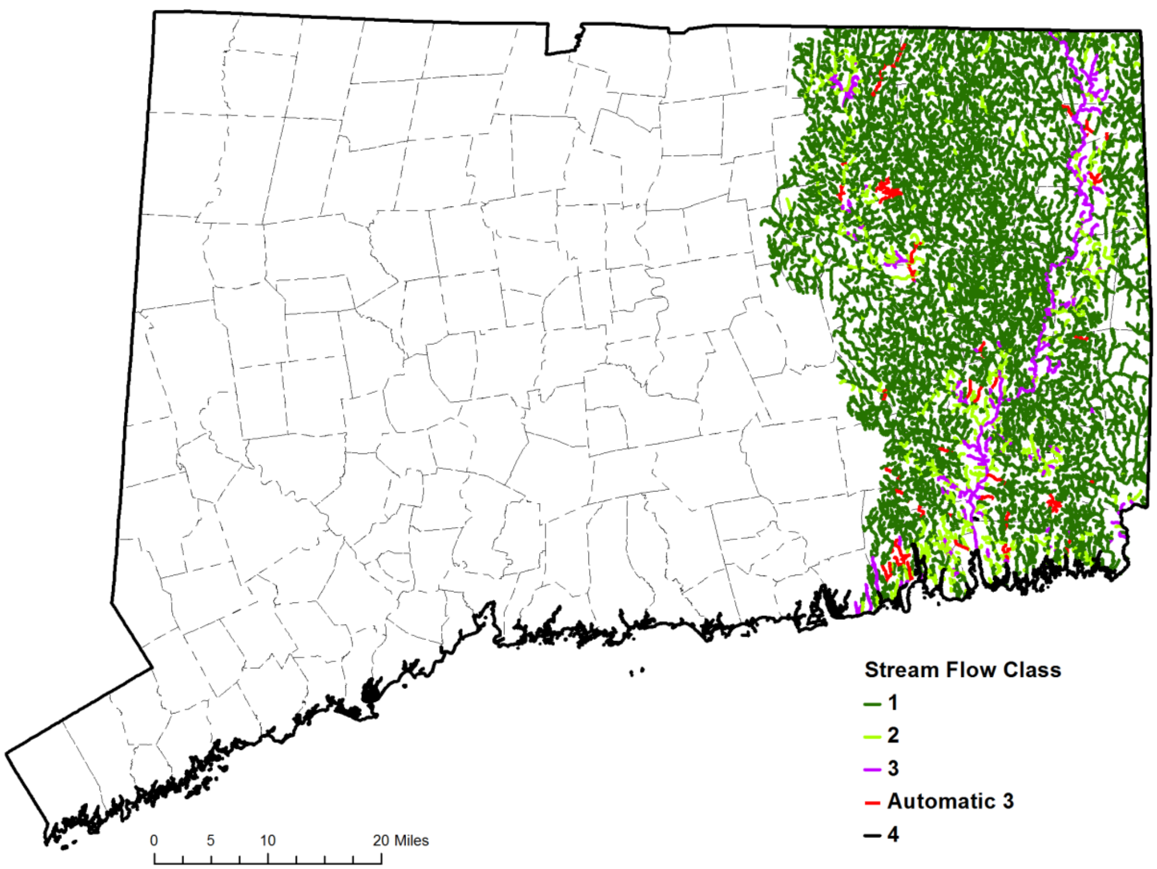

Figure 7. Stream flow classifications adopted under the Stream Flow Standards and Regulations for the Thames, Southeast coast, and Pawcatuck River basins.

Landscape models can also help provide information where data are lacking. DEEP developed a statistical model of stream health for all 1^{st} -4^{th} order rivers and streams in the state using estimates of landscape condition, watershed characteristics, and measurements of stream biology (Bellucci et al 2013). This analysis can be used to inform future sampling site locations that are predicted to be healthy waters using the macroinvertebrate MMI score (Figure 8). In addition, these data can be used as a line of evidence for stream assessments, used to inform decisions where data are lacking and used to prioritize future work (e.g. additional study if a monitored stream location scores well below the stream health model projection).

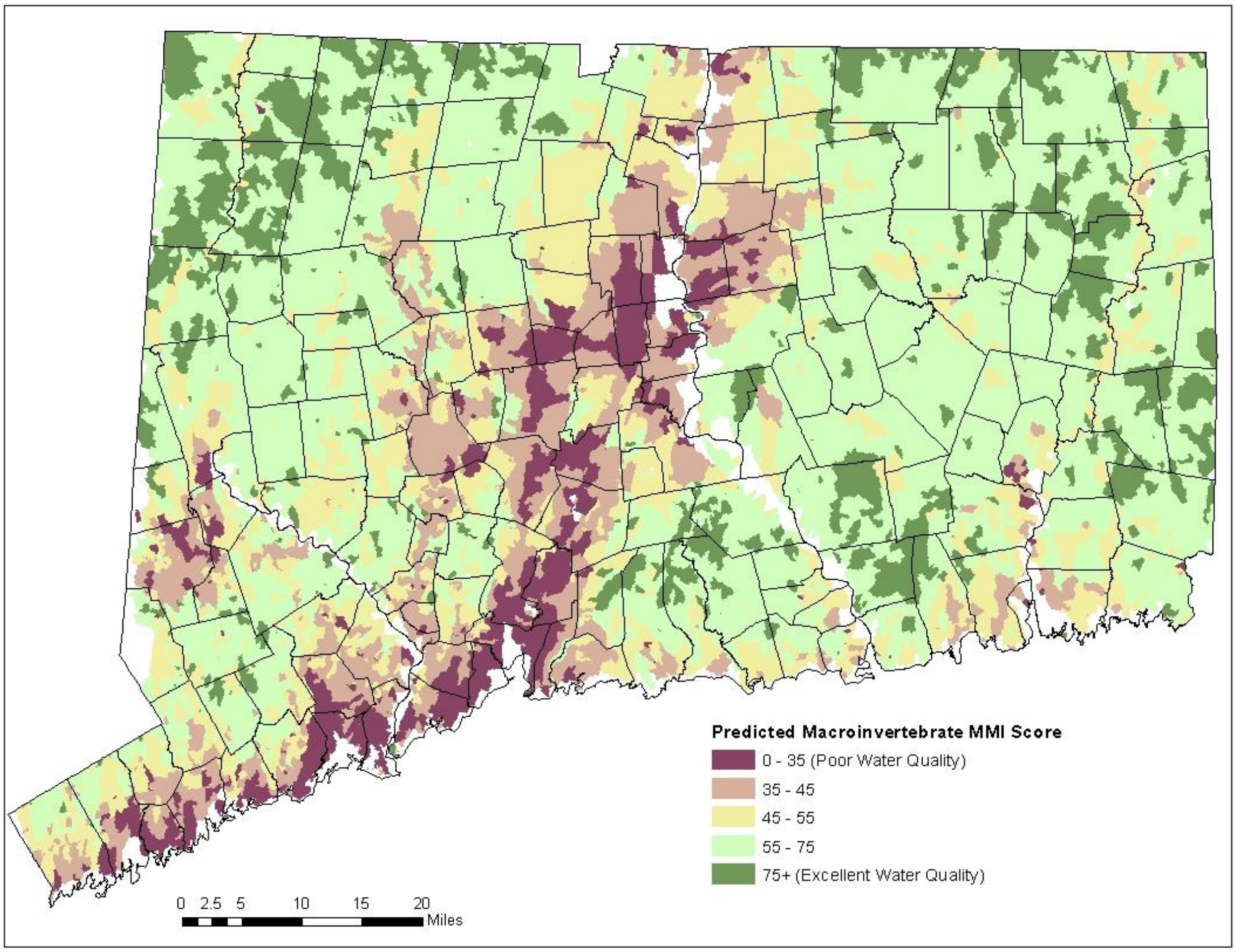

Figure 8. Stream health ranging from poor to excellent water quality as predicted by the modeled Macroinvertebrate mutlimetric index (MMI).

The landscape model for stream health has been useful to identify and target potential healthy streams that have previously been unassessed for biological monitoring by the Department. In addition, the MMI model has been used as a tool by the WMAP to provide site selection for external groups (e.g. volunteer monitoring organizations, towns) interested in identifying and monitoring healthy waters in their communities. This effort has helped to increase the miles of monitored healthy waters in the state.

There are efforts underway to use the BCG tools that can have promising utility in identifying healthy waters. Development of the BCGs and multi-metric indices (MMI) for stream macroinvertebrates (Gerritsen and Jessup 2007); BCGs and MMIs for stream fish communities (Kanno et al 2010 Stamp and Gerritsen 2013); and metrics for algal communities (Smucker et al 2013). For example, streams with data showing BCG < 3 are considered fully functional healthy ecosystems and a web mapping application showing stream locations with BCG scores indicating healthy streams is in the early stages of development.

Volunteer Monitoring

Volunteer Stream Macroinvertebrate Monitoring

The WMAP promotes A Tiered Approach for Citizen-based Monitoring of Wadeable Streams and Rivers and has reached over 2,500 volunteer citizens since the program began in 1999.The WMAP encourages volunteer monitoring by providing technical assistance and QA/QC support to volunteer monitoring projects. Presently, the volunteer monitoring program is focused on stream macroinvertebrate sampling and water temperature monitoring in wadeable rivers and streams.

Since 1999, the River Bioassessment by Volunteers (RBV) Program has been very successful at encouraging citizens to monitor waterways in their community. Along with providing data directly to the WMAP, the program supports agency goals and objectives by increasing environmental awareness and stewardship. An average of 20 groups comprised of more than 300 volunteers participate annually in the RBV Program. Collectively, volunteers submit and average of 100-150 macroinvertebrate voucher samples per year to the WMAP for consideration for ALUS assessment purposes. Each assessment cycle, RBV data typically contributes between 100-175 miles of assessed waterbodies.

The RBV program is best suited to confirm the presence of high water quality. If volunteers are able to find four or more pollution sensitive RBV taxa at a monitoring station, the segment can be considered for assessment as fully supporting ALUS. Therefore in 2014, WMAP staff began integrating the landscape model for stream health into the RBV program, branding the program as the Department's volunteer 'treasure hunt' for the state's healthiest waterbodies. At the start of the RBV season, WMAP staff provided coordinators of local volunteer groups with a list of stream segments within their geographic area of interest (e.g. watershed, town) that were predicted by the landscape model to have excellent stream health. The goal of the revised program focus is to direct volunteers towards those water bodies that are predicted to be characterized by excellent water quality but have not been previously monitored by the Department and therefore are currently unassessed. Volunteer RBV data that confirms the model predictions of high water quality will therefore help to increase the number of miles of healthy waters monitored and assessed annually within the State.

Volunteer Stream Temperature Monitoring

In 2008, the WMAP initiated a volunteer stream temperature monitoring partnership. Water temperature data loggers were obtained through the USEPA Equipment Loan Program and loaned to three volunteer groups which monitored 24 stream sites.

Since 2008, volunteer interest in conducting stream temperature monitoring in Connecticut has grown significantly, in part due to the increased availability and affordability of stream temperature loggers. In 2014, seven volunteer groups collected water temperature data from 58 stream sites. While the WMAP still offers limited equipment loans, the current model encourages volunteers to purchase the equipment needed to monitor stream temperature of their own. The WMAP continues to provide technical support related to equipment use and data collection to ensure quality controlled data. Emphasis is placed on collecting year-round data when possible to complement the WMAPs long-term stream temperature records.

Volunteer monitoring of other aquatic systems including lakes and estuaries has not been very successful due to a variety of reasons. Technical assistance to estuarine/lake volunteer monitoring groups has been limited and no formal outreach effort such as the development of a guidance document has been undertaken. A number of groups indicated interest in conducting estuarine and lake monitoring if such support existed.

Recreation and Designated Swimming Beaches

The core indicator for water recreation in surface waters is indicator bacteria. Indicator bacteria can be difficult to characterize since they share characteristics of exposure and response indicators. Use support for water recreation may also be determined by presence of known threats to public health such as combined sewer outfalls or the presence of infectious material.

At state-owned swimming beaches, WMAP contributes to a program aimed at protecting the public from swimmer related illness. This program is conducted in cooperation with the DEEP Parks Division and Connecticut Department of Public Health (CT DPH), Environmental Health Section, to evaluate health risks and make beach closure decisions at state-owned and managed swimming areas. WMAP staff sample for indicator bacteria weekly at the 23 State beaches (Figure 9). Four are located along the coast of Long Island Sound, and 19 are located at inland State Parks or Forests. Water testing at state swimming areas begins the week before Memorial Day weekend and continues through Labor Day weekend. The sanitary quality of the bathing waters are determined by analyzing for the indicator bacteria *Escherichia coli* in freshwater and enterococci group in saltwater. The CT DPH Laboratory Division's Microbiology Lab performs all of the indicator bacteria analyses. During the bathing season, current beach closure status is available toll free by phone at 1-866-287-2757 and on the State Swimming Area Water Quality Report web page. Local designated swimming areas are managed by the municipalities.

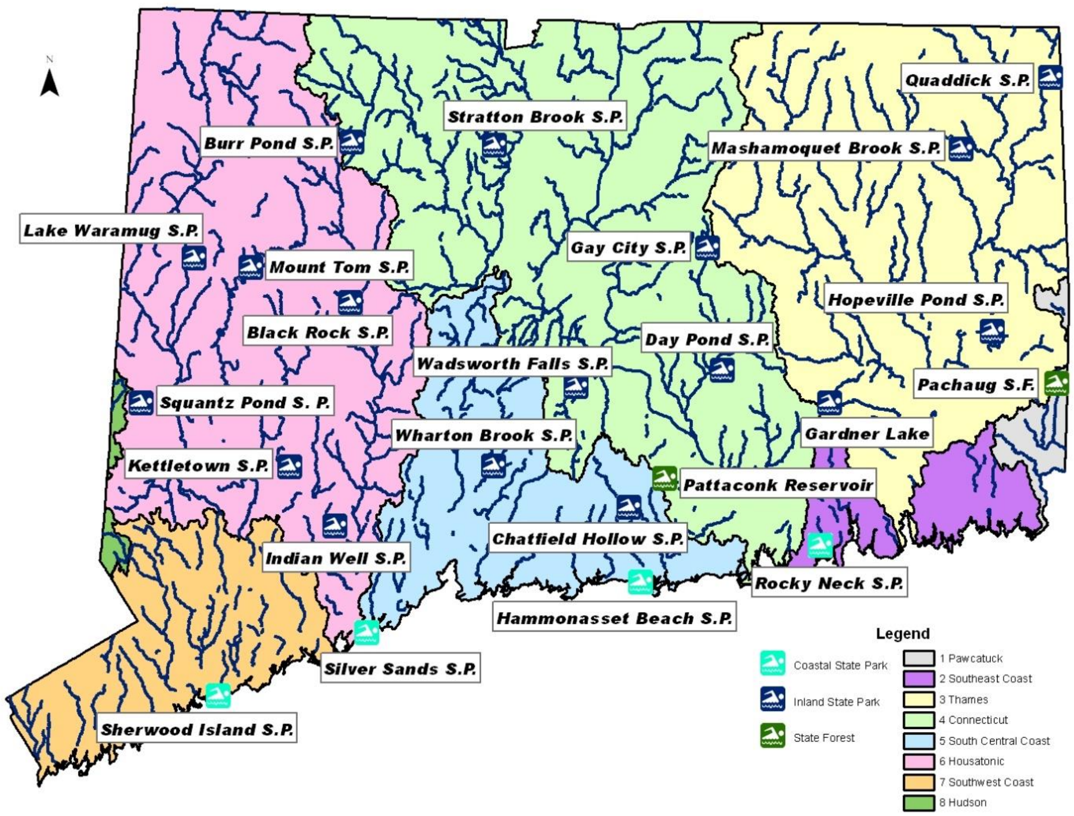

Figure 9. Twenty three state-owned beaches are located throughout the state to provide recreational opportunities to citizens from Memorial Day to Labor Day.

Tissue Monitoring

Typical monitoring of toxic contaminants in tissue includes PCBs, pesticides, and toxic metals, especially mercury. Like indicator bacteria, tissue contaminants share characteristics of exposure and response indicators and are difficult to characterize.

The primary purpose of tissue monitoring has been screening for human health risk, including more intensive assessment for development of fish tissue consumption advisories for individual water bodies Fish tissue is also collected and analyzed for other reasons including special projects, TMDL development, to evaluate spills, and trend analysis. For example, a statewide survey of mercury in fish tissue from sixty-one lakes and the Connecticut River was conducted by the University of Connecticut in 1995 (Neumann et al. 1996) and again in 2005-2006 (Vokoun and Perkins 2008) with funding from the Department. A repeat of this study at approximately ten-year intervals is planned to evaluate trends in mercury contamination as funding for this work allows. There are some areas of special interest such as the PCB Concentrations in Fish from the Housatonic River that have more robust data collection effort with the assistance of the Academy of Natural Sciences of Drexel University.

Fish tissue monitoring has been conducted since the late 1970's in cooperation with the DEEP Inland Fisheries Division, and the CTDPH Environmental Epidemiology Section. Meetings with the DEEP Inland Fisheries Division and CTDPH are held in the spring of each year to develop a priority sampling list. Fish collection is coordinated with the Inland Fisheries Division field and hatchery staff and laboratory analyses of tissue contaminants are conducted at the appropriate lab as budget allows. The fish tissue program has never had a dedicated budget and sampling has been limited over the past several years. Recently, USEPA Region 1 has assisted with laboratory analysis of fish tissue for a variety of projects.

Intensive Surveys and Stressor Identification

Intensive surveys are conducted to obtain data which provide a greater degree of spatial or temporal resolution than is generally obtained by routine fixed network or probabilistic monitoring sites. These surveys can include physical, chemical and/or biological monitoring and are sometimes program specific. They can be conducted to evaluate effectiveness of treatment facilities, calibrate water quality models or provide support to CWA section 319, 314, or Total Maximum Daily Load (TMDL) projects. Intensive surveys are coordinated with rotating basin assessment schedules to the greatest extent possible. However, given the origin and nature of these projects, they may occur outside of the general Rotating Basin schedule. Details of specific intensive surveys are provided in annual work plans.

Under section 303(d) of the CWA, DEEP is required to develop TMDLs for waters impaired by pollutants. These listed waterbodies are prioritized for TMDL development based on knowledge of the waterbody and pollutant, current resource availability, and programs in place to aid in TMDL implementation. Plans to develop TMDL alternatives are being evaluated under the TMDL Visions process.

In some instances, waters identified as impaired do not have a known cause and more data collection are necessary to make a water management decision. For example, a stream impaired for non-attainment of biological goals may be listed but the cause of impairment is not known. In these instances, targeted monitoring is conducted to collect and evaluate additional data to aid in a water management decision. The process of evaluating data to determine the most likely candidate causes of biological impairment has been the subject of many recent efforts (Bellucci and Becker 2007; Bellucci et al 2010; Cormier et al 2002;Norton et al 2002; Suter et al 2002; USEPA 2000;). The Stressor Identification Procedure used by DEEP is similar to that described in these references and involves 4 steps: 1) Listing the Candidate Causes; 2) Analyzing the Evidence; 3) Characterizing the Causes; and 4) Identifying the Probable Candidate Cause.

These steps can lead to identifying the most likely candidate cause for impairments that have an undetermined cause. Ultimately, identification of the most probable cause can lead to management actions to eliminate or control the cause. Details of stressor identification surveys are provided in annual work plans.

Stressor indicators like land use characteristics (e.g. impervious land cover), pollutant loadings and habitat quality have been used as core indicators for selection of monitoring sites.

Lake Monitoring

Connecticut has the benefit of historical lake water quality studies from the 1930's (Deevy 1940), 1970's (Norvell and Frink 1975), 1980's (Frink and Norvell 1984, CTDEP 1982, CTDEP 1998) and 1990's (Canavan and Siver 1994, 1995; Healy and Culp 1995).

Since the 1990's, the WMAP has conducted several lake projects:

- From 2005-2007, DEEP and Connecticut College conducted a project that sampled 60 lakes throughout Connecticut. Lakes were chosen from a random draw determined by the USEPA, and provide a representative sample of Connecticut lakes >20 and <1,000 acres.
- In 2007, sampling was conducted from lakes in Connecticut under the New England Lakes and Pond Project (NELP). The purpose of NELP was to determine the ecological health and integrity at the regional level, but also provided data to support water quality assessments at the state level.
- National Lakes Assessment (NLA) –The WMAP participated in the USEPA's NLA probabilistically based surveys in 2007 and 2012. Fourteen lakes in Connecticut were sampled in 2007 and 10 lakes in 2012 for this nationwide study. The goals of this

monitoring project was to assess the condition of US Lakes by determining what percentage of the lakes are in good, fair, and poor condition based on trophic, ecological, and recreational indicators. In addition, these data can be used for state assessments, to determine the importance of key stressors, establish a baseline for future monitoring of lakes, to assess trends in lake status in the past three decades, and to help build state and tribal capacity for monitoring and assessment programs. The next NLA is scheduled for 2017 and 2022.

From 2006-2014, DEEP has assessed 150-180 lakes statewide for CWA 305(b) reporting and lake monitoring (Figure 10). These probabilistic lake studies (NELP and NLA) are, in part, responsible for the increase in lakes assessed from 2006 to 2008. The number of lakes has remained static since 2008 due to staff resource constraints.

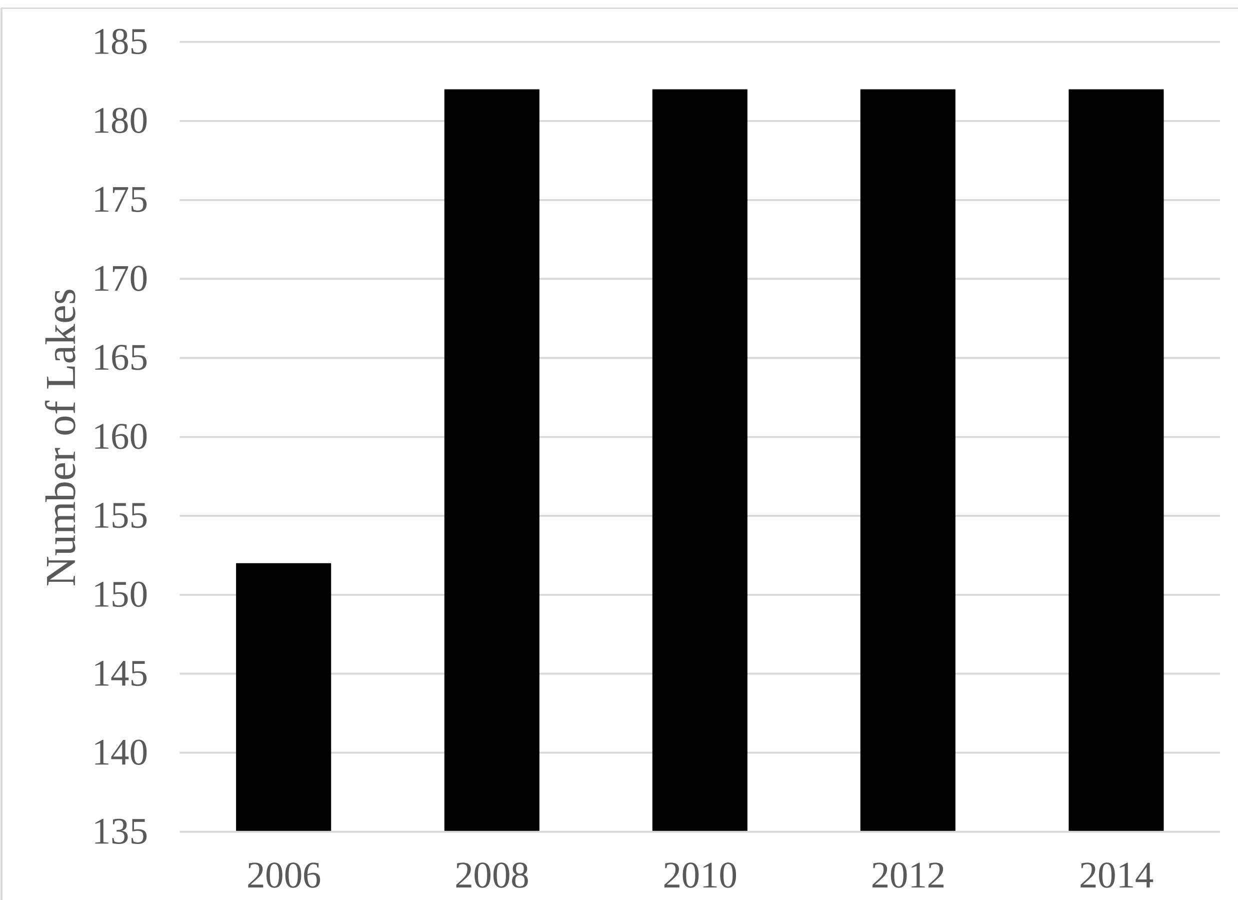

Figure 10. The number of lakes assessed for Clean Water Act Reporting from 2006-2014.

Targeted Lake Monitoring

The WMAP lake assessment methodology has been shaped by much of this historical lake water quality sampling. Sampling has focused on water chemistry collected at the deep hole of the lake during spring turnover and summer stratification. Important parameters for assessing the trophic status of lakes are chlorophyll a, total nitrogen, total phosphorus, Secchi disc transparency, and aquatic macrophyte growth. Lakes are selected using the Rotating Basin framework based on state or federal public access, presence of game fish species, potential for acidification, impaired waters listing, or providing unique or otherwise important habitats in Connecticut. Each year, WMAP will sample a minimum of 10 lakes or reservoirs and this strategy will result in a minimum of 50 lakes sampled for every 5 year basin rotation.

Lake sampling has been supplemented by the Lakes Management Grant Program, administered by DEEP. This Program funds intensive surveys and diagnostic studies in lakes identified as having special problems or special concern to communities. These studies provide valuable information regarding contamination, eutrophication, sedimentation, and extent of aquatic plant growth. The Lakes Program can benefit from increased staff and funding resources and has many lake assessments fall into the “Not Evaluated” category because existing information is outdated and no longer reliable.

Cyanobacteria

Cyanobacteria blooms can produce harmful toxins that are released into water that limit recreational opportunities and cause a public health threat. The Department, along with the State DPH, has created Interim Guidance to Local Health Departments that can assist health districts in handling cyanobacteria blooms during the recreational season. The WMAP is involved with several ongoing efforts to further the science of cyanobacteria to better inform the public in the future.

<u>Pilot Project with New England States and USEPA Region 1, and University of New Hampshire, and the University of Rhode Island</u>

The WMAP is participating in the Regional Cyanobacteria and Bloom Watch Monitoring Program Pilot Project to establish a region wide cyanobacteria monitoring and bloom watch program that will provide consistency in field sampling equipment and methodologies, establish region wide data to complement existing monitoring programs, and provide the consistency necessary in order to aggregate data for regional interpretations of bloom frequencies, cyanobacteria concentrations, and associated toxicity.

Pilot Project in cooperation with the University of Connecticut, CESE

The WMAP has partnered with the CESE at the University of Connecticut to develop and validate an integrated field and laboratory based network for the assessment of cyanobacteria abundance and species composition, cyanotoxins (microcystin and anatoxin-a), and environmental variables in Connecticut water bodies. The goal of the pilot project conducted during the summer 2014 was to collect field data at selected swimming locations to gain a better understanding of cyanobacteria species composition, toxin levels, and abundance in Connecticut's surface waters.

In addition to these pilot projects, the WMAP is participating in a Harmful Algal Bloom Workgroup that has been established through the New England Interstate Water Pollution Control Commission. Sub work groups focusing on Regulations for recreational waters, Monitoring and Analysis (coordinate with efforts already underway by USEPA), Advisories and Outreach, Guidance for drinking water facilities, and Control methods – Best Management Practices have been identified and efforts are underway to further the science on these important topics.

Wetlands

Wetlands are vital and irreplaceable resources in Connecticut that provide significant habitats for fish and wildlife, and act as buffers between terrestrial and aquatic environments. The ability of these unique areas to moderate effects of flooding and drought, and to trap and filter sediments, nutrients and contaminants makes them essential to the protection of water quality and quantity throughout the state.

Inland Wetlands and Watercourses Management Program

In 1972, the Connecticut Legislature passed the Inland Wetlands and Watercourses Act (Connecticut General Statutes Sections 22a-36 through 22a-45), recognizing the benefits of these resources and providing for the regulation of activities affecting wetlands and watercourses. By this legislation, wetlands are defined as "land, including submerged land, which consists of the soil types designated as poorly drained, very poorly drained, alluvial and floodplain by the National Soil Survey of the USDA Natural Resource Conservation Service". Watercourses include "rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs and all other bodies of water, natural and artificial, vernal or intermittent…". Marshes, swamps, bogs and areas that meet the federal definition of wetlands are regarded as surface waters of the State and are accountable to Connecticut Water Quality Standards.

Municipal Jurisdiction: DEEP delegates jurisdiction over wetlands to municipal wetlands agencies who have adopted local regulations consistent with the State statutes and regulations. Local commissions may adopt additional or more stringent regulations, as well as provisions for regulating activities in upland review areas, so long as the language is consistent with State statutes.

401 Water Quality Certifications: The DEEP Inland Water Resources Division processes 401 Water Quality Certifications for proposed activities requiring U.S. Army Corps of Engineers 404 permits in inland water and wetlands. Section 401 of the Clean Water Act requires applicants to obtain a certification or waiver from the state water pollution control agency to discharge dredged or fill materials into waters or wetlands. The State agency reviews the proposed activity's compliance with State Water Quality Standards. The 401 Water Quality Certification discourages unnecessary, avoidable, or inappropriate uses of wetlands and watercourses. DEEP staff currently review each 401 application on its individual merit, according to professional judgment and provisions of the Connecticut Water Quality Standards.

DEEP does not have a formal monitoring program for inland wetlands or coastal estuaries at this time. Staff from Inland Water Resources Division regularly attend meetings of the National and New England Biological Assessment of Wetlands Workgroups and are evaluating the pilot wetlands monitoring programs in other states. Staff from the Inland Water Resources Division and WMAP attended the training sessions for the National Wetland Condition Assessment Project in May-June 2011, but it was determined at that time that the Department did not have the staff resources to conduct the sampling. Consequently, an EPA contractor conducted the field sampling for the National Wetland Condition Assessment in 2011.

The Department has continued to work with the US Fish and Wildlife Service to complete an update of the National Wetlands Inventory for the Connecticut. This updated survey can serve as a basis for landscape level wetlands inventory. DEEP will continue to evaluate the potential to build capacity to conduct wetlands bioassessments.

Element 5-Quality Assurance

The Department is committed to implementing a quality assurance system designed to ensure that all environmental data are scientifically valid, of known precision and accuracy, complete, representative, and legally defensible. The DEEP quality assurance system will be maintained in accordance with applicable state and federal laws and rules, standards, guidance, contractual requirements, and sound management practices. The primary components of a quality assurance system include an organizational Quality Management Plan (QMP), program Quality Assurance Project Plans (QAPPs), and Standard Operating Procedures (SOPs) that accurately reflect all field and laboratory activities. Quality assurance documents provide the backbone of credible data and WMAP staff have defined roles and responsibilities that put these plans into action.

Quality Management Plan

DEEP operates under a QMP that is designed to be a practical planning document that presents a basic blueprint for developing, improving, and refining useful and practical quality system elements (CTDEP 2008). At DEEP, there is no central office or fulltime staff responsible for agency-wide quality assurance/quality control functions, either as they relate to specific EPA requirements or as they pertain to agency operations. Rather, DEEP places much of its emphasis on Quality Assurance at the program and project level using a decentralized system whereby each Bureau has assigned a Quality Assurance lead to implement the Department's quality system.

DEEP's quality assurance policy maintains that all environmental data collected, generated and processed is scientifically valid; of known precision and accuracy; sufficiently complete and representative for the intended purpose; comparable to data collections and analyses similar in scope and purpose; and legally defensible, as may be necessary for the intended purpose. The data are used as a basis for environmental program decisions, i.e., establishing environmental quality standards, emissions limitations, permit limits and resource management plans, and shall be in a form that should be clear and understandable to the public.

Under the QMP, USEPA conducts periodic Quality System Assessments. In March, 2011, the Beach Monitoring & Notification Program was audited and the review determined that:

1. Established meetings have been implemented for communicating information to all entities at the beginning of the season and the end of the season. The pre-season meeting is established for training and updating systems. The end of season meeting is for evaluation of processes and recommendations for improvement. This appears to be a very effective system for the program;
2. The program established an effective training system for seasonal personnel;
3. The program established many systems for effective communication regarding closure notification.

Overall improvements related to Quality System Assessments provide another feedback mechanism to improve quality assurance of Programs. The Assessments recommended Agency wide Quality System Awareness training, more frequent meetings of QA Coordinators, and increased documentation of Annual Reporting of Quality System Progress.

QAPPs and SOPs

Program Quality Assurance Project Plans (QAPP) and Standard Operating Procedures (SOP) are shown in Table 8. QAPPs and SOPs are reviewed annually under the Bureau's System Self Audit and Review. This process involves identifying areas for improvement, changes to programs QAPPs and SOPs, brief discussion of any formal technical field or lab audits, and report of training in the previous year.

Table 8. Program Quality Assurance Project Plans (QAPP) and Standard Operating Procedures (SOPs).

Title	Date	Responsible Staff
Standard Operating Procedures Ambient Biological Monitoring - Benthic Invertebrate Community Sampling	3/31/2013	Chris Bellucci
Standard Operating Procedures Ambient Biological Monitoring: Subsampling Procedures for Benthic Macroinvertebrate Stream Samples	7/20/2012	Brian Jennes
QAPP for Rapid Bioassessment in Wadeable Streams and Rivers by Volunteer Monitors	1/10/2003	Meghan Lally
QAPP for Aquatic Life Response to Cultural Eutrophication in CT Freshwater Wadeable Rivers and Streams (2012 – 2015)	10/24/2012	Mary Becker
Standard Operating Procedures For the Collection of Fish Community Data From Wadeable Streams for Aquatic Life Assessments	1/23/2013	Meghan Lally
Processing and Analysis Plan for Fish Tissue Quinnipiac and Eightmile River 2014	8/12/2014	Chris Bellucci
Standard Operating Procedures Processing Fish Tissue For Assessing Chemical Contaminants	3/19/2003	Chris Bellucci
Standard Operating Procedures For Measuring Continuous Water Temperature	4/12/2013	Tracy Lizotte
Standard Operating Procedures for Calibration and Field Measurement using the YSI 600 XLM Sonde and 650 Multi-parameter Display System (MDS)	6/3/2013	Tracy Lizotte, Meghan Lally
Standard Operating Procedures For Lake Monitoring	7/1/2004	Tracy Lizotte, Walter Tokarz
State of Connecticut Guidelines for Monitoring Bathing Water and Closure Protocols	4/1/2003	Tracy Lizotte, Chris Bellucci
QAPP for Beach Monitoring and Notification Program For Connecticut Coastal Beaches	8/1/2011	State DPH , Tracy Lizotte, Chris Bellucci

Laboratory Quality Assurance Plans

Center for Environmental Sciences and Engineering (CESE) Laboratory

The CESE laboratory at the University of Connecticut provides a full range of analytical methods and analytical testing to support research by faculty, government, and industry. CESE provides analytical chemistry services for DEEP through a Project Agreement and Scope of Work titled, *Analytical Support to the Connecticut Department of Energy and Environmental Protection for the Long Island Sound and Ambient Water Quality Surveys*. These agreements are typically renewed every five years.

The CESE laboratory operates under a QAPP (CESE 2008) and participates in several proficiency test programs from the State of Connecticut Department of Public Health and other NIST-approved tests providers for the analytes established by EPA for non-potable water and solid/ hazardous waste. The specific analytes and matrices analyzed are based on the current scope of the laboratory services. The Laboratory Director is responsible for ensuring that all technical laboratory staff have demonstrated proficiency and the training of its personnel is kept up-to-date, including QA/QC training for Lab Analysts.

State of Connecticut Katherine A. Kelley State Public Health Laboratory

The Katherine A. Kelley State Public Health Laboratory opened in 2012 and provides the Department with chemical and environmental microbiology services. The WMAP uses the laboratory extensively for analytical services to support the bathing beach program. The Environmental Chemistry Division tests for over 100 toxic chemical agents in public drinking water supplies, private wells, lakes, rivers, streams, wastewater, spills, and soils. The Laboratory Quality System is based on ISO 17025 and the USEPA Drinking Water Laboratory Certification manual. The laboratory is certified by USEPA Region 1.

Staff Roles and Responsibilities

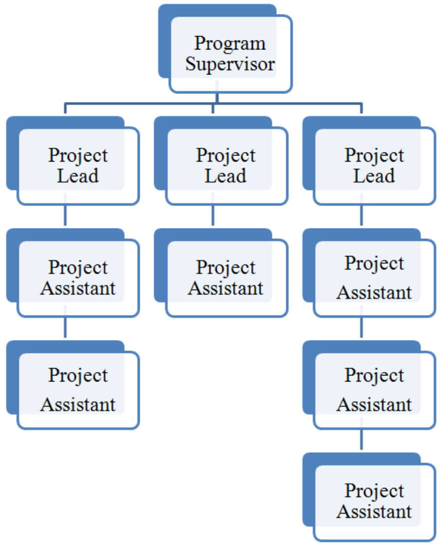

Figure 11. Organizational diagram of staff roles and responsibilities in the Water Monitoring and Assessment Program.

It is important to recognize the staff roles and responsibilities to implement this Monitoring Strategy. An organizational diagram (Table 9; Figure 11) helps to visualize how staff roles and responsibilities relate to one another. This provides clear direction to the program and is especially useful when training new staff or describing how the overall program interacts and functions.

Project Supervisor

The Project Supervisor is responsible for planning, coordination, and oversight of WMAP activities related to meeting the goals and objectives of the Ambient Water Quality Monitoring Program Strategy and implementing work to meet the objectives through the annual work plan.

Project Lead

A Project Lead will provide input and expertise for planning purposes at the program level to meet the goals and objectives of the ambient monitoring program work plan. The Project Lead will work closely with the Program Supervisor to insure that all goals and objectives of the project are met including site planning, field sampling, data management, data quality assurance, review and analysis of data, and writing data summary documents. More detail of specific responsibilities is provided below.

Site Planning- Provide input, review, and comment on project sampling design and site selection to balance programmatic needs, goals, and objectives.

Field Sampling- Schedule field sampling and coordinate field assistance to meet programmatic need goals and objectives.

Data Management- Oversee and responsible for completion of the following data management activities: establish station location and metadata, input of field trips into database in a timely manner, ensure that sample results are uploaded in a timely manner, enter and maintain project information.

Data Quality Assurance and Quality Control (QA/QC)- Oversee QA/QC of all data collected during the project including field measurements, chemistry lab results, and taxonomic QA/QC for biological samples. This includes, but not limited to, reviewing duplicate samples, field blanks, and exploratory data analysis to ensure lab errors are corrected in a timely manner per any relevant project QAPPs and SOPs.

Data Analysis-Responsible for analyzing data to make assessments for Clean Water Act reporting, exploratory data analysis of data and summarizing into information that will help inform DEEP policies through Annual and Summary Reports.

Annual Work Plan and Project Report- Responsible for contributing to Annual Work Plan with Target Date of April 1 of each year. Responsible for completion of a brief summary of annual work for dissemination to monitoring staff, other DEEP Programs, and the public.

Summary Reports- Responsible to provide input and write relevant sections of 5 year rotation summary, a more in depth analysis than Annual Report. Target for Summary Reports will be every 5 years.

Project Assistant Responsibilities

The Project Assistants will work closely with the Program Lead and Program Supervisor by providing assistance with site planning, field sampling, data management, data quality assurance, review and analysis of data, and writing data summary documents. An important role of the Project Assistants is to learn the skills needed to support all program functions and provide overlap in expertise to aid in long term succession planning for the WMAP.

Table 9. Water Monitoring and Assessment Leads and Assistants for Core Program Projects.

Project	Project Lead	Project Assistants
Fish Monitoring and Assessments	Meghan Lally	Brian Jennes, Seasonal Resource Assistants
Lake Monitoring and Assessments	Tracy Lizotte	Walter Tokarz
Macroinvertebrate Monitoring and Assessments	Chris Bellucci	Tracy Lizotte, Brian Jennes
Periphyton Monitoring, Nutrients, and Assessments	Mary Becker	Walter Tokarz, Seasonal Resource Assistants
Stream flow Classification	Mary Becker	Chris Bellucci
Swimming Beaches	Tracy Lizotte	Chris Bellucci, Brian Jennes, Seasonal Resource Assistants
Volunteer Monitoring Coordinator	Meghan Lally	All Staff as needed
Water Temperature Monitoring	Meghan Lally	Brian Jennes, Tracy Lizotte, Seasonal Resource Assistants
Data Management and Analysis	Mary Becker	All staff, Seasonal Resource Assistants
Equipment Procurement	Tracy Lizotte	Meghan Lally, Walter Tokarz
Equipment Maintenance	Walter Tokarz	Tracy Lizotte
Health and Safety	Tracy Lizotte	Brian Jennes
305b Coordination and Integrated Reporting	Walter Tokarz	All Staff

In addition to QAPP and SOP development, much of the recent progress in Quality Assurance /Quality Control has resulted from improvements in data management, which has produced significant corollary benefits for data quality. Some of the benefits resulting from use of a relational database are electronic logging of sample events and sample metadata. The database also facilitates review and analysis of QA samples like duplicates and field blanks, minimizes transcription error, and allows for value checking of laboratory results as well as overall sample tracking.

Element 6-Data Management

Monitoring Results

Since 2013, the Ambient Water Quality (AWQ) SQL Server database has served to store all ambient water quality samples collected by WMAP. AWQ is a relational database that was built with funding support from USEPA. The project took several years to implement with the assistance of the DEEP Office of Information Management and consultants. The purpose of the system is to provide safe long-term storage of physical, chemical, and biological sampling data and the appropriate metadata for water quality assessments and to meet other planning needs at DEEP. The AWQ is a comprehensive sampling and monitoring system for ambient water quality monitoring data that meets environmental sampling, analysis and results data standards as outlined in the EPA's Water Quality Exchange (WQX). Data can be uploaded to EPA's STORET Data Warehouse network node maintained by DEEP Office of Information Management (OIM).

AWQ Database Description

The major data collection projects supported by the AWQ include the following:

- Ambient water quality data (results of physical/chemical analysis)
- Biological community data (benthos, fish, diatoms)
- Fish tissue contaminant data
- Indicator bacteria data at state-owned bathing areas
- NPDES outfall data (physical/chemical and toxicity).

To manage the more complex data management requirements of the AWQ database, a database project lead and a group of "mentors" has been established to help ease the transition to this new more complex data management system. All staff using the database have gone through training to implement the AWQ. A Data Management Support group has been established and quarterly meetings are held to discuss data management issues.

Prior to 2012, all ambient water quality data collected since implementation of the Rotating Basin Strategy beginning in 1997 resides in a Microsoft Access database. Migration of this legacy data into the current SQL database can be done over time if time and resources allow.

In addition, an Environmental Data Management Policy was developed to promote data quality and consistency, and encourage a maximum return on the investment in water quality data collection. This plan includes a policy that states in part that …"All samples used to evaluate water quality collected by the WMAP will be stored and maintained in an electronic data management system. Data are subject to appropriate metadata documentation by the PSD personnel responsible for the sample collection. Water quality assessments will only be made using data that meets minimum metadata requirements". It contains additional descriptive information about database structure and metadata standards and currently serves as a user's guide for WMAP staff.

Assessment Data

Assessment data (e.g., segment descriptions, assessment methods, use-support, causes and sources of impairment) are stored electronically by waterbody segment in an Assessment Database (ADB) provided by the USEPA. This public domain software is used to manage assessment information to fulfill reporting requirements under sections 305(b) and 303(d) of the CWA. At the time of this writing, USEPA is working on an upgrade to the ADB that will incorporate the Assessment TMDL Tracking and ImplementatioN System (ATTAINS). The goal is to pilot the new system for the 2016 Integrated Report cycle.

Data Sharing

All assessment information is incorporated biennially into Integrated Water Quality Reports which are available in printed copy and are also available in electronic format on the Department website. In addition, a brief summary document for the general public is routinely prepared. The long-term plan for availability of monitoring results and meta-data is full migration to STORET, which will provide access to the public over the Internet. Currently, the monitoring results database is accessible to some DEEP staff through the Department Local Access Network. Requests for monitoring data from within or outside the Department are accommodated by the database project lead.

Element 7-Data Analysis and Assessment

Data analysis is an ongoing part of WMAP staff work flow as described in Section 5 of this report under Staff Roles and Responsibilities. In general, the AWQ is a storage warehouse for raw data, but analysis of portions of the data are conducted on a per project need using other software platforms such as Microsoft Excel, Minitab, ArcGIS, and R.

The decision-making process for assessing the quality of surface waters for the Integrated Water Quality Report is updated biennially and described in detail in Chapter 1 -Connecticut Consolidated Assessment and Listing Methodology -CT CALM (DEEP 2014). Assessment procedures generally follow guidance provided by USEPA (1997) using a variety of information and data types. The WMAP applies a "weight of evidence" approach when using multiple types of data. A waterbody is generally considered impaired when one or more sources of data or information indicate a water quality standard is not attained, providing that information is considered sufficient and fully credible. In resolving discrepancies in conflicting information within a waterbody, consideration is given to data quality, age, frequency and site-specific environmental factors. If reconciliation of conflicting data is not possible, the waterbody segment is designated as “not assessed” for the relevant use and flagged for further monitoring.

Element 8- Reporting

General Reporting

A goal of the WMAP is to turn raw data into information that can be used by DEEP programs and the public. This is accomplished, in part, by providing written updates to ambient monitoring projects periodically on the Ambient Water Quality Monitoring Reports and Publications section of WMAP Website. The Volunteer Monitoring Program produces Summary of Volunteer Reports that provides results from the annual sampling efforts of citizen science work in Connecticut.

Federal Clean Water Act Reporting

In accordance with Sections 305(b) and 303(d) of the CWA, DEEP submits an Integrated Water Quality Report to the US EPA on even numbered years. The CWA is the primary federal law that protects our nation's surface waters, including lakes, rivers, and coastal areas. In authorizing the Act, the United States Congress declared as a national goal the attainment, wherever possible, of "water quality, which provides for the protection and propagation of fish, shellfish and wildlife and provides for recreation in and on the water". This goal is popularly referred to as the "fishable / swimmable" requirement of the CWA.

The Connecticut Water Quality Standards Regulations Sections 22a-426-1 to 22a-426-9 of the Regulations of Connecticut State Agencies describes the Classification of State waters. Described for each Class are: 1) allowable discharges; 2) numeric or narrative criteria for various parameters, such as dissolved oxygen and indicator bacteria, to maintain water quality and; 3) designated uses that should be supported. Designated use support reported every 2 years in the IWQR is effectively the measure of water quality used for assessment. When waters are recognized as impaired, Implementation Planning is scheduled to improve the water quality with the goal of restoring the designated uses.

Implementation Planning

Under section 303(d) of the CWA, states are required to develop TMDLs or acceptable alternatives such for waters impaired by pollutants (DEEP 2014a). TMDLs provide a framework for restoring impaired waters by establishing the maximum amount of a pollutant that a waterbody can receive without adverse impact to fish, wildlife, recreation, or other designated uses. Alternatives must show that the pollutant is being addressed by other pollution control requirements other than a TMDL and are expected to address the impairment. The 303(d) program is currently undergoing a New Vision Framework. While the Vision provides a new framework for implementing the CWA 303(d) Program, it does not alter State and EPA responsibilities or authorities under the CWA 303(d) regulations.

The Department's Nonpoint Source Management Program Plan was approved by USEPA in September 2014 (DEEP 2014b). The Plan is a framework for the activities for the next five years of DEEP's Nonpoint Source Program funded under USEPA Section 319 of the Clean Water Act. DEEP also administers a 319 Grant Program with a limited portion of those funds dedicated to developing Watershed Based Plans, and the majority focused on implementing projects with the goal of restoring impaired waters to meet Connecticut Water Quality Standards. The Program Plan also commits DEEP to working with stakeholders to protect threatened and high quality waters.

The goal of watershed based plans is to implement actions leading to restoration of a polluted or otherwise impaired waterbody. Watershed Based Plans share common elements with TMDLs, and in many cases, it would be possible to build upon existing TMDLs to produce Watershed Based Plans or vice-versa.

Element 9-Programmatic Evaluation

Performance Partnership Agreement

The Regional Administrator for USEPA Region 1 and the Commissioner of DEEP share their joint goals to protect and enhance the environment in a Performance Partnership Agreement (PPA). The PPA contains priorities and commitments that are discussed at annual meetings to jointly move programs related to Clean Water; Clean Air; Climate Change and Energy Opportunities; Landscape Stewardship; and Compliance Assurance and DEEP Decision-Making. Annual discussion between the WMAP and the Monitoring Coordinator with USEPA Region 1 regarding priorities and commitments in the PPA influence the work incorporated into the annual work plan.

Critical Technical Elements Evaluations

Region 1 of the USEPA has supported Critical Technical Elements Evaluations (CEE) of monitoring and assessment programs, which is a technical program evaluation conducted by national experts outside of DEEP. The program evaluation includes both the 13-element technical review (e.g., selecting indicator assemblages, locating reference sites and calibrating regional reference conditions, choosing appropriate index periods, and addressing important methodological questions) as well as review of the policy and water quality standards context of the water management programs (Davies and Yoder, 2011, USEPA 2013). The 13 technical elements examined in the CEE are considered essential to a robust water management program (Table 10). Programs are scored by dividing the total points obtained from the 13 element technical review and dividing by 60 (the maximum score possible) and expressed as a percentage. Technical rigor is expressed in terms of attainment of a CEE Level from 1 to 4, with 4 representing the highest level of rigor - Level 1: <70%; Level 2: 70-84.9%; Level 3: 85-94.9%; Level 4: >95% (after Barbour and Yoder 2010).

Table 10. The 13 technical elements examined in the Critical Technical Elements Evaluations that are considered essential to a robust water management program.

Element Number	Technical Element
	Biological Assessment Design
1	Index Period
2	Spatial Sampling Design
3	Natural Variability
4	Reference Site Selection
5	Reference Conditions
	Data Collection and Compilation
6	Taxa and Taxonomic Resolution
7	Sample Collection
8	Sample Processing
9	Data Management
	Analysis and Interpretation
10	Ecological Attributes
11	Discriminatory Capacity
12	Stressor Association
13	Professional Review

The CEE review emphasizes biological issues and concerns because aquatic life usually represents the most sensitive use designated for most waterbodies and intuitively should serve as a primary driver of other water quality management requirements and decisions. CEE's were initially conducted at DEEP over a three day period, October 31 – November 2, 2006. The program received a raw CEE score of 45 (75% CEE score) which is a Level 2 program. A follow up CEE was conducted at DEEP in 2009 and the CEE score improved to 88% which is upper Level 3 program (Figure 12). A Level 3 program is classified as Advanced Program Development (Davies and Yoder, 2011).

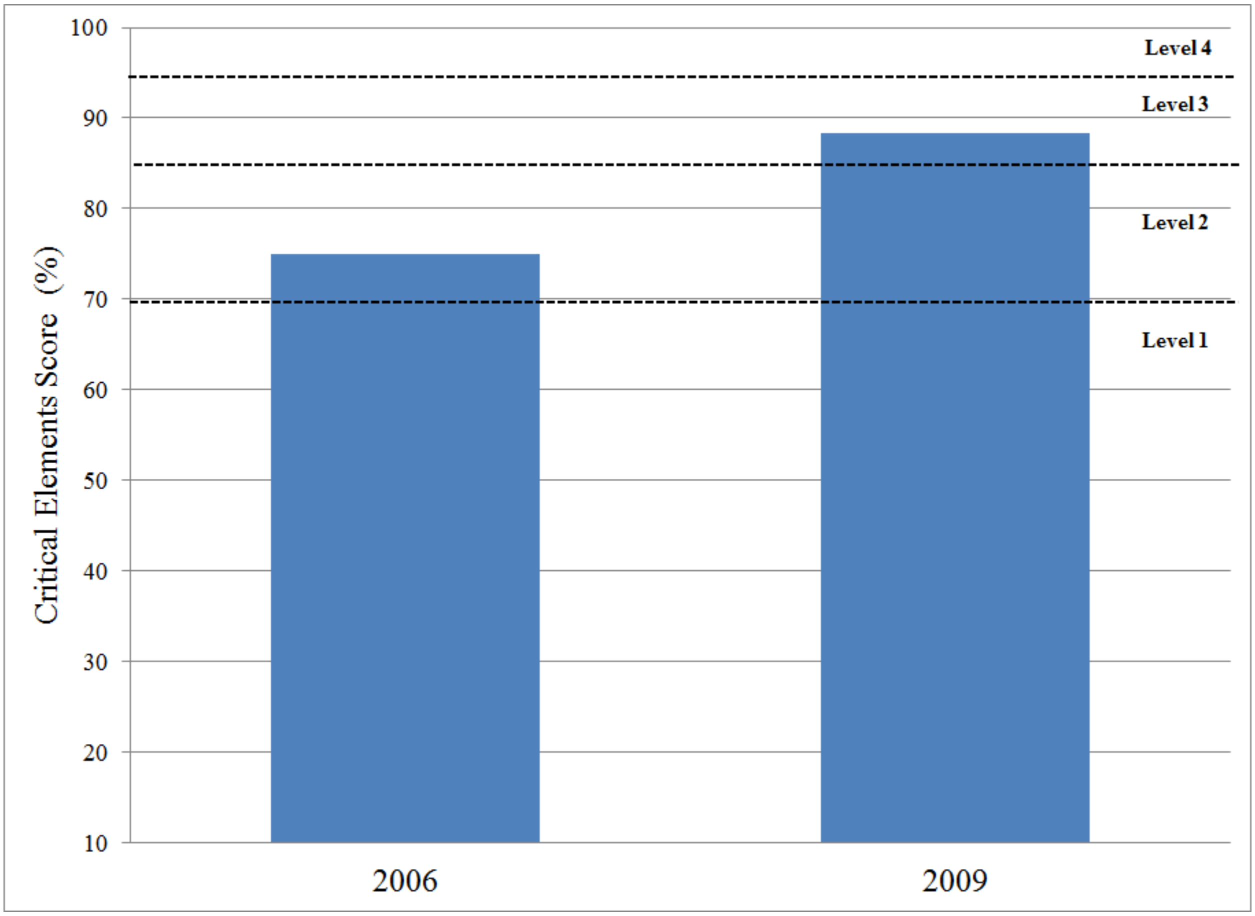

Figure 12. Critical Elements Review scores from Connecticut's Water Monitoring and Assessment Program in 2006 and 2009.

The CEE review cited that the DEEP Program is an example of the rapid progress that can be made given motivated state managers and technical staff, and the infusion of even a modest amount of additional resources. All Elements that assess classification, reference conditions, and BCG-based endpoints (e.g. Element 3, 4, 7, 10, and 11) have improved markedly due to the commitment to technical development.

Since the 2009 CEE, the WMAP has continued to grow and use the CEE process to improve the program. In particular, the CEE recommended summarizing work in peer reviewed articles, and the program has published and supported several articles since 2011. Much of the work has focused on improving our assessments, studies related to land cover and impacts to aquatic life, and classification of healthy watersheds. DEEP supports independent program evaluations such as CEE and encourages the USEPA to continue the technical and monetary support for this program. DEEP considers the CEE Process as something that should occur at periodic intervals, perhaps once every 10 years to coincide with revision of states Monitoring Strategy updates.

Independent Assessment of Phosphorus Strategy by the Connecticut Academy of Science and Engineering

Public Act No. 12-155, An Act Concerning Phosphorous Reduction in State Waters, sets forth a process for making recommendations regarding a statewide strategy to reduce phosphorus loading in non-tidal waters. DEEP established working groups and a coordinating committee to address the issues mandated by this legislation.

Three working groups were charged with formulating recommendations for the purpose of policy development: Working Group #1: Statewide Response to Phosphorus Non-point Pollution; Working Group #2: Methods to Measure Phosphorus and Make Future Projections; and Working Group #3: Municipal Options for Coming into Compliance with Water Quality Standards. The overarching Coordinating Committee comprises the co-chairs of the three working groups with oversight by a DEEP deputy commissioner and a representative from a Connecticut town. The Coordinating Committee was tasked with guiding the project, with responsibility for overall direction and timing, and addressing cross-cutting issues.

At the request of DEEP, the Connecticut Academy of Science and Engineering (CASE) was engaged to conduct a study of specified tasks regarding the science involved and to make recommendations for the development of methods to measure phosphorus and make future projections for the consideration of Working Group #2**.** The CASE recommendations (CASE 2015) will be summarized in a report back to the legislature and will help guide the sampling program that is evaluating phosphorus in non-tidal streams and rivers and future recommendations to support nutrient management for non-wadeable streams and rivers.

Continuous Planning and Potential for Program Growth

The following agenda items and recommendations are goals for WMAP growth for the period 2015-2024, while recognizing the uncertainty of staff and budgetary resources support. More detail on staffing resources to support program growth are outlined in Element 10-General Support and Infrastructure.

Agenda Item: Data management

Recommendation: Investigate assigning dedicated staff to support data management to meet the objectives of this Monitoring Strategy. Two potential ideas to explore are 1) assigning dedicated Office of Information Management (OIM) staff to support data management or 2) hiring staff with skill sets that will support data management in the WMAP.

Data management is one of the most critical functions of a program such as the WMAP. To meet the objectives of this Strategy (***Element 2***) staff resources will be needed to improve data management. Historically, data management has been conducted by staff biologists that have learned the skills necessary to build and maintain a relational database using Microsoft Access to store and retrieve data generated by the WMAP. Recently, DEEP OIM has stopped supporting Microsoft Access applications in preference of more robust data management platforms such as Microsoft SQL Server. While these systems provide a more robust and secure system for long term data storage and provide the mechanism to transfer data to USEPA's STORET, the WMAP is now completely dependent on the DEEP OIM staff to support the database such as the AWQ system. Assistance with data management requires staff with advanced computer programming skills. OIM staff have many competing demands for their time, and allocating time to AWQ has been challenging thus far. This raises concerns about the future of data management in the WMAP.

Agenda Item: Assessment Methodology

Recommendation: Establish a process to use the BCGs tools to identify healthy waters and better define water quality assessment by the 2016 IWQR cycle. Continue to work on improving Connecticut's Stream Assessment Process. Ultimately refining assessments using the biological community tools such as BCG Tiers and MMIs will allow for higher resolution of tiered aquatic life assessments that will support the healthy waters initiative and better support stressor causal analysis.

A. The WMAP has developed an MMI and BCGs for macroinvertebrates (Gerritsen and Jessup 2007), two fish MMIs (Kanno et al 2010), and completed a BCG for stream fish in Connecticut (Stamp and Gerritsen 2013). This work has set the stage for refinement of stream health assessments by establishing tiered aquatic life assessments during this work plan.
B. Establish a diatom index and diatom BCG to be incorporated into aquatic life assessments by the 2020. A pilot project to monitor periphyton was initiated during a

statewide probabilistic survey of wadeable streams in 2002 – 2003. After initial promising results, a five year project is underway (Becker 2012) to evaluate diatoms as an assessment tool as well as characterize the ability to use the diatom community to support nutrient management in Connecticut's wadeable streams (Becker 2014; Smucker et al 2013).

C. Establish a macroinvertebrate index for low gradient habitat by 2020. Historically, the WMAP sampling in streams and rivers has focused on riffle habitat. A pilot project was established from 2010-2015 to collect samples from other habitat types in rivers and streams, mainly low gradient habitat.

Agenda Item: Nutrient Monitoring

Recommendation: In recent years, the USEPA has identified 'cultural eutrophication' as one of the primary factors resulting in impairment of U.S. surface waters. Eutrophication is the process which leads to an increase in the level of primary production or biomass occurring within a water body. Eutrophication is a slow natural process that occurs within a water body, but human activity can greatly speed up the process primarily through the addition of excess nutrients. USEPA is encouraging all states to develop strategies that identify and address impairments caused by cultural eutrophication. In 2012 the Connecticut Legislature passed Public Act No. 12-155, *An Act Concerning Phosphorous Reduction in State Waters*. As part of this Act, CASE was engaged to conduct a study regarding the science involved to make recommendations for the development of methods to measure phosphorus (CASE 2015). Part of their recommendations include continuing diatom community assemblage sampling and adding diurnal dissolved oxygen monitoring in inland rivers and streams.

A. Implement monitoring recommendations for inland river and streams from the CASE Phosphorus Study by 1) Investigating ability of USGS to continuously monitoring dissolved oxygen at gages and 2) identify funding to continue diatom assemblage sampling program by the WMAP (Becker 2012).
B. Assess available lake data and identify additional monitoring needs to develop an assessment methodology that implements Connecticut's numeric WQS for nutrients in lakes.
C. Evaluate the need for additional monitoring to support regulatory thresholds for nutrients in estuaries.

Agenda Item: Volunteer Monitoring

Recommendation: Continue the RBV Coordinator Program and investigate ways to hire staff resources to support Volunteer Monitoring Program expansion as resources allow.

A. The WMAP has over 15 years' experience conducting volunteer monitoring primarily focused on the RBV Program. The RBV Program is focused on using macroinvertebrates in streams to provide data and assessments in high quality waters. This experience has helped develop relationships with leaders in the volunteer community. Over the years, several opportunities to expand the Volunteer Monitoring Program have emerged. Potential areas to expand the program exist for lakes and estuaries monitoring if resources allow.

Agenda Item: Healthy Waters Program

Recommendation: Increase the miles of monitored healthy waters and map their locations in Connecticut using web mapping technologies to transfer this information to DEEP Programs and the public. The Healthy Waters Program has benefitted greatly from directing monitoring resources to identify healthy water over the last several years. One study has initiated the location of healthy waters in Connecticut (Bellucci et al 2011), although this list was not meant to be final or exhaustive.

A. Use the refinement of stream health assessments (described above under **Assessment Methodology)** to identify the locations of healthy river and streams throughout Connecticut to develop a healthy waters list.
B. Continue to support the RBV Program and promote the "Treasure Hunt" for healthy waters
C. Complete stream flow classifications for the entire state by 2018. This will allow more refined characterization of healthy waters by identifying rivers and streams that have the least impacted flow regimes in the state.
D. Continue to track the healthy river and stream miles in Connecticut (e.g. Figure 6).
E. Continue development of web application to communicate information about healthy waters in Connecticut.

Agenda Item: Critical Elements Evaluation

Recommendation: Participate in Critical Elements Evaluation of the WMAP at least one time during 2015-2025.Encourage USEPA to support the technical aspects of the Critical Elements Evaluations so that state programs can use this program as part of the continual improvement process. Encourage USEPA to establish a Critical Elements Evaluation program that includes a 5 year schedule.

Agenda Item: Lakes Program

Recommendation: Develop a communication pathway for programs that monitor lakes and develop a database to store important parameters and indicators of lake trophic structure. Several groups and organizations are interested in lakes in Connecticut and collect sampling data. These data are not integrated into a central database. Investigate potential collaboration with other agencies and universities conducting lake work to maximize use of data for lakes assessments. Target cooperators have been identified as the Connecticut Agriculture Experiment Station, DEEP Fisheries, lake associations, and university researchers. This process can help establish a comprehensive list of lakes to be monitored to meet multiple project objectives and help with prioritizing workloads.

Agenda Item: USGS Monitoring and Stream Flow Gaging Network

<u>Recommendation:</u> Create a stable funding source to support the USGS stream flow and monitoring network. Historically, the DEEP budget to support the USGS network has been subject to uncertainties in state budget cycles and the trend has been a reduction in monitoring and stream flow gages in Connecticut.

These data sources are critical to support the objectives of this Monitoring Strategy. They are the sole source of data with sufficient frequency and data quality required to assess trends for some important parameters such as nutrients (e.g. Long Island Sound TMDL, Phosphorus Reduction Strategy for Inland Non-Tidal Waters) that are prominent in our policy making

Stream flow gaging provide information on the quantity and timing of stream flow to help ensure adequate water resources to support a healthy environment and economy and facilitate planning for future floods and droughts. Long-term records of stream flow (more than 30 years of record) are vital to the characterization of regional hydrologic conditions (for purposes of water supply planning, stream flow regulation, and flood-hazard assessments) as well as documenting and understanding changes that occur in stream flow due to changes in land use, water use, groundwater withdrawal, and climate.

Agenda Item: Laboratory Support

<u>Recommendation:</u> Assess the possible alternatives to support the WMAPs growing laboratory needs.

A. Create a stable funding source to support laboratory analysis for fish tissue sampling program. Long-term trend monitoring of important fish tissue contaminants such as mercury cannot be fully understood if funding is not available to conduct the research. For example, statewide survey of mercury in fish tissue from sixty-one lakes was conducted by the University of Connecticut in 1995 (Neumann et al. 1996) and again in 2005-2006 (Vokoun and Perkins 2008) with funding from the Department. This research recommends repeating the study at approximately ten-year intervals to evaluate trends in mercury contamination as funding for this work allows.
B. Since 2006, benthic macroinvertebrate samples have been sent out to contract laboratories for taxonomic identifications every year. This shift from in house identifications to using contract labs began with the loss of a full time taxonomist position that was never replaced. Future discussions should include reestablishing the capacity to conduct the identifications in-house or continuing to fund the laboratory identifications.
C. The periphyton project has been sending samples out to contract laboratories for taxonomic identifications. Future discussions should include building the capacity to conduct the identifications in-house or continuing to fund the laboratory identifications.
D. Laboratory needs to support the cyanobacteria project include identification and quantification of species and laboratory analysis of toxins should be examined following completion of pilot projects.
E. Personal care products, endocrine disrupting compounds, and other emerging issues may

require prioritization and budgeting to support pilot projects.

Agenda Item: Rotating Basin Framework

Recommendation: Continue to communicate the predictability of the Rotating Basin framework to programs and encourage opportunities for collaboration and data sharing. One strength of the Rotating Basin Framework is that it provides a predictable schedule that can allow for well-coordinated annual work plans. This can help communicate program workload and provides opportunities to coordinate permits, implementation plans such as TMDLs, TMDL alternatives, and Watershed based Plans, monitoring activities conducted by other programs in the Department (e.g. Inland Fisheries Division) and outside of the Department.

Agenda Item: Promote Growth in Biological Monitoring Program

Recommendation: As resources allow for program expansion, develop pilot programs to expand monitoring capabilities and grow the biological monitoring program for non-wadeable rivers, tidal fresh and brackish streams and estuaries, lakes, and wetlands.

Biological monitoring is a key component to the WMAP. The historical focus of biological monitoring has been on rivers and streams because these waters receive the majority of point source discharges in Connecticut and technical resources (e.g. Plafkin et al 1989) have been available to encourage program growth and development for decades. This experience can support expanding biological monitoring to monitor and assess non-wadeable rivers, tidal fresh and brackish streams and estuaries, lakes, and wetlands.

Agenda Item: Staff Professional and Personal Growth

Recommendation: Endorse staff opportunity to participate in technical and personal growth training as budget allows.

A. Technical training pertaining to advances in monitoring techniques, sample collection methods, analytical and taxonomic techniques, quality control, statistical methodology, and other subjects related to activities in the WMAP.

B. Support at least one staff to attend the following Professional Meetings - the New England Association of Environmental Biologists Annual Conference, Society for Freshwater Science Annual Meeting, American Fisheries Society Annual Meeting, and North American Lakes Management Society Annual Meeting.

C. The State In-Service Training Program provides diverse training opportunities to all Connecticut state employees through a partnership of the Department of Administrative Services and the Community College System. Courses focus on business skills, leadership skills, and computer skill to enhance personal growth.

Element 10-General Support and Infrastructure Planning

The WMAP is in the Bureau of Water Protection & Land Reuse, Planning and Standards Division. In addition to the WMAP, Programs in the Planning and Standards Division include Municipal Water Pollution Control, Water Quality Standards, Aquifer Protection and Water Supply Coordination, Watershed Low Impact Development and Nonpoint Source Program, Lakes Program, TMDL Program and Long Island Sound Implementation. These Programs are under a Division Director and Assistant Director who oversee these programs (Figure 13).

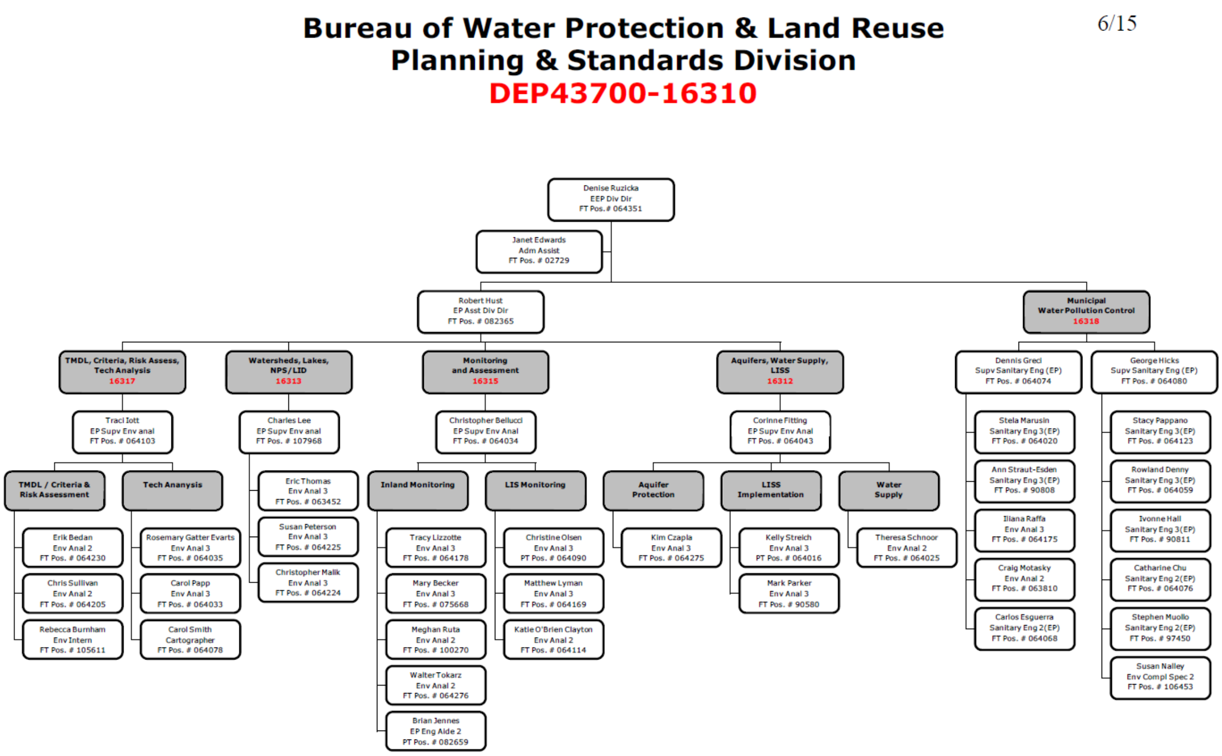

Figure 13. Organizational chart for the Bureau of Water Protection and Land Reuse Planning and Standards Division.

The WMAP Program is currently staffed by a supervisor, eight full-time employees and one part-time employee. Five full time staff and one part-time employee are dedicated to the inland monitoring program and 3 full time staff are dedicated to Long Island Sound monitoring. Staff are augmented seasonally by up to eight Seasonal Resource Assistants, a temporary job class.

Private and university laboratories provide support for water chemistry analysis, benthic macroinvertebrate taxonomy, diatom taxonomy, and toxicity testing. Contractor support to support the macroinvertebrate and diatom programs for these laboratory support needs should be institutionalized in order to maintain our existing level of assessment quality and program support. This is especially important since the program relies on biological monitoring as the cornerstone of the program.

This strategy was designed to be implemented with currently available staff resources. While potential for program growth exists if staff levels are maintained, loss of one or more key staff would put successful implementation of this Monitoring Strategy in jeopardy. Equipment (Table 11) resources to maintain existing programs and staff resources for significant program expansion to meet all of the agenda items in Element 9-Programmatic Evaluation are described in Table 12.

Table 11. Projected equipment needs (greater than $5,000) to maintain existing Water Monitoring and Assessment Programs from 2015-2024. Projected needs within the first 5 years of the plan are highlighted in **Bold**.

Equipment	Use	Year Purchased	Projected Year to Purchase	Estimated cost
Electrofishing Backpack unit	**Fish Community Assessments**	**2002,2008**	**2016**	**$12,000**
Water Quality Multi-parameter meters	**Stream, River and Lake Assessments**	**1999-2001**	**2017**	**$40,000**
Jon Boat and Motor (15 hp)	**Lake monitoring program, Non-Wadeable River, Estuary Monitoring**	**1995 (3 hp)**	**2017**	**$20,000**
Weather Stations (5 stations)	**Stream temperature monitoring and beach monitoring program**	**New**	**2016**	**$10,000**
Lake Monitoring Equipment	**Lake monitoring program**	**New**	**2016**	**$7,500**
Handheld water proof computing devices	**All Monitoring programs**	**New**	**2017**	**$10,000**
Database contract to build field forms for handheld computers	**All Monitoring programs**	**New**	**2018**	**$50,000**
Water Treatment System	All Monitoring programs	2014	2024	$10,000

Table 12. Projected needs to maintain and expand existing Water Monitoring and Assessment Programs from 2015-2024. Projected needs within the first 5 years of the plan are highlighted in **Bold**.

Program	Need	Projected Cost
Biomonitoring	**Macroinvertebrate and Diatom taxonomist- Requires specialized training and important for succession planning and program stability**	**2 FTEs at Environmental Analyst 2 level- $192,000/year. Developing capacity of WMAP to staff taxonomist should be discussed with next item, using contract laboratories.**
Biomonitoring	**Laboratory costs for macroinvertebrate and diatom identifications**	**$50,000/year through state contracted laboratories.**
Biomonitoring	**Technical Support for diatom MMI/BCG Model Development**	**$100,000 through consulting firm or university.**
Biomonitoring	**Technical Support for low gradient MMI Model Development**	**$75,000 through consulting firm or university.**
Laboratory Support	**Statewide Mercury in Fish Tissue Study**	**A repeat of the 2005-2006 (Vokoun and Perkins 2008) and 1995 surveys (Neumann et al 1996) to determine mercury trends in fish tissue and inform fish consumption advisories.** **$120,000 through consulting firm or university.**
Laboratory Support	**Cyanobacteria Monitoring**	**$50,000/year through consulting firm or university.**

Laboratory Support	Emerging Contaminants such as Personal Care Products, endocrine disrupting compounds.	$100,000 pilot study through consulting firm or university.
Data Management	Technical staff trained in database management.	1 FTE at Environmental Analyst 2 or equivalent level to support data management, quality assurance, data analysis and reporting $96,500/year.
Lakes	Limnologist or aquatic biologist to support the lakes program. Requires specialized training and important for succession planning and program stability	1 FTE at Environmental Analyst 2 level to provide field sampling and data analysis support for lakes monitoring program $96,500/year.
Nutrients	**Continuous dissolved oxygen monitoring to support nutrient work in streams**	**$50,000-100,000/year to support nutrient work through USGS network of sites.**
Staff Professional and Technical Growth	**Provide training opportunities through participation in Technical Meetings and other training opportunities through State In-Service Training Program**	**$4,000 per year to support staff growth**
Volunteer Monitoring	Develop Volunteer Lake and Estuary Monitoring Program	1 FTE Environmental Analyst 2 level to expand Volunteer Monitoring Program $96,500/year.

Infrastructure

The WMAP occupies two facilities in the greater Hartford area. Office facilities are located at the DEEP headquarters office building, 79 Elm Street in Hartford, CT. Field and laboratory work is conducted out of a DEEP facility located at 9 Windsor Ave, Windsor, CT that houses staff from WMAP, DEEP Bureau of Air Management, and Consumer Protection. The WMAP lab consists of 4,077 square feet of work space for microscopic bench work, benthic macroinvertebrate sample processing, fish tissue processing, equipment storage, and a general field sampling staging area used for survey preparations. Laboratory areas are well equipped with sinks, fume hoods and health and safety equipment which complies with state and OSHA safety requirements. Laboratory space is currently adequate to meet the basic needs of the program.

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Appendix 1. Sentinel Sites that are scheduled for annual biological and water temperature monitoring. Several sites are collocated at USGS gages and highlighted in bold in the location description.

Waterbody	Location Description	Town	Latitude	Longitude
Bunnell Brook	at recreation area at Vineyard Rd and Clear Bk Rd near **USGS gage**	Burlington	41.7807	-72.9630
Flat Brook	at Lower Barrack Rd	Canaan	41.9459	-73.3200
Brown Brook	at Route 63	Canaan	41.9267	-73.2799
Stonehouse Brook	downstream Palmer Rd	Chaplin	41.7812	-72.1509
Salmon River	downstream 0.7 miles Railroad Bridge near **USGS gage**	Colchester	41.5742	-72.4294
Day Pond Brook	at mouth	Colchester	41.5623	-72.4338
Sandy Brook	opposite Grange Hall off Riverton Rd	Colebrook	41.9740	-73.0406
Burnhams Brook	at mouth	East Haddam	41.4603	-72.3343
Hemlock Valley Brook	at Bone Mill Road	East Haddam	41.4283	-72.4226
Mott Hill Brook	off Hunt Ridge Dr	Glastonbury	41.6615	-72.5365
West Branch Salmon Brook	upstream 50 meters Barndoor Rd	Granby	41.9372	-72.8215
Hubbard River	upstream Route 20 on MDC property near **USGS gage**	Hartland	42.0356	-72.9384
Beaver Brook	downstream bridge at 55-123 Beaver Bk Rd	Lyme	41.4100	-72.3289
Green Fall River	upstream confluence with Wyassup Bk upstream Clarks Fall Rd	North Stonington	41.4568	-71.8169
Pendleton Hill Brook	upstream Grindstone Hill Rd at **USGS gage**	North Stonington	41.4748	-71.8342
Saugatuck River	downstream Route 107 & Route 53 Junction at **USGS gage**	Redding	41.2945	-73.3948
Little River	at Newtown Turnpike	Redding	41.2931	-73.3678
Shepaug River	downstream Wellers Bridge Road (Route 67) at **USGS gage**	Roxbury	41.5489	-73.3308
Jakes Brook	at Route 272	Torrington	41.8646	-73.1679
Tankerhoosen River	upstream Tunnel Rd	Vernon	41.8272	-72.4640
Rugg Brook	upstream first road crossing from reservoir	Winchester	41.9328	-73.1214
Weekeepeemee River	downstream Jacks Bridge Rd at **USGS gage**	Woodbury	41.5575	-73.2155
Nonewaug River	at **USGS gage** adjacent to Route 6	Woodbury	41.5783	-73.1745