# Salmon Falls Headwaters Watershed Management Plan Implementation Project – Phase 1:

## Great East Lake, Lake Ivanhoe, Horn Pond, Wilson Lake & Lovell Lake

**A Final Report to**

**The New Hampshire Department of Environmental Services**

**Acton Wakefield Watersheds Alliance**

**May 2012**

This Report is Submitted by
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NEW HAMPSHIRE DEPARTMENT OF Environmental Services

Additional support was provided by
Adelard E. and Valeda Lea Roy Foundation
Alden N Young Trust
Jane B Cook 1983 Charitable Trust
Town of Acton, Maine
Town of Wakefield, New Hampshire
Great East Lake Improvement Association
Horn Pond Association
Lovell Lake Association
Wilson Lake Association
Local businesses
Generous individual donors

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# Executive Summary

*Watershed Implementation (Phase 1) and Road Management Plan: Great East Lake, Lake Ivanhoe, Horn Pond, Wilson Lake, and Lovell Lake*

In 2010 AWWA presented the *Salmon Falls Headwater Lakes Watershed Management Plan*, a pro-active watershed-based management plan for the high quality lake watersheds that flow into the Salmon Falls River including Great East Lake, Lake Ivanhoe, Horn Pond, Wilson Lake and Lovell Lake. The plan evaluated available data to determine realistic long-term water quality goals; conducted watershed surveys to identify sources of pollution; reviewed local land use regulations; mitigated identified erosion issues with its existing Youth Conservation Corps; and conducted an outreach campaign designed to raise stakeholder stewardship. The Acton Wakefield Watersheds Alliance (AWWA) coordinated this project as a catalyst for strengthening the efforts to protect the region's waters to preserve their ecological, recreational and economic value.

The community-driven Action Plan identified five key action categories. Phase 1 of the implementation project for the plan included activities within each of the recommended categories: Private and Public Roadway BMPs, Residential BMPs, Community Planning and Development, Outreach and Education and Land Conservation. These activities have resulted in measurable reductions of phosphorus inputs and have laid the foundation for future reductions.

The project began on March 26, 2010 and concluded in December of 2011 excepting the completion of this report. The total project cost was $228,507 which included the $107,952 grant award and $120,555 non-federal match. Match was provided by the following generous supporters:

| | |
|---|---|
| Alden N. Young Trust | Town of Acton ME |
| Jane B Cook 1983 Charitable Trust | Lake associations |
| Adelard & Valeda Roy Foundation | Individual donations |
| Town of Wakefield NH | In-kind and volunteer time |

In addition to the excellent support from the NH Department of Environmental Services Watershed Assistance Section and particularly Project Manager Sally Soule, AWWA's project partners included:

| | |
|---|---|
| FB Environmental Associates | Salmon Falls Watershed Collaborative |
| Great East Lake Improvement Association | Three Rivers Land Trust |
| Horn Pond Association | Town of Acton |
| Lovell Lake Association | Town of Wakefield |
| Maine Congress of Lake Associations | UNH Cooperative Extension |
| Moose Mountains Regional Greenways | UNH Lakes Lay Monitoring Program |
| National Resource Conservation Service | UNH Stormwater Center |
| NH Lakes Association | Wilson Lake Association |

All four objectives of the Salmon Falls Headwater Lakes Management Plan project were met over the course of the project period.

- The AWWA staff and Board of Directors worked diligently to identify capacity needs and provide all necessary ability to successfully manage the project.
- Installation of 111 BMPs at 30 project sites within the Salmon Falls watershed resulted in a load reductions of 37.1 tons/year sediment and 31.8 lbs/year phosphorus.
- An additional 50 site-specific designs were delivered to landowners wishing to install their own BMPs or be considered as future Youth Conservation Corps hosts.
- The *Road Management Plan for Brackett and Pond Roads, Wakefield, NH* was presented to the Wakefield Board of Selectmen on May 25, 2011. The Board accepted the Plan and unanimously agreed to move forward with the quest to find grant funds to support implementation of the Plan.
- AWWA's Roundtables, Intercept Survey, Discovery Cruises and School Programs engaged 234 local stakeholders in learning about land-use practices that maintain or improve water quality.
- Lake specific flyers with watershed maps were created and distributed to each lake association.
- 105 lake residents pledged to reduce their P Footprint by signing the Reduce Your P Footprint Pledge form.
- AWWA supported the volunteer lake water quality monitors and coordinated with the UNH Lakes Lay Monitoring Program to distribute the reports.

# Introduction

The Acton Wakefield Watersheds Alliance (AWWA) is a non-profit volunteer organization formed in 2004 to protect and improve water quality in the lakes and streams in the Acton, ME, Wakefield, NH border region and ultimately in the rivers, estuaries and bays into which they flow. The Alliance is registered with the State of New Hampshire and holds 501(c)3 status. AWWA has nine active directors and officers who bring a wide range of expertise and affiliations to the group. The mission of AWWA is to protect and restore water quality by affecting land use practices and policies and in the border region of Acton, ME and Wakefield, NH.AWWA focuses its efforts on prevention of non-point source pollution, primarily as it is delivered through stormwater.

The project area encompasses the headwaters of the Salmon Falls River which includes the watersheds of Lake Ivanhoe, Great East Lake, Wilson Lake, Horn Pond, and Lovell Lake. These watersheds cover approximately 26 $mi^2$ along the border of New Hampshire and Maine. The Salmon Falls River forms the state border to its confluence with the Cocheco River in Dover, NH where it becomes the Piscataqua River and flows into the Gulf of Maine. Lake Ivanhoe and Lovell Lake are entirely in NH, Wilson Lake is in ME and Great East Lake and Horn Pond are bisected by the border.

Both communities are primarily rural and forested with very little industrial or commercial development. While much of the land is undeveloped very little is permanently protected through conservation easements. The Hydrologic Unit Codes are 010600030403 and 010600030401.

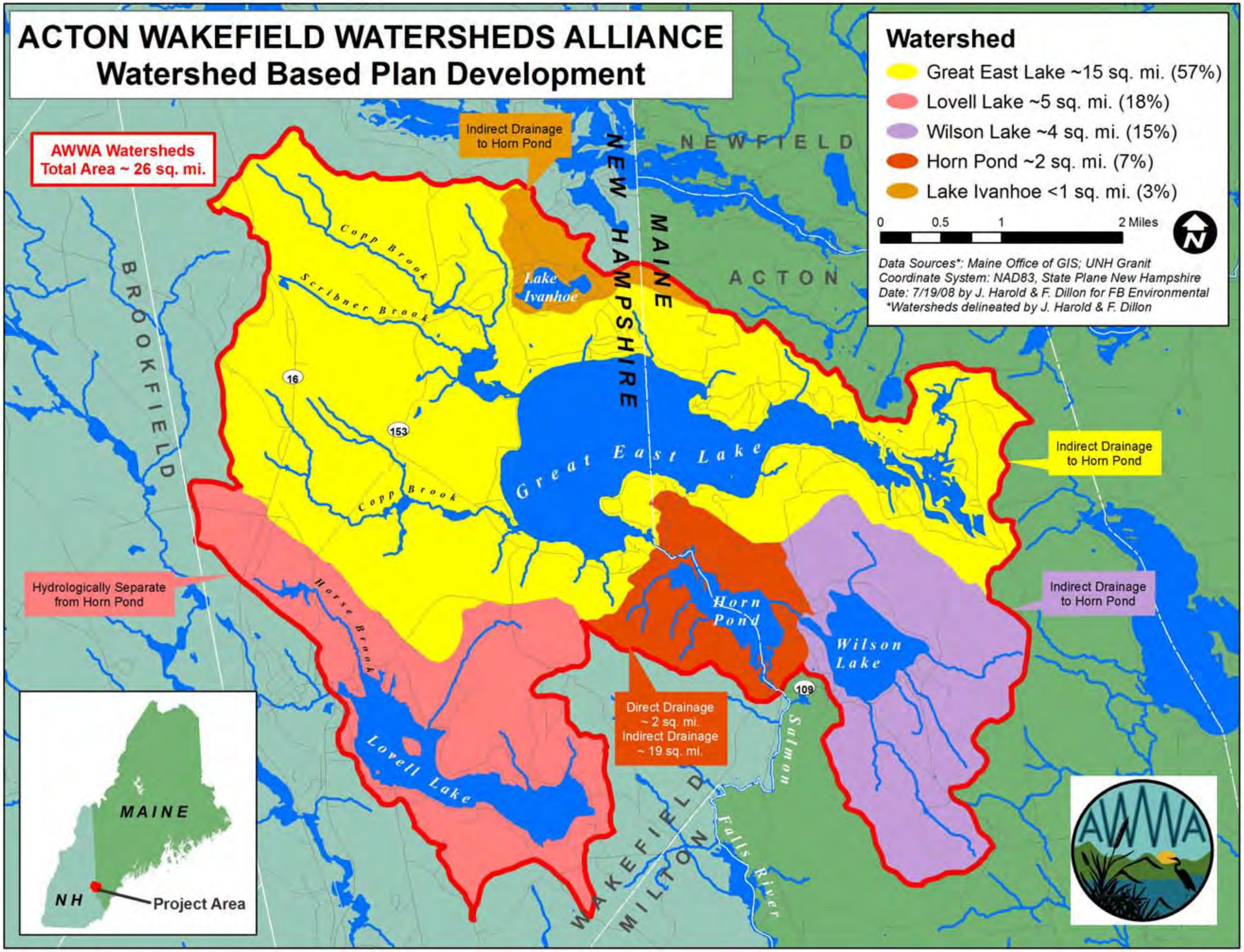
The lakes are a valuable resource in these communities providing recreation, relaxation, drinking water and a large percentage of the town revenues in the form of property taxes. Lakes and their surrounding lands also provide habitat for plants, wildlife and aquatic life. While clean water is essential for all life, pollution and irresponsible water use plague the waterbodies, making proactive protection of water resources essential. The Acton-Wakefield region in Western Maine and Eastern New Hampshire has an economy that depends greatly on the local waterbodies, including those that form the Salmon Falls Headwaters.

In 2006, AWWA received its first 319 grant from the NH DES to initiate a Youth Conservation Corps program. After two years of focusing on the YCC program AWWA directors recognized the need for a more comprehensive understanding of the watershed characteristics, potential problems and threats and current water quality of the lakes and applied for additional funding through the 319 program. AWWA chose to focus on the Salmon Falls headwater lakes based on available data for analysis and the stakeholder support from the communities and lake associations.

In early 2010, AWWA presented the “Salmon Falls Headwater Lakes Watershed Management Plan” which established measurable water quality goals and provided a detailed action plan for implementation. Later in 2010 AWWA applied once more for funding through the NH Watershed Assistance Section for 319 funding to implement recommendations from the Plan. Phase 1 of implementation focused on the development of a road management plan for problematic gravel roads around Lovell Lake, continued focus on residential erosion control through the YCC and Technical Assistance programs, lake association outreach with the Clean Lakes Campaign and capacity building projects.

The desired outcome of this project was to maintain and protect the water quality of the high quality waters of the AWWA region including Great East Lake, Horn Pond, Lake Ivanhoe, Lovell Lake and Wilson Lake, through implementation of recommendations in the “Salmon Falls Headwater Lakes Watershed Management Plan.”

## Watershed Map



# Project Performance Targets and Milestones

## Draft Objectives and Tasks for AWWA Full Proposal

**Objective 1:** Organizational capacity is sufficient to carry out the requirements of the project.

- **How will success be measured?** The AWWA Board has completed a visioning process to identify staffing, volunteer and partner needs. Necessary staff has been hired, partners identified, and volunteers recruited. Reports have been submitted in a timely manner, funding has been applied for and insurance has been purchased.
    - **Deliverable 1A:** The AWWA Board completes a list of tasks and identifies roles and responsibilities.
        - Task 1: Complete two visioning sessions to identify goals and tasks and present results to the Board.
        - Task 2: The Board accepts the job descriptions and agrees to hire staff.
    - **Deliverable 1B:** AWWA staff is hired and contracts are signed.
        - Task 3: Hire staff and complete all necessary contracts.
    - **Deliverable 1C**: Partnership Agreements with UNH Stormwater Center (UNHSC) and York County Soil and Water Conservation District (YCSWCD) are developed and signed.
        - Task 4: Complete UNH Sponsored Services Agreement and YCSWCD contract
    - **Deliverable 1D:** All required reports are submitted, funding options are investigated, insurance policy is contracted and administrative duties are complete.
        - Task 5: Document all project costs, match and revenues.
        - Task 6: Communicate project progress on a monthly basis between ED, PM, and AWWA Board
        - Task 7: Submit all required reports in a timely manner.
        - Task 8: Research and apply for funding.
        - Task 9: Purchase necessary liability insurance.
    - **Deliverable 1E**: Convene WBMP Steering Committee at least three times throughout project period to track progress on current project and plan implementation for Phase 2.
        - Task 10: Develop agenda for steering committee meetings
        - Task 11: Schedule, coordinate meetings and convene meetings
        - Task 12: Distribute minutes of meetings, report on progress and recommendations
    - **Deliverable 1F**: Coordinate membership management including recruitment, cultivation and database management.
        - Task 13: Plan and implement regular membership drives
        - Task 14: Maintain organizational database

**Objective 2:** By September 2012, at least 24 NPS pollution problems identified by watershed surveys conducted by AWWA as part of its watershed-based management plan project will be corrected with Best Management Practices implementation resulting in a minimum of 10 tons sediment reduction annually.

- **How will success be measured?** Recommended BMPs will be installed at a minimum of 24 private or public sites resulting in a reduction of at least 10 tons of sediment reduction annually as measured by the Region 5 model. The numerical load reductions will be supplemented by photographic documentation using the NH DES SOP for Photographic Documentation.
  - **Deliverable 2A**: At least 60 landowners receive a technical assistance as a result of the watershed survey identification.
    - Task 15: Solicit TA requests through letters to identified site landowners and lake association newsletter articles
    - Task 16: Perform TA visits with interested landowners to provide general water quality information as well as site specific BMP design recommendations.
    - Task 17: Submit all TA designs to the YCSWCD for technical review
    - Task 18: Create and deliver TA design recommendations
    - Task 19: Technical Director recommends sites for YCC projects based on severity of pollution loading, suitability for the YCC crew and logistical factors.
  - **Deliverable 2B**: At least 40 landowners whose sites are not chosen as YCC projects sign Pledge Cards and at least 10% install the recommended BMPs during the grant period.
    - Task 20: Complete Pledge card with landowner
    - Task 21: Landowner installs recommended BMPs
    - Task 22: Develop follow-up survey and distribute it to participating landowners.
    - Task 23: Perform site visits to corroborate compliance and document with photos.
    - Task 24: Compile and evaluate data from surveys and visits.
  - **Deliverable 2C:** AWWA YCC installs BMPs to fix erosion or runoff problems on a minimum of 20 private or public sites.
    - Task 25: Recruit, interview, hire staff and complete contracts.
    - Task 26: Train staff at beginning of employment including YCC techniques, First Aid and CPR.
    - Task 27: Technical Director and YCC Committee select project sites based on severity of pollution loading, suitability for the YCC crew, logistical factors, landowner commitment and geographical distribution.
    - Task 28: Technical Director and YCSWCD visit selected sites to verify implementation plan.
    - Task 29: Enter into Letters of Agreement with YCC Project site landowners.
    - Task 30: Acquire necessary local and state permits and coordinate procurement of materials.
    - Task 31: Implement completed designs on project sites using recommended BMPs.
    - Task 32: Install signage at all BMP installation sites to increase AWWA visibility and encourage dialogue about NPS pollution solutions.
    - Task 33: Perform before and after photographic documentation and sediment load reduction estimations.
    - Task 34: Develop follow-up survey and distribute it to participating landowners.

        - Task 35: Compile and evaluate data from surveys and visits.
        - Task 36: Complete season end YCC reports at close of each season for distribution to community stakeholders.
    - **Deliverable 2D:** Develop a Road Management Plan with identified problem areas and proposed solutions along with estimated cost/benefits. The plan will also include general road design suggestions and include road maintenance recommendations for identified problem sites on Brackett and Pond roads in Wakefield.
        - Task 37: UNHSC will perform site visits and consult relevant existing literature and design sources to develop the Road Management Plan; Critical areas and proposed BMP solutions will be prioritized based on estimated sediment reduction and estimated BMP cost; Present Brackett and Pond Road recommendations to Wakefield Board of Selectmen to encourage implementation.

**<u>Objective 3</u>:** By September 2012, at least 200 local stakeholders participated in programs promoting land-use practices that maintain or improve water quality.

- **How will success be measured?** Two implementation partnerships have been established, report on survey results has been completed and distributed to appropriate stakeholders, map brochures have been distributed to at least 100 community residents and at least 30 floating classroom participants have signed phosphorus footprint reduction pledges.
    - **Deliverable 3A**: Hold at least two roundtables with local lake associations and/or concerned citizens to discuss recommendations in the watershed-based management plan and to brainstorm projects resulting in letters of commitment for at least two implementation partnerships.
        - Task 38: Identify roundtable participants and develop agenda
        - Task 39: Host roundtable and complete letters of commitment for implementation partnerships
        - Task 40: Develop, complete and analyze evaluation tool
    - **Deliverable 3B**: Conduct intercept survey of summer residents and to identify behaviors, barriers to change and possible incentives to adopt lake friendly practices.
        - Task 41: Develop survey
        - Task 42: Coordinate survey volunteers, pick survey locations and conduct survey
        - Task 43: Analyze survey results and make recommendations
    - **Deliverable 3C**: Provide flyers and maps to lake residents and visitors to help them visualize their watershed connection.
        - Task 44: Develop and distribute watershed specific brochures via lake associations
    - **Deliverable 3D**: Conduct at least one floating classroom program for adults and youth on each target waterbody including monitoring demonstration, benthic grab sample, zooplankton sample and aquatic plant identification. At least 30 participants pledge to reduce their **Phosphorus Footprint**.
        - Task 45: Develop curriculum for a 3 hour tour including **Phosphorus Footprint** pledge form
        - Task 46: Develop schedule and coordinate logistics
        - Task 47: Recruit participants
        - Task 48: Implement 3 hour tour

        - Task 49: Evaluate 3 hour tour
    - **Deliverable 3E**: Deliver at least four presentations about AWWA's efforts and NPS pollution to lake associations, community organizations and other interested groups.
        - Task 50: Develop, promote and coordinate presentations
        - Task 51: Deliver at least four presentations
        - Task 52: Develop, deliver and evaluate presentation
    - **Deliverable 3F**: Create and maintain an informational website to communicate AWWA activities and provide educational resources for watershed stakeholders.
        - Task 53: Manage, maintain and update www.AWwatersheds.org on a timely basis.
        - Task 54: Track website traffic, evaluate content visits and adjust accordingly.

**Objective 4:** Monitoring on each target waterbody has been conducted to evaluate the effectiveness of the implementation efforts over time as measured against the criteria established in the Salmon Falls Headwaters Watershed-based Management Plan.

- **How will success be measured?** Monitoring program has been implemented according to the protocols of the UNH Lakes Lay Monitoring Program.
    - **Deliverable 4:** Volunteer monitors are recruited, trained as needed, and mobilized for each target waterbody.
        - Task 55: Identify current or potential monitors for each target waterbody.
        - Task 56: Coordinate with UNH LLMP to implement monitoring program.

# Project Performance Target Verification

ORGANIZATIONAL CAPACITY

The AWWA staff and volunteers spent many hours ensuring that organizational capacity remains sufficient to successfully execute the projects as well as ensure that the organization will continue to thrive as a valuable resource for the communities in the campaign to protect water quality. Necessary staffing changes during the project period ensured that AWWA would be able to meet, and then exceed, the grant requirements.

The Executive Director continued to expand partnership opportunities to bring expertise to enhance the project performance, in particular, the partnerships with the UNH Stormwater Center and the York County Soil and Water Conservation District.

The ED was able to secure additional grants and local support to provide the necessary funding to complete the project. During the project period the number of donors increased by 226% and the value of donations increased by 330%. All required reports were submitted in a timely manner and appropriate insurance policies were contracted.

YCC

The AWWA Youth Conservation Corps installed 111 BMPs on 30 properties within the Salmon Falls watershed reducing the estimated sediment load by 37.1 tons/year exceeding the goal of 10 tons/year. In addition to the 30 designs created for the YCC projects, the AWWA Program Manager delivered an additional 50 technical assistance designs. Each of the technical assistance clients signed a pledge to install at least one of the recommended BMPs. Of those, 9 (18%) applied to host a project and 10 (20%) installed the recommended BMPs themselves. YCC Season reports can be downloaded at http://awwatersheds.org/links/publications.

"MANAGEMENT PLAN FOR BRACKETT AND POND ROADS, WAKEFIELD, NH"

The UNH Stormwater Center presented the "Management Plan for Brackett and Pond Roads, Wakefield, NH" to the Wakefield Board of Selectmen on May 25, 2011. The selectmen unanimously voted to accept the Plan and move forward with a partnership with AWWA to secure funding to implement the recommendations. The Road Management Plan Steering Committee - comprised of representatives from AWWA, the Wakefield Road Agent, Wakefield Town Administrator, Lovell Lake Association members and Brackett Road property owners - met several times during the project period to ensure that the Plan would address the issues of concern, be well received and fit the capacity of the town's resources. The full plan can be downloaded at http://awwatersheds.org/links/publications.

OUTREACH PROGRAMMING

Roundtables – AWWA convened two roundtables during the project period.

On September 21, 2010 AWWA hosted 27 community leaders at the Acton Wakefield

Stormwater Management Project Kickoff. Forrest Bell of FB Environmental delivered an interactive presentation about the benefits of, and barriers to, adopting or enhancing regulations to control stormwater runoff at the municipal level. The roundtable resulted in both the Acton and Wakefield Planning boards committing to review their stormwater management policies and work with PREP and FBE to develop stronger policies.

On June 11, 2011 42 lake association members, including eight association presidents joined AWWA for the Clean Lakes Campaign kickoff. The morning long event included a panel discussion including low impact development, drinking water protection, land conservation, water quality monitoring, invasive species and regulations; playing the Watershed Game; and presentation of the Clean Lakes Toolkit and discussion. The Great East Lake Improvement Association, Wilson Lake Association, Horn Pond Association, Lovell Lake Association, Province Lake Association signed pledges to implement at least one of the Clean Lakes projects. As a result of the Clean Lakes Campaign, Horn Pond and two lakes outside of the SFHL region started Lake Host programs and the Province Lake Association is working towards developing a watershed management plan. While these lakes are not within the Salmon Falls watershed their efforts have a great impact on increasing the local political will to protect water resources. The Clean Lakes Campaign Lake Association Toolkit can be downloaded at http://www.awwatersheds.org/programs/37-clean-lakes-campaign/89-clean-lakes-campaign-toolkit-contents

Intercept Survey

In the summer of 2011 the Acton Wakefield Watersheds Alliance (AWWA) conducted an intercept survey in the town of Wakefield, NH. The AWWA Youth Conservation Corp (YCC) was separated into small groups and stationed at the Union Post Office, Wakefield Town Hall, 7 Lakes Provisions, and Country Goods Grocery. The YCC were given a two-hour course in the proper technique in administering the survey and conducted 65 surveys on August 4th and 9 surveys on September 13th. A total of 74 surveys were conducted and documented for analysis on the public's relation to and thoughts on stormwater management and water quality. The full report is included in Appendix A.

Flyers & Maps

Lake specific flyers were developed and distributed to members of each lake association to provide information about the characteristics of each watershed, activities being carried out by the lake associations and helpful hints about protecting water quality. The flyers can be downloaded at http://www.awwatersheds.org/links/publications.

Reduce Your P Footprint Campaign

The Reduce Your P Footprint pledge was developed and distributed at lake association meetings and on the Discovery Cruises. A total of 105 pledges were signed. The P Footprint Pledge form is included with the Discovery Cruise information in Appendix B.

Discovery Cruises

The AWWA Discovery Cruise is designed to introduce lake visitors to various aspects of lake ecology including water characteristics, the aquatic food web and invasive species; to encourage personal connections to aquatic organisms; and to demonstrate the relationship between activities on land and lake water quality. 35 people took the cruises on Great East, Wilson and Lovell Lakes. Every participant indicated they learned something new and would recommend the cruises to a friend. The Discovery Cruise overview and P Footprint pledge form is included in Appendix B.

NPS Presentations, School Programs

AWWA staff and volunteers shared information about NPS pollution at the Great East, Lovell, Horn and Wilson lake association meetings in both 2010 and 2011. In addition, AWWA delivered a series of three lessons to 56 6th grade students at the Wakefield Paul School. These lessons included biodiversity and invasive species, watershed science and groundwater education. Each of the lessons included a brief lecture with hands-on activities. The YCC crew gave a tour of some of their project sites at the close of each season and filmed a video to be shown on the AWWA website. Signs are placed at each project site to encourage interest in the project and highlight lake friendly practices and landowners.

Website

www.AWwatersheds.org continues to be a resource for disseminating information about AWWA's activities as well as useful links and tips for protecting water resources. It is updated as often as possible but could be more dynamic if staff time is available.

MONITORING

The UNH Lakes Lay Monitoring Program (LLMP) coordinated the volunteer monitoring for Great East Lake, Horn Pond, Lake Ivanhoe and Lovell Lake. Volunteers with the Maine Volunteer Lakes Monitoring Program coordinated those on Wilson Lake. Copies of the 2010 Great East Lake and Lovell Lake reports are included in Appendix C. UNH has not yet completed the 2010 reports for Lake Ivanhoe and Horn Pond or the 2011 reports for all. They will be posted at www.AWwatersheds.org when available.

## Project Outcomes & Measurable Results

The desired outcome for the watershed-based plan implementation project is to preserve the High Quality Water status of the Salmon Falls Headwaters including Great East Lake, Horn Pond, Lake Ivanhoe, Lovell Lake and Wilson Lake. Residential and roadway BMPs will reduce pollutant loading by at least 15 tons of sediment and 10 lbs of phosphorus per year as a result of Phase 1 of this project. The activities associated with the project resulted in load reductions of 37 tons/year sediment and 32 lbs/year phosphorus. (Pollutants Controlled Reports for installed BMPs are on file at NH DES.)

Water quality reports indicate that all the lakes remain within the guidelines set for High Quality Waters status.

## Conclusions and Recommendations

Phase 1 of the *Watershed Implementation (Phase 1) and Road Management Plan: Great East Lake, Lake Ivanhoe, Horn Pond, Wilson Lake, and Lovell Lake* project successfully addressed action items in each of the five recommended action categories in the management plan.

<u>Roadway BMPs</u> were developed by the UNH Stormwater Center and included in the "Road Management Plan for Brackett and Pond Roads, Wakefield NH." The publication of the road management plan and presentation to the Wakefield selectmen resulted in a successful grant application to implement the plan in 2012-13. Additional road sites have been identified and effort should be made to address them in future phases. A key to future success in roadway maintenance will be strong partnerships with the Town Road Agents and private road association members.

The efforts on <u>Community Planning and Development</u> continue to move forward but slowly given the current local political climate. AWWA partnered with the Piscataqua Region Estuaries Partnership (PREP) and FB Environmental to assist the Wakefield and Acton Planning Boards in their review of stormwater management policies through the PREP Community Technical Assistance Program. The Acton Planning Board is actively working on a stormwater management ordinance in early 2012. AWWA's President, Dick DesRoches, took his concern for the future of the local water resources to the next level and became an alternate with the Wakefield Planning Board. His voice and knowledge are sure to have a positive effect on the future of planning decisions in Wakefield. AWWA and its members will continue to gain trust and to encourage adoption of low impact development practices and policies from the individual landowner level to the municipal regulatory perspective.

The AWWA Youth Conservation Corps worked with landowners to install <u>Residential BMPs</u> to control erosion on residential properties. AWWA's program manager met with additional do-it-yourself landowners to design best practices. Future phases of this implementation project will focus on septic systems and riparian buffer enhancement.

Education and Outreach continue to be a primary focus for implementation efforts as it is clear that understanding the connections between land use activities and water quality is an essential step in the decision-making process for each individual. AWWA's outreach efforts are aimed at distinct groups – shorefront property owners, upland residents, community decision-makers and students. Information about our water resources is gathered and shared through lake association meetings, community events, press releases, website and social marketing venues, municipal public meetings, Discovery Cruises, and classroom visits. AWWA continues to seek out innovative and effective methods of communication and will work to engage all watershed stakeholders in the conversation about healthy water resources.

While land conservation is not within the auspices of AWWA's capabilities it is an important element to water resource protection. The designation of the Salmon Falls watershed as being within the watershed most at risk in the nation for water quality decline due to the development of forest land illustrated the urgency to protect critical forests. AWWA partnered with the local land trusts to inform large landowners about available programs to protect forest land with the "Your Land, Clean Water, Your Legacy" events sponsored by the National Resource Conservation Service. Moving forward AWWA will partner when possible to offer to assist with restoration activities as a match for land conservation proposals.

Phase 2 of the *Watershed Implementation and Road Management Plan: Great East Lake, Lake Ivanhoe, Horn Pond, Wilson Lake, and Lovell Lake* project will begin in Spring 2012. The NHDES Watershed Assistance grant will support installation of Brackett Road BMPs, continued YCC projects and technical assistance, seasonal resident guide to lake friendly behaviors, NPS presentations and school programs. Additional funding from MEDEP's 319 program will support installation of private road BMPs, road and septic socials, YCC projects on Great East and Wilson lakes, publications and NPS presentations.

# Appendices

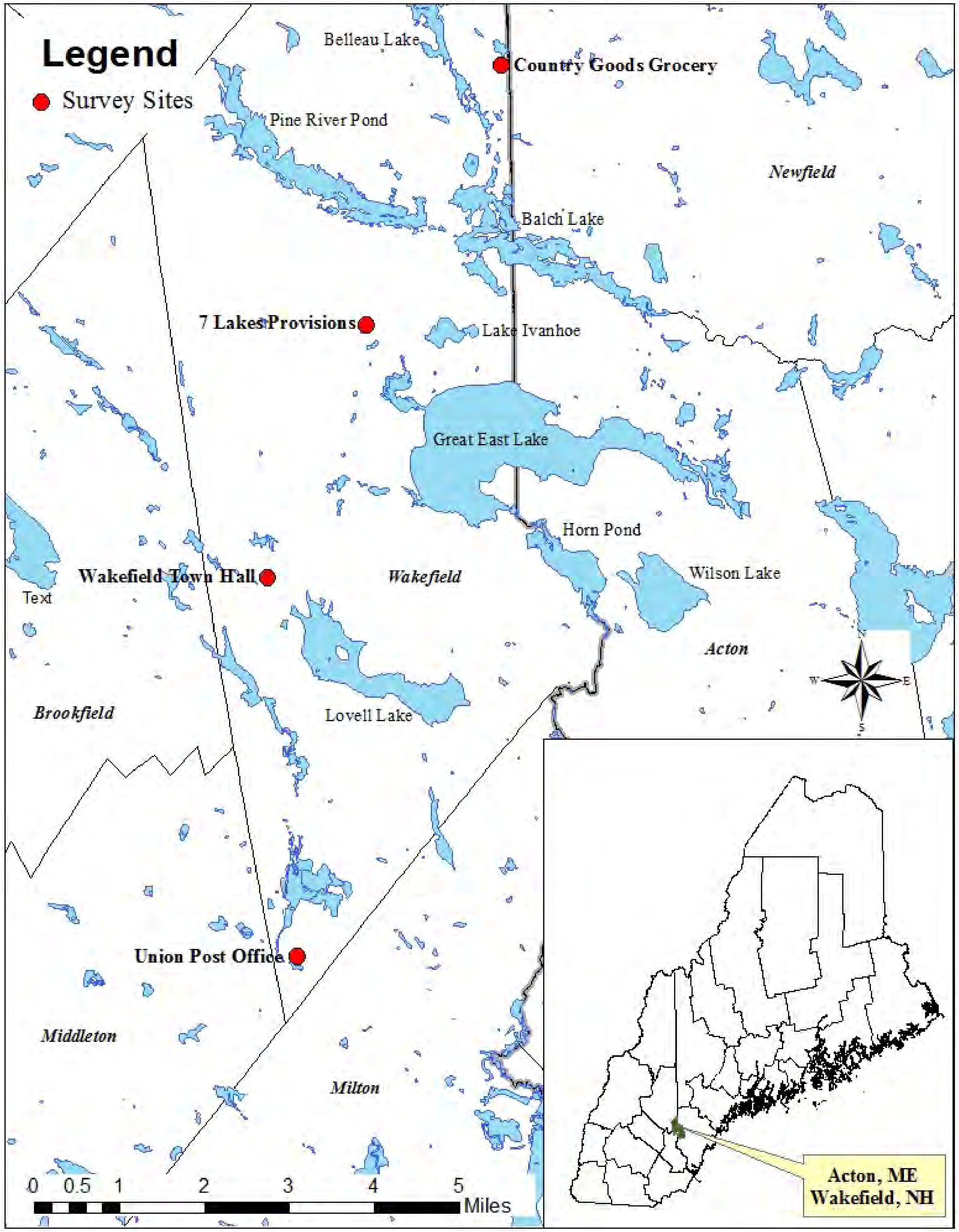
## A. Intercept Survey Report

# Intercept Survey
## Summer 2011

**Performed by the AWWA Youth Conservation Corps**

**Acton Wakefield Watersheds Alliance**
**PO Box 235, 254 Main Street**
**Union, NH 03887**
**(603) 473-2500**

# 2011 Intercept Survey Sites



# AWWA Intercept Survey

Summer 2011

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Cover Photo: 2011 Youth Conservation Corps. Standing (top to bottom): Katelyn Nichols, Chloe Routhier, Crew Leader Anthony Stanton, Crew Leader Sam Wilson, and Ryan Fabian. Sitting (left to right/top to bottom): Dylan Nichols, Jordan Shepherd, and Seth Fogg.

# Acknowledgements

**Acton Wakefield Watersheds Alliance Staff**

| | |
|---|---|
| *Linda Schier* | *Executive Director* |
| *Dustin Johnson* | *Program Manager/Technical Director* |

**Youth Conservation Corps Crew**

| | |
|---|---|
| *Anthony Stanton* | *Crew Leader* |
| *Sam Wilson* | *Crew Leader* |
| *Ryan Fabian* | *3rd Year Crew Member* |
| *Jordan Shepherd* | *3rd Year Crew Member* |
| *Katelyn Nichols* | *2nd Year Crew Member* |
| *Dylan Nichols* | *1st Year Crew Member* |
| *Chloe Routhier* | *1st Year Crew Member* |
| *Seth Fogg* | *1st Year Crew Member* |

**Local Businesses and Organizations**

*Union Post Office*
*Wakefield Town Hall*
*7 Lakes Provisions*
*Country Goods Grocery*

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Survey ID________________

Date____________________

# AWWA Intercept Survey - Summer 2011

NOTE: INTERVIEWER IS TO READ ALL WORDS IN sentence case TO THE RESPONDENT. WORDS IN UPPER CASE ARE NOT TO BE READ ALOUD.

Excuse me; do you have a few minutes to complete a short survey about a community issue?

1. First, could you please tell me if you are a part-time or full-time resident or a renter in the area?

- ☐ 1 YES, PART-TIME
- ☐ 2 YES, FULL-TIME
- ☐ 3 YES, RENTER, Seasonal renter or year-round? _________________________________
- ☐ 4 NO, NOT A RESIDENT, THANK RESPONDENT AND TERMINATE INTERVIEW
- ☐ 9 DON’T KNOW/REFUSED, THANK RESPONDENT AND TERMINATE INTERVIEW

2. Are you a resident of a lake in the area?

- ☐ 1 YES, What lake? _______________________________
- ☐ 2 NO
- ☐ 9 DON’T KNOW/REFUSED TO ANSWER

3. Are you a member of a local lake association?

- ☐ 1 YES, Which association? _______________________________
- ☐ 2 NO
- ☐ 9 DON’T KNOW/REFUSED TO ANSWER

4. How concerned are you with the quality of our local lakes and rivers? Would you say you are…?
READ SCALED RESPONSES ONLY

| 4 | 3 | 2 | 1 | 9 |
|---|---|---|---|---|
| Very Concerned | Somewhat Concerned | Not Very Concerned | Not At All Concerned | DON'T KNOW/ REFUSED TO ANSWER |

5. How much of an impact does storm water runoff have on the quality of our lakes and rivers? Would you say it has…? READ SCALED RESPONSES ONLY. IF ASKED WHAT "STORM WATER RUNOFF" IS, PLEASE REPLY:

| 4 | 3 | 2 | 1 | 9 |
|---|---|---|---|---|
| A Major Impact | Somewhat of an Impact | Not Much of an Impact | No Impact At All | DON'T KNOW/ REFUSED TO ANSWER |

6. Polluted storm water runoff refers to pollution that is carried into rivers, lakes, and the ocean by rain or snowmelt. What types of pollution do you think of when you think of pollution being carried into lakes and rivers by storm water runoff? RECORD VERBATIM

| |
|---|
| |

TRY TO GET THREE OR MORE. AFTER THE FIRST AND SECOND RESPONSE: Any others?

7. How interested are you in personally taking action to reduce pollution from storm water runoff or storm water pollution? Would you say you are…? READ SCALED RESPONSES

| 4 | 3 | 2 | 1 | 9 |
|---|---|---|---|---|
| Very Interested | Somewhat Interested | Not Very Interested | Not Interested At All | DON'T KNOW/ REFUSED TO |

| | | | | ANSWER |
|---|---|---|---|---|

8. Have you heard of or do you know of any efforts by local organizations to reduce pollution from storm water runoff? DO NOT READ RESPONSES. RECORD "YES" COMMENTS IN BOX.

☐ 1 YES, What or who have you heard of?
☐ 2 NO
☐ 9 DON'T KNOW/REFUSED TO ANSWER

| 7a. |
|---|

9. Have you heard of the Acton Wakefield Watersheds Alliance? DO NOT READ RESPONSES. RECORD "YES" COMMENTS IN BOX.

☐ 1 YES, What have you heard?
☐ 2 NO
☐ 9 DON'T KNOW/REFUSED TO ANSWER

| 8a. |
|---|

10. Have you taken any specific actions as a result of this local effort? DO NOT READ RESPONSES. RECORD "YES" COMMENTS IN BOX.

☐ 1 YES, What actions?
☐ 2 NO
☐ 9 DON'T KNOW/REFUSED TO ANSWER

| 9a. |
|---|

Now I would like to ask you about the likelihood that you will take a specific action. For each of the following actions please tell me on a scale of 1 to 7, where 7 is very likely and 1 is not at all likely, how likely you are to take this action:

READ THE QUESTION FOLLOWED BY READING THE SCALED RESPONSES ONLY.

11. Reduce the amount of lawn fertilizers, pesticides, and herbicides that you use…

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 10 | 11 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Very Likely | | | | | | Not At All Likely | ALREADY DO OR DONE | DOES NOT APPLY | DON'T KNOW/ REFUSED |

12. Seed, plant, or mulch bare areas in your yard…

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 10 | 11 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Very Likely | | | | | | Not At All Likely | ALREADY DO OR DONE | DOES NOT APPLY | DON'T KNOW/ REFUSED |

13. Plant trees, shrubs, and/or ground cover plants to reduce the size of your lawn…

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 10 | 11 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Very Likely | | | | | | Not At All Likely | ALREADY DO OR DONE | DOES NOT APPLY | DON'T KNOW/ REFUSED |

14. When in public places pick up your pet's waste and throw it in the trash…

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 10 | 11 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Very Likely | | | | | | Not At All Likely | ALREADY DO OR DONE | DOES NOT APPLY | DON'T KNOW/ REFUSED |

15. Mow your lawn no shorter than 2.5 to 3 inches…

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 10 | 11 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Very Likely | | | | | | Not At All Likely | ALREADY DO OR DONE | DOES NOT APPLY | DON'T KNOW/ REFUSED |

16. Use phosphorus free fertilizers on your lawn…

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 10 | 11 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Very Likely | | | | | | Not At All Likely | ALREADY DO OR DONE | DOES NOT APPLY | DON'T KNOW/ REFUSED |

17. If you were looking for information on any of the previous actions, where would you go?

- ☐ 1 Internet
- ☐ 2 Friend or family
- ☐ 3 Hardware store or Garden nursery
- ☐ 4 OTHER; What/where? ____________________
- ☐ 9 DON'T KNOW/REFUSED TO ANSWER

18. Are you aware of the states shoreland regulations? DO NOT READ RESPONSES. RECORD "YES" COMMENTS IN BOX.

- ☐ 1 YES, Do you think this is an effective program?
- ☐ 2 NO
- ☐ 3 DON'T KNOW/REFUSED TO ANSWER

| 18a. |
| --- |
| |

19. Can you please stop me when I reach your age group? READ EACH AGE CATEGORY

- ☐ 1 Less than 25 years of age
- ☐ 2 25-34
- ☐ 3 35-44
- ☐ 4 45-54
- ☐ 5 55-64
- ☐ 6 65 years of age and over
- ☐ 9 DON'T KNOW/REFUSED TO ANSWER

20. What is the zip code of the town you are in when in this area? ___________________

21. RECORD GENDER BY OBSERVATION

- ☐ 1 MALE
- ☐ 2 FEMALE
- ☐ 9 DON'T KNOW

# List of Figures

# EXECUTIVE SUMMARY

The 2011 Intercept Survey conducted by the Acton Wakefield Watersheds Alliance (AWWA) Youth Conservation Corps (YCC) was a great success as well as a great learning experience. The survey provides useful data from the Acton and Wakefield full time, part time, and seasonal renters of both lake homes and non-lake homes. Thirty-three lake residents and forty-one non-lake residents were asked questions pertaining to water quality, activities they would feel inclined to change to promote better water quality, and questions involving Maine and New Hampshire's shoreland regulations.

Some major findings included that 71% of part-time lake residents were members of their lake association, while only 23% of full-time lake residents were members of their lake association. This is crucial data for lake associations to consider as well as where to focus efforts in promoting activities that help maintain or improve water quality. The majority of participants were concerned with water quality and familiar with the effects of polluted runoff, however many were not very enthusiastic about personally taking action to reduce pollution from stormwater. This data indicates that organizations need to promote easy ways for people to take action and make a difference without feeling like they are giving up their free time.

Over 84% of full-time lake residents had heard of AWWA as well as over 57% of part-time lake residents. The AWWA message is being received, but has room for growth in the region among part-time and seasonal renters. The survey identified that most residents were willing to change many of their lakefront activities and land uses to promote water quality. This information indicates that lake associations and organizations need to continue pushing for many of these actions among lakefront homeowners and educating them on the effects of stormwater runoff, erosion, and degrading water quality.

This pilot survey gives AWWA a baseline to work from while also providing plenty of data to analyze for future focus. AWWA will be able to make slight adjustments to the survey in the future to gain as much useful information possible to continue building the program effectively and help local residents limit their polluted runoff from entering the lakes they care so much about.

# GRAPHICAL SUMMARY

**Lake Residency**

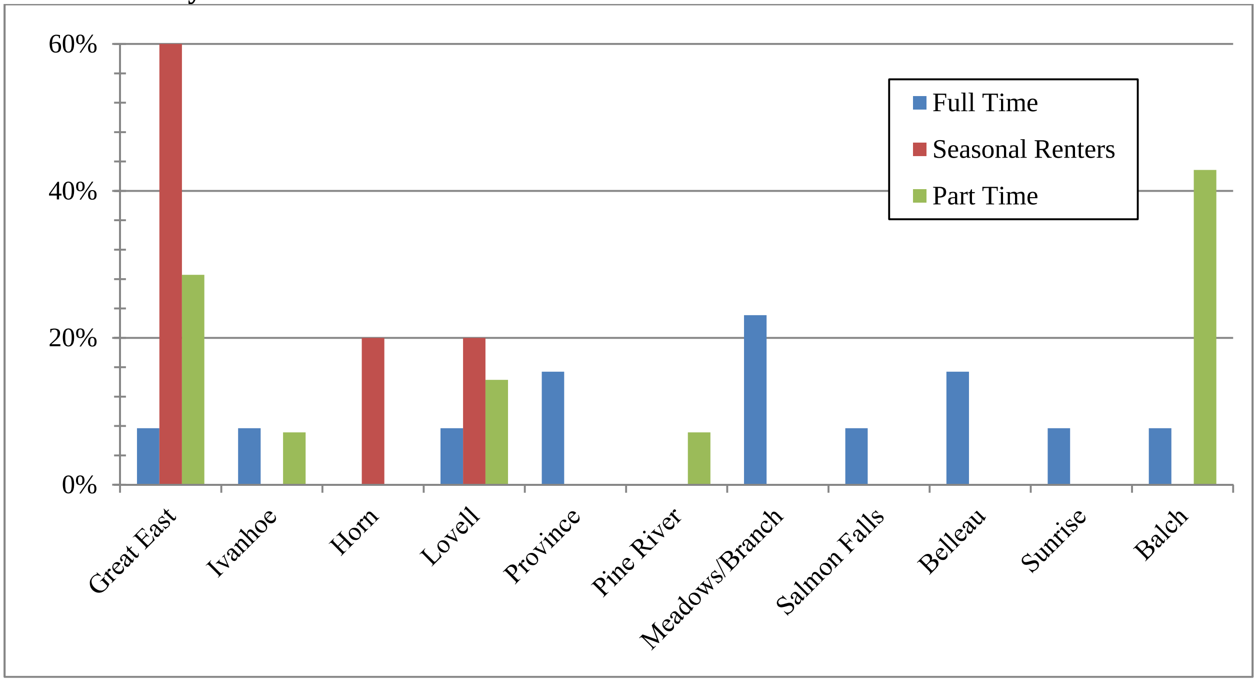


**Figure 1.1.** The distribution of lake residents surveyed. Lake residents comprised 32 of the 74 people interviewed.

**Lake Association Members**

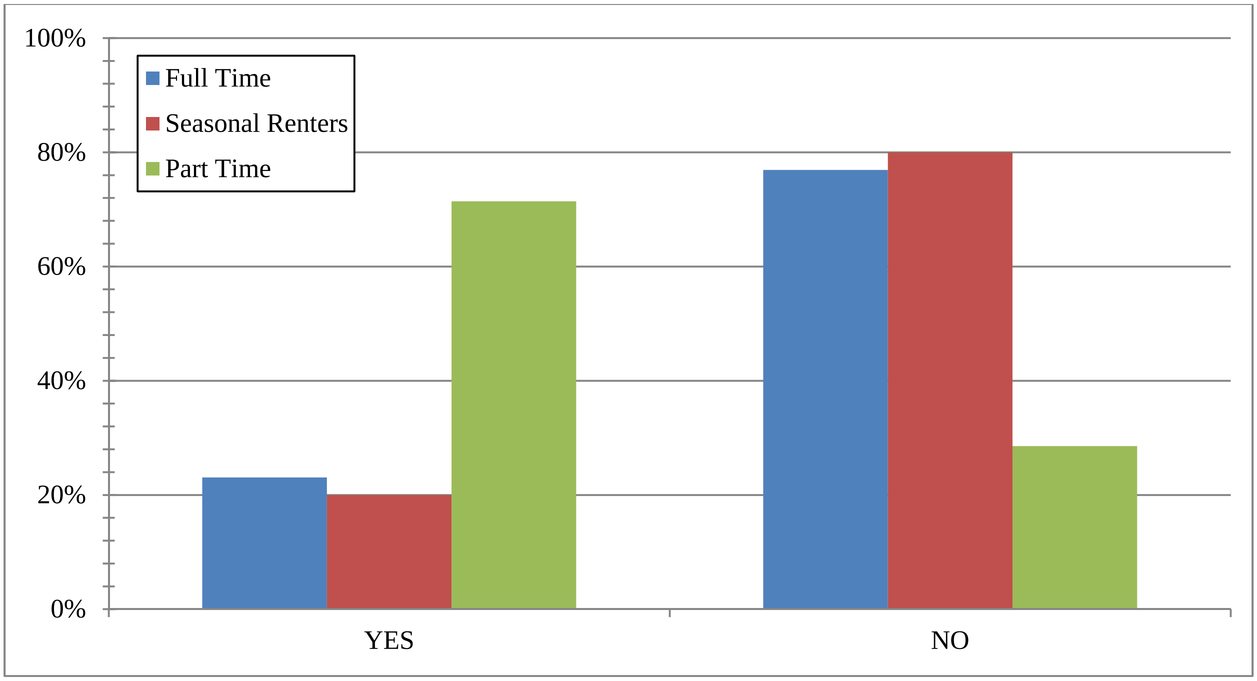


**Figure 1.2**. There is a significant difference in the lake association memberships held by part-time residents compared to full-time residents and seasonal renters.

**Water Quality Concerns**

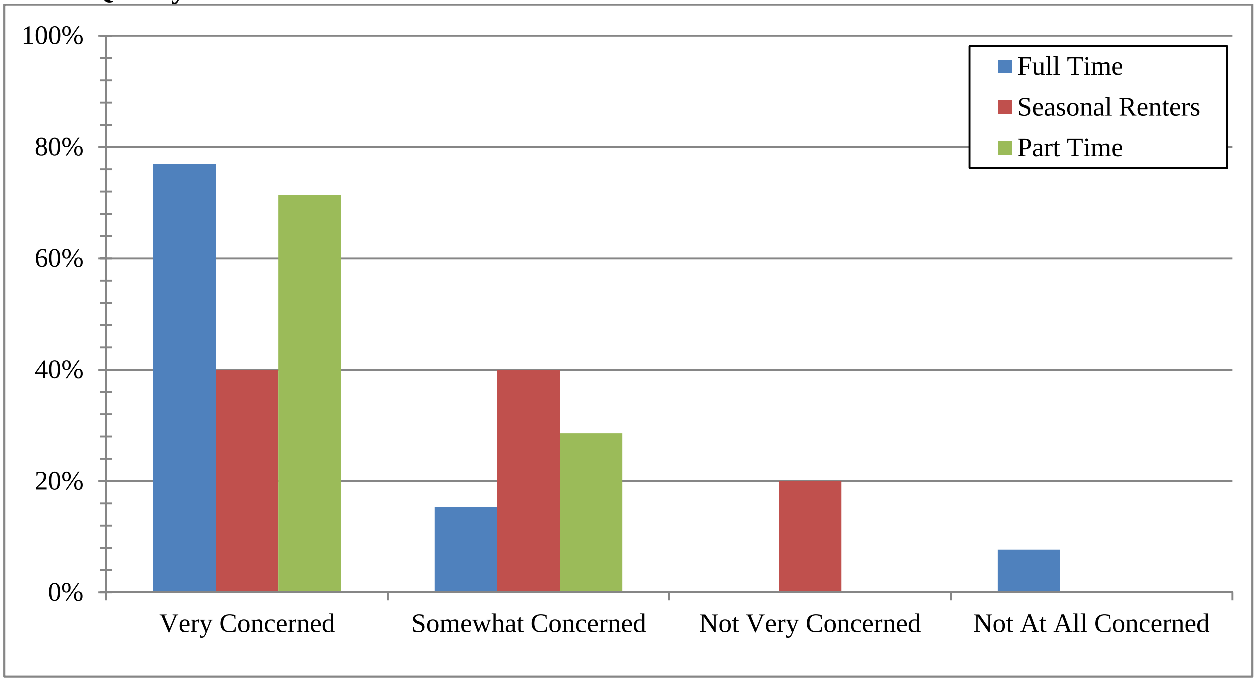


**Figure 1.3.** *Question: How concerned are you with the quality of our lakes and river?* The most concern is expressed by the full-time and part-time residents, but lacking in seasonal renters.

**Stormwater Runoff Impact on Lake/River Water Quality**

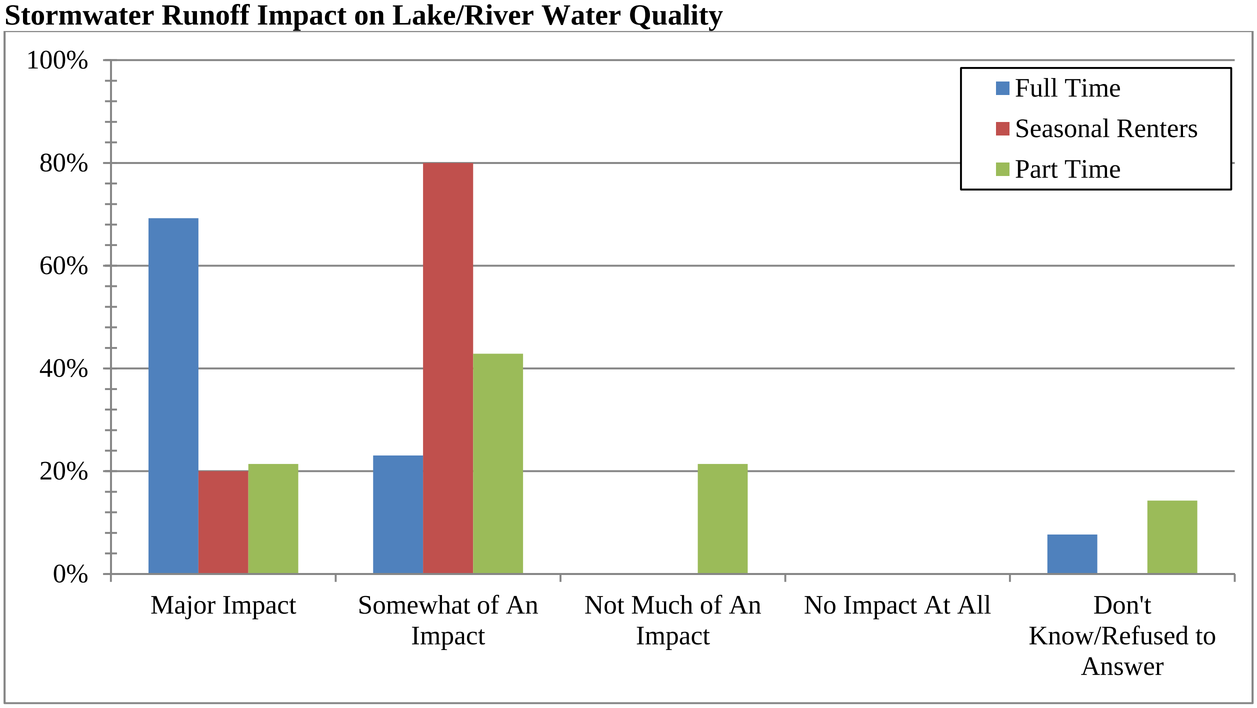


**Figure 1.4.** *Question: How much of an impact does stormwater runoff have on the quality of our lakes and rivers?* There is a distinct difference between full-time and part-time resident's views on the impact of stormwater runoff.

**Types of Pollution Being Transported by Stormwater Runoff**

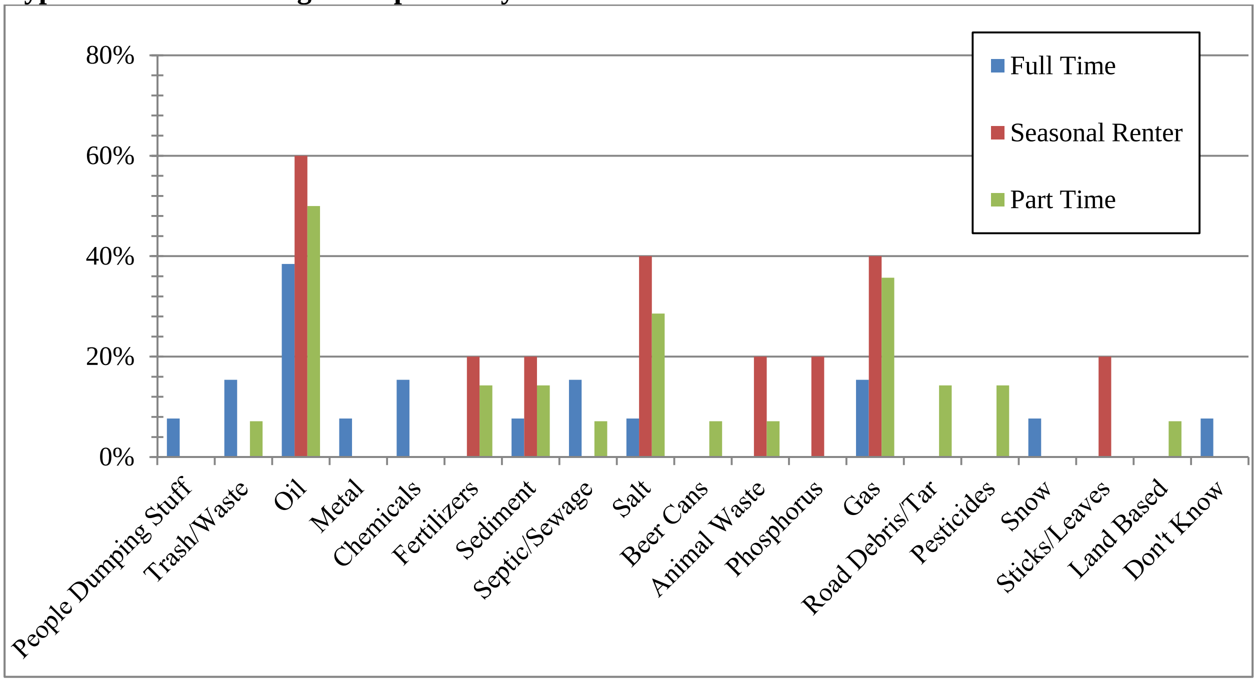


**Figure 1.5.** *Question: What types of pollution do you think of when you think of pollution being carried into lakes and rivers by stormwater runoff?* Oils, salt, and gas dominated the list of items residents mentioned as pollutants carried by stormwater runoff. An effort should be made to further educate residents about the harm of soil erosion.

**Personal Interest in Action**

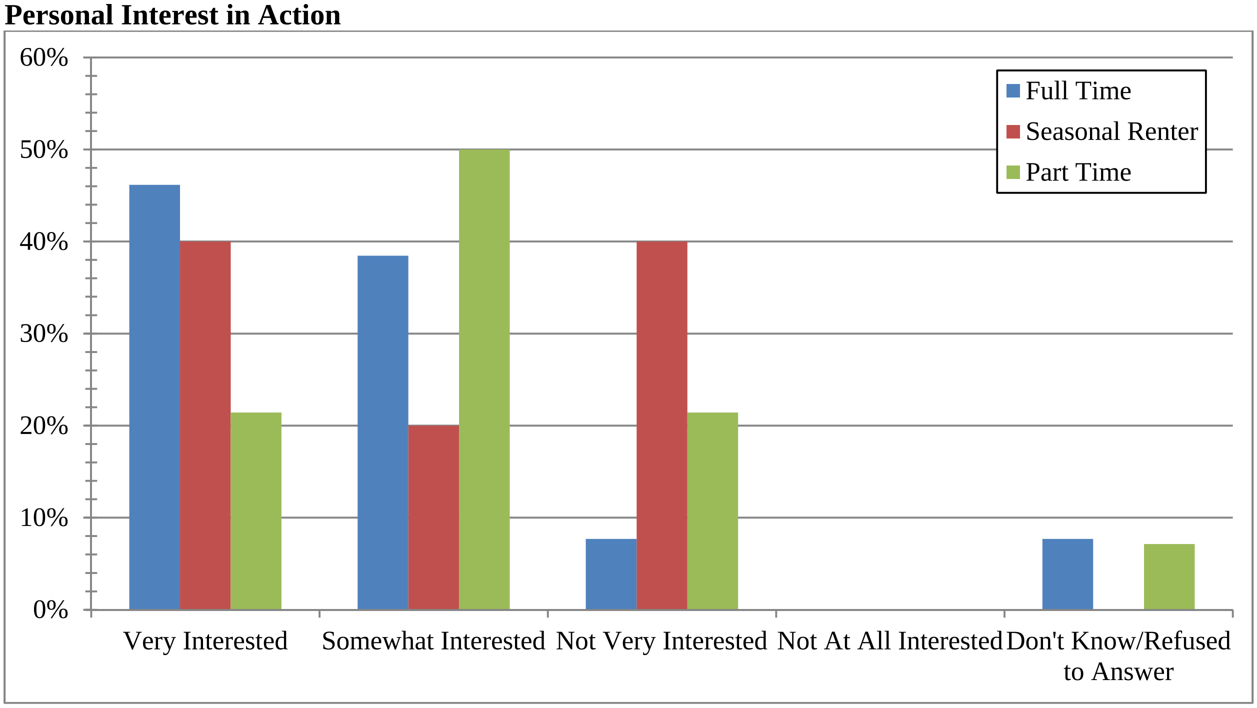


**Figure 1.6.** *Question: How interested are you in personally taking action to reduce pollution from stormwater runoff or stormwater pollution?* Some interest was expressed in personal action, but due to a significant lack in interest, more information on easy, at home ways to be active should to be focused on.

**Efforts by Local Organizations**

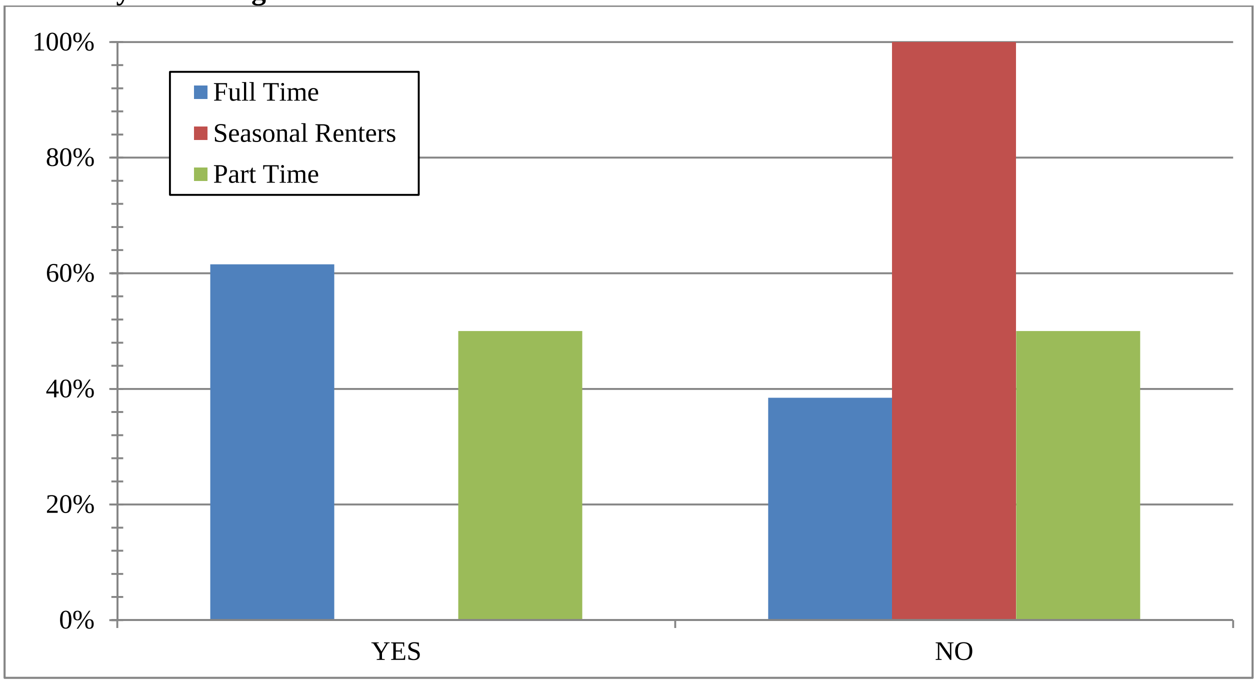


**Figure 1.7.** *Question: Have you heard of or do you know of any efforts by local organizations to reduce pollution from stormwater runoff?* Both full-time and part-time residents are split between having heard of efforts by local groups. Extra effort should be made to engage seasonal renters as well as residents.

**Have You Heard of AWWA**

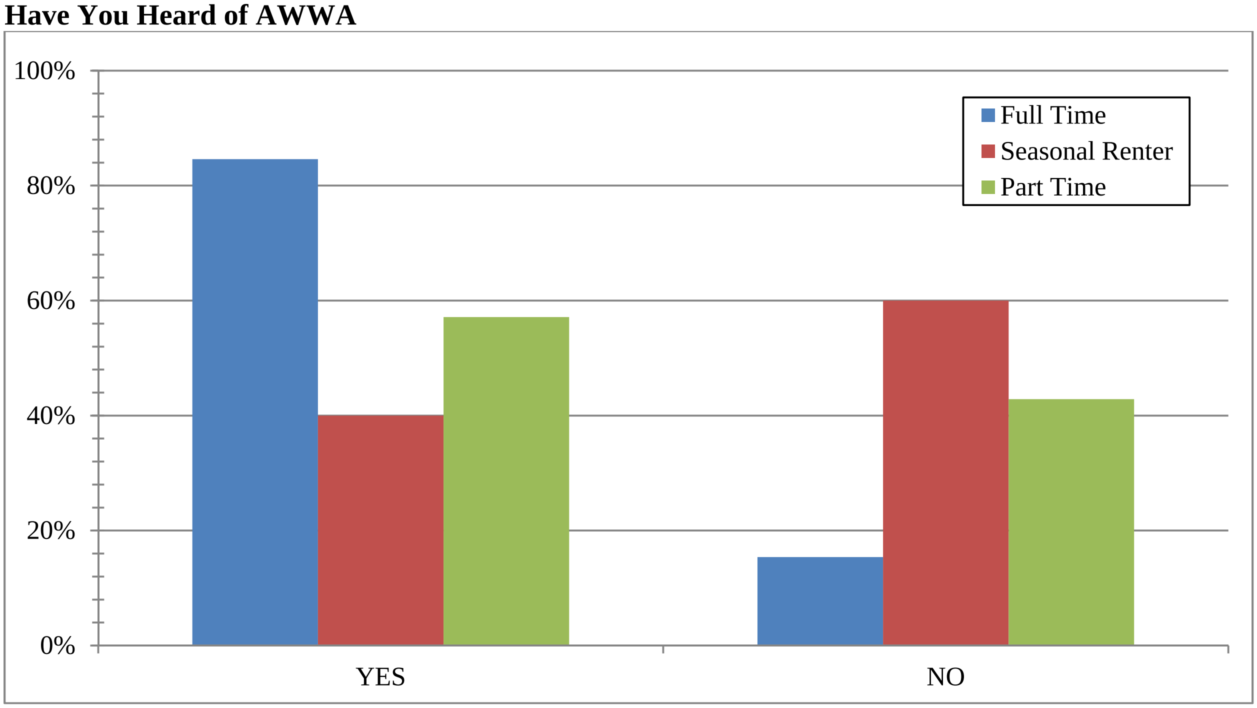


**Figure 1.8.** *Question: Have you heard of the Acton Wakefield Watersheds Alliance?* There is a great response from full-time residents, mediocre response from part-time residents, and below par response from seasonal renters. Overall the response to having heard of AWWA was great (66.7% of all lake residents interviewed and 50.7% of all respondents).

**What Have You Heard About AWWA**

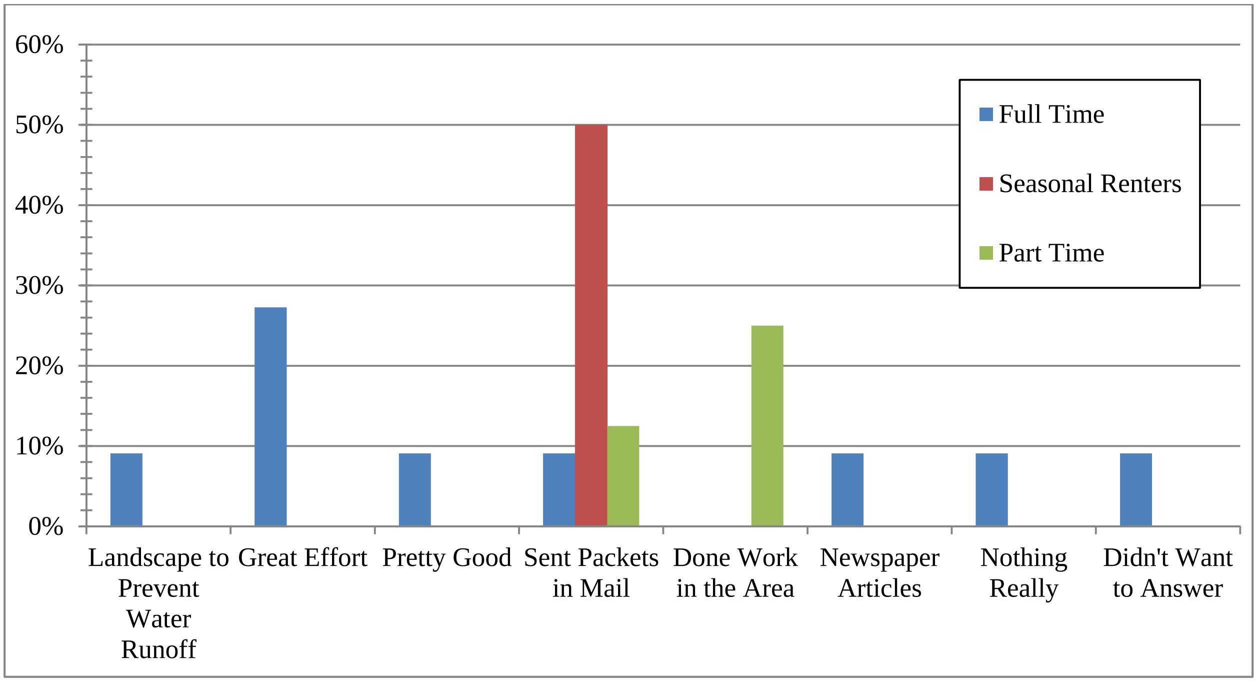


**Figure 1.9.** *Question: What have you heard about AWWA?* Various responses from full-time residents about what AWWA does.

**Specific Actions**

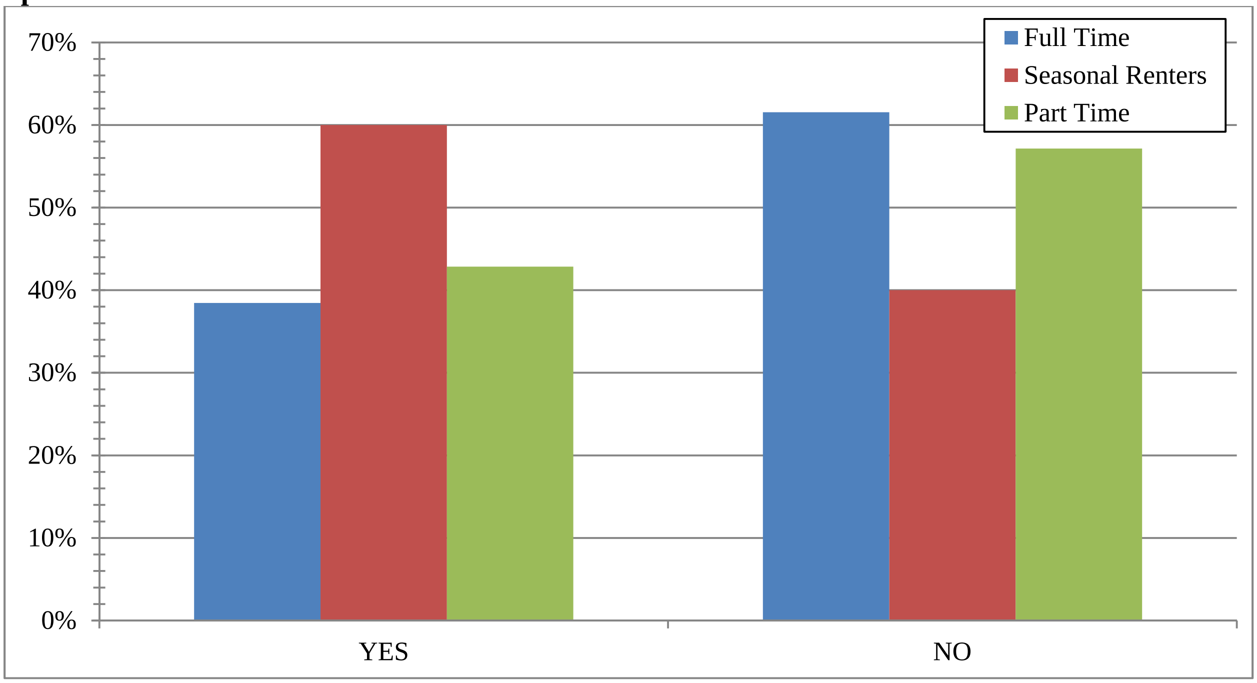


**Figure 1.10.** *Question: Have you taken any specific actions as a result of this local effort?* Less than half of interviewees have taken specific action indicating that more effort needs to be placed on easy, at home actions people can take to reduce stormwater pollution. This is especially evident for full-time residents.

**Reduce the Amount of Lawn fertilizers, Pesticides and/or Herbicides You Use**

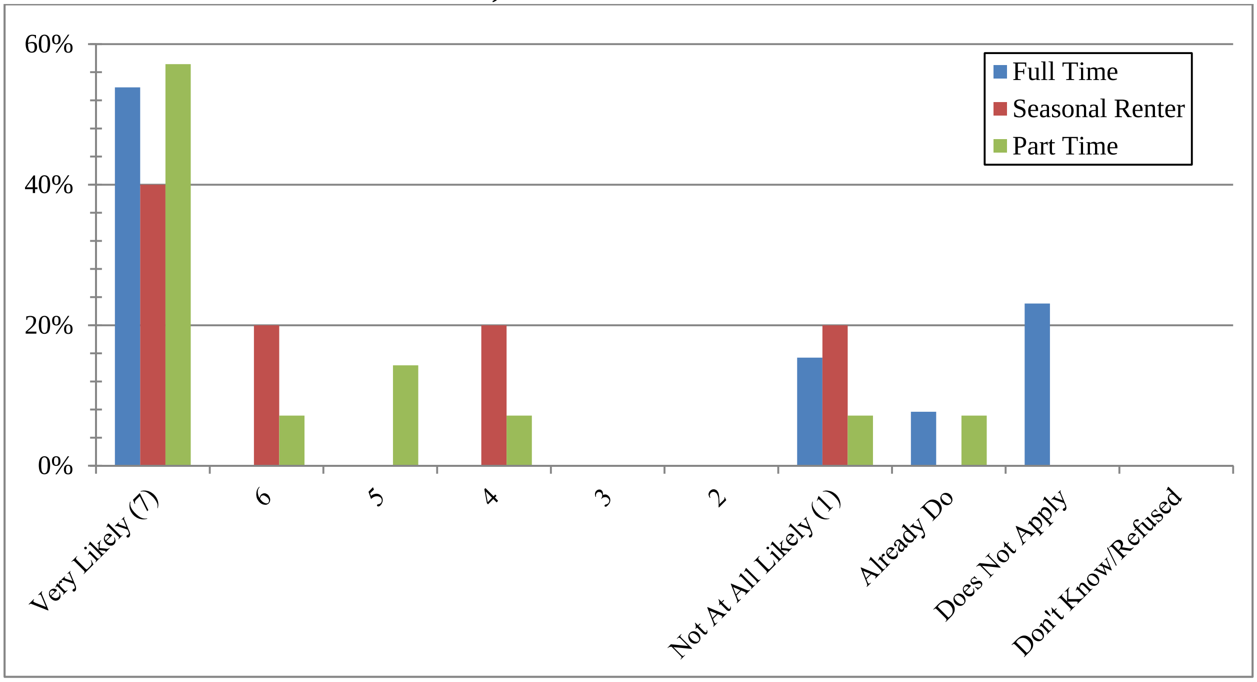


**Figure 2.1.** *Question: How likely are you to reduce the amount of lawn fertilizers, pesticides, and herbicides that you use?* Most residents were very likely to adopt this practice.

**Seed, Plant, or Mulch Bare Areas in Your Yard**

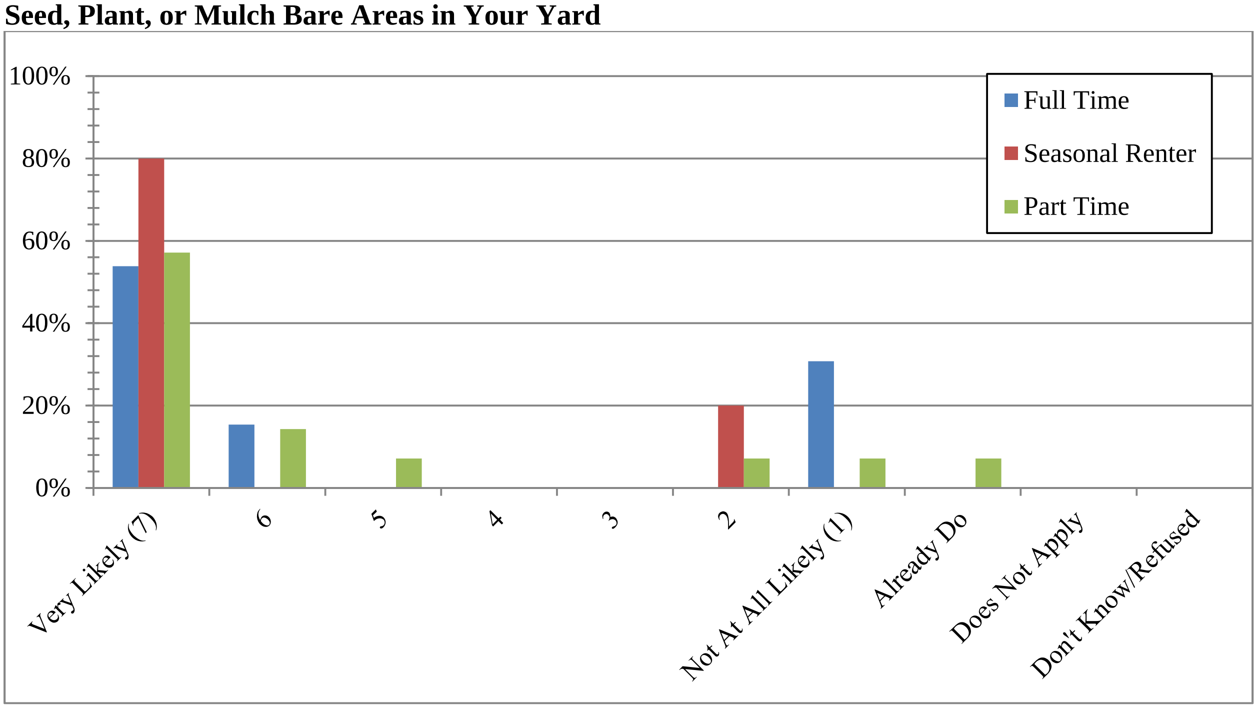


**Figure 2.2.** *Question: How likely are you to seed, plant, or mulch bare areas in your yard?* The majority of residents were very likely to adopt this practice.

**Plant Trees, Shrubs and/or Ground Cover Plants to Reduce the Size of Your Lawn**

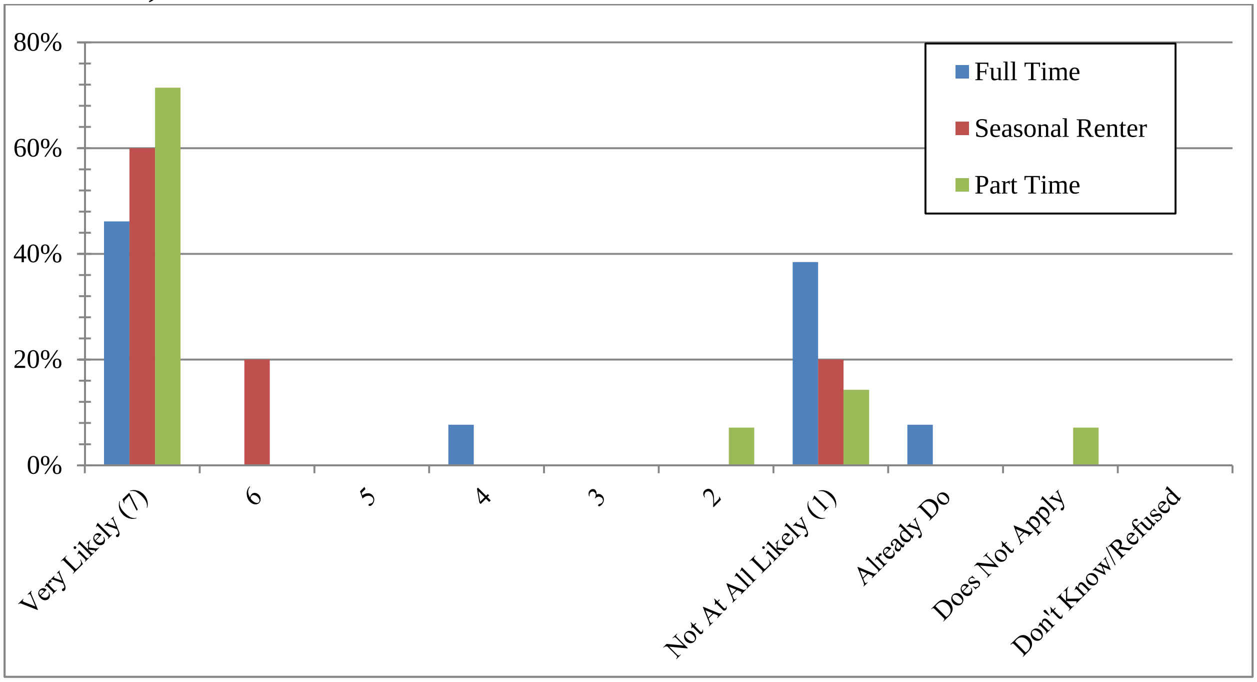


**Figure 2.3.** *Question: How likely are you to plant trees, shrubs, and/or ground cover to reduce the size of your lawn?* There is an especially good response from part-time residents, with a split between full-time residents.

**Pick Up Your Pet's Waste When in Public Places**

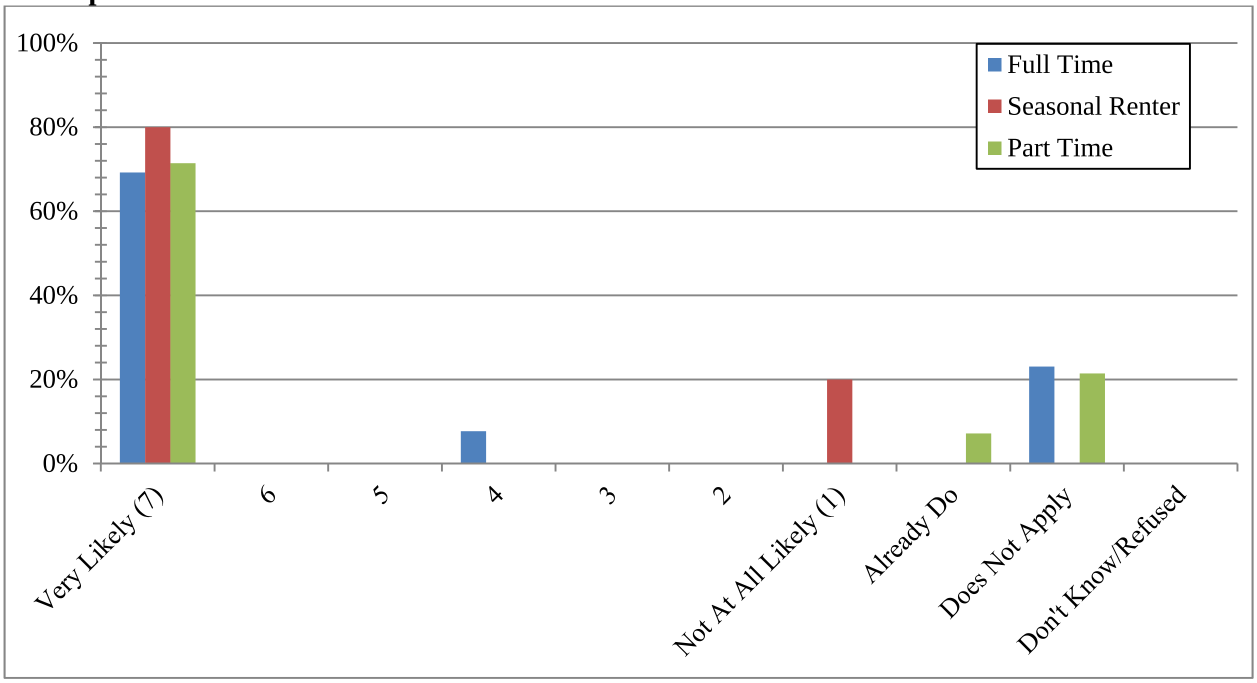


**Figure 2.4.** *Question: How likely are you to pick up your pet's waste in public places?* There is an overwhelmingly positive response from all residents on this topic.

**Mow Your Lawn No Shorter Than 2.5-3 Inches**

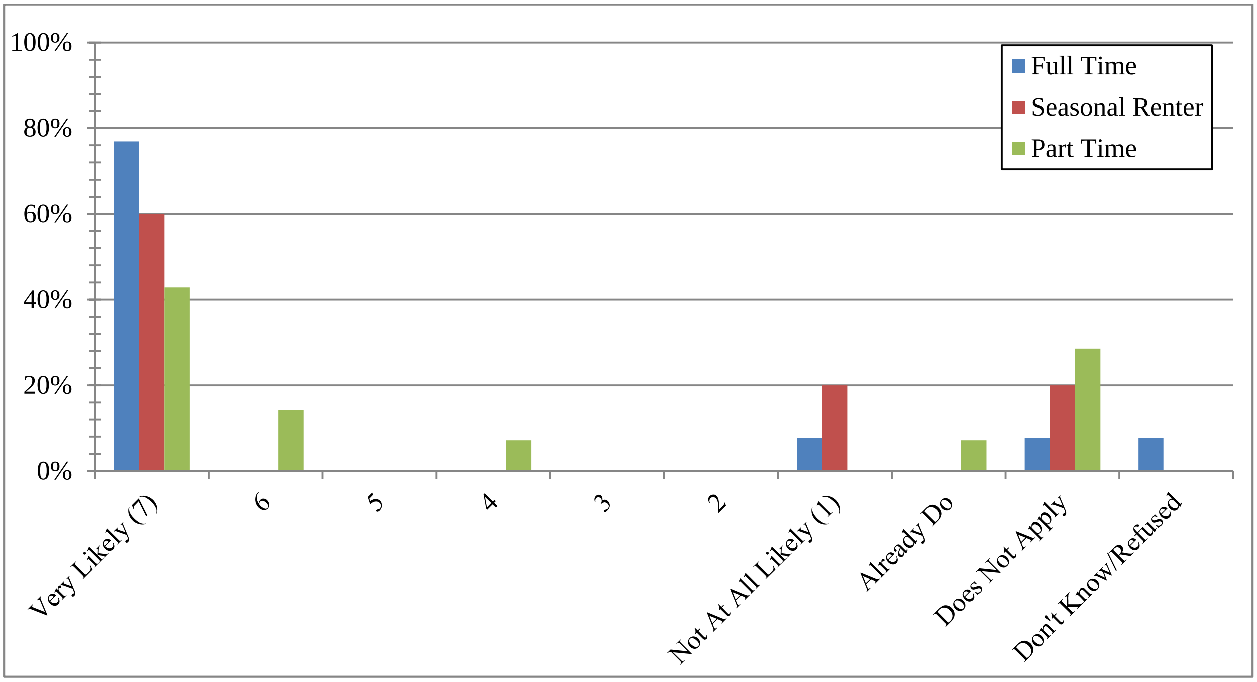


**Figure 2.5.** *Question: How likely would you be to mow your lawn no shorter than 2.5-3 inches?* There is a much greater likelihood that full-time residents will keep their lawns longer than the part-time residents.

**Use a Phosphorus Free Fertilizer**

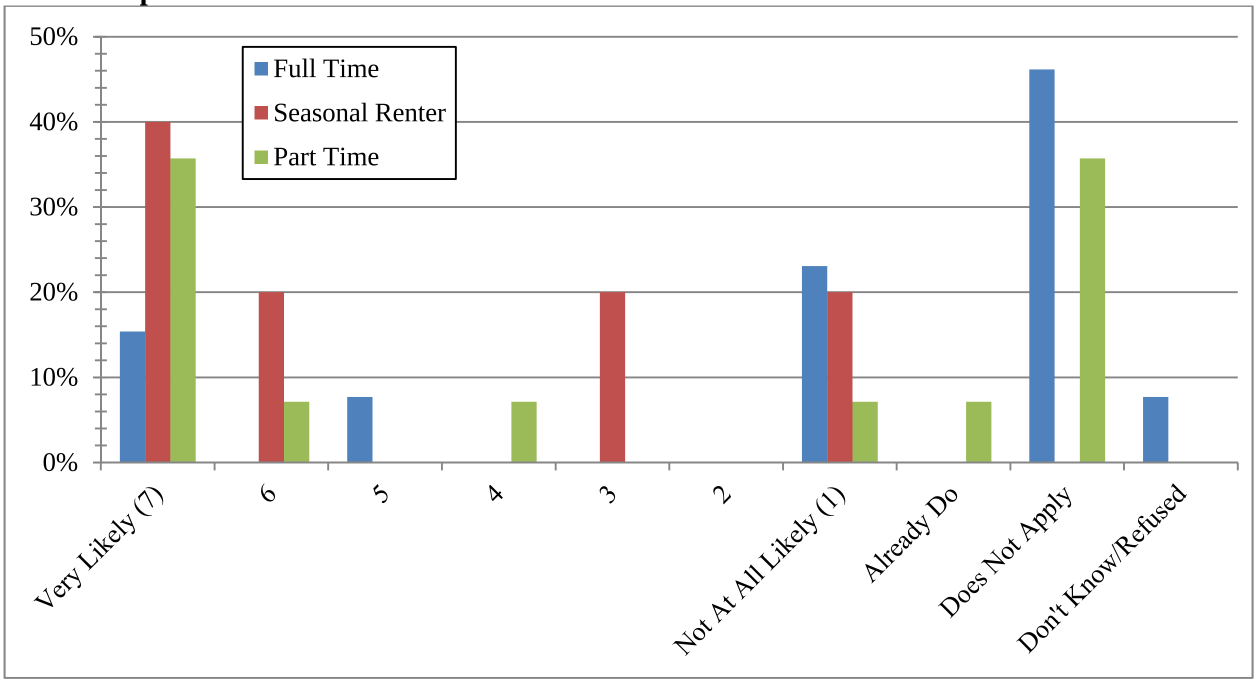


**Figure 2.6.** *Question: How likely are you to use phosphorus free fertilizers?* The full-time residents give an interesting response as they do not wish to use a no phosphorus fertilizer. Part-time and seasonal residents are more accepting of this practice.

**Information Gathering**

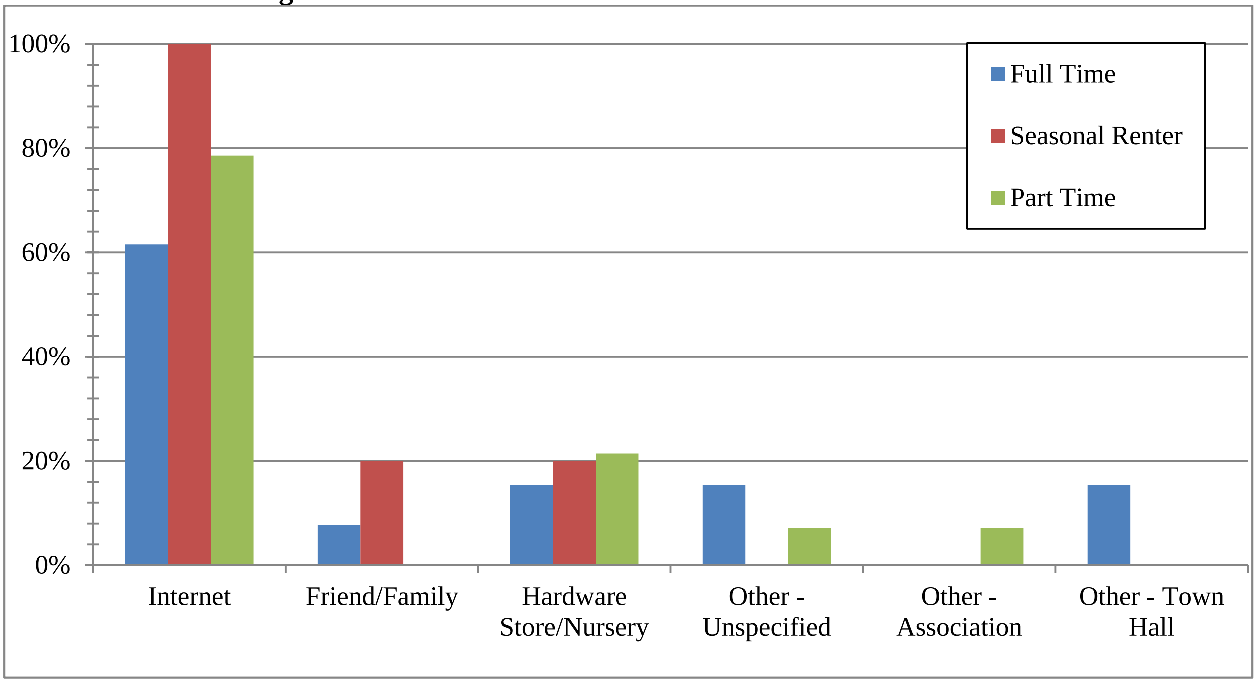


**Figure 2.7.** *Question: If you were looking for information on any of the previous actions, where would you go?* The internet is the overwhelming source of information for all residents.

**State Shoreland Regulations**

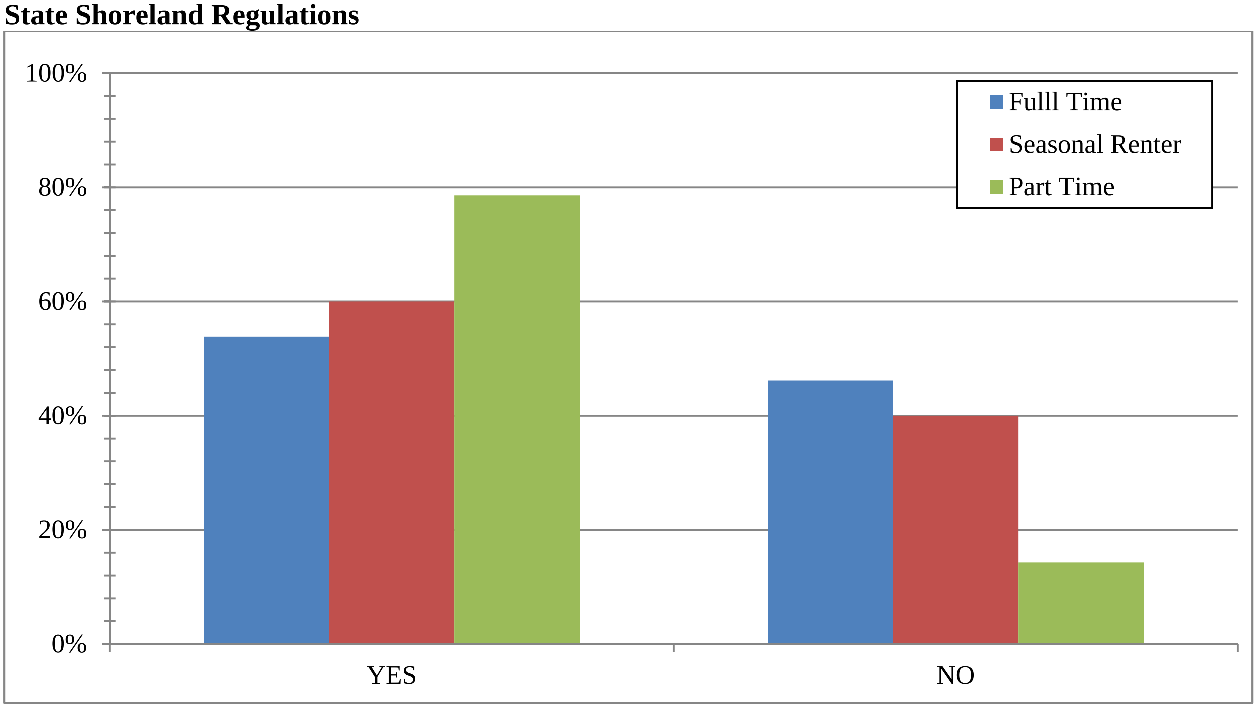


**Chart Figure 3.1.** *Question: Are you aware of the state's shoreland regulations?* Over half of all residents have heard of the state's shoreland regulations, including 79% of part time residents.

**Shoreland Regulations Program Effectiveness**

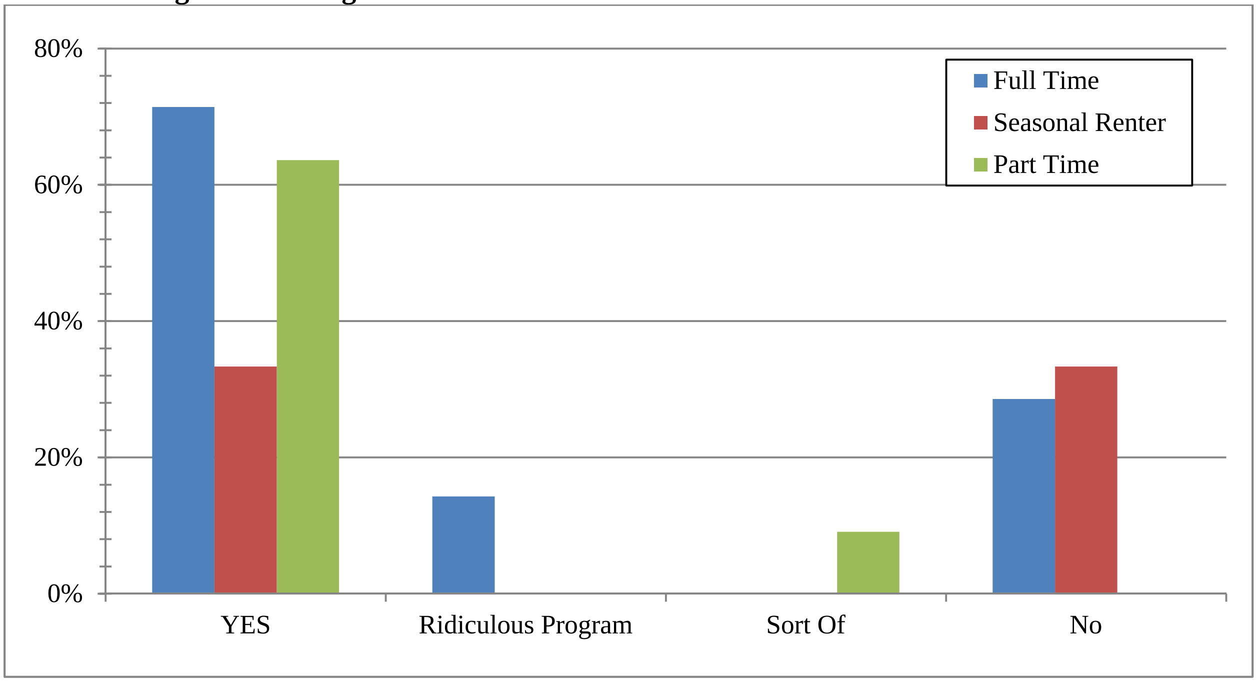


**Figure 3.2.** *Question: For those that answered "yes" to having heard of their state's shoreland regulations, do you think it is an effective program?* There is an overall positive response for the state's shoreland program.

# 1. Introduction

In the summer of 2011 the Acton Wakefield Watersheds Alliance (AWWA) conducted an intercept survey in the town of Wakefield, NH. The AWWA Youth Conservation Corp (YCC) was separated into small groups and stationed at the Union Post Office, Wakefield Town Hall, 7 Lakes Provisions, and Country Goods Grocery. The YCC were given a two hour course in the proper technique in administering the survey and conducted 65 surveys on August 4$^{th}$ and 9 surveys on September 13$^{th}$. A total of 74 surveys were conducted and documented for analysis on the public's relation to and thoughts on stormwater management and water quality.

# 2. Methodology

The idea to do an intercept survey was first addressed in the spring of 2011. After careful deliberation by the AWWA staff on what the focus of the survey should be and how best to gather the information, a draft was put together using the ME Department of Environmental Protection Research Report: Administering an Intercept Communications Survey. The draft was viewed and edited by AWWA board members as well as members of the NH Department of Environmental Services to complete a working survey for use in the summer of 2011.

The survey was conducted during the middle of the YCC season by YCC crew members. A date was selected to go to various locations in the town of Wakefield that would provide non-biased reporting. The crew underwent a two hour training session conducted by the AWWA Program Manager/Technical Director on the proper way to give an intercept survey. At the end of the training session, the crew was comfortable with the wording and presentation of the survey material. The following day the crew was separated into groups of two or three and sent to the locations that were previously determined by the Program Manager.

The crew spent seven hours at each of the four locations intercepting patrons of the businesses and asking if they would participate in a survey. The survey information and sponsor was not provided to interviewees until after the completion of the interview to avoid bias in answers. The crew reported back to the Program Manager and turned in the completed surveys. The Program Manager took the surveys and compiled the data in format that would make reading and analyzing most effective.

# 3. Demographics

Seventy-four people were interviewed at the four sites in Wakefield, NH designated in the introduction. Of the respondents, forty-seven (62.7%) were full time residents of the area; 36.2% from Union, 25.5% from Wakefield, 23.4% from Sanbornville, and 2.1% from Milton Mills and Acton, ME. Part-time residents made up the next largest proportion at 24%. There were also 8 seasonal renters (10.7%), 1 year-round renter (1.3%) and 1 non-resident (1.3%).

There were thirty-three lake residents (44%) interviewed residing on eleven lakes; Great East (27.3%), Lake Ivanhoe (6.1%), Horn Pond (3.0%), Lovell Lake (12.1%), Province Lake (6.1%), Pine River Pond (3.0%), the Branch River or Union Meadows (9.1%), Salmon Falls River (3.0%), Belleau Lake (6.1%), Sunrise Lake (3.0%), and Balch Lake (21.2%). Of the residents living on a lake, fifteen (45.5%) were members of a lake association. Forty-one respondents were non-lake residents of which two were members of lake associations.

There was a range of ages among respondents; 5.3% were less than 25 years old, 4% were 25-34, 20% were 35-44, 17.3% were 45-54, 33.3% were 55-64, and 18.6% were older than 65 years old. Of the 75 respondents, 39 were male (52%) and 36 were female (48%).

# 4. SURVEY

## 4.1. Lake Residents

The interviews identified that 33 of 75 people were residents of lakes (44%). Of the lake residents, fourteen were part-time residents (42.4%) and thirteen were full time residents (39.4%). There were also five seasonal renters (15.2%), and one year-round renter (3.0%). Of the thirty-three lake residents, fifteen were members of a lake association (45.5%).

After determining respondent's residence, they were asked *how concerned they were with the quality of our local lakes*. Respondents answered that they were primarily very concerned (69.7%) with water quality with 24.2% being somewhat concerned and only one person who was not very concerned (3.0%) and not at all concerned with water quality. The next question addressed a similar topic asking *how much of an impact stormwater runoff has on lake/river quality*. Respondents were split between runoff having a major impact (42.4%) and having somewhat of an impact (39.4%) with only 9.1% responding that it does not have much of an impact an no one responding that it has no impact at all. Three people did not know or refused to answer (9.1%).

A variety of responses were provided when interviewees were asked *what type of pollution they think is carried into lakes/rivers by runoff*. Respondents were able to list as many items as they could think of. The top three concerns for respondents were oil (45.5%), gas (27.3%), and salt (21.2%). Sediment was a close fourth with 12.1%. Among other responses were, trash and waste (9.1%), fertilizers (9.1%), septic and sewage (9.1%), animal waste (6.1%), chemicals (6.1%), road debris (6.1%), pesticides (6.1%), snow (6.1%), metal (3.0%), people dumping stuff (3.0%), phosphorus (3.0%), sticks and leaves (3.0%), land based (3.0%), and do not know (3.0%).

When asked *how interested people were personally in taking action to reduce pollution from stormwater*, respondents were somewhat interested (42.4%) and very interested (33.3%) with only six people saying they were not very interested (18.2%) and two who did not know or refused to answer (6.1%). While 69.7% of respondents were very concerned with the quality of our lakes, only 33.3% of respondents were very interested in personally taking action to reduce pollution from stormwater.

After gathering information on people's views on stormwater pollution, what they think causes it, and how they feel about taking action, respondents were then asked about local organizations and actions they were willing to take to protect the lakes. Fifteen respondents (45.5%) answered yes to *having heard of any efforts by local organizations to reduce stormwater* *pollution*. Of those answering yes, several organizations or people were listed; AWWA (40%), Great East Lake Improvement Association (GELIA) (13.3%), Balch Lake Improvement Association (BLIMP) (13.3%), NH Department of Environmental Services (6.7%), Belleau Lake (6.7%), Pete Kasprzyk (6.7%), conservation (6.7%), and the Brackett Road repairs (6.7%).

Respondents were then asked if they *have heard of AWWA*, which showed that 66.7% of lake residents had heard of AWWA. Several responses were given when asked *what they have heard about the organization*, including; sent packets in the mail (18.2%), "Great Effort" or "Great Job" (13.6%), done work in the area (9.1%), and landscape to prevent water runoff (4.5%). When asked if people *have taken any specific actions as a result of these local efforts*, 42.4% of people said they had. Specific actions included mulching (21.4%), collecting trash or taking trash out of the river (14.3%), talking with organization (7.1%), putting up diverters (7.1%), growing plants and blueberry bushes (7.1%), and turning in people for dumping snow on the ice (7.1%).

Respondents were then asked to rate how likely it would be for them to undergo a certain action pertaining to stormwater management. The questions were rated from "7" being *very likely* to undergo a certain action to "1" being *not at all likely* to undergo a certain action. This data will be reported by giving the number of the largest response as well as giving the weighted average of the responses.

When asked *how likely respondents would be to reduce the amount of lawn fertilizers, pesticides, and/or herbicides they use*, 54.5% responded with a "7" (very likely) with a weighted average of 5.7 indicating that most lake residents could be encouraged to reduce their usage of lawn chemicals. Interviewees were similarly likely to *seed, plant, or mulch bare areas* in their yards with 57.6 % responding with a "7" (very likely) and a weighted average of 5.5. There were a larger number of respondents (15.2%) who give a "1" (not at all likely) indicating that they would not seed, plant, or mulch bare areas. A similar question asked *how likely people would be to plant trees, shrubs, and/or groundcover to reduce the size of their lawn*. Again, the largest percent of responses were "7" (57.6%). However, because 25% responded with a "1" (not at all likely), the weighted average was a 5, closer to middle ground on the topic. A friendly lakefront practice to keep a lawn as a functioning buffer is to not mow it any shorter than 2.5-3 inches. Interviewees were asked *how likely they were to follow this practice*, with 57.6% saying they were very likely to mow no shorter than this. The weighted average was 6.3 with 6.1% of people saying it was not at all likely that they would mow no shorter than the recommended length. A final yard question was asked to see *how likely people were to use phosphorus free fertilizers*. This was split between very likely (27.3%) and not at all likely (15.2%). The weighted average was 4.8, indicating that people were a little more than 50/50 on using phosphorus free fertilizers.

Switching the topic away from yards and lawns, respondents were asked *how likely they were to pick up their pet's waste when in public places*. The responses here were overwhelmingly positive as 69.7% responded with a "7" (very likely). The weighted average was a 6.4 as this question did not apply to 18.2% of people. The survey then addressed where people were likely to gain information pertaining to any of the previous action listed above. The majority of people would seek information from the internet (75.8%) while 18.2% would go to a local hardware store or nursery.

To close out the survey, participants were asked *if they were aware of the states shoreland regulations*. Of the thirty-three respondents, twenty-two (66.7%) had heard of the program with fourteen of the twenty-two (63.6%) indicating that they thought the program was effective, one person (4.5%) indicated that the program was sort of effective, and ten people (30.3%) indicated the program is not effective.

**4.2. Non-Lake Residents**

Of the people interviewed, 41 of 75 were not residents of lakes (55.4%). Of the lake nonresidents, thirty-four were full time residents (81%), four were part time residents (9.5%), three were seasonal renters (7.1%), and one was not a resident of the area (2.4%). The nonresident of the area was thanked and no further questions were asked, thus results are out of 41 respondents. Due to not living on a lake, 85.2% of non-lake residents were not part of a lake association while two were.

When asked *how concerned they were with the water quality of our local lakes*, respondents were split between being very concerned (39%) and somewhat concerned (46.3%). Only 12.2% said they were not very concerned and one person said they were not at all concerned. The follow-up question asked respondents *how much of an impact they think stormwater runoff has on lake/river quality*. The majority of responses were that it had somewhat of an impact (48.8%) with 31.5% saying it had a major impact and 7.3% saying it did not have much of an impact. Five people (12.2%) didn't know or refused to answer.

Non-lake residents provided a similar variety of response as lake residents when asked *what type of pollution they think is carried into lakes/rivers by runoff.* The top three items were oil (34.1 %), gas (26.8%), and fertilizers (17.1%). Other responses included; salt (14.6%), trash and waste (12.2%), sediment (12.2%), pesticides (9.8%), animal waste (7.3%), chemicals (7.3%), commercial farming/farm waste/agriculture (7.3%), septic and sewage (4.9%), erosion (2.4%), phosphorus (2.4%), milfoil (2.4%), home contamination (2.4%), smog/ozone (2.4%), boats (2.4%), car debris (2.4%), pools (2.4%), and sticks and leaves (2.4%). Three people (7.3%) did not know or refused to answer.

After answering questions on the impact of stormwater and what sort of pollution they thought was carried into lakes, respondents were asked *how interested they were in personally taking action to reduce pollution from stormwater.* Almost half (48.8%) answered that they were somewhat interested with 22% saying they were not very interested and another 19.5% responding that they were very interested. Only three people (7.3%) responded that they were not at all interested.

After gathering information on people's response to stormwater pollution, what they think causes it, and how they feel about taking action, respondents were then asked about local organizations and actions they were willing to take to protect the lakes. Thirteen respondents (31.7 %) answered yes to *having heard/known of any efforts by local organizations to reduce stormwater pollution.* Of those answering *yes*, several organizations were listed; AWWA (53.8%), Moose Mountain Regional Greenways (MMRG) (15.4%), lake associations (7.7%), and boat launches (7.7%). As a follow-up, respondents were asked *if they had heard of AWWA*, to which 39% said yes. Those answering *yes* were asked *what they had heard*, again several things were listed; that AWWA was pretty good and did good things (6.3%), done work in the area (6.3%), newspaper articles/read something (6.3%), fix things (6.3%), heard the name (6.3%), they volunteer (6.3%), seen the signs (6.3%), seen the truck (6.3%), helping lakes (6.3%), and monitoring water (6.3%). Respondents were then asked *if they had taken any specific actions as* *a result of this local effort.* Only 12.2% answered *yes* to this, with specific actions including; being careful about what's in the ground (20%), washing off their boat before entering lakes (20%), called about erosion (20%)

The survey then addressed the likelihood of people to perform a certain action pertaining to erosion and runoff control. Answers were given on a numerical scale from "7" being very likely to "1" being not at all likely. The data will summarize the most popular response as well as a weighted average based on the number of responses given.

Respondents were first asked *how likely it would be for them to reduce the amount lawn fertilizers, pesticides, and/or herbicides they use.* The majority, 41.5%, said they would be very likely ("7") to do so. The weighted average for this question was a "5.4" as many people were less likely to perform this action. Respondents were similarly likely to *seed, plant, or mulch bare areas*, as 68.3% responded with a "7" and a weighted average of "6.1". Along the same lines, people were asked *how likely they would be to plant trees, shrubs, and/or groundcover to reduce the size of their lawns.* Again the majority (56.1%) answered with a "7" indicating they were very likely to do so and a weighted average of "5.7". The next question asked *how likely people would be to mow their lawns no shorter than 2.5-3"*, which people overwhelmingly responded with a "7" (70.7%) and a weighted average of "6.3". A final question referring to people's likelihood to adjust their land use practices asked *if they would use phosphorus free fertilizers.* Respondents were more reluctant, but the majority answered "7" (43.9%) with a weighted average of "5.3" as 14.6% responded with a "1" (not at all likely).

One question addressed a slightly different field than the others, asking people *how likely they were to pick up their pet's waste in a public place.* The majority of respondents answered with a "7" (61%) and a weighted average of 5.7. The survey then addressed where people were most likely to obtain information pertaining to the previous series of questions. Overwhelmingly, respondents would seek information from the internet (75.6%) with a few seeking information from hardware stores and nurseries (14.6%) or friends and family (12.2%).

To end the survey, respondents were asked *if they were aware of the state's shoreland regulations.* Only 26.8% said they were while the other 73.2% said they were not. Of the people answering yes, 36.4% thought it was an effective program while 18.2% thought it was not an effective program while several people were inbetween.

# 5. KNOWLEDGE AND IMPACTS

## 5.1. Lake Residents - Full Time Vs. Part Time Residency

The results show several interesting comparisons between the full time lake residents (FTR) and part time lake residents (PTR). There was an even split between full and part time lake residents interviewed, thirteen and fourteen respectively. There were also five seasonal renters interviewed. Surprisingly, only 23.1% of FTR were members of a lake association while 71.4% of PTR were members. By being a member of a lake association, these people should be receiving more information pertaining to proper lake practices and how best to protect their investment.

Both FTR and PTR were equally concerned with the quality of the lakes with 76.9% of FTR and 71.4% of PTR answering that they were *very* concerned. The FTR felt that stormwater runoff had a major impact (69.2%) while the PTR were more likely saying that it had somewhat of an impact (42.9%). Only 21.4% of PTR felt stormwater had a major impact and another 21.4% felt it did not have much of an impact. The pollution types that FTR and PTR thought were entering the lakes were the same suspects that the whole survey identified; oil and gas.

While FTR were very concerned with the lake quality and thought stormwater had a major impact on the lakes and rivers, only 46.2% were very interested in doing something personally to reduce pollution from stormwater and 38.5% were somewhat interested. Despite the drop-off in personal responsibility, FTR were still far more interested in taking action than the PTR. Only 21.4% of PTR were very interested in personally taking action, with 50% being somewhat interested and 21.4% not very interested. Maybe due to the limited time they spend on the lakes, they are not interested in forfeiting any of that time towards protection of lake quality.

Both the FTR and PTR had heard of efforts by local organizations, 61.5% and 50% respectively. Of the organizations listed, 37.5% of FTR listed AWWA and 42.9% of PTR listed AWWA. When prompted about hearing of AWWA, 84.6% of FTR and 57.1% of PTR said they had heard of AWWA. While still doing an excellent job getting the word out, more effort should be dedicated to part time lake residents. Despite the knowledge of these local efforts helping protect water quality, only 38.5% of FTR and 42.9% of PTR had taken any action as a result of the local efforts. This indicates more effort should be made to motivate people into action.

When asked about specific actions they may consider, most were willing and ready to make the effort. Full time residents were very likely (53.8%) to reduce the amount of fertilizers, pesticides and herbicides they use, while 57.1% of PTR were very likely to do the same. The same numbers applied to those that would seed, plant, or mulch bare areas. However, 30.8% of FTR said that it was not at all likely they would perform his task. When it came to planting trees, shrubs, or groundcover, PTR were 71.4% very likely to do so, while only 46.2% of FTR would do the same. Again, 38.5% of FTR said that it was not at all likely. This indicates that FTR are less likely to landscape to protect water quality at their homes. A large difference between FTR and PTR was how they would mow their lawns. 76.9% of FTR said it was very likely that they would mow no shorter than 2.5-3 inches, while only 42.9% of PTR answered the same. Another big drop off occurred when the phosphorus free fertilizer question was asked. Only 15.4% of FTR and 35.7% of PTR were very likely to use phosphorus free fertilizers. This indicates that knowledge should be spread about these fertilizers and how they are mostly unnecessary for grass growth in our area (most people did respond that the question did not apply to them). Both FTR and PTR were very likely to pick up their pets waste when in public places, 69.2% and 71.4% respectively. The internet was the dominate source of information if people wanted to research any of the previous topics with 61.5% of FTR and 78.6% of PTR using this resource.

In closing, 53.8% of FTR and 78.6% of PTR had heard of the state's shoreland regulations. Of the FTR that answered yes, 71.4% said it was an effective program while 28.6% thought it was not and one person saying it was "a ridiculous program". Of the 78.6% of PTR who answered yes, 63.6% thought it was an effective program.

### 5.2. Non-Lake Residents

Of interviewees that did not live on a lake, 81% of them were full time residents. This leads to an unbalanced representation in the results when comparing the full time residents (FTR) to the part time residents (PTR) and how they feel about lake and water quality. Therefore, the focus will be placed on the 34 of 38 respondents who are FTR, with any interesting comparisons noted. One interesting point to note is that both the FTR and PTR who do not live on lakes had one person who was a member of a lake association.

When FTR were asked how concerned they were with local water quality, the answers spread the board; 38.2% were very concerned, 47.1% were somewhat concerned, 11.8% were not very concerned and 2.9% were not at all concerned. Similar results showed that 32.4% of FTR thought stormwater had a major impact on water quality while 47.1% said it had somewhat of an impact, 8.8% said it did not have much of an impact, and 11.8% did not know or refused to answer. Following up the general question of water quality, residents were asked to list specific pollution sources. Several responses kept popping up; oil (29.4%), gas (29.4%), fertilizers (20.6%), salt (14.7%), trash/waste (14.7%), and sediment (11.8%). Respondents were then asked how likely they were to take personal action to reduce stormwater pollution which 58.8% of the people who responded said that they were somewhat interested with only 11.8% being very interested. There were also 17.6% of people who were not very interested and 8.8% not interested at all.

The next series of questions addressed respondent's knowledge of organizations that help reduce stormwater pollution. Thirteen people (38.2%) had heard of efforts by local organizations, with 53.8% of them listing AWWA. When prompted about AWWA, 44.1% said they had heard of the organization. Despite a fair number of people hearing of local efforts, only 14.7% of people said they had personally taken action because of these organizations. Some actions people took included; washing their boat before entering lakes (20%), calling about erosion (20%), and being careful what's in the ground (20%).

Respondents were then asked of series of questions where they were to rank how likely it would be for them to undergo the listed scenario where "7" was very likely and "1" was not at all likely. When it came to reducing the amount of fertilizers, pesticides, and/or herbicides people use, 38.2% said they were very likely to do so with only 8.8% saying it was not at all likely. A majority of people (67.6%) said they were very likely to seed, plant, or mulch bare areas in their yard. Likewise, 58.8% of respondents were very likely to plant trees, shrubs or groundcover to reduce the size of their lawn. Continuing on this trend, 73.5% of people were very likely to mow their lawns no shorter than 2.5-3 inches. A littler more variation was seen when respondents were asked about using phosphorus free fertilizers, almost half (44.1%) said they were very likely to do so, but 14.7% were not at all likely. A final question addressed a slightly different area, but saw that 61.8% were very likely to pick up their pet's waste in public places. The internet was still the dominate source of information with 76.5% of people going there for information pertaining to the previous questions.

A final question asked respondents if they were aware of the state's shoreland regulations. A little more than a quarter of people (29.4%) had heard of the regulations and 40% of them thought it was an effective program while 10% said it was not an effective program and one person said it had extreme regulations.

### 5.3. Lake Residents Vs Non-Lake Residents

There are several major differences in the people who live on lakes in the area and the people who do not. The difference starts with the overall concern for the quality of the lakes in our area. Lake residents were 30% more concerned with lake quality than non-lake residents. Lake residents also had a lower percentage of people who were not very concerned or not at all concerned, 6% compared to 14.6%. The views were a little closer when it came to the impact of stormwater runoff on lake/rive quality as 81.8% of lake residents and 80.5% of non-lake residents thought it had either a major impact or somewhat of an impact. The specific contributors to pollution remained fairly equal with the top three being oil, gas, and salt. Non-lake residents also ranked fertilizers pretty high (17.1%). Since lake residents were 30% more concerned with lake quality, they were 13.8% more interested in taking personal action to reduce pollution from stormwater.

Both lake residents and non-lake residents had heard of local efforts by organizations to reduce stormwater pollution. Lake residents had heard a little bit more, mainly coming from lake associations. An interesting note, 53.8% of non-lake residents who had heard of local efforts listed AWWA while only 40% of lake residents did the same. When prompted about having heard of AWWA, 66.7% of lake residents acknowledged hearing of AWWA while only 39% of non-lake residents had heard of AWWA. The largest contributor to lake resident's knowledge of AWWA was from packets sent in the mail (18.2%). Despite the knowledge of these local efforts, personal action remained low. Lake residents were far more likely to take specific actions, 42.4% compared to 12.2% of non-lake residents. This indicates that more information needs to be out there on simple tasks people can perform to protect water quality.

The lake residents and non-lake residents were in agreement for most of the "rate how likely" question series. Lake residents were 14% more likely to reduce to the amount of lawn fertilizers, pesticides, and/or herbicides they use. However, at the other end of the spectrum, they were 4.8% more likely to not stop using them at all. Non-lake residents were 11.3% more likely to seed, plant, or mulch bare areas in their lawns than the lake residents while lake residents were 4.9% more likely to *not* seed, plant, or mulch bare areas compared to non-lake residents. Lake residents and non-lake residents were equally likely (57.6% to 56.1% respectively) to plant trees, shrubs, or groundcover to reduce their lawn size. They were also equally likely to pick up their pet's waste when in public (69.7% of lake residents to 61% of non-lake residents). A large difference was found between residents when asked about mowing their lawns to no shorter than 2.5-3 inches. Non-lake residents were 13.1% more likely to mow no shorter than the lake residents. This is likely due to how more people can see lake front owner's lawns. Another difference showed that 16.6% of non-lake residents are more likely to use a phosphorus free fertilizer than lake residents. A similar percent of both residents said they were not at all likely to use phosphorus free fertilizers. The results suggest that non-lake residents are interested in both planting and reducing potentially harmful pollutants from their yards while lake residents are interested in plantings and things that will improve their yards without taking away things that could cause a decrease in ascetics.

A major difference existed between residents when asked about the state's shoreland regulations. Only 26.8% of non-lake residents had heard of the state's shoreland regulations and of them only 36.4% thought it was an effective program. Two thirds of the lake residents had heard of the state's shoreland regulations with 63.6% of them saying it is an effective program. This makes sense as many people who live on lakes have had to deal with the state's shoreland regulations.

**5.4. Lake Residents by Lake (Primarily Balch and Great East Lakes)**

The thirty-three lake residents were spread out over eleven lakes in the area. The majority of lake residents in the survey were residents of Great East Lake (9) or Balch Lake (7). The views expressed by these residents does not vary much from the views between which lake respondents live on, but does show some areas where focus could be placed for outreach.

The majority of respondents from both Great East Lake and Balch Lake belonged to a lake association, 66.7% and 57.1% respectively. The lake association connection could be a reason why 77.8% and 71.4% of Great East and Balch respondents said they were very concerned for the quality of local lakes respectively. However, only 44.4% of Great East residents and 0% of Balch residents said stormwater runoff had a major impact. Among all lake resident respondents, the specific pollution identified remained the same; oil (50-85.7%) and gas (33.3-57.1%). Despite this, only 14.3% of Balch residents and 44.4% of Great East residents were very interested in taking personal action to reduce pollution from runoff.

While numbers were a little low for those that had heard of efforts by local organizations, when prompted about AWWA, 71.4% of Balch residents, 44.4% of Great East, 100% (2 people) of Ivanhoe, 100% of Horn (1 person), 50% of Lovell (2 people), 50% of Province (1 person), 100% of Pine River (1 person), 100% of the Meadows (3 people), no one form the Salmon Falls River, 100% if Belleau (2 people), and 100% of Sunrise (1 person). Balch residents were less likely to take action as a result of the local efforts (28.6%), while Great East residents were 55.6% likely to have taken action.

Some large difference between Great East Lake and Balch Lake residents occurred when asked about things they would do to limit runoff. 88.9% of Great East residents would reduce the use of lawn fertilizers, pesticides, and herbicides compared to 28.6% of Balch residents. 77.8% of Great East residents would seed, plant, or mulch bare areas compared to 57.1% of Balch residents. 77.8% of Great East residents would plant trees, shrubs, or groundcover compared to 42.9% of Balch residents. 66.7% of Great East residents would mow no shorter than 2.5-3 inches compared to 57.1% of Balch residents. 66.7% of Great East residents would use a phosphorus free fertilizer compared to 42.9% of Balch residents.

Finally, 100% of Great East residents had heard of the state's shoreland regulations, with 66.7% saying it was an effective program. 71.4% of Balch residents had heard of it, with 60% saying it was effective.

## 6. CONCLUSIONS/RECOMMENDATIONS

### 6.1. Lake and Non-Lake Residents

There are several conclusions that can be pulled out of the data gathered from this survey. Lake residents tend to be more concerned with the quality of the local lakes and rivers likely because they want to protect their investment and they see the water from a different standpoint. From this, lake residents also see stormwater runoff as more of a major impact than non-lake residents for likely the same reason. Lake residents have probably witnessed runoff flowing into the lakes and taken note how dirty that runoff may look.

Unfortunately, despite living on the lakes and being somewhat more interested than non-lake residents, there is still a lake of personal action and/or wanting to take personal action. An area of focus should be educating people on how easy it is to take personal action to prevent polluted runoff from entering the lakes. Many people are only here for a short time and may not want to do any extra work, but there are so many easy, quick fixes to landscapes or practices that can help prevent excess runoff from entering the lakes.

AWWA is doing their part with both lake and non-lake residents having heard of the organization. Far less non-lake residents have heard of the organization and this should be a new area for outreach as many practices away from the water's edge can influence the lakes. Again, getting people to take specific actions from their awareness of local efforts is below where the organization would like it to be. Further outreach and explanation into simple ways to involve homeowners/landowners would be a good course of action to improve these numbers. Most lake and non-lake residents are willing to partake in several practices that improve the buffers around their properties, although, non-lake residents are more likely to perform these tasks than lake residents. One major point that needs work is that lake residents were unlikely to use a phosphorus free fertilizer, which means that they are unaware that they really don't need phosphorus for their lawn and plants because the soils in this area are already high in phosphorus.

More outreach and education should be attempted toward non-lake residents as very few were aware of shoreland regulations. They may not live on the water, but it is likely that they use the water at one point or another during the year.

### 6.2. Lake Residents by Lake

The majority of the lake residents interviewed reside on Great East Lake or Balch Lake. However, regardless of the lake, continued efforts need to be made to get people to join their local lake association. A lot of information is conveyed through these organizations and a large effort to protect the lakes. Where most lakes showed over 50% of respondents being part of an association, this number needs to be closer to 75%.

A conflict occurred as most people were very concerned with local lake water quality, but very few viewed stormwater runoff as having a major impact. Work needs to be done to connect these two ideas with the general public. Along the same lines, not enough people were interested in personally taking action to reduce pollution from runoff, thus a more straight forward message providing simple methods to help protect the lakes should be developed.

A majority of residents from all lakes had heard of AWWA, which allows the organization to focus on its outreach and education of lake front land owners. Most lakes showed that around 50% of people had taken personal action due to this local effort. This is a number, again, that the organization would like to see near 75%. Outreach should begin focusing on non-lake residents as well as their actions influence water quality by living in a watershed.

Most respondents from all lakes, except Balch, were responsive to changing their practices to create buffers and protect the lake from runoff through planting, mulching, and mowing practices. As with most residents, lake or non-lake, they were unlikely to use phosphorus free fertilizers. This should be a major focus point in upcoming outreach materials.

Finally, a majority had heard of the state's shoreland regulations and usually over 60% of respondents said it was an effective program. It will be important to keep residents updated on changes to the program as they occur.

## B. Discovery Cruise Itinerary

Join AWWA for a

# DISCOVERY CRUISE

Do you know how far down you can see in Horn Pond?

Did you know there are carnivorous plants in the lake?

Have you ever seen a daphnia up close?

- Learn how we determine how good our water quality is
- Get to know our native aquatic plants and how we tell them apart from the invaders
- Meet some of the tiny critters that keep the fish fed

## SIGN UP TODAY !!

Or Call AWWA at (603) 473-2500

**AWWA's Floating Classroom Comes to [*insert Lake*]**

Have you ever wondered…

is the water clean enough to swim in?
how to tell an invasive from a native aquatic plant?
who lives in your lake?

Join the Acton Wakefield Watersheds Alliance on a 3-hour guided tour of your lake where you'll practice water quality sampling, learn how to identify invasive plants and meet some of the critters that share your lake. The program is fun and interesting for all ages 8 and above. Children and adults are encouraged to participate. The dates and times will be set when we know who is interested so call or email soon to reserve a spot or ask for more info. (603) 473-2500 or info@AWwatersheds.org.

**Discovery Cruise Overview**

Long term Objective: The lakes in the AWWA region will support healthy ecosystems and meet the criteria for all their designated uses.

Cruise objectives: Cruise participants will

- demonstrate increased knowledge about lake ecosystems
- express increased concern for clean lakes
- pledge to reduce their phosphorus footprint

Summary**:** The AWWA Discovery Cruise is designed to introduce lake visitors to various aspects of lake ecology including water characteristics, the aquatic food web and invasive species; to encourage personal connections to aquatic organisms; and to demonstrate the relationship between activities on land and lake water quality.

Estimated Time: 2 hours

Materials:

- Pontoon boat w/ anchor
- Coast Guard approved PFDs
- Water & cups
- AWWA Brochures
- P Footprint Pledge forms
- DC evaluations
- Water Characteristics
  1. LLMP and/or VLMP data recording sheets
  2. Pencils
  3. Secchi Disk
  4. View Scope(s)
  5. Temperature probe
  6. Grab sampling equipment
  7. Collection bottles
- Plankton
  1. Plankton Net
  2. Spray bottles
  3. 1 pt. containers
  4. Discovery Scopes
  5. Food Web chart
  6. Plankton key
- Aquatic Plants
  1. Aquatic Plant keys
  2. Weed Weasel or long-handled cultivator
  3. White dishpans
  4. Weed Watcher and/or Plant Patroller kits
  5. Invasive plant specimens in sealed jar

Introduction (10 min):

1. Welcome aboard, don PFD's and/or explain stow location
2. Set sail for deep spot sampling location
3. Ask for names, relationship to lake, reason for coming
4. Brief intro to AWWA
    a. Founded by volunteers to protect unpolluted lakes
    b. Focus on relationship between human activity & WQ
    c. Role of phosphorus and mechanics of runoff
    d. Lake Protection Begins on Land
    e. "I hope that after our cruise you will know a bit more about who and what lives in this lake and why they need us to take care of them."
    f. Describe agenda
5. Set anchor

Water Quality Station (30 min):

1. Explain that volunteers collect information about the water in the lake from ice out to ice in and send the data to LLMP or VLMP for analysis
2. Key parameters to measure are transparency (how much stuff is in the water column), phosphorus level (how much plant food), chlorophyll a (how much algae growth), dissolved color (how much decomposition), alkalinity (how well the lake can handle acidity), and DO (how much $O_2$ for aquatic animals)
3. Today we are going to use the Secchi Disk to measure transparency, the temp probe to get a temp profile of the water column to determine where the layers of warm productive water end and the cold layer begins; and take a sample of that top layer known as the epilimnion. That sample will then go to the lab for analysis of the other parameters. DO is measured with a meter that we won't use today.
4. Ask for a recording secretary (could be captain if everyone wants to sample)
5. Gather weather info
6. Transparency
    a. Ask 2 volunteers to be the Secchi disk monitors, one with the scope, one with the disk
    b. Repeat with other interested guests on other side, without scope, etc
    c. Record and compare – what would account for any differences?
    d. What would make the water more or less transparent?
    e. What could property owners do to keep transparency deep?
7. Temperature (can be during transparency readings)
    a. 2 volunteers – 1 to lower probe at .5 m increments, 1 to read temp
    b. Go to bottom if possible
    c. Confer with recorder to determine thermocline – at least $5^o$ drop within .5m
8. Collect sample
    a. Use grab sampler to collect sample of epilimnion column, repeat as necessary to fill bottle
9. Discuss P, how it is delivered, what excess levels can cause

Plankton Station (30 min):

1. Define plankton as organisms that are carried by currents - from Greek meaning “to wander or drift.”
2. Explain phytoplankton (autotroph - makes its own food from sunlight and nutrients), zooplankton (heterotroph - must eat other plankton)
3. Show food web poster - discuss interdependence – if one level is out of balance whole ecosystem may respond
4. Have volunteer tie plankton net to boat then lower, swoosh around, pull up
5. Pour into containers, fill Discovery Scopes, pass them around
6. While they look, encourage them to describe what they see
    a. How are organisms moving?
    b. What features do they have?
    c. How these features might be useful?
    d. What sort of behavior?
    e. Encourage descriptive words
7. Use illustrations in the key to help identify.
8. Laptop w/ microscope?
9. Discuss how diverse populations are more healthy, indicate rich ecosystems, have resiliency

Aquatic Plants (Macrophytes) (30 Min):

1. Pull up anchor and motor to area with abundant aquatic plant growth
2. Distribute weed watcher/PP kits
3. Revisit importance of biodiversity
4. Discuss plants’ needs – space, water, nutrients, sunlight
5. Discuss competition for needs – explain how organisms that “outcompete” become invasive (greater surface area, vigorous root growth, shading)
    a. Examine samples for ideas on how each competes
6. Take samples and compare to keys
7. How might invasive species get established?
    a. Where would they come from?
    b. What might make it easier for them? Disturbed sediments, excess nutrients, removal of native species
8. What can individuals do?
    a. Become a weed watcher/plant patroller
    b. Adopt an area of the lake bottom
    c. Encourage friends and neighbors to inspect boats before launching
    d. Support efforts with $$ and support to towns

Wrap Up (20 min):

1. Head back to dock
2. Any other questions or concerns?
3. Pass out P Footprint Pledges and DC Evaluations
4. Read through P Footprint Pledge and ask for any other ideas
5. Discuss what other ways the lake can be protected (land conservation, road repairs, careful boating…)
6. Ask them to complete the evaluation (5 min)
7. Thanks for coming!

# - Evaluation -
## AWWA Discovery Cruise

1. **On which lake did you go on an AWWA Discovery Cruise?**

| | | |
|---|---|---|
| ☐ Balch Lake | ☐ Horn Pond | ☐ Pine River Pond |
| ☐ Belleau Lake | ☐ Lake Ivanhoe | ☐ Province Lake |
| ☐ Great East Lake | ☐ Lovell Lake | ☐ Wilson Lake |

2. **Please rate your experience with the following portions of the Discovery Cruise by circling the appropriate number:**

**1 - 2 - 3 - 4 - 5**
**not informative — satisfactory — very informative**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Water Quality Testing** | 1 | - | 2 | - | 3 | - | 4 | - | 5 |
| **Zooplankton Tow** | 1 | - | 2 | - | 3 | - | 4 | - | 5 |
| **Aquatic Plant ID** | 1 | - | 2 | - | 3 | - | 4 | - | 5 |

3. **How has your knowledge about the impact of human activity on water quality changed as a result of the cruise?** *Please circle one answer*

   No Change    Slightly Increased    Greatly Increased    Cannot Rate

4. **How has your knowledge about approaches to water quality protection changed as a result of this cruise?** *Please circle one answer*

   No Change    Slightly Increased    Greatly Increased    Cannot Rate

5. **As a result of this cruise have you pledged to reduce your phosphorus footprint?** *Please circle one answer*

   Yes, I pledged to reduce my P footprint    I had already pledged    No, I don't plan to

6. **Below is a list of the ways in which you can reduce your individual Phosphorus footprint.**

*Please circle all that apply.*

| | | | | |
|---|---|---|---|---|
| **Say NO to fertilizers** | I will | I already do | I'm not planning to | Not sure |
| **Use phosphate-free detergents** | I will | I already do | I'm not planning to | Not sure |
| **Change your cleaning habits** | I will | I already do | I'm not planning to | Not sure |
| **Scoop the Poop** | I will | I already do | I'm not planning to | Not sure |
| **Check your septic tank** | I will | I already do | I'm not planning to | Not sure |
| **Have a soil erosion consultation** | I will | I already do | I'm not planning to | Not sure |
| **Plant a shoreline buffer** | I will | I already do | I'm not planning to | Not sure |
| **Use NO soaps in the water** | I will | I already do | I'm not planning to | Not sure |
| **Control your roof runoff** | I will | I already do | I'm not planning to | Not sure |
| **Boat Responsibly** | I will | I already do | I'm not planning to | Not sure |

7. **Would you recommend an AWWA Discovery Cruise to family or friends? ___ YES ___NO**

8. **Additional Comments.**

Thank you!

**Optional Contact info:**

_______________________________________________

Name Phone

_______________________________________________

Email

# Shrink Your Phosphorus "Footprint" Pledge

I pledge to reduce the amount of phosphorus entering my lake by modifying at least one of the behaviors listed below:

- ☐ Say NO to fertilizers. Many lawn fertilizers contain phosphorus that can wash into the lake after a rainstorm. Most lawns in this area don't need additional phosphorus to be healthy.
- ☐ Use phosphate-free laundry detergent. Commercial detergents contain phosphates that enter your leech field and then enter surrounding water bodies after it rains.
- ☐ Change your cleaning habits. Exchanging commercial cleaners for common household items such as; baking soda, lemon, borax, white vinegar, isopropyl alcohol, cornstarch, and/or a citrus solvent keeps excess phosphates out of your leech field.
- ☐ Scoop the poop. Your pet's waste contains phosphorus that will easily enter the nearest waterbody after a rain storm.
- ☐ Check your septic tank. Have your septic holding tank emptied every 1 to 2 years to avoid a backup or the leaking of phosphorus into groundwater.
- ☐ Have a soil erosion consultation. Having a professional look at your property and recommend solutions could prevent a lot of phosphorus from entering the lake.
- ☐ Plant a buffer. Planting or maintaining trees and shrubs along the water's edge helps prevent excess phosphorus in runoff from entering your waterbody.
- ☐ No soaps in the water. Not bathing or washing your dog with soaps in your local water body prevents the phosphates in the soap from entering the waterbody.
- ☐ Control your roof runoff. Directing the flow of roof runoff into a rain barrel, dripline trench, rain garden, or catch basin prevents excess polluted runoff from entering a waterbody.
- ☐ Boat responsibly! Slow down near the shore to stop erosion and the release of phosphorus from the shore soils.

Please tear off at the dotted line, turn in the pledge and keep the top for your reference

# I pledge to Shrink My Phosphorus Footprint!

________________________________________

Signature

____________________________ ____________________ _____________

Name (Print) Lake Date

______________________________________________________________

Address

_________________________________________ _____________________

Email address Phone #

## C. Water Quality Reports

# GREAT EAST LAKE

## Water Quality Monitoring: 2010
## Summary and Recommendations
## NH LAKES LAY MONITORING PROGRAM

By: Robert Craycraft & Jeffrey Schloss

**Center for Freshwater Biology**
**University of New Hampshire**

UNIVERSITY of NEW HAMPSHIRE
COOPERATIVE EXTENSION

**To obtain additional information on the NH Lakes Lay Monitoring Program (NH LLMP) contact the Coordinator (Jeff Schloss) at 603-862-3848 or Assistant Coordinator (Bob Craycraft) at 603-862-3696.**

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# PREFACE

This report contains the findings of a water quality survey of Great East Lake located in Wakefield, New Hampshire and Acton, Maine. Sampling was conducted in the summer of 2010 by the University of New Hampshire **Center for Freshwater Biology (CFB)** in conjunction with the Great East Lake Improvement Association.

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of the 2010 results as well as more detailed "Introduction" and "Discussion" sections. Graphic display of data is included, in addition to listings of data in appendices, to aid visual perspective.

# ACKNOWLEDGMENTS

2010 was the twenty-fourth year the Great East Lake Improvement Association participated in the **New Hampshire Lakes Lay Monitoring Program (LLMP)**. The volunteer monitors involved in the water quality monitoring effort are highlighted in Table 1 while Charles Hodsdon again coordinated the volunteer monitoring activities on Great East Lake and acted as liaison to the **Center for Freshwater Biology (CFB)**. The **CFB** congratulates the volunteer monitors on the quality of their work, and the time and effort put forth. We invite other interested residents to join the Great East Lake water quality monitoring effort in 2011 and expand upon the current database. Funding for the water quality monitoring program was provided by the Great East Lake Improvement Association.

**Table 1: Great East Lake Volunteer Monitors (2010)**

| Name |
|---|
| Charles & Marcia Hodsdon |
| Dave & Carol Lafond |
| Martin & Linda Schier |
| Doug Smith |

The **New Hampshire Lakes Lay Monitoring Program** is a not-for-profit citizen based research program coordinated by Robert Craycraft and directed by Jeff Schloss, Associate Director of the UNH CFB. Members of the **CFB-LLMP** summer field team included Gabrielle Hodgman, Lejla Kadic and Andrew Middleton while Elizabeth Adejuyigbe, Emma Carroll, Emma Leslie, Emily Ramlow, Choe Shannon and Jessica Waller provided additional assistance in the fall analyzing, compiling and organizing the water quality data.

The **LLMP** acknowledges the University of New Hampshire Cooperative Extension for funding and furnishing office and storage space while the College of Life Sciences and Agriculture provided laboratory facilities and additional storage space. The **LLMP** would like to thank the **Caswell Family Foundation** for their continued generosity in providing long-term support for undergraduate assistantships while additional support for administering the **NH LLMP** comes from the **United States Department of Agriculture Cooperative State Research, Education and Extension Service** through support from the New England Regional Water Quality Program, (http://www.usawaterquality.org/newengland/).

Participating groups in the **LLMP** include: Acton-Wakefield Watershed Alliance, Green Mountain Conservation Group, North River Lake Monitors, the associations of Baboosic Lake, Bow Lake Camp Owners, Chocorua Lake, Conway Lake Conservation, Crystal Lake, Goose Pond, Great East Lake, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Lovell Lake, Mendums Pond, Merrymeeting Lake, Milton Three Ponds Lake Lay Monitoring, Mirror Lake (Tuftonboro), Moultonborough Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake Region, Nippo Lake, Silver Lake (Madison), Squam Lakes, Sunset Lake, Swains Lake, Lake Wentworth, Winnisquam Drive, and the

towns of Alton, Amherst, Enfield, Madison, Meredith, Merrimack, Milton, Strafford and Wolfeboro.

Major collaborators with the UNH CFB in 2010 included the NH Water Resources Research Center, New Hampshire Lakes Association, New Hampshire Department of Environmental Services, Lakes Regional Planning Commission, Dartmouth Hitchcock Medical Center, Sandy Point Discovery Center (NH Fish and Game and Great Bay National Estuary Research Reserve), EPA New England, the Volunteer Monitoring National Facilitation Project (USDA) and the Northeastern States and Caribbean Islands Regional Water Center (USDA National Institute of Food and Agriculture).

# Great East Lake Water Quality Monitoring 2010

Great East Lake remains one of Wakefield's natural resource assets providing recreational opportunities to the lakefront property owners, town residents and out of town visitors. Long-term water quality monitoring was instituted on Great East Lake to generate a database to which future water quality data could be compared, to identify potential problems around the lake and to proactively address water quality threats to the lake which will help ensure that Great East Lake remains a natural resource for future generations.

## *2010 Water Quality Data*

Volunteer water quality monitoring has been ongoing in Great East Lake since 1987. In 2010, the volunteers collected bi-weekly data during the "growing season" that spanned May 2 to September 23. The water quality monitoring focused on the collection of water quality data at four in-lake sampling locations that provide insight into the overall condition of Great East Lake.

Water transparency measurements are collected with a standardized eight inch diameter black and white disk that is lowered into the water column while looking through a view scope until it can no longer be seen. The scope negates the influence of waves and sun reflection to allow more precise measurement. The Great East Lake water transparency measurements remained high throughout the summer months and included a maximum visibility of approximately 38.7 feet (11.8 meters) that was documented on September 23, 2010. The 2010 Great East Lake water clarity data continued to exhibit some of the higher water transparency measurements that have been documented among our New Hampshire Lakes.

The amount of microscopic plant growth (visually detectible as golden or green water) generally remained low through the summer months and remained well below nuisance levels. The corresponding phosphorus (nutrient) concentrations were low to moderate at each of the Great East Lake sampling locations and corresponded to the low to moderate levels of algal growth. However, the microscopic plant samples collected in the most embayed (isolated) sampling location were significantly higher than the corresponding samples that were collected at the more open water sampling locations.

Dissolved oxygen concentrations, required for a healthy fishery, remained high throughout the water column at the open water sampling sites and remained well within the optimum range for coldwater fish species such as rainbow trout and salmon.

## *Common Concerns among New Hampshire Lakes*

Many lakeshore property owners throughout New Hampshire express concerns that increased aquatic plant "weed" growth and the amount of slime that coats the lake bottom in the shallows has been steadily increasing over the years. While sufficient data have not been generated to quantitatively support these assertions, communications from Great East Lake monitors and camp owners indicate these are also common concerns for their lake. As the lakeshore and the surrounding uplands are converted from a well forested landscape to a more suburbanized setting, more nutrients oftentimes enter the lake and in turn promote plant growth. Keep in mind, the same nutrients that stimulate growth of our lawns will also stimulate growth in our lakes. Nutrients can originate from a number of sources within the Great East Lake watershed that include septic system effluent, lawn fertilizer runoff and sediment washout. While some nutrient loading will occur naturally even in our most remote New Hampshire lakes, there are steps you can take to minimize nutrient runoff, that increases microscopic plant growth (greenness), contributes to the slimy coatings we find on rocks along our beaches and allows for new, or the expansion of, existing weed beds in the shallows of Great East Lake.

## *10 Recommendations for Healthy Lakeshore and Streamside Living*

Given the concerns discussed above make sure you consider the following recommendations and spread the word to your lake association and neighbors.

1. Encourage shoreside vegetation and protect wetlands - Shoreside vegetation (also known as **riparian vegetation**) and wetlands provide a protective buffer that "traps" pollutants before reaching the lake. These buffers remove materials both chemically (through biological uptake) and physically (settling materials out). As riparian buffers are removed and wetlands lost, pollutant materials are more likely to enter the lake and in turn, favor declining water quality. Shoreline vegetation grown tall will also discourage geese invasions and shade the water reducing the possibility of aquatic weed recruitment including the dreaded invasive milfoil.

2. Limit fertilizer applications - Fertilizers entering the lake can stimulate aquatic plant and algal growth and in extreme cases result in noxious algal blooms. Increases in algal growth tend to diminish water transparency and under extreme cases culminate in surface "scums" that can wash up on the shoreline and can also produce unpleasant smells as the material decomposes. Excessive nutrient concentrations also favor algal forms known to produce toxins which irritate the skin and under extreme conditions, are dangerous when ingested. Use low maintenance grasses such as fescues that require less nutrients and water to grow. Do not apply any fertilizers until you have had your soils tested. Oftentimes a simple pH adjustment will do more good and release nutrients already in the soils. After a lawn is established a single application of fertilizer in the late fall is generally more than adequate to maintain a healthy growth from year to year.

3. Prevent organic matter loading - Excessive organic matter (leaves, grass clippings, etc.) are a major source of nutrients in the aquatic environment. As the vegetative matter decomposes nutrients are "freed up" and can be-

come available for aquatic plant and algal growth. In general, we are not concerned with this material entering the lake naturally (leaf senescence in the fall) but rather excessive loading of this material as occurs when residents dump or rake leaf litter and grass clippings into the lake. This material not only provides large nutrient reserves which can stimulate aquatic plant and algal growth but also makes great habitat for leaches and other potentially undesirable organisms in swimming areas.

4. Limit the loss of vegetative cover and the creation of impervious surfaces - A forested watershed offers the best protection against pollutant runoff. Trees and tall vegetation intercept heavy rains that can erode soils and surface materials. The roots of these plants keep the soils in place, process nutrients and absorb moisture so the soils do not wash out. Impervious surfaces (paved roads, parking lots, building roofs, etc.) reduce the water's capacity to infiltrate into the ground, and in turn, go through nature's water purification system, our soils. As water seeps into the soil, pollutants are removed from the runoff through absorption onto soil particles. Biological processes detoxify substances and/or immobilize substances. Surface water runoff over impervious surfaces also increases water velocities which favor the transport of a greater load of suspended and dissolved pollutants into your lake.

5. Follow the Flow - Try to landscape and re-develop with consideration of how water flows on and off your property. Divert runoff from driveways, roofs and gutters to a level vegetated area or a rain garden so the water can be slowed, filtered and hopefully absorbed as recharge.

6. Discourage the feeding ducks and geese - Ducks and geese that are locally fed tend to concentrate in higher densities around the known food source and can result in localized water quality problems. Waterfowl quickly process food into nutrients that are capable of stimulate microscopic plant ("algal") growth. Ducks and geese are also host to the parasite responsible for swimmers itch. While not a serious health threat, swimmers itch is very uncomfortable especially for young children.

7. Maintain septic systems - Faulty septic systems are a big concern as they can be a primary source of water pollution around our lakes in the summer. Septic systems are loaded with nutrients and can also be a health threat when not functioning properly. Inspect your system on a timely basis and pump out the septic tank every three to five years depending on tank capacity and household water use. Since the septic system is such an expensive investment often costing a minimum of $10,000 for a complete overhaul, it is advantageous to assure proper care is taken to prolong the system's life. Additionally, following proper maintenance practices will reduce water quality degradation.

8. Take care when using and storing pesticides, toxic substances and fuels as it only takes a small amount to pollute lake, stream and ground water. Store, handle and use with attention paid to the label instructions.

9. Stabilize access areas and beaches - Perched beaches (cribbed areas) that keep sand and rocks in-place are preferred if you have to have that type of access. Do not create or enhance beach areas with sand (contains phosphorus, smothers aquatic habitat, fills in the lake as it gets transported away by currents and wind and encourages invasive plants and algal blooms).

10. Review the updated New Hampshire Comprehensive Shoreland Protection Act (CSPA) if you have shoreland property. The CSPA sets legal regulations aimed at protecting water quality. If you have any questions regarding the act or need further information contact the Shoreline Protection Act Coordinator at (603) 271-3503.

**Note: Consult materials such as those listed below, for further guidance on assessing and implementing corrective actions that can maintain or improve the quality of surface and subsurface (septic) runoff that may otherwise impact water quality.**

- Pipeline: Summer 2008. Vol. 19, No. 1. Septic Systems and Source Water Protection: Homeowners can help improved community water quality.
http://www.nesc.wvu.edu/pdf/WW/publications/pipline/PL_SU08.pdf
- Landscaping at the Water's Edge: an Ecological Approach. $20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824.
http://extension.unh.edu/resources/ to order a bound copy of the manual.
http://extension.unh.edu/resources/files/Resource001799_Rep2518.pdf - to downlaod an electronic, pdf, file of the entire manual.
- Integrated Landscaping: Following Nature's Lead. $20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824.
http://extension.unh.edu/resources/
- The Best Plants for New Hampshire Gardens and Landscapes - How to Choose Annuals, Perennials, Small Trees & Shrubs to Thrive in Your Garden. University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824.
http://extension.unh.edu/resources/
- Buffers for Wetlands and Surface Waters: A Guidebook for New Hampshire Municipalities. Audubon Society of New Hampshire. 1997.
http://www.nh.gov/oep/resourcelibrary/referencelibrary/b/buffers/documents/handbook.pdf
- New Hampshire Homeowner's Guide to Stormwater Management: Do-It-Yourself Stormwater Solutions for Your Home. March 2011. New Hampshire Department of Environmental Services. 29 Hazen Drive. Concord NH 03301.
http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/wd-11-11.pdf

# Great East Lake
# 2010 Executive Summary

Water quality data were collected by the Great East Lake volunteer monitors between May 2 and September 23, 2010 at four in-lake sampling locations (Figure 9). Supplemental water quality data were collected by the University of New Hampshire **Center for Freshwater Biology** on September 9, 2010 at the deep sampling sites, Sites 1 Center, 2 Canal Basin, 3 Maine Mann and in the 2nd Basin. Generally speaking, the 2010 Great East Lake water quality remained excellent as summarized in Table 2. The Great East Lake water transparency was high and averaged 28.9 feet (8.8 meters) among the three deep, open water, sampling stations while the average chlorophyll *a* concentration (a measure of microscopic plant "algal" growth) and the 2010 total phosphorus concentrations were generally low and generally remained within the range considered typical of an unproductive "pristine" New Hampshire Lake (Table 2).

**Table 2: 2010 Great East Lake Seasonal Average Water Quality Readings and Water Quality Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.**

| Parameter | Oligotrophic "Pristine" | Mesotrophic "Transitional" | Eutrophic "Enriched" | Great East Lake Average (range) | Great East Lake Classification |
|---|---|---|---|---|---|
| **Water Clarity (meters)** | > 4.0 | 2.5 - 4.0 | < 2.5 | 8.8 meters (range: 4.5 – 11.8) | Oligotrophic |
| **Chlorophyll a (ppb)** | < 3.0 | 3.0 - 7.0 | > 7.0 | 1.4 ppb (range: 0.4 – 4.2) | Oligotrophic |
| **Phosphorus (ppb)** | < 15.0 | 15.0 - 25.0 | > 25.0 | * 7.0 ppb (range: 3.2 – 14.1) | Oligotrophic |

* *Total Phosphorus data reported in Table 2 were collected in the surface waters (epilimnion) by the volunteer monitors.*

The following section discusses the 2010 and historical Great East Lake water quality data. *Refer to Appendix D for a complete listing of the 2010 Great East Lake water quality data and refer to Appendix E for an overview of the Box and Whisker plots that are referenced in this section.*

1) **Water Clarity (measured as Secchi Disk transparency)** – The 2010 Great East Lake water clarity values were consistently visible in excess of 4 meters, that is considered the boundary between an unproductive "pristine" and more nutrient enriched "transitional" New Hampshire lake, at the four sampling stations: Sites 1 Center, 2 Canal Basin, 3 Maine Mann and the 2nd Basin (Table 3 and Appendix A).

**Table 3: 2010 Water Clarity data summary for the Great East Lake deep sampling stations.**

| Site | Seasonal Average Water Transparency (meters) |
|---|---|
| 1 Center | 10.3 meters (range: 9.1 – 11.8) |
| 2 Canal | 9.9 meters (range: 8.0 – 11.5) |
| 3 MMann | 9.6 meters (range: 8.5 – 10.8) |
| 2nd Basin | 5.4 meters (range: 4.5 – 5.8) |

An inter-site comparison among the four Great East Lake sampling locations, Sites 1 Center, 2 Canal, 3 Maine Mann and the 2nd Basin, indicates the water was clearer at the more open water centrally located sampling sites, Site 1 Center, 2 Canal and 3 Maine Mann relative to the most embayed of the sampling sites, the 2nd Basin (Figure 10).

The 2010 Great East Lake, Sites 1 Center, 2 Canal Basin, 3 Maine Mann and 2nd Basin, Secchi Disk transparency data generally remained within the range of historical water quality measurements that have been documented since volunteer water quality was instituted on Great East Lake in 1987 (Appendix B). The 2010 sampling season included a new water transparency maximum of 10.8 meters documented at Site 3 Maine Mann on May 20.

**2) Microscopic plant, algal, abundance "greenness" (measured as chlorophyll *a*)** – The 2010 Great East Lake chlorophyll *a* concentrations generally remained below the concentration of 3 parts per billion (ppb) that is considered the boundary between a nutrient poor and more nutrient enriched "green-"greener" lake (Appendix A). Only the 2nd Basin sampling location, the most embayed of the sampling sites, included chlorophyll *a* concentrations that reached levels considered more typical of a moderately productive, greener, lake (Tables 2 & 4 and Appendix A).

**Table 4: 2010 Chlorophyll *a* data summary for the Great East Lake deep sampling stations.**

| Site | Seasonal Average Chlorophyll *a* (ppb) |
|---|---|
| 1 Center | 1.1 ppb (range: 0.4 – 1.6) |
| 2 Canal | 1.0 ppb (range: 0.6 – 1.6) |
| 3 Mmann | 1.3 ppb (range: 0.8 – 2.4) |
| 2nd Basin | 2.1 ppb (range: 0.5 – 4.2) |

An inter-site comparison among the four Great East Lake sampling locations indicates the median chlorophyll *a* concentrations were lower (i.e. less algal greenness) at Sites 1 Center, 2 Canal and 3 MMann and highest (i.e. greenest water) at the 2nd Basin sampling location (Figure 11).

The 2010 median chlorophyll *a* concentration documented at Sites 1 Center, 2 Canal Basin, 3 Maine Mann and 2nd Basin generally remained within the range of historical values documented since volunteer water quality monitoring was initiated on Great East Lake in 1987 (Appendix B). However, a new chlorophyll *a* minimum was documented in the 2nd Basin on August 10, 2010.

**3) Background (dissolved) water color : often perceived as a "tea" color in more highly stained lakes** – The 2010 Great East Lake dissolved color concentration averaged 13.8 chloroplatinate units (cpu) and fell within the classification of a slightly "tea" colored lake (Table 5). Dissolved color, or true color as it is sometimes called, is indicative of dissolved organic carbon levels in the water (a by-product of microbial decomposition). Small increases in water color from the natural breakdown of plant materials in and around a lake are not considered to be detrimental to water quality. However, increased

**Table 5. Dissolved Color Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.**

| Range | Classification |
|---|---|
| 0 - 10 | Clear |
| 10 - 20 | Slightly colored |
| 20 - 40 | Light tea color |
| 40 - 80 | Tea colored |
| > 80 | Highly tea colored |

color can lower water transparency, and hence, change the public perception of water quality.

**4) Total Phosphorus: the nutrient considered most responsible for elevated microscopic plant growth in our New Hampshire Lakes.** - Total phosphorus concentrations, measured in the surface waters (epilimnion), were generally low to moderate when measured by the Great East Lake volunteer monitors during the 2010 sampling season and ranged from 3.2 to 14.1 parts per billion; ppb (Tables 2 and 6). The 2010 Great East Lake total phosphorus concentrations were generally below the concentration of 10 ppb that is considered to stimulate a short term algal bloom. Higher total phosphorus concentrations were documented in the more embayed, 2nd Basin, sampling station relative to the other sites (Table 6 and Figure 12).

**Table 6: 2010 Total Phosphorus data summary for the Great East Lake deep sampling stations.**

| Site | Seasonal Average Total Phosphorus (ppb) |
|---|---|
| 1 Center | 5.7 ppb (4.3 – 7.4) |
| 2 Canal | 6.5 ppb (4.3 – 9.4) |
| 3 MMann | 5.8 ppb (3.2 – 8.0) |
| 2nd Basin | 10.2 ppb (6.5 – 14.1) |

**5) Resistance against acid precipitation (measured as total alkalinity)** – The 2010 Great East Lake alkalinity of 6.7 milligrams per liter (mg/l) is characteristic of a lake with a moderate vulnerability to acid precipitation according to the standards developed by the New Hampshire Department of Environmental Services (Table 7). Generally speaking, the geology of the region does not contain the mineral content (e.g. limestone) which increases the buffering capacity in our surface waters. Thus, lakes in the vicinity (i.e. Ossipee Lake and Wentworth Lake) have naturally low alkalinities.

**Table 7. Alkalinity Classification Criteria used by the New Hampshire Department of Environmental Services**

| Range | Classification |
|---|---|
| < 0 | Acidified |
| 0 -2 | Extremely Vulnerable |
| 2.1 - 10.0 | Moderately Vulnerable |
| 10.1 - 25.0 | Low Vulnerability |
| > 25.0 | Not Vulnerable |

**6) Dissolved salts: measured as specific conductivity** – Specific Conductivity levels, documented in Great East Lake were low and ranged from 64.0 to 66.0 micro-Siemans (*u*S) when measured at the deep, open water, sampling stations: Sites 1 Center, 2 Canal and 3 Maine Mann (Appendix D). Specific Conductivity was more variable at the more encoved 2nd Basin sampling location where the specific conductivity ranged from 65.0 to 70.0 *u*S and increased near the lakebottom. High specific conductivity values can be an indication of problem areas around a lake where failing septic systems, heavy fertilizer applications and sedimentation contribute "excessive" nutrients that make their way into Great East Lake. High specific conductivity values can also be associated with road salt runoff that is flushed into our New Hampshire Lakes.

**7) Temperature and dissolved oxygen profiles** – Temperature profiles collected by the volunteer monitors indicate Great East Lake becomes stratified into three distinct thermal layers during the summer months; a warm upper water layer, the **epilimnion**, overlies and a deep cold-water layer, the **hypolimnion.** The upper and lower layers are separated by a zone of rapidly decreasing temperatures, the **thermocline.** The formation of thermal stratification limits the replenishment of oxygen in the deeper waters and under adverse conditions can result in oxygen depletion near the lake-bottom.

**Dissolved oxygen concentrations required for a healthy fishery** – The Great East Lake dissolved oxygen concentrations, documented by the **Center for Freshwater Biology** and the volunteer monitors, became reduced below 5 milligrams per liter (mg/l) near the lakebottom by late July/Early August (Appendix C). A dissolved oxygen concentration of 5 mg/l is commonly considered the minimum oxygen concentration required for the successful growth and reproduction of most coldwater fish that include the rainbow trout and brown trout. The dissolved oxygen concentrations became reduced below 5 mg/l in the entire **hypolimnion** of Site 1 Center by early September and may have restricted the cold water fishery to the upper reaches of the hypolimnion and into the metalimnion. While oxygen concentrations were marginal for the cold water fishery late in the summer, the cold metalimnetic waters remained well oxygenated and were capable of supporting the salmonoid population.

**8)** Based on the current and historical water quality data, Great East Lake would be considered an unproductive "pristine" New Hampshire lake. A first step towards preserving the high water quality characteristic of Great East Lake is to take action at the local level and do your part to minimize the number of pollutants (particularly sediment and the nutrient phosphorus) that enter the lake. Refer to the sections, "10 Recommendations for Healthy Lakeshore and Streamside Living", "Go with the Flow: Understanding how water moves onto, through and away from your house site" and "Lake Friendly Lawn Care", that discuss measures landowners can take to improve water quality.

# COMMENTS AND RECOMMENDATIONS

1) We recommend that each participating lake association, including the Great East Lake Association, continue to develop its database on lake water quality through continuation of the long-term monitoring program. The database currently provides information on the short-term and long-term cyclic variability that occurs in Great East Lake while continued monitoring would enable more reliable predictions of both short-term and long-term water quality trends.

2) We suggest interested residents and public officials review the Salmon Falls Headwater Lakes Watershed Management Plan, http://www.awwatersheds.org/images/stories/SFHeadwaterLakesWMP_April2010.pdf. The document includes a summary of the Great East Lake water quality, identifies threats to Great East Lake and provides suggestions aimed at minimizing future water quality degradation through a watershed management approach that encompases the entire Great East Lake drainage basin.

3) We recommend continued early season sampling (April/May) to document Great East Lake's reaction to the nutrient and acid loadings that typically occur during and after spring thaw. Sampling should include alkalinity, chlorophyll *a*, dissolved color, Secchi Disk transparency and total phosphorus measurements.

4) Frequent "weekly" water quality samples, necessary to assess the current condition of Great East Lake, should continue to be collected whenever possible. Continued sampling of chlorophyll *a*, Secchi Disk transparency, dissolved color, alkalinity and total phosphorus samples will be useful to track variations in nutrient loading during the summer months.

5) Some lakes have expanded their monitoring programs to include supplemental near-shore sampling locations that would help screen for problem areas and, when problems are identified, would help target resources (i.e. money and volunteer hours) to the most critical areas within the watershed where future monitoring and corrective efforts should be directed. Expanded water quality monitoring could be as simple as collecting additional near-shore/tributary total phosphorus or chlorophyll *a* samples or expanded water quality monitoring could involve the collection of additional water quality parameters such as dissolved oxygen and specific conductivity measurements. Advanced water quality monitoring efforts might also include more in-depth shoreline/watershed surveys aimed at visually identifying the land-use patterns and potential problem areas within the drainage basin. If you are interested in discussing additional water

quality monitoring options that would meet your needs please contact Bob Craycraft @ 862-3696 or via email, bob.craycraft@unh.edu.

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# REPORT FIGURES

# INTRODUCTION

## *The New Hampshire Lakes Lay Monitoring Program*

The 2010 sampling season marked the thirty-second anniversary for the **NH Lakes Lay Monitoring Program (LLMP).** The **LLMP** has grown from a university class project on Chocorua Lake and pilot study on the Squam Lakes to a comprehensive state-wide program with over 500 volunteer monitors and more than 100 lakes participating. Originally developed to establish a database for determining long-term trends of lake water quality for science and management, the program has expanded by taking advantage of the many resources that citizen monitors can provide (Figure 1).

**Figure 1. LLMP Objectives**

**LLMP OBJECTIVES:**

***Baseline Lake Water Quality Info- for Change and Trends***
***Lake Volunteer Monitoring Training***
***Shoreline & Watershed Surveys***
***Survey for Non-Native Species***
***Tie-In with Youth & Adult Education***

The **NH LLMP** has gained an international reputation as a successful cooperative monitoring, education and research program. Current projects include: the use of volunteer generated data for non-point pollution studies using high tech analysis system (Geographic Information Systems and Satellite Remote Sensing), and intensive watershed monitoring for the development of watershed nutrient budgets, investigations of water quality impacts, including the formation of blue green bacteria blooms, associated with land use changes.

The key ingredients responsible for the success of the program include innovative cost share funding and cost reduction, assurance of credible data, practical sampling protocols and, most importantly, the interest and motivation of our volunteer monitors.

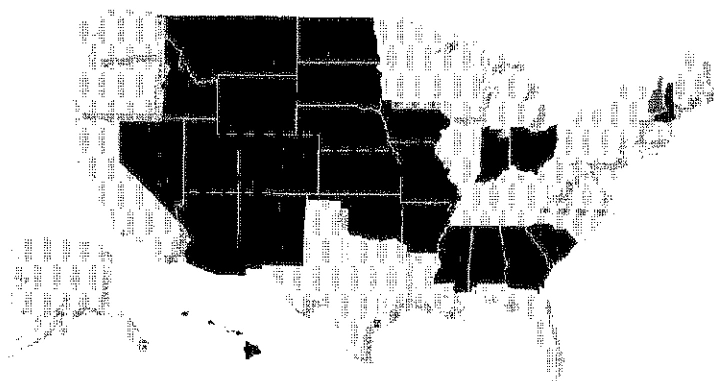
**Table 8. Awards & Recognition**

1983- NH Environmental Law Council Award
1984- Governor's Volunteer Award
1985- CNN Science & Technology Today
1988- Governor's "Gift" award funded
1990- NH Journal TV coverage NHPTV
1991- Renew America Award
Environmental Success Index
White House Reception / Briefing
1992- EPA Administrators Award
1993- NH Lakes Association Award
1994- EPA Office of Watersheds Award
1995- Winnipesaukee Watershed Project
1998- Governor's Proclamation for 20th Anniversary
1999- EPA Watershed Academy Host
2001- Lake Chocorua Project highlighted at national conferences (invited presentations)
2002- Chocorua Project receives Technical Excellence Award from the North American Lake Management Society
2003- UNH CE Maynard and Audrey Heckel Extension Fellowship awarded to LLMP
2004- Participatory Research Model of NH LLMP highlighted at National Water Quality Monitoring Conference
2005- LLMP Coordinator J. Schloss receives the prestigious Secchi Disk Award from the North American Lakes Management Society
2007- Lake friendly landscaping manual introduced receives praise from New Hampshire agencies and waterfront landowners.
2008- NH LLMP's 30th year of sampling NH lakes!
2009- EPA Equipment support grant to the NH LLMP.
2010- NH LLMP becomes first citizen program to monitor cyanotoxins

The 2010 sampling season was another exciting year for the **New Hampshire Lakes Lay Monitoring Program.** National recognition for the high quality of work by you, the volunteer monitors, culminated with program awards, requests for program information and invitations to speak at national conferences (Table 8).

**Figure 2. National LLMP Support to Volunteer Monitoring Programs**

NH LLMP Directly inolved with the Initiation, Expansion or Support of Volunteer Programs in 24 States.



Light gray shading denotes LLMP assisted states

The NH LLMP and its long-term database has been instrumental in supporting the efforts of NH DES and lake communities across New Hampshire in setting nutrient goals for various lake watersheds. Besides our continued worked with the Newfound Lakes Region Association (highlighted in last year's reports) we have been heavily involved with work on the Winnipesaukee Watershed Project, collaborating with the Lake Winnipesaukee Association and the Lakes Region Planning Commission, as well as the communities of Meredith, Laconia and Guilford (see http://winnipesaukeegateway.org/about/ ) We are also excited by the continued results of teaming up students, educators and local lake residents through our Multidisciplinary Lakes Management course and our summer Watershed Ecology course that are held annually (the course for educators, community leaders and other interested persons). Some of the lake management recommendations made as part of the student coursework requirements have been successfully implemented by lake associations.

Our active collaboration with the UNH Center for Freshwater Biology continues to drive relevant applied research: The CFB was involved in supporting the zooplankton analysis for regional and national lake surveys.

We continue the research initiated by collaborators Dr. John Sasner and Dr. Jim Haney focusing on how watershed development and our activities on the landscape play a role in creating potentially toxic plankton blooms. Analogous to the 'red tide" of estuaries, certain blue-green bacteria (microscopic bacteria that are very much like algae) can produce toxins that are heath risks to animals and humans.

Additional ongoing research is focusing on the use of satellite and aerial imagery as well as on-lake optical devices as a means of determining the water transparency and amount of microscopic plant "algal" growth in our New Hampshire Lakes, particularly blue green algae. Water quality data, collected by the volunteer monitors, have served as ground truthed data to assess whether or not the satellite imagery shows promise. Data generated through this project have been presented at national conferences and are testament to the high quality data generated by our volunteer monitors.

Recent interest in the success of our NH LLMP participatory science research model has resulted in invited presentations at national conferences and provided the basis of a series of articles in the Volunteer Monitor, the national newsletter with a distribution of over 10,000. We continue to be listed as a model citizen-monitoring program on the Environmental Success Index of Renew America, the Environmental Network Clearinghouse and the National Awards Council for Environmental Sustainability. To date, the approach and methods of the **NH LLMP** have been adopted by new or existing programs in twenty-four states and eleven countries (Figure 2)!

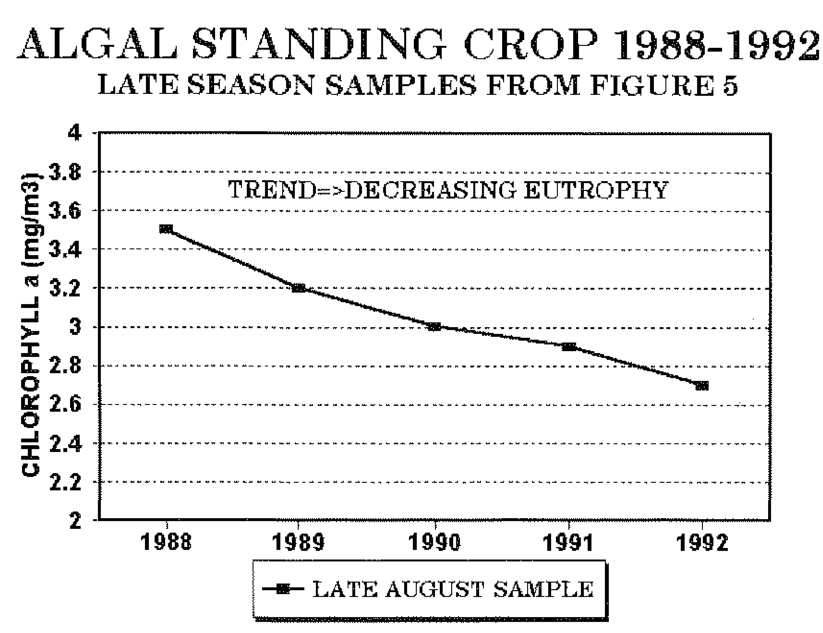
## *Importance of Long-term Monitoring*

A major goal of our monitoring program is to identify any short or long-term changes in the water quality of the lake. Of major concern is the detection of cultural eutrophication: increases in the productivity of the lake, the amount of algae and plant growth, due to the addition of nutrients from human activities. Changes in the natural buffering capacity of the lakes in the program is also a topic of great concern, as New Hampshire receives large amounts of acid precipitation, yet most of our lakes contain little mineral content to neutralize this type of pollution.

For over two decades, weekly data collected from lakes participating in the **New Hampshire Lakes Lay Monitoring Program** have indicated there is quite a variation in water quality indicators through the open water season (April through November) on the majority of lakes. Short-term differences may be due to variations in weather, lake use, or other chance events. Monthly sampling of a lake during a single summer provides some useful information, but there is a greater chance that important short-term events such as algal blooms or the lake's response to storm run-off will be missed. These short-term fluctuations may be unrelated to the actual long-term trend of a lake or they may be indicative of the changing status or "health" of a lake.

Consider the hypothetical data depicted in Figure 3. Limiting sampling of only once a year during August, from 1988 to 1992, produced a plot suggesting a decrease in eutrophication. However, the actual long-term term trend of the lake, increasing eutrophication, can only be clearly discerned by frequent sampling over a ten-year period (Figure 4). In this instance, the information necessary to distinguish between short-term fluctuations, the "noise", and long-term trends, the actual "signal", could only be accomplished through the

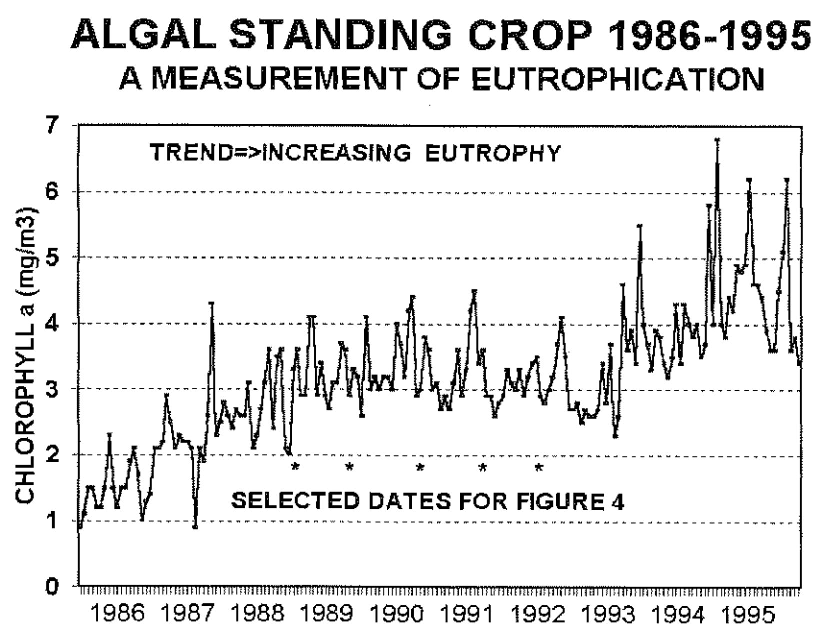
**Figure 3.**



frequent collection of water quality data over many years. To that end, the establishment of a long-term database was essential to determining trends in water quality.

The number of seasons it takes to distinguish between the "noise" and the signal is not the same for each lake. Evaluation and interpretation of a long-term database will indicate that the water quality of the lake has worsened, improved, or remained the same. In addition, different areas of a lake may show a different response. As more data are collected, predictions of current and future trends can be made. No matter what the outcome, this information is essential for the intelligent management of your lake.

Figure 4




There are also short-term uses for lay monitoring data. The examination of different stations in a lake can disclose the location of specific problems and corrective action can be initiated to handle the situation before it becomes more serious. On a lighter note, some associations post their weekly data for use in determining the best depths for finding fish!

It takes a considerable amount of effort as well as a deep concern for one's lake to be a volunteer in the **NH Lakes Lay Monitoring Program**. Many times a monitor has to brave inclement weather or heavy boat traffic to collect samples. Sometimes it seems that one week's data does not differ from the next week's data, but every sampling provides important information on the variability of the lake.

We are pleased with the interest and commitment of our Lay Monitors and are proud that their work is what makes the **NH LLMP** the most extensive, and we believe, the best volunteer program of its kind.

## *Purpose and Scope of This Effort*

The primary purpose of annual lake reporting is to discuss results of the current monitoring season with emphasis on current conditions of New Hampshire lakes including the extent of eutrophication and the lakes' susceptibility to increasing acid precipitation. If you have additional water quality concerns, we advise the lake association to contact our program staff to discuss additional monitoring options. When applicable we also strive to place the recent results into a historical context using past NH LLMP data as well as historical data from other sources. This information is part of a large data base of historical and more recent data compiled and entered onto our computer files for New Hampshire lakes that include New Hampshire Fish and Game surveys of the 1930's through the 1950's, the surveys conducted by the New Hampshire Water Supply and Pollution Control Commission and the **UNH CFB/FBG** surveys. However, care must be taken when comparing current results with early studies. Many complications arise due to methodological differences of the various analytical facilities and technological improvements in testing.

# Climatic Summary - 2010

### *Water Quality and the Weather*

Water quality variations are commonly observed over the course of the year and among years in our New Hampshire lakes, ponds, wetlands and streams. The most commonly noticed changes are those associated with decreasing water clarities, increasing algal growth (greenness), and increasing plant growth around the lake's periphery. Over the long haul, changes such as these are attributed to a lake's natural aging process that is referred to as **eutrophication**. However, short-term water quality changes such as those mentioned above are often encountered even in our most pristine lakes and ponds. These water quality changes often coincide with variations in weather patterns such as precipitation and temperature fluctuations, and even variations in the sunlight intensity which can accelerate or suppress the photosynthetic process.

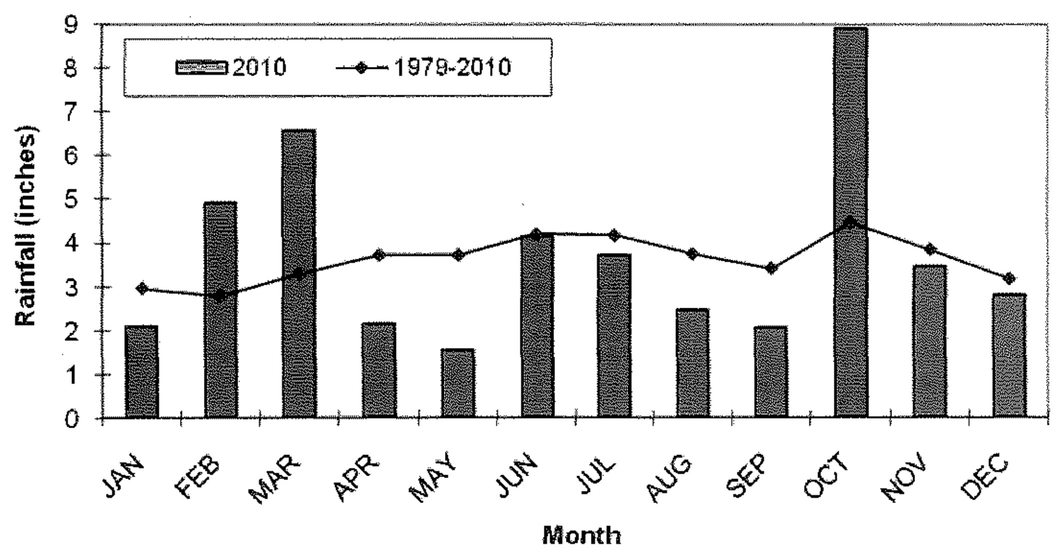
Climatic "swings" can have a profound effect on water quality, sometimes positive and other times negative. For instance, 1996 was a wet year relative to other years of LLMP water quality monitoring. The wet conditions translated into reduced water clarities, elevated microscopic plant "algal" growth and increased total phosphorus concentrations for most participating LLMP lakes. "Excessive" runoff associated with wet periods often facilitates the transport of pollutants such as nutrients (including phosphorus), sediment, dissolved colored compounds, as well as toxic materials such as herbicides, automotive oils, etc. into water bodies. As a result, lakes often respond with shallower water clarities and elevated algal abundance (greenness) during these periods as evidence by historical monitoring through the NH LLMP. Similarly, short-term storm events can have a profound effect on the water quality. Take for instance the "100 year storm" (October 21-22, 1996) that blanketed southern New Hampshire with approximately 6 inches of rain over a 30-hour period. This storm resulted in increased sedimentation and organic matter loading into our lakes as materials were flushed into the water bodies from the adjacent uplands. More recently, an August 11, 2008 precipitation event (1.91") included turbidity (particulate debris) and total phosphorus (nutrient) concentrations that were elevated nearly two orders of magnitude (100x) above baseline concentrations in Newfound Lake tributary inlets. While events such as the October 1996 and the August 2008 storms are short lived, they can have a profound effect on our water quality in the weeks to months that follow, particularly when nutrients that stimulate plant growth are retained in the lake. They also highlight the importance of low impact development practices to minimize the storm water loadings that occur after significant storms.

**NH LLMP** data collected during dry years such as 1985 and 2001, on the other hand, have coincided with improved water quality for many New Hampshire lakes. Reduced pollutant transport into the lake often results in higher water quality measured as deeper water transparencies, lower microscopic plant "algae" concentrations and lower nutrient concentrations. Do all lakes experience poorer water quality as a result of heavy precipitation events? Simply stated, the answer is no. While most New Hampshire lakes are characterized by reduced water clarities, increased nutrients and elevated plant "algal" concentrations following periods, or years, of heavy precipitation, a handful of lakes actually benefit from these types of events. The water bodies that improve during wet periods are generally lakes characterized by high nutrient concentrations and high "algal" concentrations that are diluted by watershed runoff and thus benefit during periods, or years, of heavy rainfall. However, these more nutrient enriched lakes remain susceptible to nutrients entering the lake from seepage sources such as poorly functioning septic systems.

**Precipitation (2010)**

The 2010 annual precipitation (reported as "rainfall" water equivalent) measured 44.81 inches and was slightly higher than the 32 year, 1979-2010, average of 43.42 inches (note: precipitation data are reported for the Lakeport 2 Climatological sampling station located in Laconia New Hampshire: 43°33'N and 71°28'W). 2010 began with below average January rainfall that was followed by atypically wet conditions in February and March (Figure 5). The spring and summer weather pattern was characterized by below average precipitation with greater than one-inch below average rainfall in April, May, August and September and near-average precipitation during the months of June and July. Wet conditions returned in September when the monthly rainfall of 8.91" was

**Figure 5: Lakeport 2 Climatological Sampling Station (Laconia, NH)**
**Monthly Precipitation (1979-2010)**



nearly double the long term-average of 4.46" (1979-2010). The year closed out with near to slightly below above average rainfall during the months of November and December.

**Temperature (2010)**

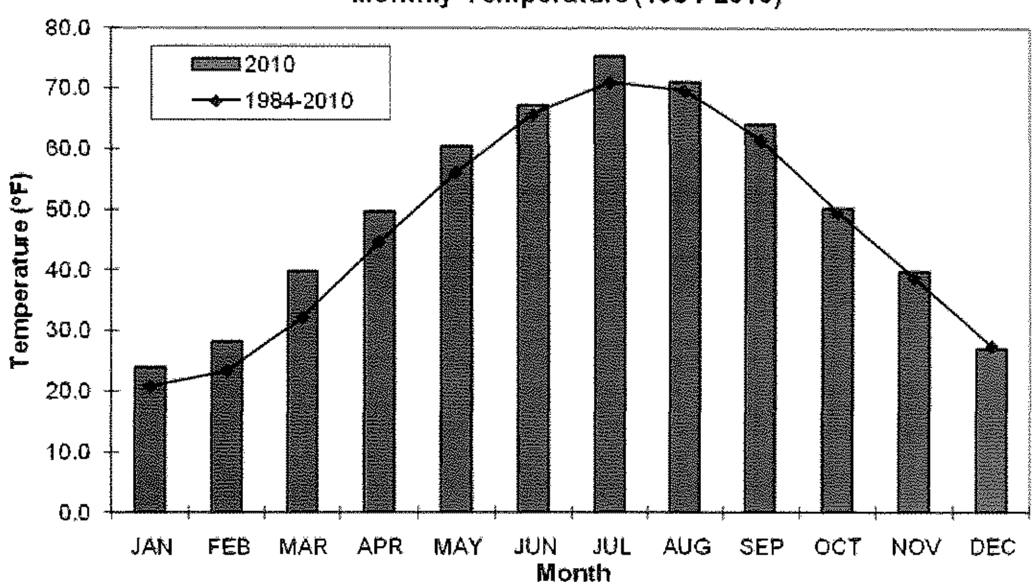
Similar to the impact of precipitation extremes, temperature extremes can have far reaching effects on the water quality, particularly early in the year and during the summer months. Atypically cold winter periods can promote the accumulation of snowpack while atypically warm periods can account for a rapid snowpack melt resulting in flooding and a massive influx of materials (e.g. nutrients, sediments) into our lakes during the late winter and early spring months. Early spring runoff periods coincide with minimal vegetative cover (that acts as a pollutant filter and soil stabilizer) and thus leaves the landscape highly susceptible to erosion. As we progress into the summer months, atypically warm periods can enhance both microscopic "algal" and macroscopic aquatic "weed" plant growth. During the summer growing season, above average temperatures often result in algal blooms that can reach nuisance proportions under optimal conditions. These nuisance blooms can include surface algal "scums" that cover the lake and wash up on the windward lakeshores.

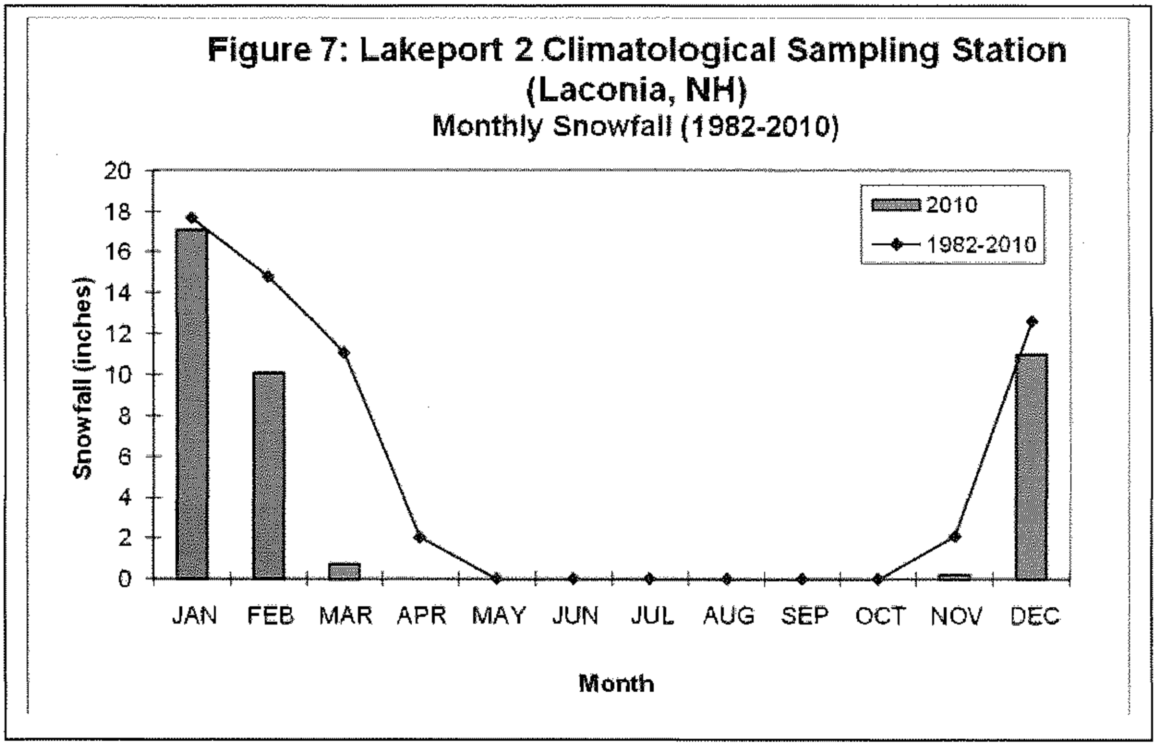
During years such as 1994 and 1995, when above average temperatures exemplified the summer months, participating **NH LLMP** lakes were generally characterized by increased algal concentrations, particularly in the shallows, where filamentous cotton-candy-like clouds of algae (i.e. Mougeotia) flourished. Other **NH LLMP** lakes had increased algal growth (greenness) and shallower water transparencies during these "hot" periods.

The average January, February and March, 2010 monthly temperatures

**Figure 6: Lakeport 2 Climatological Sampling Station (Laconia, NH)**

Monthly Temperature (1984-2010)






were over five degrees warmer than the twenty-seven year (1984-2010) monthly average at the Lakeport 2 Climatological sampling station (Figure 6). The lack of significant snowpack accumulation during the winter months, partially associated with the above average temperature (Figures 6 & 7), resulted in short-term periods of heavy watershed runoff during the months of February, March and April. Above average temperatures continued into the months of April through September and contributed to elevated in-lake water temperatures during the summer months that can be conductive to microscopic plant "algal" growth.

## *Water Quality Impacts*

### Water Transparency and Dissolved "tea" Colored Water

As previously mentioned, shallower water transparency readings are characteristic of most New Hampshire lakes during wet years and following short term precipitation events. Wet periods often coincide with greater concentrations of dissolved "tea" colored compounds (dissolved organic matter resulting from the breakdown of vegetation and soils) washed in from surrounding forests and wetlands. Dissolved water color is not indicative of water quality problems (although large increases in dissolved color sometimes follow large land clearing operations) but in some of our more pristine program lakes, it nevertheless has a large effect on water clarity changes. Data collected by the **Center for Freshwater Biology (CFB)** since 1985 indicate most lakes are characterized by higher dissolved "tea" colored water during wet years relative to years more typical in terms of annual precipitation levels. In some of our more highly "tea" colored lakes the early spring months are also characterized by higher dissolved color concentrations, relative to mid-summer levels, due to the heavy runoff periods that flush highly colored water into our lakes during the period of spring snowmelt and following heavy spring rains.

**Sediment Loading**

Sediments are continuously flushed into our lakes and ponds during periods of heavy watershed runoff, particularly during snowmelt and again during and following sporadic storm events during the summer and fall months. Many New Hampshire lakes experience water clarity decreases following storm events such as those described above. Lakes, ponds and rivers are particularly susceptible to sediment loadings in the early spring months when vegetated shoreline buffers, often referred to as riparian buffers, are reduced. With limited vegetation to trap sediments and suspended materials, a high percentage of the particulate debris and dissolved materials are flushed into the lake. Human activities such as logging, agriculture, construction and land clearing can also increase sediment displacement during and following heavy storm events throughout the year. As sediment is transported into surface waters it can degrade water quality in a number of ways. When fine sediments (silt) enter a lake they tend to remain in the water column for relatively long periods of time. These suspended sediments can be abrasive to fish gills, ultimately leading to fish kills. Suspended sediments also reduce the available light necessary for plant growth that can result in plant die-offs and the subsequent oxygen depletion under extreme conditions.

As sediments settle out of the water column they can smother bottom dwelling aquatic organisms and fish spawning habitat. As the dead materials begin to decay the result can be noxious odors as well as stimulation of nuisance plant growth (i.e. scums along the lake-bottom; new macroscopic plant growth). Note: one should keep in mind that nuisance plants such as water milfoil (Myriophyllum heterophyllum) will generally regenerate more rapidly than more favorable plant forms. This can result in more problematic weed beds than those present before the disturbance. Habitat changes associated with the accumulation of fine sediments and associated "muck" might also favor increased nuisance plant growth in the future. Another unfavorable attribute of sediment loading is that the sediments tend to carry with them other forms of contaminants such as pathogens, nutrients and toxic chemicals (i.e. herbicides and pesticides).

Early symptoms of excessive sediment runoff include deposits of fine material along the lake-bottom, particularly in close proximity to tributary inlets and disturbed regions previously discussed (i.e. construction sites, logging sites, etc.). Silt may be visible covering rocks or aquatic vegetation along the lake-bottom. During periods of heavy overland runoff the water might appear brown and turbid which reflects the sediment load. As material collects along the lake-bottom you might notice a change in the weed composition reflecting a change in the substrate type (note: aquatic plants will display natural changes in abundance and distribution, so be careful not to jump to hasty conclusions). If excessive sediment loading is suspected, take a closer look in these areas and assess whether or not the change is associated with sediment loading (look for the warning signs discussed above) or whether the changes might be attributable to other factors.

**Nutrient Loading**

Nutrient loading is often greatest during heavy precipitation events, particularly during the periods of heavy watershed runoff. Phosphorus is generally considered the limiting nutrient for excessive plant and algal growth in New Hampshire lakes. Elevated phosphorus concentrations are generally most visible when documented in our tributary inlets where nutrients are concentrated in a relatively small volume of water. Much of the phosphorus entering our lakes is attached to particulate matter (i.e. sediments, vegetative debris), but may also include dissolved phosphorus associated with fertilizer applications and septic system discharge.

**Microscopic "Algal" and Macroscopic "Weed" Plant Growth**

Historical **Lakes Lay Monitoring Program** data indicate most lakes experience "algal blooms" during years with above average summer temperatures (June, July and August) while years with heavy precipitation are also associated with an increased frequency and occurrence of "algal blooms." Algal blooms are often green water events associated with decreases in water clarity due to their ability to absorb and scatter light within the water column, but can also accumulate near the lake bottom in shallow areas as "mats" or on the water surface as "scums" and "clouds." During some years, such as 1996, the "algal blooms" are predominantly green water events composed of algae distributed within the water column. New Hampshire lakes were particularly susceptible to algal blooms in 1996 as a function of the heavy runoff associated with an atypically wet year. Wet years such as 1996 can be particularly hard on lakes where excessive fertilizer applications, agricultural practices and construction activities favor the displacement of nutrients into surface waters. The occasional formation of certain algal blooms is a naturally occurring phenomenon and is not necessarily associated with changes in lake productivity. However, increases in the occurrence of bloom conditions can be a sign of eutrophication (the "greening" of a lake). Shifts from benign (clean water) forms to nuisance (polluted water) cyanobacterial forms such as Anabaena, Aphanizomenon and Oscillatoria, can also be a warning sign that improper land use practices are contributing excessive nutrients into the lake.

Filamentous cotton-candy-like "clouds" of the nuisance green algae, Mougeotia and related species, have been well documented in 1994 and 1995 when the temperatures during the months of June and July were well above normal. These algal "clouds" often develop within nearshore weed beds where they can be seen along the lake-bottom and tend to flourish during warm periods. During cooler years, this type of algal growth is kept "in check" and generally does not reach nuisance proportions. In other lakes, metalimnetic algae, algae which tend to grow in a thin layer along the thermocline gradient in a lake's middle depths, sometimes migrate up towards the lake surface causing a "bloom" event. If these algae are predominantly "nuisance" forms, like certain green or blue-green algae, they can be an early indication of nutrient loading.

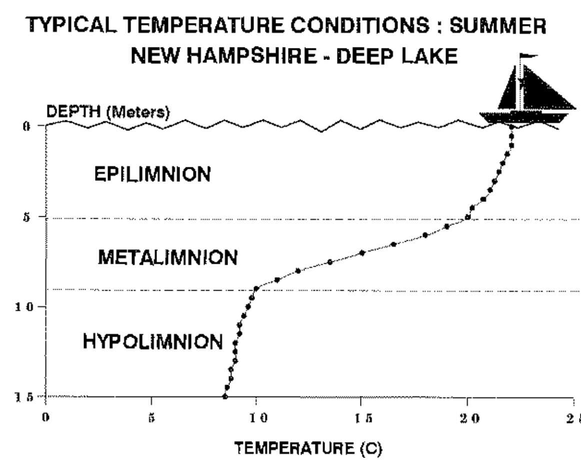
# DISCUSSION OF LAKE AND STREAM MONITORING MEASUREMENTS

The section below details the important concepts involved for the various testing procedures used in the **New Hampshire Lakes Lay Monitoring Program**. Certain tests or sampling performed at the time of the optional **Center for Freshwater Biology** field trip are indicated by an asterisk (*).

## *Thermal Stratification in the Deep Water Sites*

Lakes in New Hampshire display distinct patterns of temperature stratification, that develop as the summer months progress, where a layer of warmer water (the **epilimnion**) overlies a deeper layer of cold water (**hypolimnion**). The layer that separates the two regions characterized by a sharp drop in temperature with depth is called the **thermocline** or **metalimnion** (Figure 8). Some shallow lakes may be continually mixed by wind action and will never stratify. Other lakes may only contain a developed epilimnion and metalimnion.

**Figure 8**




## *Water Transparency*

Secchi Disk depth is a measure of the water transparency. The deeper the depth of Secchi Disk disappearance, the more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and non-living particles) to absorb and scatter it.

In the shallow areas of many lakes, the Secchi Disk will hit bottom before it is able to disappear from view (what is referred to as a "Bottom Out" condition). Thus, Secchi Disk measurements are generally taken over the deepest sites of a lake. Transparency values greater than 4 meters are typical of clear, unproductive lakes while transparency values less than 2.5 meters are generally an indication of highly productive lakes. Water transparency values between 2.5 meters and 4 meters are generally considered indicative of moderately productive lakes.

## *Chlorophyll a*

The chlorophyll *a* concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. **Eutrophic** lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Characteristics include accumulated organic matter in the lake basin and lower dissolved oxygen in the bottom waters. Summer chlorophyll *a* concentrations average above 7 mg $m^3$ (7 milligrams per cubic meter; 7 parts per billion). **Oligotrophic** lakes have low productivity and low nutrient levels and average summer chlorophyll *a* concentrations that are generally less than 3 mg $m^3$. These lakes generally have cleaner bottoms and high dissolved oxygen levels throughout. **Mesotrophic** lakes are intermediate in productivity with concentrations of chlorophyll *a* generally between 3 mg $m^3$ and 7 mg $m^3$. Testing is sometimes done to check for **metalimnetic algal populations**, algae that layer out at the thermocline and generally go undetected if only epilimnetic (point or integrated) sampling is undertaken. Chlorophyll concentrations of a water sample collected in the thermocline is compared to the integrated epilimnetic sample. Greater chlorophyll levels of the point sample, in conjunction with microscopic examination of the samples (see Phytoplankton section below), confirm the presence of such a population of algae. These populations should be monitored as they may be an early indication of increased nutrient loading into the lake.

## *Turbidity **

Turbidity is a measure of suspended material in the water column such as sediments and planktonic organisms. The greater the turbidity of a given water body the lower the Secchi Disk transparency and the greater the amount of particulate matter present. Turbidity is measured as nephelometric turbidity units (NTU), a standardized method among researchers. Turbidity levels are generally low in New Hampshire reflecting the pristine condition of the majority of our lakes and ponds. Increasing turbidity values can be an indication of increasing lake productivity or can reflect improper land use practices within the watershed which destabilize the surrounding landscape and allow sediment runoff into the lake.

While Secchi Disk measurements will integrate the clarity of the water column from the surface waters down to the depth of disappearance, turbidity measurements are collected at discrete depths from the surface down to the lake bottom. Such discrete sampling can identify layering algal populations (previously discussed) that are undetectable when measuring Secchi Disk transparency alone.

## *Dissolved Color*

The dissolved color of lakes is generally due to dissolved organic matter from **humic substances**, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters. Increases in dissolved watercolor can be an indication of increased development within the watershed as many land clearing activities (construction, deforestation, and the resulting increased run-off) add additional organic material to lakes. Natural fluctuations of dissolved color occur when storm events increase drainage from wetlands areas within the watershed. As suspended sediment is a difficult and expensive test to undertake, both dissolved color and chlorophyll information are important when interpreting the Secchi Disk transparency

Dissolved color is measured on a comparative scale that uses standard chloroplatinate dyes and is designated as a color unit or ptu. Lakes with color below 10 ptu are very clear, 10 to 20 ptu are slightly colored, 20 to 40 ptu are lightly tea colored, 40 to 80 ptu are tea colored and greater than 80 ptu indicates highly colored waters. Generally the majority of New Hampshire lakes have color between 20 to 30 ptu.

## *Total Phosphorus*

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources arise primarily through human related activity in a watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton. As little as 10 parts per billion of phosphorus in a lake can cause an algal bloom.

Generally, in the more pristine lakes, phosphorus values are higher after spring melt when the lake receives the majority of runoff from its surrounding watershed. The nutrient is used by the algae and plants which in turn die and sink to the lake bottom causing surface water phosphorus concentrations to decrease as the summer progresses. Lakes with nutrient loading from human activities and sources (agriculture, logging, sediment erosion, septic systems, etc.) will show greater concentrations of nutrients as the summer progresses or after major storm events.

## *Soluble Reactive Phosphorus **

Soluble reactive phosphorus is a fraction of the (total) phosphorus that consists largely of orthophosphate, the form of phosphorus that is directly taken up by algae and that stimulates growth. Soluble reactive phosphorus is obtained by filtering a water sample through a fine mesh filter, generally a 0.45 micron membrane filter, which effectively removes the particulate matter from the sample. Soluble reactive phosphorus concentrations are thus less than, or equal to, the measured total phosphorus concentrations for a water sample.

Soluble reactive phosphorus typically occurs in trace concentrations while applications of fertilizers as well as septic system effluent can be associated with elevated concentrations. Knowledge of both the total phosphorus and the soluble reactive phosphorus is important to understanding the sources of phosphorus into a lake and to understanding the lake's response to the phosphorus loading. For instance, a lake experiencing soluble reactive phosphorus runoff from a fertilized field may exhibit immediate water quality decline (i.e. increased algal growth) while lakes experiencing elevated total phosphorus concentrations associated with sediment washout may not exhibit clear symptoms of increased nutrient loading for years.

## *Streamflow*

Streamflow, when collected in conjunction with stream channel information, is a measure of the volume of water traversing a given stream stretch over a period of time and is often expressed as cubic meters per second. Knowledge of the streamflow is important when determining the amount of nutrients and other pollutants that enter a lake. Knowledge of the streamflow in conjunction with nutrient concentrations, for instance, will provide the information necessary to calculate phosphorus loading values and will in turn be useful in discerning the more impacted areas within a watershed.

## *pH* *

The pH is a way of expressing the acidic level of lake water, and is generally measured with an electrical probe sensitive to hydrogen ion activity. The pH scale has a range of 1 (very acidic) to 14 (very "basic" or alkaline) and is logarithmic (i.e.: changes in 1 pH unit reflect a ten times difference in hydrogen ion concentration). Most aquatic organisms tolerate a limited range of pH and most fish species require a pH of 5.5 or higher for successful growth and reproduction.

## *Alkalinity*

Alkalinity is a measure of the buffering capacity of the lake water. The higher the alkalinity value, the more acid that can be neutralized. Typically lakes in New Hampshire have low alkalinities due to the absence of carbonates and other natural buffering minerals in the bedrock and soils of lake watersheds.

Decreasing alkalinity over a period of a few years can have serious effects on the lake ecosystem. In a study on an experimental acidified lake in Canada by Schindler, gradual lowering of the pH from 6.8 to 5.0 in an 8-year period resulted in the disappearance of some aquatic species, an increase in nuisance species of algae and a decline in the condition and reproduction rate of fish. During the first year of Schindler's study the pH remained unchanged while the alkalinity declined to 20 percent of the pretreatment value. The decline in alkalinity was sufficient to trigger the disappearance of zooplankton species, which in turn caused a decline in the "condition" of fish species that fed on the zooplankton.

The analysis of alkalinity employed by the **Center for Freshwater Biology** includes use of a dilute titrant allowing an order of magnitude greater sensitivity and precision than the standard method. Two endpoints are recorded during each analysis. The first endpoint (gray color of dye; pH endpoint of 5.1 ) approximates low level alkalinity values, while the second endpoint (pink dye color; pH endpoint of 4.6) approximates the alkalinity values recorded historically, such as NH Fish and Game data, with the methyl-orange endpoint method.

The average alkalinity of lakes throughout New Hampshire is low, approximately 6.5 mg per liter (calcium carbonate alkalinity). When alkalinity falls below 2 mg per liter the pH of waters can greatly fluctuate. Alkalinity levels are most critical in the spring when acid loadings from snowmelt and run-off are high, and many aquatic species are in their early, and most susceptible, stages of their life cycle.

## *Specific Conductivity **

The specific conductance of a water sample indicates concentrations of dissolved salts. Leaking septic systems and deicing salt runoff from highways can cause high conductivity values. Fertilizers and other pollutants can also increase the conductivity of the water. Conductivity is measured in **micromhos** (the opposite of the measurement of resistance **ohms**) per centimeter, more commonly referred to as micro-Siemans (υS). Specific conductivity implies the measurements are standardizes to the equivalent room temperature reading as conductivity will increase with increasing temperature.

## *Sodium and Chloride **

Low levels of sodium and chloride are found naturally in some freshwater and groundwater systems while high sodium and chloride concentrations are characteristic of the open ocean and are elevated in estuarine systems as well. Elevated sodium and chloride concentrations in freshwater or groundwater systems, that exceed the natural baseline concentrations, are commonly associated with the application of road salt. Sodium and particularly chloride are highly mobile and, relatively speaking, move into the surface and groundwater relatively unimpeded. Sodium and chloride concentrations can become elevated during periods of heavy snow pack melt when the salts are flushed into surface waters and have also been observed in elevated concentrations during the summer months when low flow conditions concentrate the sodium and chloride.

Road salt runoff is known to adversely impact roadside vegetation as is oftentimes evidenced by bleached (discolored) leaves and needles and in more extreme instances dead trees and shrubs. The United States Environmental Protection Agency (EPA) has set the standard for protection of aquatic life, both plants and animals, at 230 milligrams per liter (mg/l). The EPA has also established a secondary maximum contaminant level of 250 mg/l for both sodium and chloride, predominantly for taste, while the sodium advisory limit for persons with hypertention is 20 mg/l

## *Dissolved Oxygen and Free Carbon Dioxide **

Oxygen is an essential component for the survival of aquatic life. Submergent plants and algae take in carbon dioxide and create oxygen through **photosynthesis** by day. **Respiration** by both animals and plants uses up oxygen continually and creates **carbon dioxide**. Dissolved oxygen profiles determine the extent of declining oxygen concentrations in the lower waters. High carbon dioxide values are indicative of low oxygen conditions and accumulating organic matter. For both gases, as the temperature of the water decreases, more gas can be dissolved in the water.

The typical pattern of clear, unproductive lakes is a slight decline in hypolimnetic oxygen as the summer progresses. Oxygen in the lower waters is important for maintaining a fit, reproducing, cold water fishery. Trout and salmon generally require oxygen concentrations above 5 mg per liter (parts per million) in the cool deep waters. On the other hand, carp and catfish can survive very low oxygen conditions. Oxygen above the lake bottom is important in limiting the release of nutrients from the sediments and minimizing the collection of undecomposed organic matter.

Bacteria, fungi and other **decomposers** in the bottom waters break down organic matter originating from the watershed or generated by the lake. This process uses up oxygen and produces carbon dioxide. In lakes where organic matter accumulation is high, oxygen depletion can occur. In highly stratified eutrophic lakes the entire hypolimnion can remain unoxygenated or **anaerobic** until fall mixing occurs.

The oxygen peaks occurring at surface and mid-lake depths during the day are quite common in many lakes. These characteristic **heterograde oxygen curves** are the result of the large amounts of oxygen, the by-product of photosynthesis, collecting in regions of high algal concentrations. If the peak occurs in the thermocline of the lake, metalimnetic algal populations (discussed above) may be present.

## *Underwater Light* *

Underwater light available to photosynthetic organisms is measured with an **underwater photometer** which is much like the light meter of a camera (only waterproofed!). The **photic zone** of a lake is the volume of water capable of supporting photosynthesis. It is generally considered to be delineated by the water's surface and the depth that light is reduced to one percent surface iridescence by the absorption and scattering properties of the lake water. The one percent depth is sometimes termed the **compensation depth**. Knowledge of light penetration is important when considering lake productivity and in studies of submerged vegetation. Discontinuity (abrupt changes in the slope) of the profiles could be due to metalimnetic layering of algae or other particulates (discussed above). The underwater photometer allows the investigator to measure light at depths below the Secchi Disk depth to supplement the water clarity information.

## *Indicator Bacteria* *

Certain disease causing organisms, pathogenic bacteria, viruses and parasites, can be spread through contact with polluted waters. Faulty septic systems, sewer leaks, combined sewer overflows and the illegal dumping of wastes from boats can contribute fecal material containing these pathogens. Typical water testing for pathogens involves the use of detecting coliform bacteria. These bacteria are not usually considered harmful themselves but they are relatively easy to detect and can be screened for quickly. Thus, they make good surrogates for the more difficult to detect pathogens.

**Total coliform** includes all coliform bacteria that arise from the gut of animals or from vegetative materials. **Fecal coliform** are those specific organisms that inhabit the gut of warm blooded animals. Another indicator organism **Fecal streptococcus** (sometimes referred to as **enterococcus**) also can be monitored. The ratio of fecal coliform to fecal strep may be useful in suggesting the type of animal source responsible for the contamination. In 1991, the State of New Hampshire changed the indicator organism of preference to *E. coli* which is a specific type of fecal coliform bacteria thought to be a better indicator of human contamination. The new state standard requires Class A "bathing waters" to be under 88 organisms (referred to as colony forming units; cfu) per 100 milliliters of lakewater.

Ducks and geese are often a common cause of high coliform concentrations at specific lake sites. While waterfowl are important components to the natural and aesthetic qualities of lakes that we all enjoy, it is poor management practice to encourage these birds by feeding them. The lake and surrounding area provides enough healthy and natural food for the birds and feeding them stale bread or crackers does nothing more than import additional nutrients into the lake and allows for increased plant growth. As birds also are a host to the parasite that causes "swimmers itch", waterfowl roosting areas offer a greater chance for infestation to occur. Thus while leaving offerings for our feathered friends is enticing, the results can prove to be detrimental to the lake system and to human health.

## *Phytoplankton* *

The planktonic community includes microbial organisms that represent diverse life forms, containing photosynthetic as well as non-photosynthetic types, and including bacteria, algae, crustaceans and insect larvae (the insect larvae and zooplankton are discussed below in separate sections). Because planktonic algae or "phytoplankton" tend to undergo rapid seasonal cycles on a time scale of days and weeks, the levels of populations found should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

The composition and concentration of phytoplankton can be indicative of the trophic status of a lake. Seasonal patterns do occur and must be considered. For example **diatoms**, tend to be most abundant in April-June and October-November, in the surface or epilimnetic layers of New Hampshire lakes. As the summer progresses, the dominant types might shift to **green algae** or **golden algae**. By late season **Blue-green bacteria** generally dominate. In nutrient rich lakes, nuisance green algae and/or bluegreen bacteria might dominate continually. After fall mixing diatoms might again be found to bloom.

## *Zooplankton* *

There are three groups of zooplankton that are generally prevalent in lakes: the **protozoa**, **rotifers** and **crustaceans**. Most research has been devoted to the last two groups although protozoa may be found in substantial amounts. Of the rotifers and the crustaceans, time and budgetary constraints usually make it necessary to sample only the larger zooplankton (macrozooplankton; larger than 80 or 150 microns; 1 million microns make up a meter). Thus, zooplankton analysis is generally restricted only to the larger crustaceans. Crustacean zooplankton are very sensitive to pollutants and are commonly used to indicate the presence of toxic substances in water. The crustaceans can be divided into two groups, the **cladocerans** (which include the "water fleas") and the **copepods**.

Macrozooplankton are an important component in the lake system. The filter feeding of the herbivorous ("grazing") species may control the population size of selected species of phytoplankton. The larger zooplankton can be an important food source for juvenile and adult planktivorous fish. All zooplankton play a part in the recycling of nutrients within the lake. Like the phytoplankton, zooplankton, tend to undergo rapid seasonal cycles. Thus, the zooplankton population density and diversity should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

## *Macroinvertebrates* *

Macroinvertebrates generally refer to the aquatic insect community living near the bottom substrate (i.e. sediments) while other invertebrate groups such as the crayfish, leeches and the aquatic worms are also included. Like the phytoplankton and zooplankton, previously discussed, the macroinvertebrates undergo seasonal cycles and are most representative of conditions for particular periods of the year. The mayflies are probably the most well known example of a seasonal aquatic macroinvertebrate as mayfly populations metamorphosize into adults as the water temperatures increase in the spring and thus giving rise to the name "mayflies". Macroinvertebrates are also sensitive to environmental conditions such as streamflow, temperature and food availability and are most representative of particular habitats along the stream continuum (i.e. some organisms prefer slower moving stream reaches while others prefer rapidly flowing waters).

Macroinvertebrates are an essential component to a healthy aquatic habitat. Macroinvertebrates help decompose organic matter entering the system such as leaves and twigs and also serve as a food source for many fish species.

While some macroinvertebrates are capable of breathing air as we do, others have gills and utilize oxygen dissolved in the water much as fish do. Macroinvertebrates also vary in their tolerance to depleting dissolved oxygen concentrations making them a good indicator of pollutants coming into the water body. The caddis flies (Trichop-tera), the mayflies (Ephemeroptera) and the stoneflies (Plecoptera) are often considered highly sensitive to pollution while the "true" flies (Diptera) are often considered highly tolerant to pollution. However, exceptions to the above categorizations are often encountered.

A variety of indices have been proposed to characterize water bodies over a gradient of pollution levels ranging from least polluted to most polluted scenarios and often designated by assigning a numerical delineator (i.e. 1 is least polluted while 10 is most polluted). Such an index, the Hilsenhoff Biotic Index (HBI), or a modification thereof, is commonly used by stream monitoring programs around the country. Macroinvertebrate data are useful in discerning the more impacted areas within the watershed where corrective efforts should be directed. Unlike chemical measurements that represent ambient conditions in the water body, the macroinvertebrate community composition integrates the water quality conditions over a longer period (months to years) and can identify "hot" spots missed by chemical sampling. If you are interested in more information regarding macroinvertebrate monitoring contact the **LLMP** coordinator.

## *Fish Condition*

The assessment of fish species "health" is another biological indicator of water quality. Because fish are at the top of the food chain, their condition should reflect not only water quality changes that affect them directly but also those changes that affect their food supply. The fish condition index utilized by the **New Hampshire Fish Condition Program** is based on two components; fish scale analysis and a fish condition index.

Like tree trunks, fish scales have annual growth rings (annuli) that reflect their growth history and hence, provide a long-term record of past conditions in the lake. The fish condition index, based upon length and weight measurements, is a good indicator of the fish's health at the time of collection.

The resulting fish condition data can be compared among different lakes or among different years, or the index for a particular species can be compared to standard length-to-weight relationships that have been developed by fisheries biologists for many important fish species. In the end, the “health” of the various fish species reflects the overall water quality in the respective lake or pond.

UNIVERSITY of NEW HAMPSHIRE
COOPERATIVE EXTENSION

# Understanding Lake Aging (Eutrophication)

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A common concern among **New Hampshire Lakes Lay Monitoring Program (NH LLMP)** participants is a perceived increase in the density and abundance of aquatic plants in the shallows, increases in the amount of microscopic plant "algae" growth (detected as greener water), and water transparency decreases; what is known as **eutrophication**. Eutrophication is a natural process by which all lakes age and progress from clear pristine lakes to green, nutrient enriched lakes on a geological time frame of thousands of years. Much like the fertilizers applied to our lawns, nutrients that enter our lakes stimulate plant growth and culminate in greener (and in turn less clear) waters. Some lakes age at a faster rate than others due to naturally occurring attributes: watershed area relative to lake area, slope of the land surrounding the lake, soil type, mean lake depth, etc. Since our New Hampshire lakes were created during the last ice-age, which ended about 10,000 years ago, we should have a natural continuum of lakes ranging from extremely pristine to very enriched.

Classification criteria are often used to categorize lakes into what are known as **trophic states**, in other words, levels of lake plant and algae productivity or "greenness" Refer to Table 9 below for a summary of commonly used eutrophication parameters.

**Table 9: Eutrophication Parameters and Categorization**

| Parameter | Oligotrophic "pristine" | Mesotrophic "transitional" | Eutrophic "enriched" |
|---|---|---|---|
| **Chlorophyll a (*ug*/l) *** | <3.0 | 3.0-7.0 | >7.0 |
| **Water Transparency (meters) *** | >4.0 | 2.5-4.0 | <2.5 |
| **Total Phosphorus (*ug*/l) *** | <15.0 | 15.0-25.0 | >25.0 |
| **Dissolved Oxygen (saturation) #** | high to moderate | moderate to low | low to zero |
| **Macroscopic Plant (Weed) Abundance** | low | moderate | high |

*** Denotes classification criteria employed by Forsberg and Ryding (1980).**
**# Denotes dissolved oxygen concentrations near the lakebottom.**

**Oligotrophic** lakes are considered "unproductive" pristine systems and are characterized by high water clarities, low nutrient concentrations, low algae concentrations, minimal levels of aquatic plant "weed" growth, and high dissolved oxygen concentrations near the lake bottom. **Eutrophic** lakes are considered "highly productive" enriched systems characterized by low water transparencies, high nutrient concentrations, high algae concentrations, large stands of aquatic plants and very low dissolved oxygen concentrations near the lake bottom. **Mesotrophic** lakes have qualities between those of oligotrophic and eutrophic lakes and are characterized by moderate water transparencies, moderate nutrient concentrations, moderate algae growth, moderate aquatic plant "weed" growth and decreasing dissolved oxygen concentrations near the lake bottom.

Is a pristine, oligotrophic, lake "better than" an enriched, eutrophic, lake? Not necessarily! As indicated above, lakes will naturally exhibit varying degrees of productivity. Some lakes will naturally be more susceptible to eutrophication than others due to their natural attributes and in turn have aged more rapidly. This is not necessarily a bad thing as our best bass fishing lakes tend to be more mesotrophic to eutrophic than oligotrophic; an ultra-oligotrophic lake (extremely pristine) will not support a very healthy cold water fishery. However, human related activities can augment the aging process (what is known as cultural eutrophication) and result in a transition from a pristine system to an enriched system in tens of years rather than the natural transitional period that should take thousands of years. Cultural eutrophication is particularly a concern for northern New England lakes where large tracts of once forested or agricultural lands are being developed, with the potential for increased sediment and nutrient loadings into our lakes, which augment the eutrophication process.

Additionally, other pollutants such as heavy metals, herbicides, insecticides and petroleum products might also affect your lake's "health". A "healthy" lake, as far as eutrophication is concerned, is one in which the various aquatic plants and animals are minimally impacted so that nutrients and other materials are processed efficiently. We can liken this process to a well-managed pasture: nutrients stimulate the growth of grasses and other plants that are eaten by grazers like cows and sheep. As long as producers and grazers are balanced, a good amount of nutrients can be processed through the system. Impact the grazers and the grass will overgrow and nuisance weeds will appear, even if nutrients remain the same. In a lake, the producers are the algae and aquatic weeds while the grazers are the microscopic animals (**zooplankton**) and aquatic insects. These organisms can be very susceptible to a wide range of pollutants at very low concentrations. If impacted, the lake can become much more productive and the fishery will be impacted as well since these same organisms are an important food source for most fish at some stage of their life.

Development upon the landscape can negatively affect water quality in a number of ways:

- <u>Removal of shore side vegetation and loss of wetlands</u> - Shore side vegetation (what is known as **riparian vegetation**) and wetlands provide a protective buffer that "traps" pollutants before reaching the lake. These buffers remove materials both chemically (through biological uptake) and physically (settling materials out). As riparian buffers are removed and wetlands lost, pollutant materials are more likely to enter the lake and in turn, favor declining water quality.

- Excessive fertilizer applications - Fertilizers entering the lake can stimulate aquatic plant and algal growth and in extreme cases result in noxious algal blooms. Increases in algal growth tend to diminish water transparency and under extreme cases culminate in surface "scums" that can wash up on the shoreline producing unpleasant smells as the material decomposes. Excessive nutrient concentrations also favor algal forms known to produce toxins, which irritate the skin and under extreme conditions, are dangerous when ingested.

- Increased organic matter loading - Organic matter (leaves, grass clippings, etc.) is a major source of nutrients in the aquatic environment. As the vegetative matter decomposes nutrients are "freed up" and can become available for aquatic plant and algal growth. In general, we are not concerned with this material entering the lake naturally (leaf senescence in the fall) but rather excessive loading of this material as occurs when residents dump or rake leaf litter and grass clippings into the lake. This material not only provides large nutrient reserves which can stimulate aquatic plant and algal growth but also makes great habitat for leaches and other potentially undesirable organisms in swimming areas.

- Septic problems - Faulty septic systems are a big concern as they can be a primary source of water pollution around our lakes. Septic systems are loaded with nutrients and can also be a health threat when not functioning properly.

- Loss of vegetative cover and the creation of impervious surfaces - A forested watershed offers the best protection against pollutant runoff. Trees and tall vegetation intercept heavy rains that can erode soils and surface materials. The roots of these plants keep the soils in place, process nutrients and absorb moisture so the soils do not wash out. Impervious surfaces (paved roads, parking lots, building roofs, etc.) reduce the water's capacity to infiltrate into the ground, and in turn, go through nature's water purification system. As water seeps into the soil, pollutants are removed from the runoff through absorption onto soil particles. Biological processes detoxify pollutants and/or immobilize substances. Surface water runoff over impervious surfaces also increases water velocities that favor the transport of a greater load of suspended and dissolved pollutants into your lake.

## *How can you minimize your water quality impacts?*

- Minimize fertilizer applications whenever possible. Most people apply far more fertilizers than necessary, with the excess eventually draining into your lake. This not only applies to those immediately adjacent to the lake but to everybody within the watershed. Pollutants in all areas of the watershed will ultimately make their way into your lake. Have your soil tested for a nominal fee (contact your county UNH Cooperative Extension Office for further information) to find out how much fertilizer and soil amendments are really needed. Sometimes just an application of crushed lime will release enough nutrients to fit the bill. If you do use fertilizer try to use low phosphorus, slow release nitrogen varieties. And remember that under the current NH Comprehensive Shoreline Protection Act (CSPA) you cannot apply any fertilizers or amendments within 25 feet of the shore.

- Don't dump leaf litter or leaves into the lake. Compost the material or take it to a proper waste disposal center. Do not fill in wetland areas. Do not create or enhance beach areas with sand (contains phosphorus, smothers aquatic habitat, fills in lake as it gets transported away by currents and wind).
- Septic systems will not function efficiently without the proper precautionary maintenance. Have your septic system inspected every two to four years and pumped out when necessary. Since the septic system is such an expensive investment often costing around $10,000 for a complete overhaul, it is advantageous to assure proper care is taken to prolong the system's life. Additionally, following proper maintenance practices will reduce water quality degradation. Refer to:

  *Pipeline: Summer 2008 Vol. 19, No. 1. Septic Systems and Source Water Protection: Homeowners can help improved community water quality.*

  http://www.nesc.wvu.edu/pdf/WW/publications/pipline/PL_SU08.pdf
- Try to landscape and re-develop with consideration of how water flows on and off your property. Divert runoff from driveways, roofs and gutters to a level vegetated area or a rain garden so the water can be slowed, filtered and hopefully absorbed as recharge. Refer to:

  *Landscaping at the Water's Edge: an Ecological Approach 2nd Edition. $20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824.*

  *Integrated Landscaping: Following Nature's Lead. $20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824.*
- Maintain shore side (riparian) vegetative cover when new construction is undertaken. For those who have pre-existing houses but lack vegetative buffers, consider shoreline plantings aimed at diminishing the pollution load into your lake. Refer to:

  *Landscaping at the Water's Edge: an Ecological Approach 2nd Edition. $20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824.*

  *Buffers for Wetlands and Surface Waters: A Guidebook for New Hampshire Municipalities.* Audubon Society of New Hampshire.

  http://www.nh.gov/oep/resourcelibrary/documents/buffershandbook.pdf

# Lake Friendly Lawn Care

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Below is an expanded version of an article written by the author and published in the Spring 2009 "Lakeside", the newsletter of the NH Lakes Association.

The recent publication, "**Landscaping at the Water's Edge: An ecological approach, 2nd edition**" from UNH Cooperative Extension covers the importance of considering how you may landscape your shoreline property for both the improvement of water quality as well as the enhancement of your property. Lawns and lawn care, specifically for shoreline properties, are among the most popular requests for information. While the publication goes into much greater and more specific detail, the information below is a good start when considering lawns and their potential impacts to water quality.

There is often controversy and confusion regarding lawns on shoreland properties. Some consider lawns inconsistent with the natural shoreland ecology while others want to bring to their shoreland home the same look and feel as the neighborhoods in surburbia that they have grown up with. As all vegetation provides at least some water quality functions, a lawn managed in the proper way can still allow for stabilized soils, filtered water infiltration into the ground and some nutrient and pollutant capture. And as with all vegetation, lawns sequester carbon dioxide, produce oxygen and, by doing so, cool the planet. Thus, lawns still make a better alternative to pavement or patios which create greater runoff conditions and impede groundwater recharge. Of course, if managed improperly and located too close to the water, lawns and their care can add to pollutant and nutrient loading to our surface and ground waters, attract nuisance weeds and insect pests (and even big pests like Canadian Geese!), impact important plant and wildlife species, as well as greatly reduce the available potable water supply with their potential need for irrigation. So how might you maintain a lawn area to enjoy on your shoreland property (or any property for that matter) while minimizing your impacts to the water quality and natural ecology?

- <u>Everything in moderation</u> - We often hear from our health providers that moderation is the key to healthy living and the same holds true for natural systems. Questions to ask yourself here include: How much lawn or open space do we really need for our intended use? Do we need to have all of our open space as a monoculture of a single type of grass or can we live with a combination of grasses and groundcovers that match our use? There are many varieties of grasses depending on the type and frequency of use (ie: occasionally picnicking to kids playing ball everyday) and site conditions (soils, sun exposure and slope). Recently developed fescues, for example, require less maintenance (water, mowing and fertilizing) and can even be obtained with symbiotic fungi in their roots that make the grass better resistant to pests and diseases. The best approach is a mix of grass species with even some other groundcovers and white clover (or another low growing legume to naturally supply nitrogen to the soil). Talk to your county Extension educator, landscaper, or garden center expert about your options.

- **Location, location, location** - Yes, the mantra of real estate agents also works well for lawns. Additional maintenance of a lawn, even when not excessive, can still threaten water quality. To make up for this residents might consider locating the lawn as away from the shore as possible and maintaining a significant buffer area downslope from the lawn with a mix of shrubs and woody plants. A lawn right down to the water is the worst thing for the water and it will serve to attract nuisance geese. It's a known fact that keeping the vegetation high at the water's edge will discourage geese from coming onto a property. It also provides many water quality and wildlife (aquatic and near shore) related benefits.
- **Test first, apply later** - It is most important to test your soil before even thinking about applying fertilizers. Once a lawn is established, fertilizing more than once a year (unless the yearly dosage is applied in fractions) is generally excessive and can lead to excess nitrogen loading to surface and groundwater. Lawns tend to need more basic soils so sometimes even applying crushed limestone to raise the pH can release enough nutrients that were bound to the soil to maintain the lawn. A soil test will let you know exactly what you need to maintain a healthy lawn. If the test informs you that only nitrogen is needed, look for low to no phosphorus fertilizer blends (middle number of the N-P-K rating on the bag is zero) as phosphorous causes algae blooms in lakes and ponds. Generally, a well established lawn can survive adequately with no more than 1 to 2 pounds of nitrogen per 1000 square feet. The best time to apply fertilizer on an established lawn is around mid September when the grass is still active enough to incorporate the fertilizer into the plants, the summer draught is over and the surrounding vegetation is well established to capture any runoff from your lawn. Choose slow release fertilizers only, to insure less polluted runoff. Many residents apply crushed limestone in the spring and fertilize in the fall. Some residents have never felt the need to fertilize and others have had their best results just using lake water (which usually contains small amounts of N and low P) for irrigation. It is really up to you to balance the results you are looking for with the minimum applications needed. Remember the NH Comprehensive Shoreline Protection Act prohibits applying anything except limestone in areas within 25 feet of the high water line except in some circumstances like initially establishing a ground cover.
- **Read the fine print!** - A recent survey in Maine indicated that many consumers did not realize that "Weed & Feed" products contain both fertilizers and pesticides. Why pay for and put down something that can potentially threaten the health of pets, children and water quality when you may not need it in the first place? If you do have weed or insect problems consult with your county Exten-

sion educator, landscaper or garden center expert to learn of safer alternative controls. No matter what you choose always read the application directions and never over apply. Many of the plants and animals that form the foundation of the aquatic food web are extremely sensitive to pesticides so your impacts can have serious repercussions. Also be sure to apply only what you need - just because you bought a whole bag does not mean you have to apply all of it. Over-fertilization will cause more pest problems and will threaten surface and ground water supplies.

- **<u>Conserve every drop</u>** - If you are on a public water supply it is best to choose grass species with low watering requirements or use alternative irrigation supplies like rain barrels, cisterns or even the water directly from the shore. Summer water demand for lawns can be very significant in many communities. Depending on the species and soil conditions you should water, only when needed, no more than a half inch to an inch total weekly. You can use a rain gauge or a can to measure rainfall and irrigation amounts. Early morning watering is preferable to minimize evaporation loss but give the water enough time to infiltrate and to allow the leaf blades to completely dry before night so as not to encourage disease problems. Keeping the lawn height at least 3 inches or higher will also encourage deeper roots which require less water (and a mulching mower blade will allow for those grass clippings to recycle nutrients back into the soil). Remember that in times of draught and hot summer lawns are supposed to go dormant. Letting this happen is the most environmentally friendly thing you can do.

So, the choices are yours, you can have a lawn on your property with minimum impact to our waters if you can restrict its size, locate it properly, provide adequate vegetative buffer areas down-slope and use low input design and maintenance methods. To learn more about how informed landscaping can actually improve the water coming off of your property refer to "**Landscaping at the Water's Edge: An ecological approach, 2nd edition**" and/or request a presentation from your Cooperative Extension county Master Gardeners. Jeff Schloss can also be contacted to schedule a talk or workshop for your lake association.

# Go with the Flow:
## Understanding How Water Moves Onto, Through and Away from Your House Site

Water travels through a watershed (the catchment area) in two ways, across the land surface and down through the ground. As water traveling on the land surface moves along, following the path of least resistance, it passes across various types of land and land uses. In a state as geographically diverse as New Hampshire, a drop of water from irrigation, rain or snowmelt might travel across neighborhood roads and your driveway, through a wooded area or an open field. Unless it infiltrates down into the ground, gets intercepted by a plant or evaporates into the atmosphere, the drop will end up in a lake, pond, stream, wetland or estuary. As water travels downhill on the landscape it picks up small particles and soluble materials and carries them along to the waterbody at the end of its journey. It might pick up pesticides or fertilizers from a backyard garden or salts and oils from a driveway or patio. In times of heavy rain, fast moving waters can pick up large particles of soils and sediments and deliver large pollutant loads to our surface waters. This flow of water and materials from a given location across the land surface and into our water is called "runoff".

Controlling water runoff should be a major objective of any shoreland landscape design. As water collects and flows through channels, it gathers energy and increases its erosive force. The faster water flows, the greater the particle size and quantity of pollutants it can carry along to the receiving water body (pond, lake, stream, river, wetland or coastal water). Modifying the landscape with any type of development has the potential to degrade soil and water, resulting in changes in water flow, nutrient- and pollutant-loading, and groundwater recharge. However, if you start with a plan that takes into consideration the specific water runoff situation on your house site, your new landscape design could even improve the quality of water coming off it.

This overview will guide you through the process of assessing your current runoff situation and offer various strategies you can use to minimize the runoff from your house site. Combining these approaches with appropriate choices of plants and horticultural products is key to ensuring a healthy shoreland environment. More detail and instructions on how to map out your site assessment and design an integrated landscaping plan can be found in the UNH Cooperative Extension publication: **Landscaping at the Water's Edge: An ecological approach (2nd edition)** which can be ordered from the publications office : www.extension.unh.edu/publications.

### *Common Runoff Control Strategies*

**Infiltration** - allowing water to percolate into the ground where it can be filtered by soils rather than running across the land surface where it can cause erosion and collect pollutants.

**Detention** - holding back or "ponding" a volume of water to slow the speed of its outflow. In some cases water detention may also allow for infiltration and evaporation to reduce the resulting outflow volume.

**Diversion** - preventing water from traveling over the area of concern, thereby reducing surface runoff damage and minimizing the potential for erosion and the transport of nonpoint source pollutants.

**Flow Spreading** - allowing a concentrated flow to spread out over a wide, gently sloping area to reduce the water velocity and encourage infiltration.

**Plant absorption and transpiration** - the movement of water from the shallow soil into the plant roots, up through the stems and leaves and the release of water vapor through the leaf stomates (under-leaf openings) to the atmosphere.

## *Typical Techniques used to control runoff*

**Berm** – A stabilized mound of dirt or stone to create a diversion and/or redirect water flow

**Check dam** – A small mound of stabilized dirt or stone that breaks up the flow of water in a drainage ditch or trench to slow down velocity and allow for the settling of heavier materials.

**Cut-in (or Cut-out)** – A small trench that diverts water flow away from the direction of the major flow stream to prevent a significant volume of water from collecting as it runs down a driveway, walkway, or path. Multiple cut-ins may be required for long distances or high slopes.

**Infiltration trench** – A dug-in trench commonly used for roof runoff that allows for storage of runoff and encourages infiltration into the ground.

**Plunge Pool** – A dug-in hole stabilized by stone, typically placed adjacent to a drainage ditch or trench. This allows water to fall below the level of the surface to slow the runoff velocity and capture heavy particle. These are often constructed in a series along a sloped route.

**Rain Garden** – A shallow infiltration basin planted with water tolerant plant species, designed to capture concentrated runoff. Rain gardens are designed to pond water for just a few hours at a time, allowing it to be taken up and transpired by plants or infiltrate into the ground.

**Swale** – A stabilized trench that can act to store water (detention), sometimes also engineered to enhance infiltration.

**Vegetated buffer** – A relatively flat area stabilized with vegetation that allows water flow to spread out, slow down, infiltrate and be filtered by the soil, and/or be intercepted and transpired by plants.

**Waterbar** – A diversion device that diagonally crosses a sloped trail, path or road to capture and divert runoff to the side. Commonly made of a log, a stone, a small reinforced drainage channel, or a partially buried flexible material, a waterbar is most useful for small contributing areas (watersheds less than one acre) that receive light foot and vehicle traffic. Waterbars are spaced according to the slop of the land.

## *Following the flow*

Paying attention to how water flows (or will flow) into, over and through your home site before, during and after development or landscaping, is critical in determining current and potential negative impacts. Some questions you'll want to answer before proceeding:

- What is the extent of lands and roads above the site that contribute runoff water, and where does the runoff enter your property?
- Where does the water run off impervious surfaces (paved driveways and walkways, roofs, patios, compacted soils, etc) and piped sources (sumps, gutters, etc.) go?
- Where does that water, along with the additional runoff generated in your new design, run over the site? Is it treated by vegetation and infiltrated or does it accumulate?
- Where will that water flow off your site? Does it enter the water body directly?
- Most importantly, how might you modify your design to take advantage of these factors in creating diversions, detention and infiltration areas?

## *Investigate the drainageways*

Since water moves downhill, you need to walk your property boundary and note where the major water flows occur after a heavy rainstorm. Does the runoff from abutting roads or a neighbor's driveway flow onto your property? Are there any adjacent steeply sloped lands that rise above the level of your property? Are they extensive enough to contribute water flows during rains and snow melts? Make note of all of these off-site contributors to flow. Also note any occasional or perennial wet areas or streams at your property boundary that encroach on your site.

## *Investigate onsite runoff generation*

**Note any wet areas or seeps on your property.** Now consider how your house and current landscaping features generate runoff. It is always easy to point uphill and blame runoff on other properties, but many people are surprised at how much runoff their own site creates, even in low-density development. Also note whether areas on your land divert runoff onto neighboring properties.

**Take inventory of all paved and compacted areas,** such as driveways, patios and walkways. Can you find evidence of water flow moving off these areas and heading downhill? You may see just a small area of sheet erosion, indicated by the appearance of worn-down gravelly areas with small stones and roots showing because finer soil particles have been washed away. Or you may see rill, visible channels where water has eroded away materials a fraction of an inch to a few inches deep. In the worst cases, you'll find gullies where water flows through channels deep enough for you to step into them.

The potential for erosion and runoff increases with site steepness, area of impervious surfaces, and size of contributing watershed area (land above your site).

**Investigate the point sources of flows on your property** from culverts, drain pipes, and hoses, as well as rain gutters, sump pumps, and tile drainage outlets. Culverts, drain pipes, etc. concentrate diffuse flows that need treatment and diversion to ensure they don't contribute to runoff. If the house doesn't have gutters, look for areas where the roof design intercepts and dumps rainwater onto the property. As you develop your landscape plan, consider ways you might reduce the impacts of those flows.

**Account for any paths, trails and cleared areas that lead to the water.** Shoreland properties almost always have pathways and cleared areas which runoff follows directly into the water body. In the worst cases, a driveway at the top of the property allows water from the road above and the gutter runoff to collect and concentrate. Runoff flowing down a pathway directly into a cleared beach area and into the water often takes a lot of sand with it.

Note how the paths follow the slope of the land. Meandering paths may function to break up runoff before it concentrates, but straight downhill paths encourage flow directly to the water. Also, note the flow-contributing areas that lie above the access area or beach. Do swaths of vegetation above help break up the flow, or does the water pretty much flow straight down and onto the area below?

**Finally, look for areas where water tends to pond** after it rains. Even flat areas may pond water if the soils don't drain well or if there is a lot or shallow ledge or hardpan present. Be sure to keep track of these areas and prevent additional water from reaching these locations.

## *Minimize and divert runoff*

Significant flows coming onto your site may create runoff and erosion problems. Your design should take into account all flows that will come in contact with your newly landscaped area, as well as those flows that may cause runoff concerns in other areas on your property (or your neighbor's).

Of all the methods that can help deal with these situations, diversion and flow-spreading are the most reliable. If you can treat all of the incoming runoff by diverting it and spreading it out over a stable vegetated area before it leaves the properly, then by all means do so. However, in situations of high runoff flow coming from off-property sites such as roads, diverting some of the flow may be warranted to keep it from entering your property. The sources of offsite runoff can be diverse and you may not be able to take action without involving neighbors, road associations and municipalities, since road-drainage diversions and treatment systems require professional design and installation.

Use what you have (or can design) to break up, slow down and spread out the flow over or into a vegetated area. The goal is to prevent offsite and onsite flows from accumulating and divert them from impervious areas. You may be able to break up the flow by using shallow channels, stone check dams, small vegetated berms, or alternating areas of low and high vegetation.

Simple drainage cut-ins can break the flow and move the water from long driveways and pathways. In more challenging situations, for example, when sites are very steep or narrow you may need to hire a professional to install a waterbar or similar diversion.

If you can't divert the flows coming onto your site and can't find ways to prevent the flow from concentrating to a significant volume, then consider diverting the water into your existing vegetated areas. Or, create additional vegetated areas to allow the water to slow down, spread out and infiltrate the ground, thus losing most of its destructive force and most of its pollutant load. For this to work, you need an adequately sized vegetated area with minimal slope.

The denser the root systems of the plants in vegetated areas, the greater the volume of water the area can process. Mixed types of vegetation with different root depths will have the greatest impact, as contrasted with lawn like monocultures, which grow a single type of plant. However any type of vegetation is better than a bare, cleared, compacted, or impervious area.

The same holds true for dealing with runoff from pavement, roots, tile drainage, sump flows, and existing drainageways: capture the water and/or divert it by any means possible (plunge pools, waterbars, berms, swales and drainage trenches) to prevent it from running directly down to the shore. Conditions such as lack or space, steep slopes, and/or proximity to the shore create special challenges to diverting the water from a rain gutter or other concentrated flow. In these situations, consider alternative controls such as rain barrels, storage cisterns and infiltration trenches.

You may be able to cut down runoff generation at the source by replacing impervious areas with porous alternatives. For problematic and excessive stormwater volumes you may need to have something engineered to capture water and pump it into other areas for treatment.

If you have enough space, consider installing a rain garden, a shallow, dug-in area planted with water-tolerant plant species. Rain gardens can collect a significant volume of water during a storm, allowing the water that doesn't get used by plants to infiltrate the ground quickly and prevents it from becoming runoff. When designed and constructed correctly, the surface of a well-designed rain garden will not flood, eliminating concerns about standing water. The publication, **Landscaping at the Water's Edge**, includes resources for more information on rain garden design and appropriate plants. Or call your county Cooperative Extension office for more information.

Properly designed pathways and trails should meander across the slope and allow each segment to throw water off the trail, rather than letting it flow in a straight path, accumulating velocity and pollutants as it moves downhill. The best trails are those that follow the ridges and contours of the property. Some low vegetation planted at the corners of the meanders or staggered alternately on the sides of steeper pathways will help break up, capture, and slow down the flow of water as it moves downhill.

To maximize water quality protection as you consider the ways you want to use and enjoy your waterfront property, the key is to remove as little vegetation as possible. For all lake shores and large rivers, the state's Comprehensive Shoreland Protection Act requires that in the "waterfront buffer" (0-50 feet from shore) natural ground cover and duff (forest litter) shall remain intact. No cutting or removal of vegetation under 3 feet in height (excluding lawns) is allowed. Stumps, roots and rocks must remain intact in and on the ground. In addition, within the waterfront buffer, tree coverage is managed with a 50 foot by 50 foot grid and point system that ensures adequate forest cover and prevents new clear cutting. Within the "natural woodland buffer" (50-150 feet from shore) there are additional protections where 25 to 50 percent of that buffer must remain undisturbed dependent on lot size. See the NH DES Comprehensive Shoreline Protection Act web site for more detailed information (http://des.nh. gov/organization/divisions/water/wetlands/cspa/index.htm).

Plan to stabilize a major portion of the shoreline area with a good mix of plants. The more protective vegetation you remove from near the shore, the more you increase the area's potential for transporting pollutants to the lake or stream. Removing taller plants also opens the shore area to receive more sunlight. Exposure to more sun heats up the water, making it less desirable for aquatic organisms and more conducive to submerged and emergent weed growth including exotic invasive species.

Where you locate your water access area is also important. Areas that don't receive significant runoff from the land above make the best locations for minimizing potential impacts. Water access areas that lie directly below a runoff flow may allow the runoff to reach the water without any reduction in impact. If you have no choice of access location, try to create a diversion of the flow away from the shoreline opening and into a more vegetated area using one or more or the approaches discussed above.
**Note**: State wetland laws forbid dumping sand or other materials on the shoreline to make a beach. Wetland permits are required for any beach construction. Sand beaches not naturally present are discouraged as they tend to get washed away. In locations where a small opening, with stable groundcover and perhaps a few flat stones or steps will not do, you can apply for a permit for a small perched beach located just above the shoreline. Contact the Department of Environmental Services Wetlands Bureau for more information, (http://des.nh.gov/organization/divisions/water/wetlands/index.htm).

## *Structural approaches*

Most structural modifications for dealing with flow and runoff require professional design and installation. However, homeowners might try one or more of these simpler approaches before calling in the pros:

- Clear existing drainage-ways of accumulated materials, including loose sediments and litter, before the snow melts and the spring rains arrive. Encourage vegetative growth in these drainageways however, as the vegetation removes sediments and pollutants from the water as it passes through.
- If possible, divert other flows into your existing drainageways (as long as they themselves don't directly flow into the water body) by some shallow channeling, the use of check dams of stone or gravel, or by using small berms.

- Break up the water flow by alternating small berms down a sloped area, diverting water off into vegetated areas before it can accumulate in significant volume.

In general, anything you can do by hand or using hand tools doesn't require a permit, as long as you stay at least 25 feet away from the shoreline. Any time you have to use a power tool, vehicle or power equipment, or your project requires significant earthmoving within the 250 foot Shoreland Protection Zone, you will probably need a state permit, and possibly one or more local permits as well.

## *Making a Difference*

A typical small shorefront lot on a moderate slope with conventional development (house, paved driveway, vegetation cleared for lawn) can increase water runoff, phosphorus pollution and sediment erosion about 5, 7, and 18 times, respectively, compared to an undisturbed, forested lot. By re-growing out a shoreland buffer of 50 feet and infiltrating the roof runoff through trenching or a rain garden, the impacts can be reduced significantly: to only 1.5 times the runoff, 2 times the phosphorus loading and less than 3 times the sediment erosion compared to the undisturbed lot.

With the knowledge of how water flows over and currently runs off your site, you now may want to consider adding water diversions, as well as vegetated buffers and infiltration areas into your landscape design to take advantage of the water-treatment properties of vegetation. The full publication: **Landscaping at the Water's Edge** contains further information on how to maintain and establish shoreline buffers, choose the appropriate plant systems for low impact and low maintenance, and how to plant and maintain lawn areas in an environmentally-friendly way.

Adapted by Jeff Schloss, UNH Extension Professor of Biological Sciences and Cooperative Extension Water Resources Specialist from his contributed chapter in: **Landscaping at the Water's Edge: An ecological approach, 2nd edition**
www.extension.unh.edu/resources - to order a bound copy of the manual.
http://extension.unh.edu/resources/files/Resource001799_Rep2518.pdf - to download an electronic copy of the manual.

JAS 3/15/10

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# REPORT FIGURES

**Figure 9.** Location of the 2010 and historical Great East Lake deep and shallow sampling stations, Sites 1 Center, 2 Canal Basin and 3 Maine Mann, 1st Basin (Narrows), 2nd Basin and 3rd Basin, Town of Wakefield New Hampshire.

# Great East Lake Sampling Sites

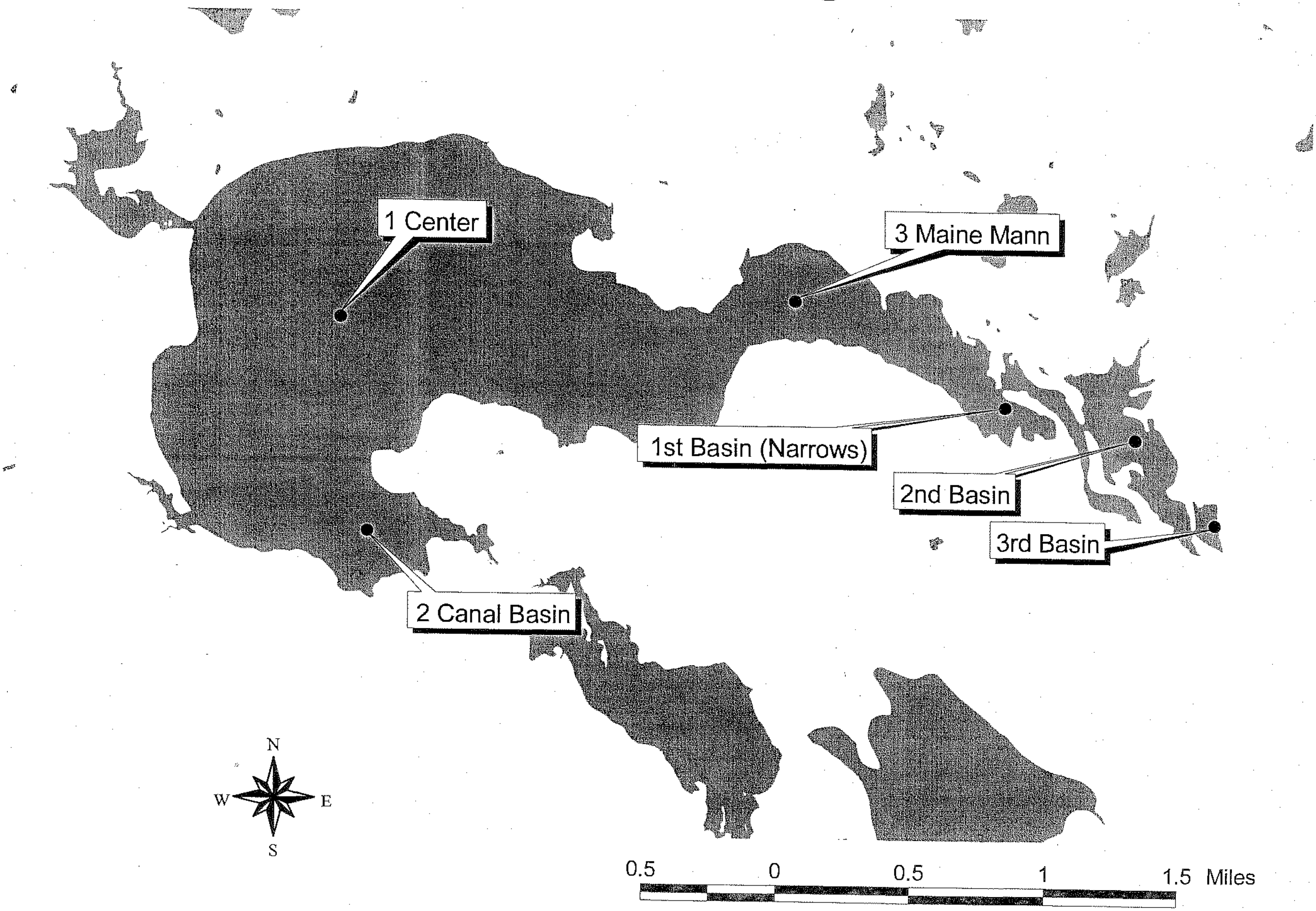
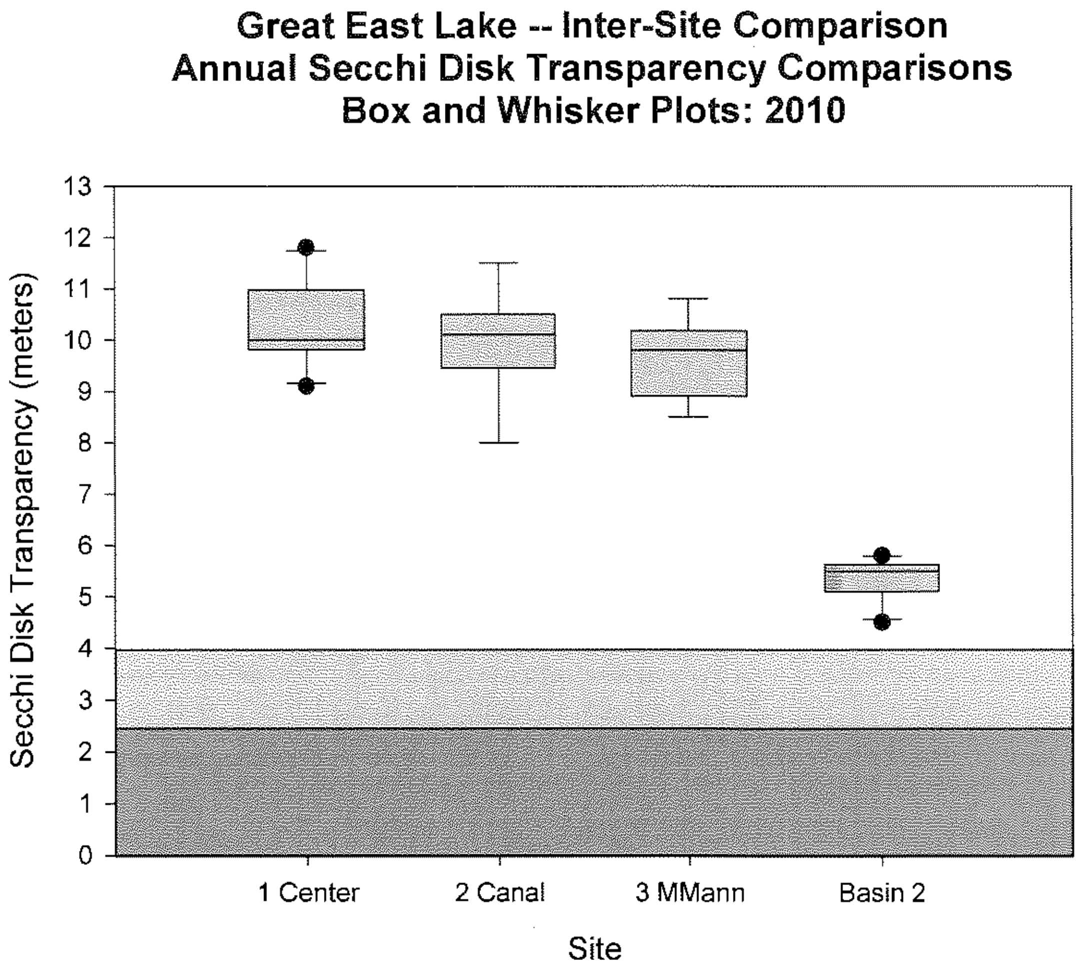
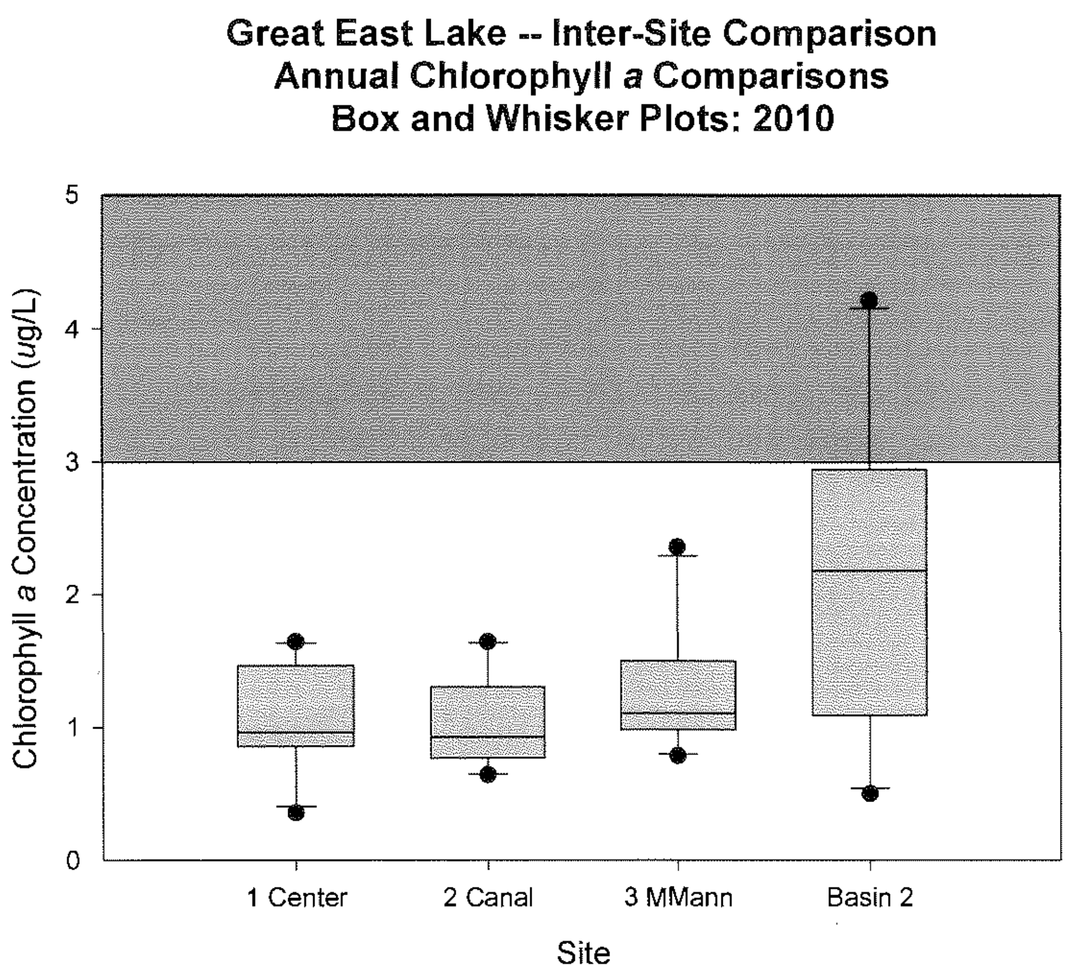


**Figure 10.** Great East Lake inter-site comparison of the 2010 lay monitor Secchi Disk transparency data that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded regions on the graph are representative of water transparency conditions considered typical of an unproductive (clear), a moderately productive (light gray shading) and a highly productive (dark gray shading) lake.

**Figure 11.** Great East Lake inter-site comparison of the 2010 lay monitor Chlorophyll *a* data that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded region on the graph is representative of conditions considered typical of a moderately productive lake while the clear region of the graph represents the range considered typical of an unproductive lake.



Great East Lake -- Inter-Site Comparison
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 2010
Secchi Disk Transparency (meters)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
1 Center
2 Canal
3 MMann
Basin 2
Site

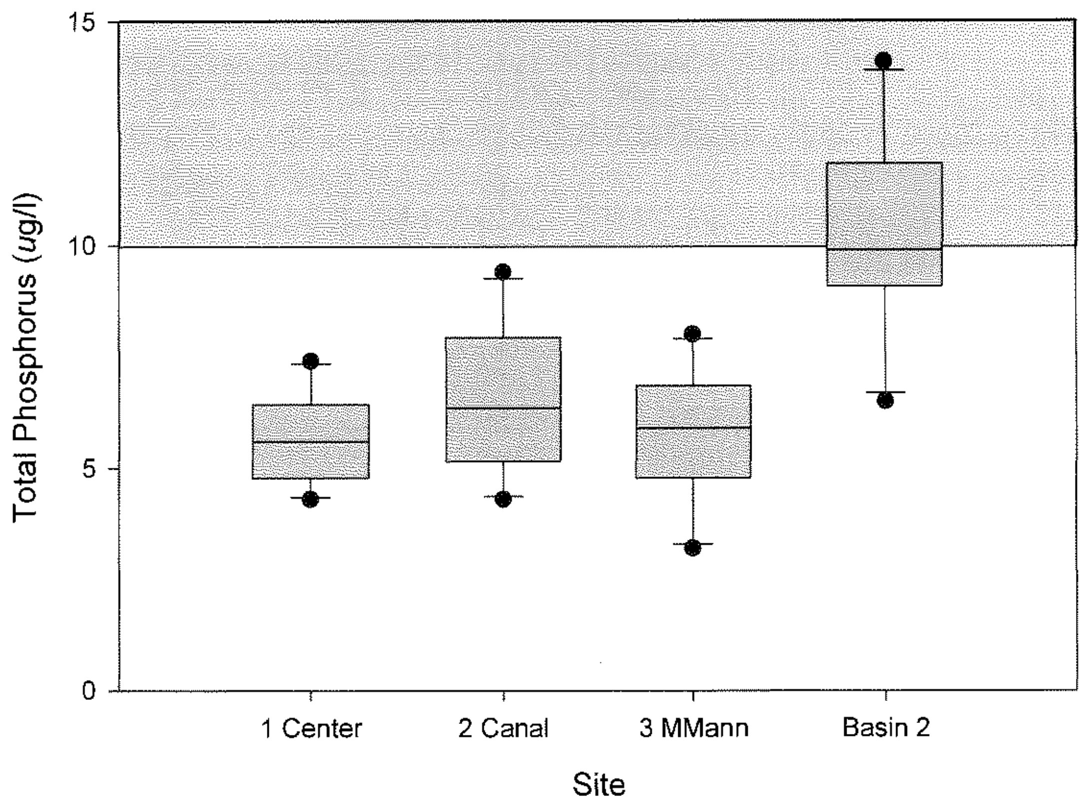



Great East Lake -- Inter-Site Comparison
Annual Chlorophyll a Comparisons
Box and Whisker Plots: 2010
Chlorophyll a Concentration (ug/L)
0
1
2
3
4
5
1 Center
2 Canal
3 MMann
Basin 2
Site

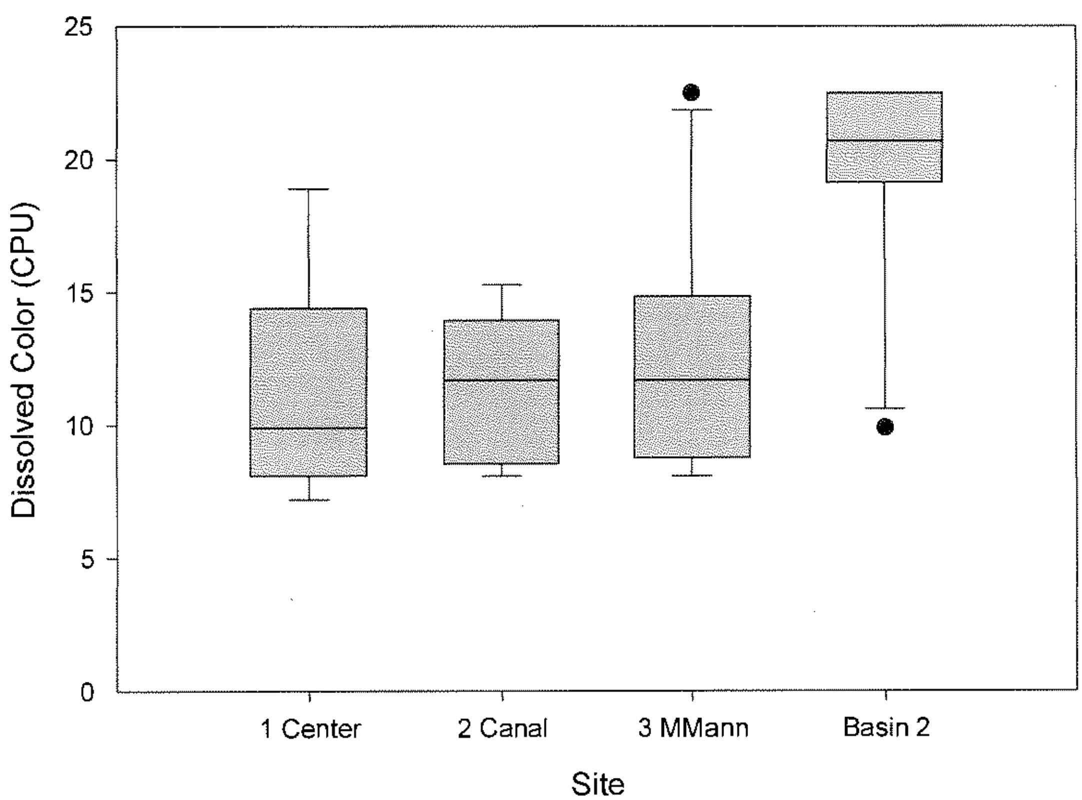
**Figure 12.** Great East Lake inter-site comparison of the 2010 lay monitor Total Phosphorus data that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded region on the graph is representative of total phosphorus concentrations considered capable of stimulating an algal bloom.

**Figure 13.** Great East Lake inter-site comparison of the 2010 lay monitor Dissolved Color data that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The higher the dissolved color concentration the more "tea" colored the water.

## Great East Lake -- Inter-Site Comparison
## Annual Total PhosphorusComparisons
## Box and Whisker Plots: 2010




## Great East Lake -- Inter-Site Comparison
## Annual Dissolved Color Comparisons
## Box and Whisker Plots: 2010

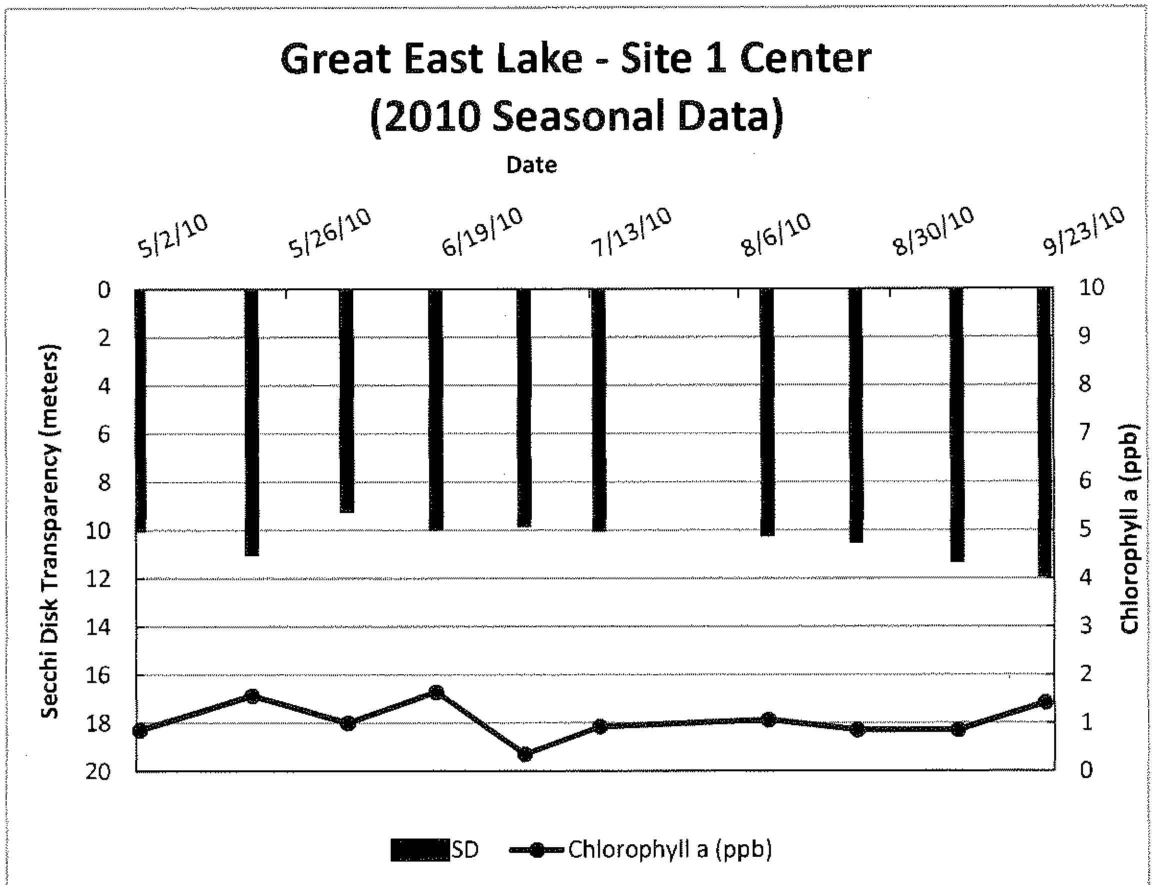


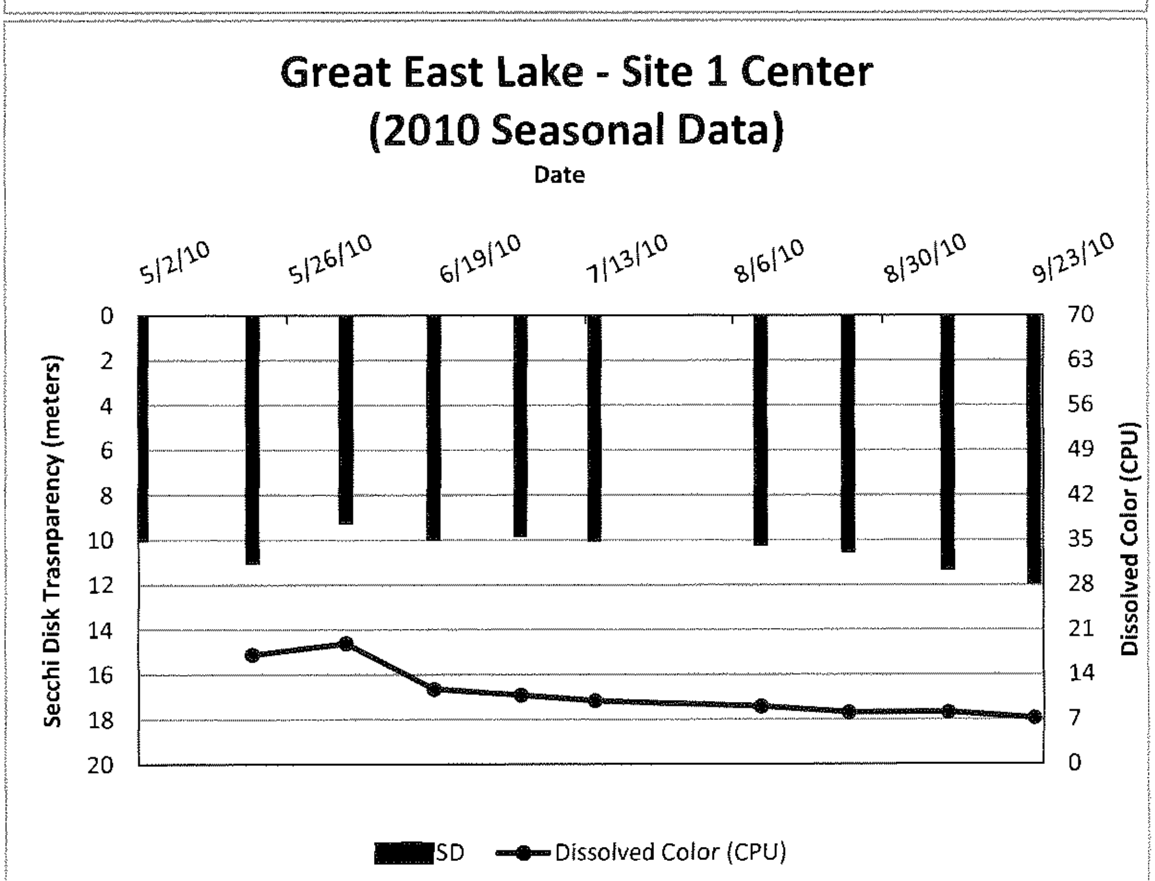
# APPENDIX A

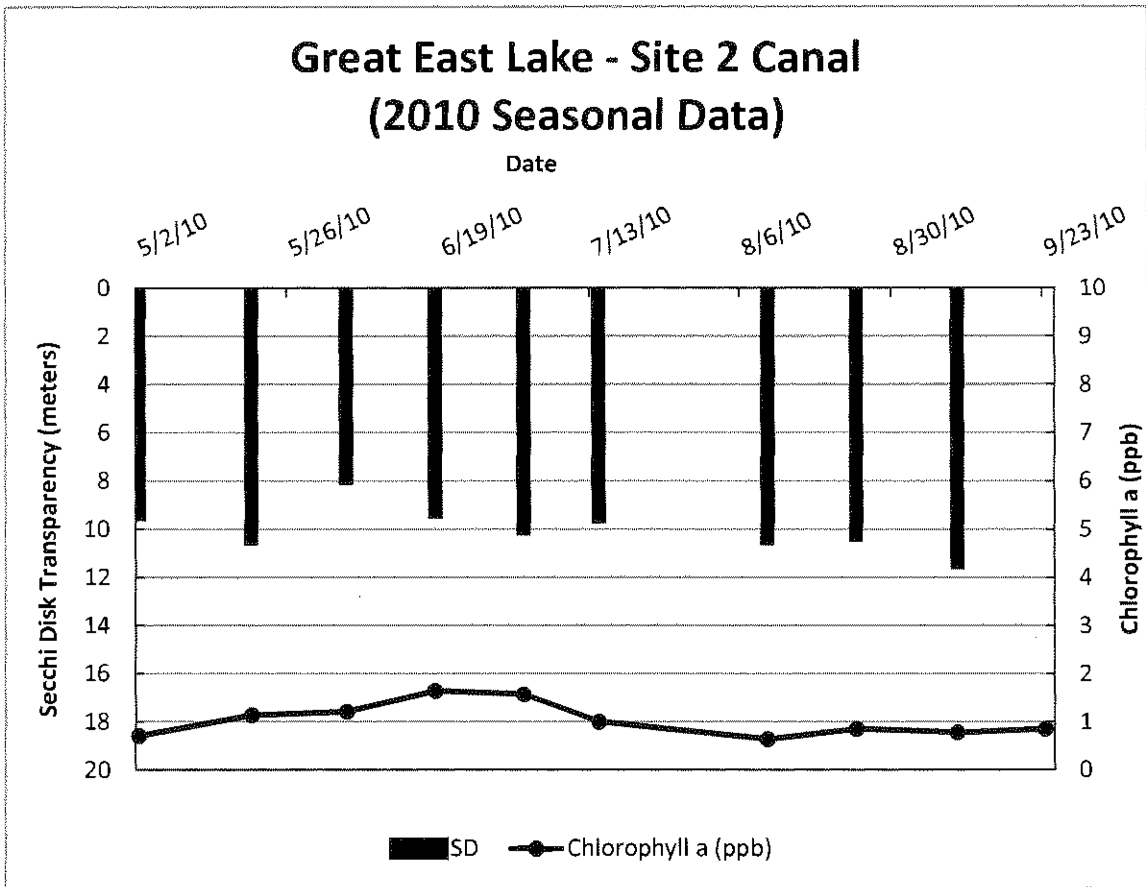
Great East Lake, 2010. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Sites 1 Center, 2 Canal, 3 Maine Mann and 2$^{nd}$ Basin. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

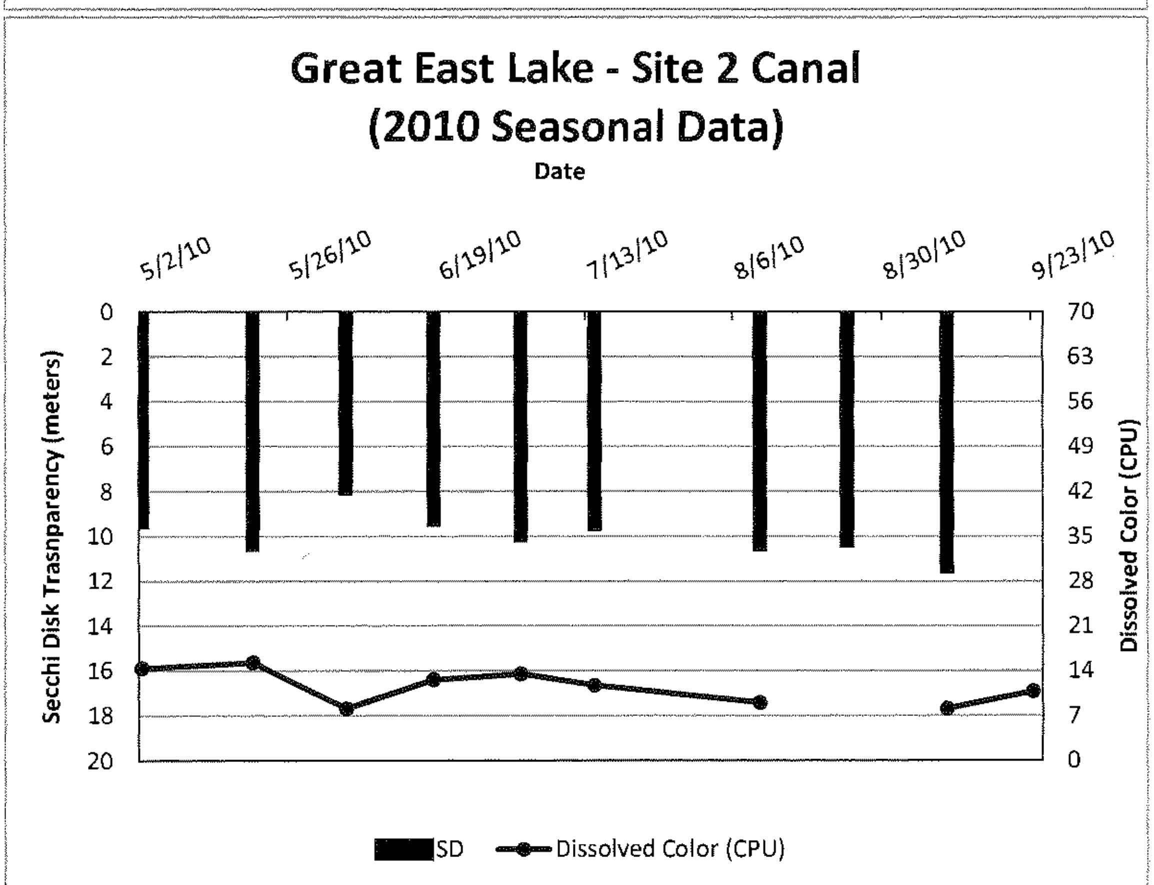
Great East Lake, 2010. Seasonal Secchi Disk (water transparency) and dissolved color trends for Sites 1 Center, 2 Canal, 3 Maine Mann and 2$^{nd}$ Basin. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

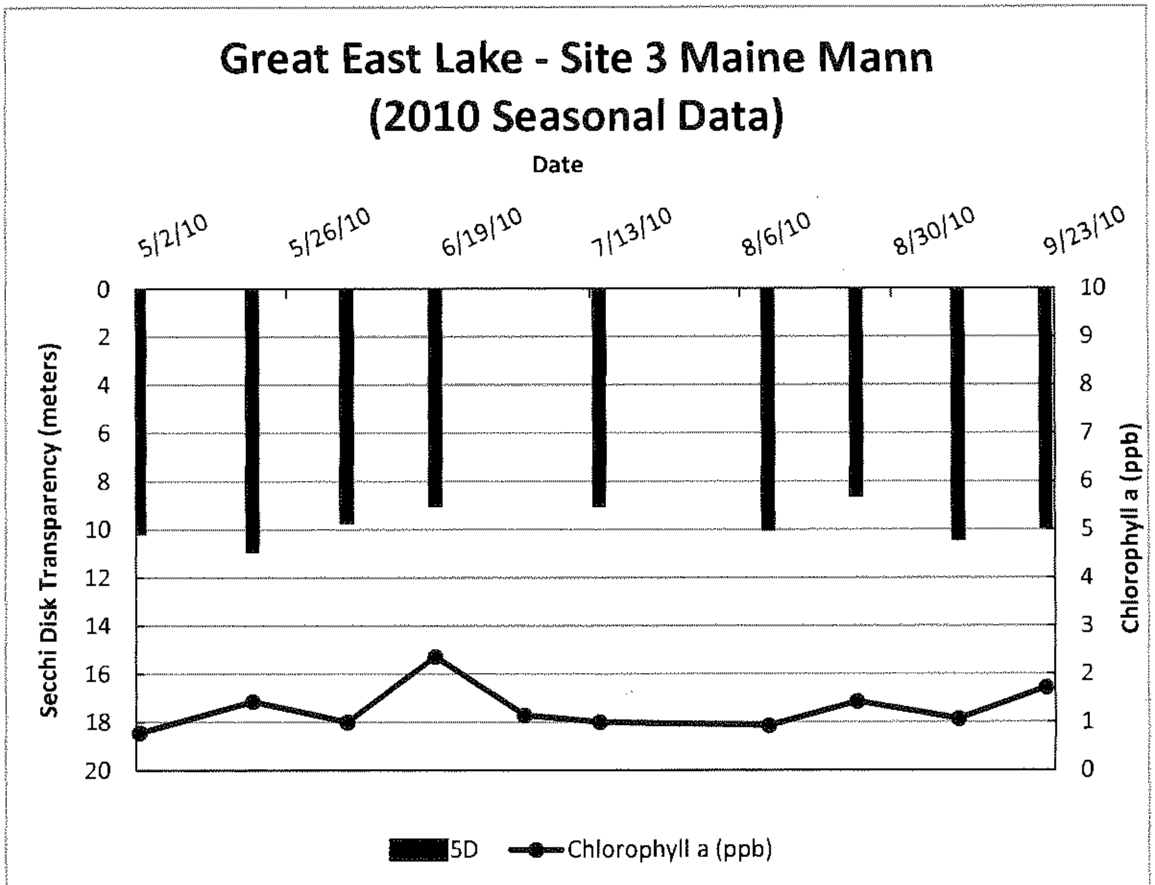
Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).

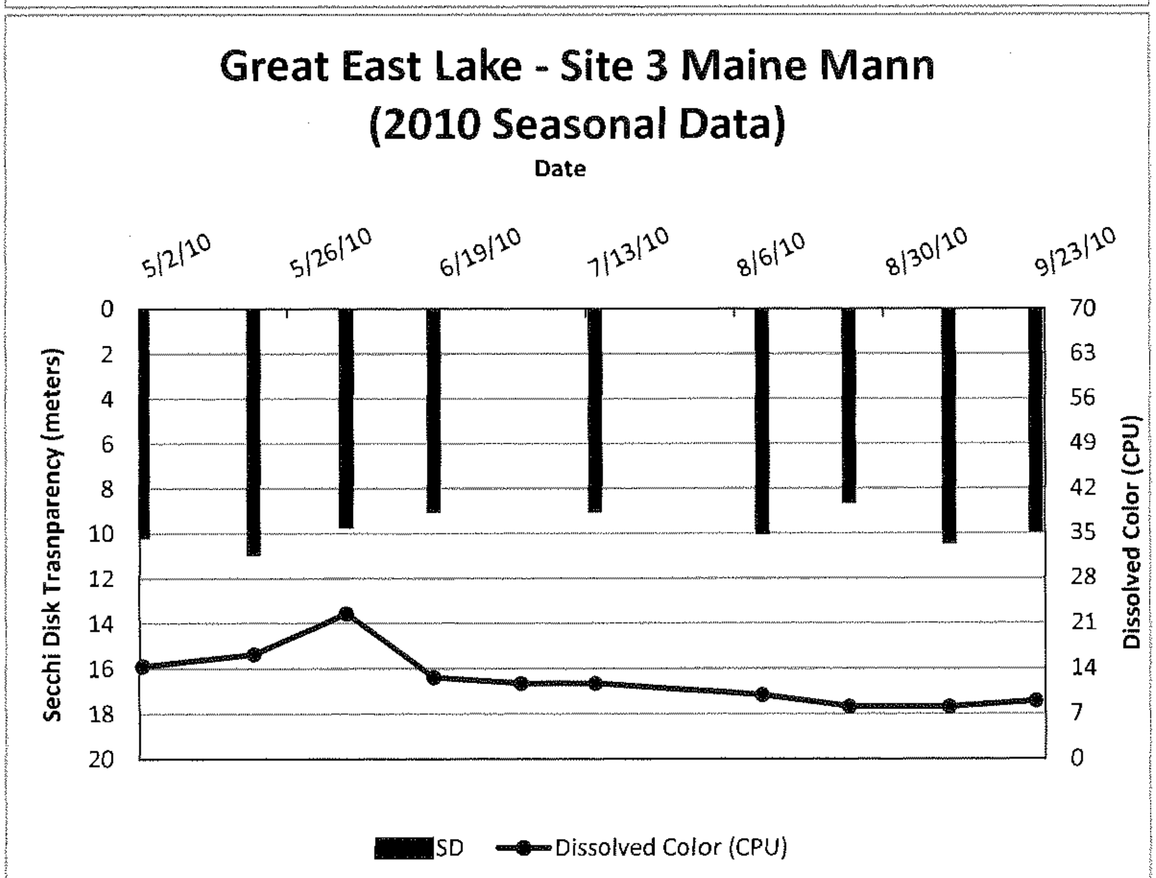

Great East Lake - Site 1 Center
(2010 Seasonal Data)
Date
5/2/10
5/26/10
6/19/10
7/13/10
8/6/10
8/30/10
9/23/10
Secchi Disk Transparency (meters)
0
2
4
6
8
10
12
14
16
18
20
Chlorophyll a (ppb)
10
9
8
7
6
5
4
3
2
1
0
SD
Chlorophyll a (ppb)

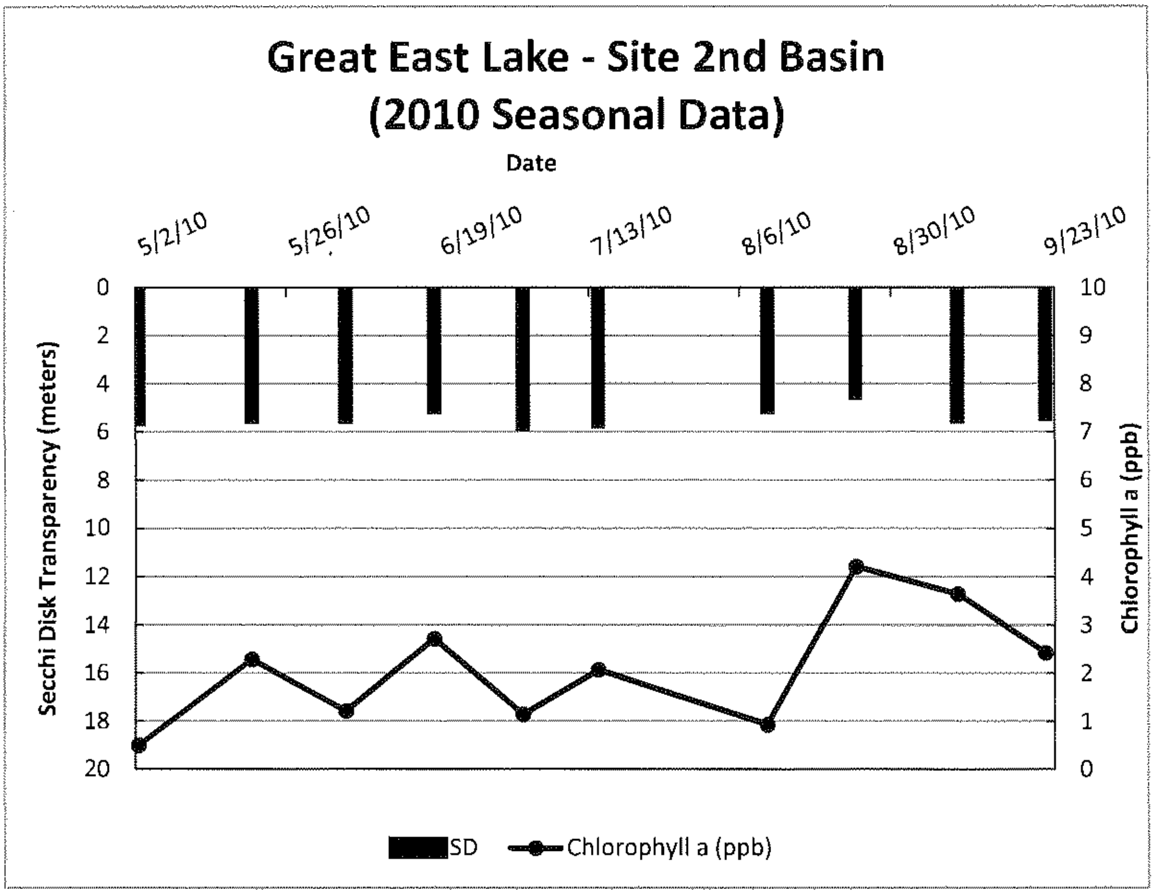

Great East Lake - Site 1 Center
(2010 Seasonal Data)
Date
5/2/10
5/26/10
6/19/10
7/13/10
8/6/10
8/30/10
9/23/10
Secchi Disk Trasnparency (meters)
0
2
4
6
8
10
12
14
16
18
20
Dissolved Color (CPU)
70
63
56
49
42
35
28
21
14
7
0
SD
Dissolved Color (CPU)

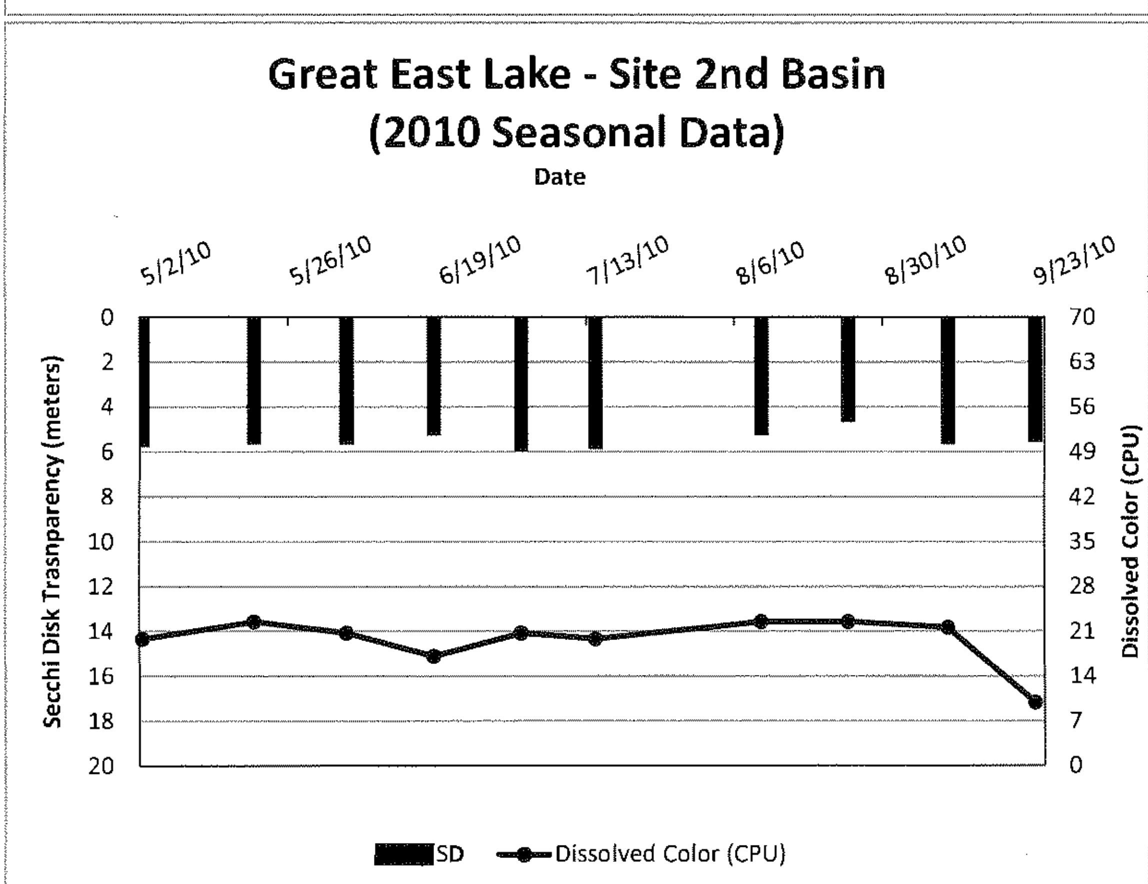

Great East Lake - Site 2 Canal
(2010 Seasonal Data)
Date
5/2/10
5/26/10
6/19/10
7/13/10
8/6/10
8/30/10
9/23/10
Secchi Disk Transparency (meters)
0
2
4
6
8
10
12
14
16
18
20
Chlorophyll a (ppb)
10
9
8
7
6
5
4
3
2
1
0
SD
Chlorophyll a (ppb)


Great East Lake - Site 2 Canal
(2010 Seasonal Data)
Date
5/2/10
5/26/10
6/19/10
7/13/10
8/6/10
8/30/10
9/23/10
Secchi Disk Trasnparency (meters)
0
2
4
6
8
10
12
14
16
18
20
Dissolved Color (CPU)
70
63
56
49
42
35
28
21
14
7
0
SD
Dissolved Color (CPU)


Great East Lake - Site 3 Maine Mann
(2010 Seasonal Data)
Date
5/2/10
5/26/10
6/19/10
7/13/10
8/6/10
8/30/10
9/23/10
Secchi Disk Transparency (meters)
0
2
4
6
8
10
12
14
16
18
20
Chlorophyll a (ppb)
10
9
8
7
6
5
4
3
2
1
0
SD
Chlorophyll a (ppb)


Great East Lake - Site 3 Maine Mann
(2010 Seasonal Data)
Date
5/2/10
5/26/10
6/19/10
7/13/10
8/6/10
8/30/10
9/23/10
Secchi Disk Trasnparency (meters)
0
2
4
6
8
10
12
14
16
18
20
Dissolved Color (CPU)
70
63
56
49
42
35
28
21
14
7
0
SD
Dissolved Color (CPU)


Great East Lake - Site 2nd Basin
(2010 Seasonal Data)
Date
5/2/10
5/26/10
6/19/10
7/13/10
8/6/10
8/30/10
9/23/10
Secchi Disk Transparency (meters)
Chlorophyll a (ppb)
SD
Chlorophyll a (ppb)

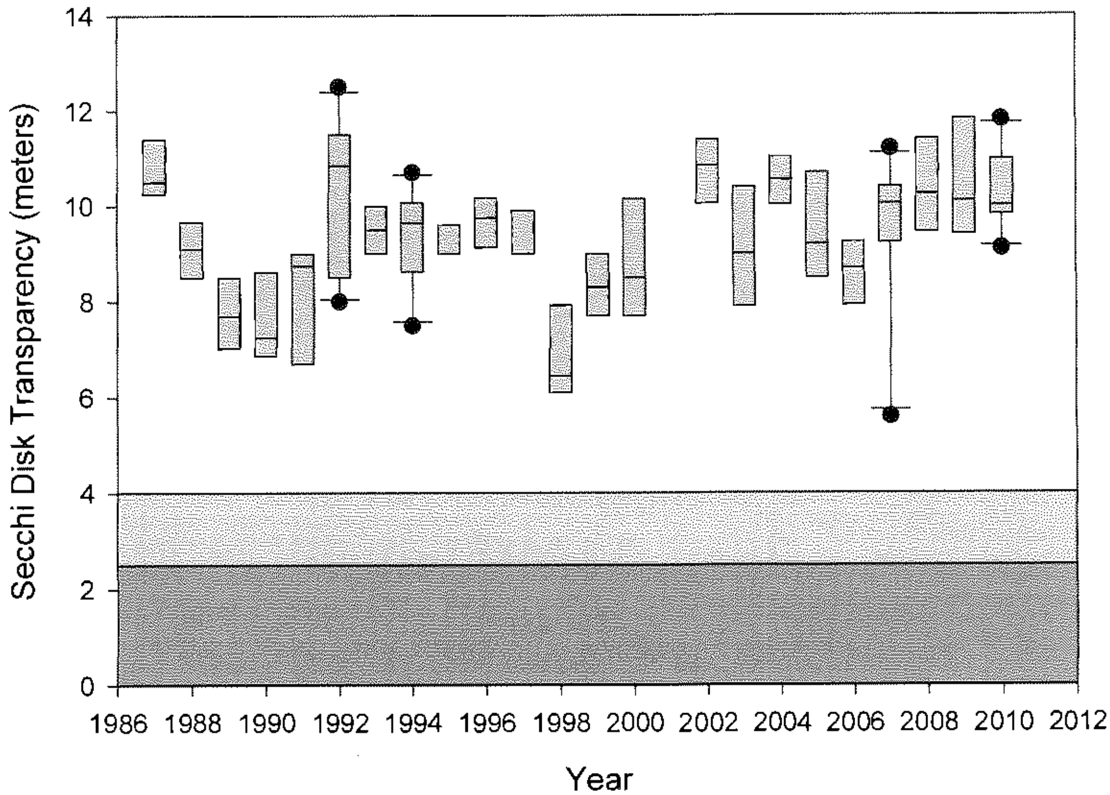

Great East Lake - Site 2nd Basin
(2010 Seasonal Data)
Date
5/2/10
5/26/10
6/19/10
7/13/10
8/6/10
8/30/10
9/23/10
Secchi Disk Trasnparency (meters)
Dissolved Color (CPU)
SD
Dissolved Color (CPU)

# APPENDIX B

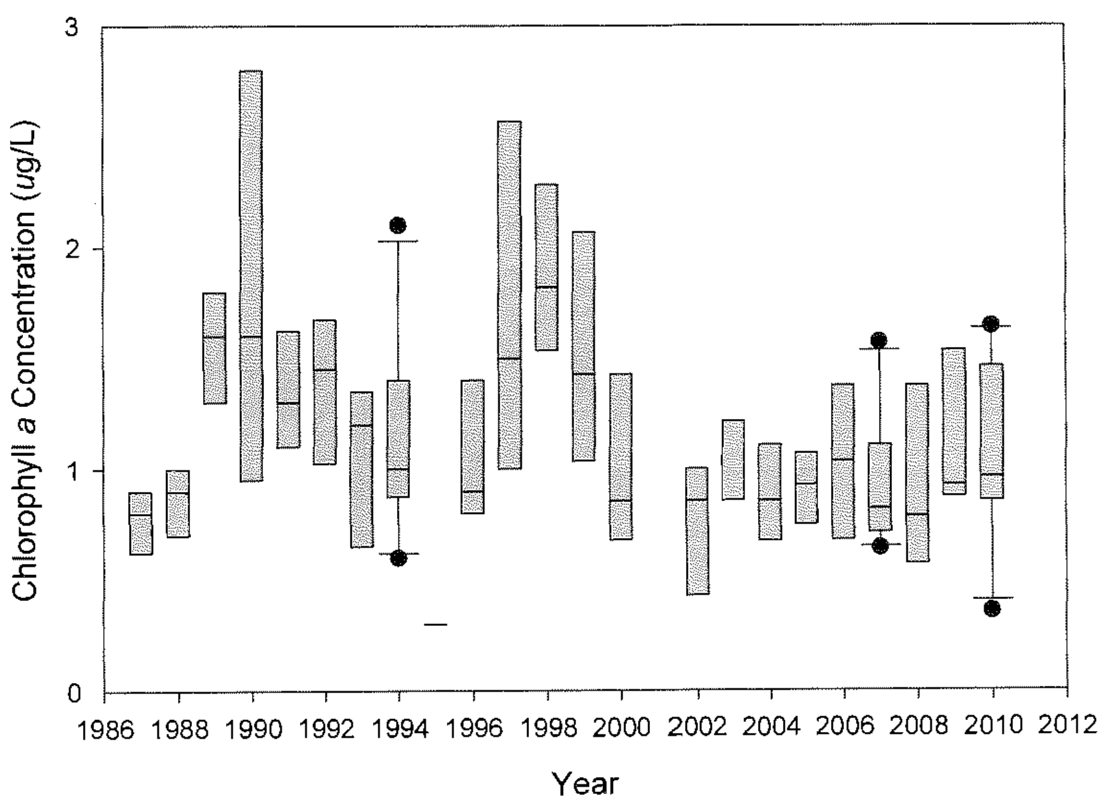
Comparison of the annual Great East Lake, lay monitor Secchi Disk transparency data that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Comparison of the annual Great East Lake, lay monitor chlorophyll *a* data that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

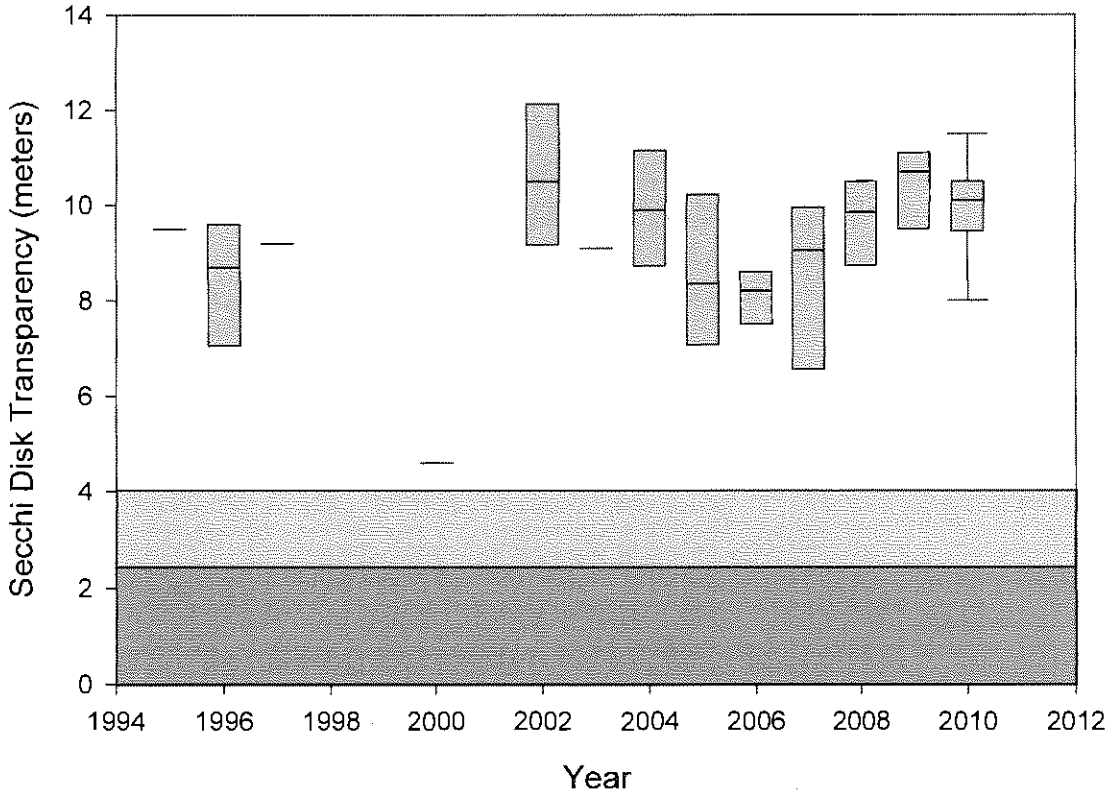
## Great East Lake -- Site 1 Center
## Annual Secchi Disk Transparency Comparisons
## Box and Whisker Plots: 1987-2010



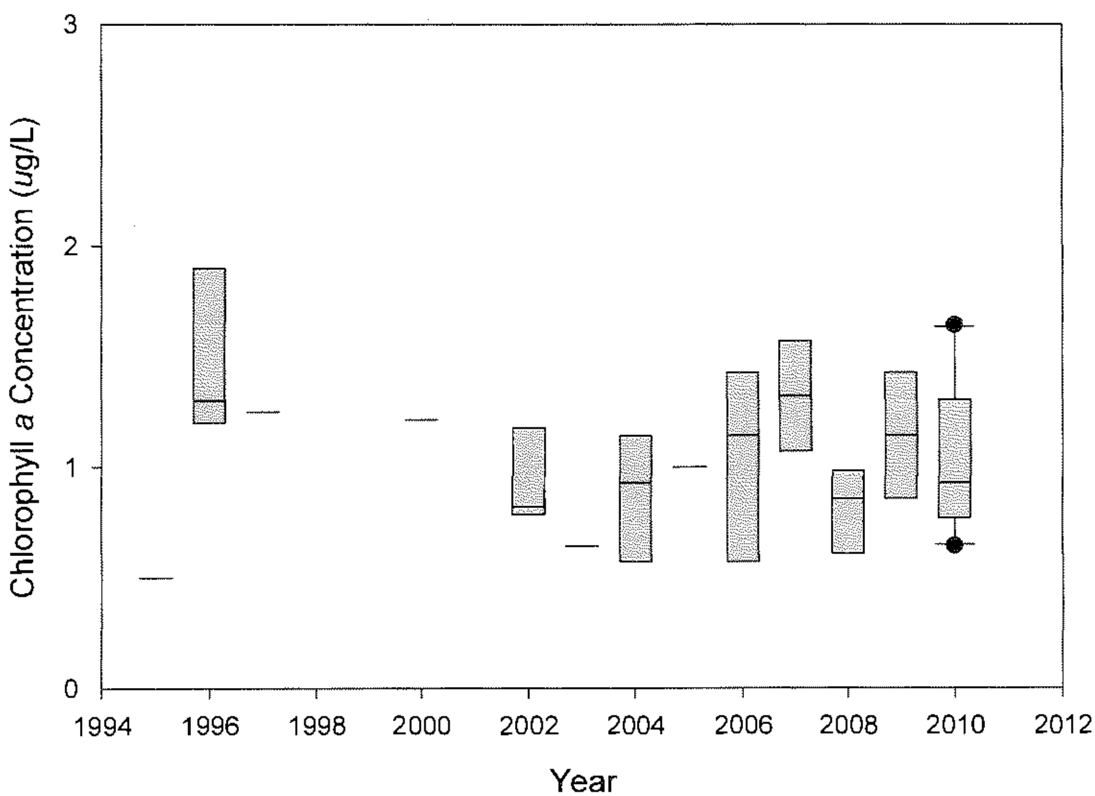

## Great East Lake -- Site 1 Center
## Annual Chlorophyll *a* Comparisons
## Box and Whisker Plots: 1987-2010



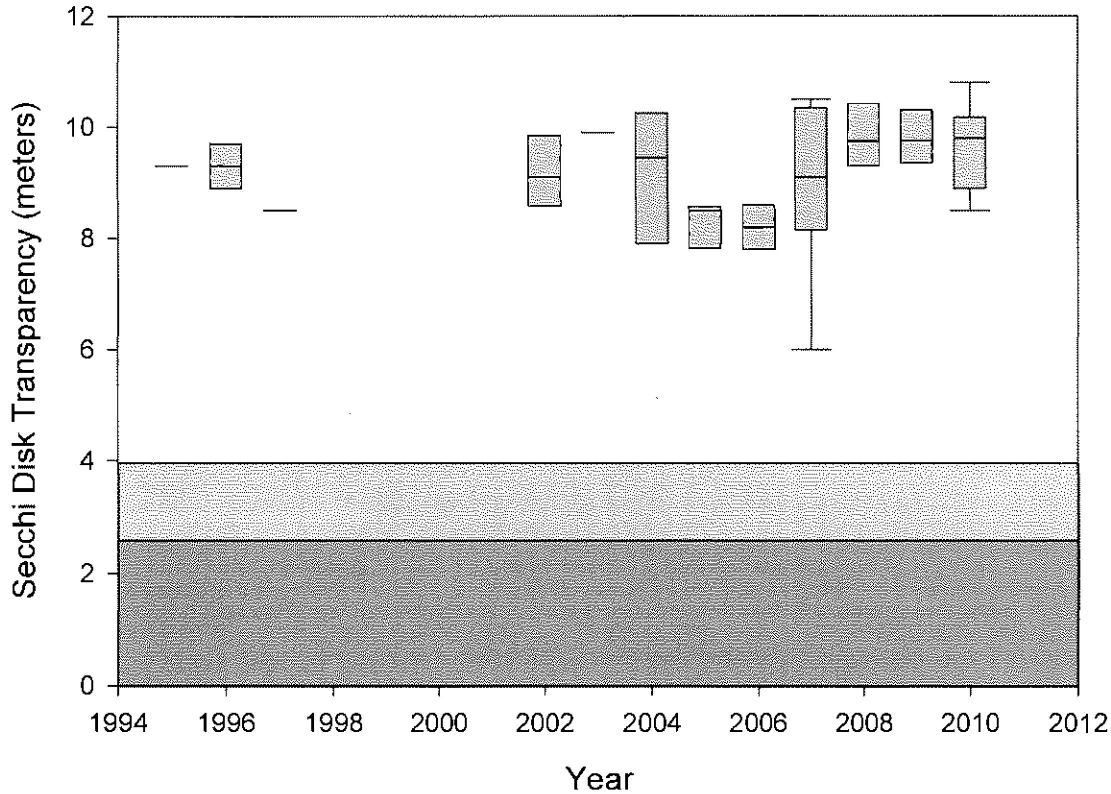
## Great East Lake -- Site 2 Canal
## Annual Secchi Disk Transparency Comparisons
## Box and Whisker Plots: 1995-2010



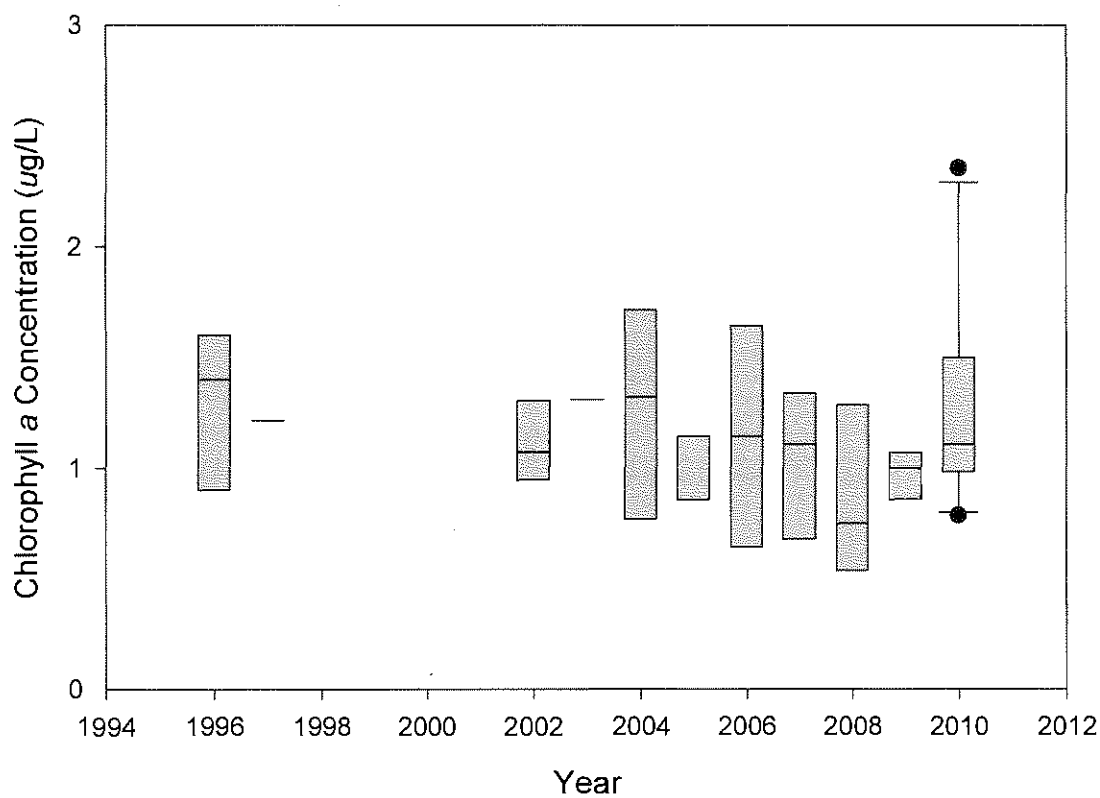

## Great East Lake -- Site 2 Canal
## Annual Chlorophyll *a* Comparisons
## Box and Whisker Plots: 1995-2010



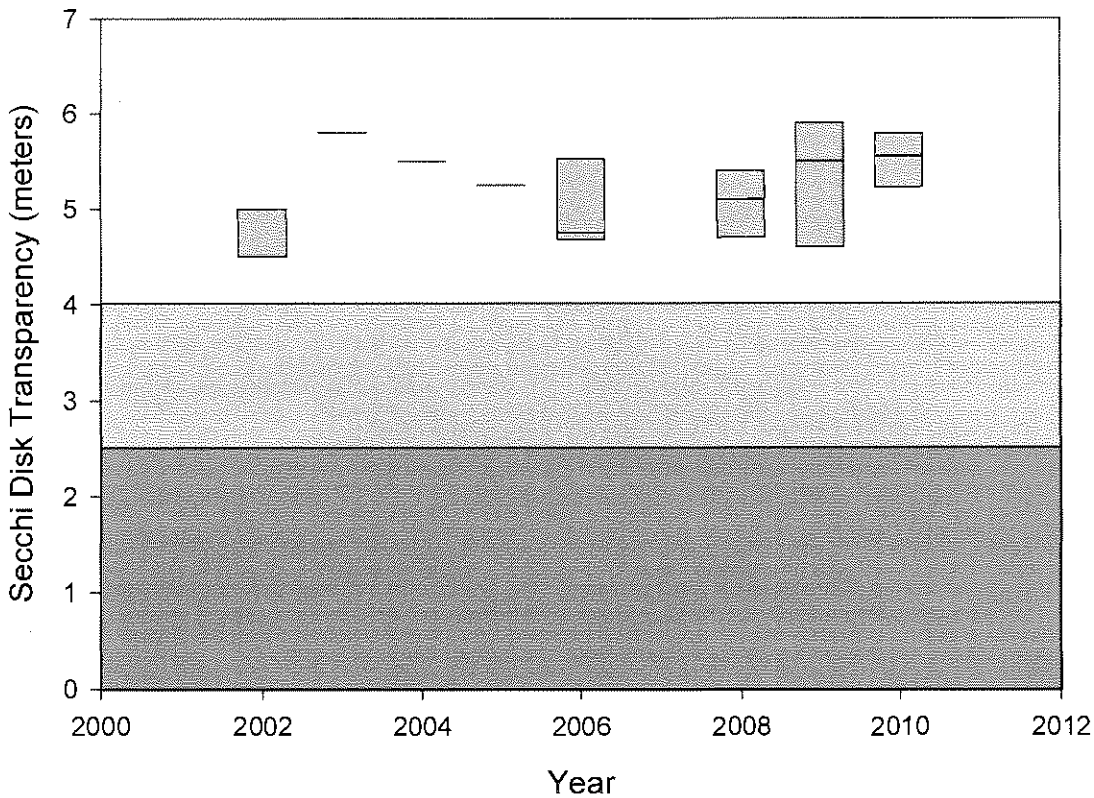
## Great East Lake -- Site 3 MMann
## Annual Secchi Disk Transparency Comparisons
## Box and Whisker Plots: 1995-2010



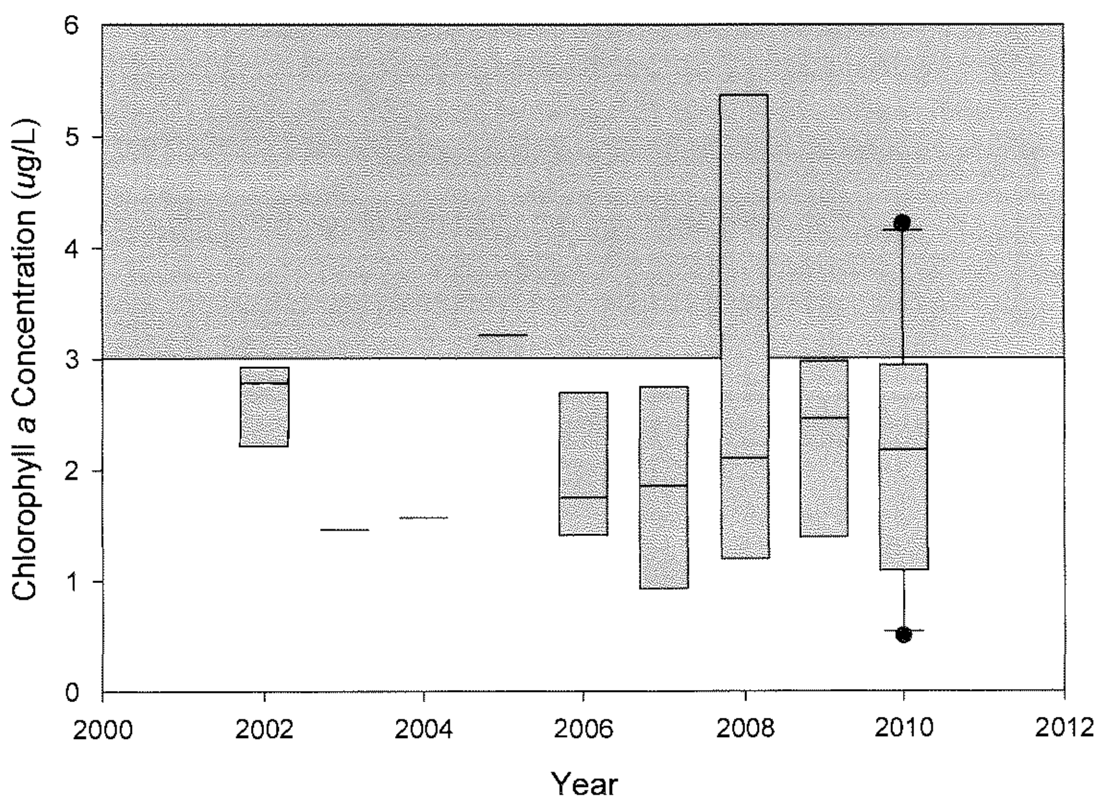

## Great East Lake -- Site 3 MMann
## Annual Chlorophyll *a* Comparisons
## Box and Whisker Plots: 1996-2010



## Great East Lake -- Site Basin 2
## Annual Secchi Disk Transparency Comparisons
## Box and Whisker Plots: 2002-2010

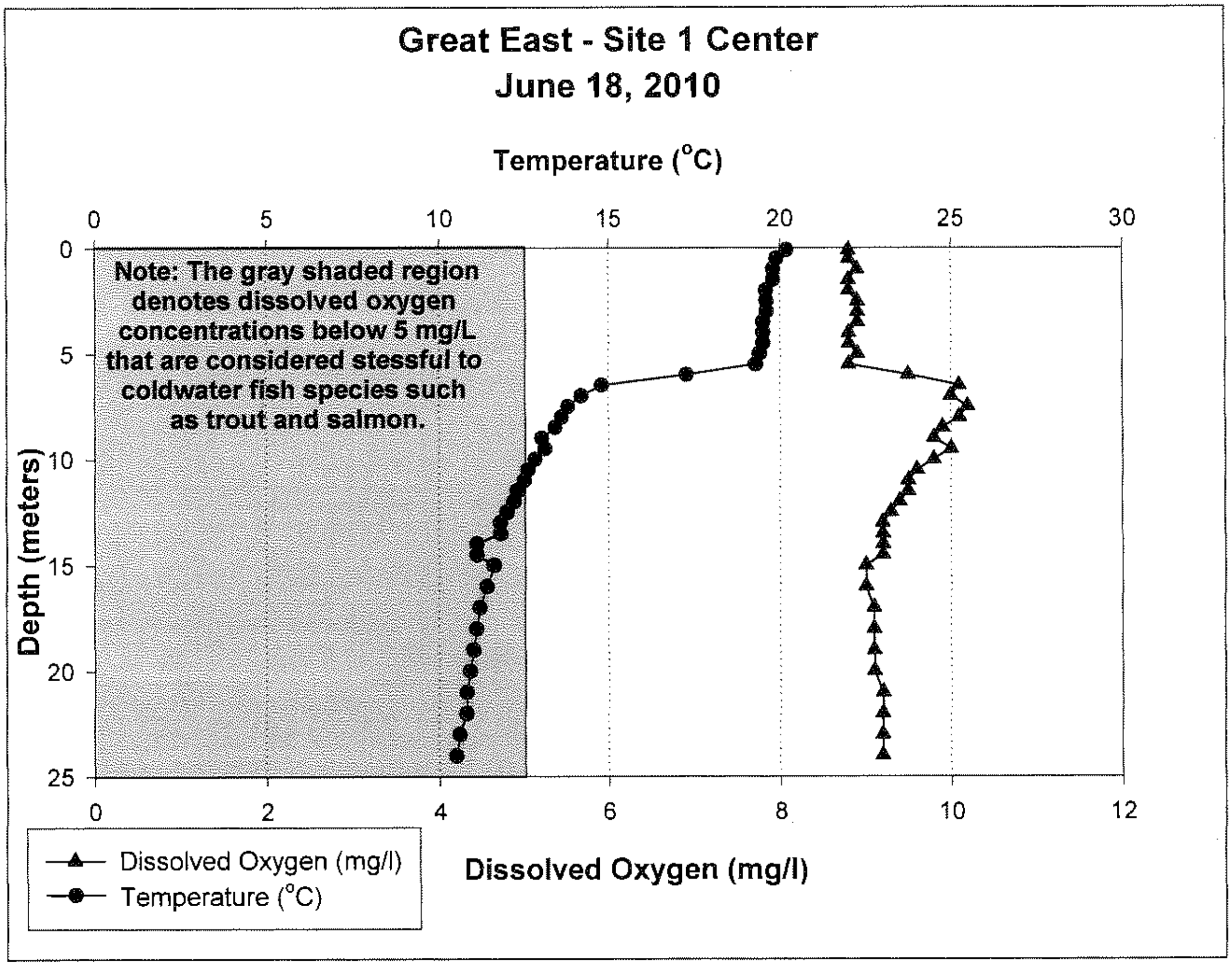



## Great East Lake -- Site Basin 2
## Annual Chlorophyll *a* Comparisons
## Box and Whisker Plots: 2002-2010

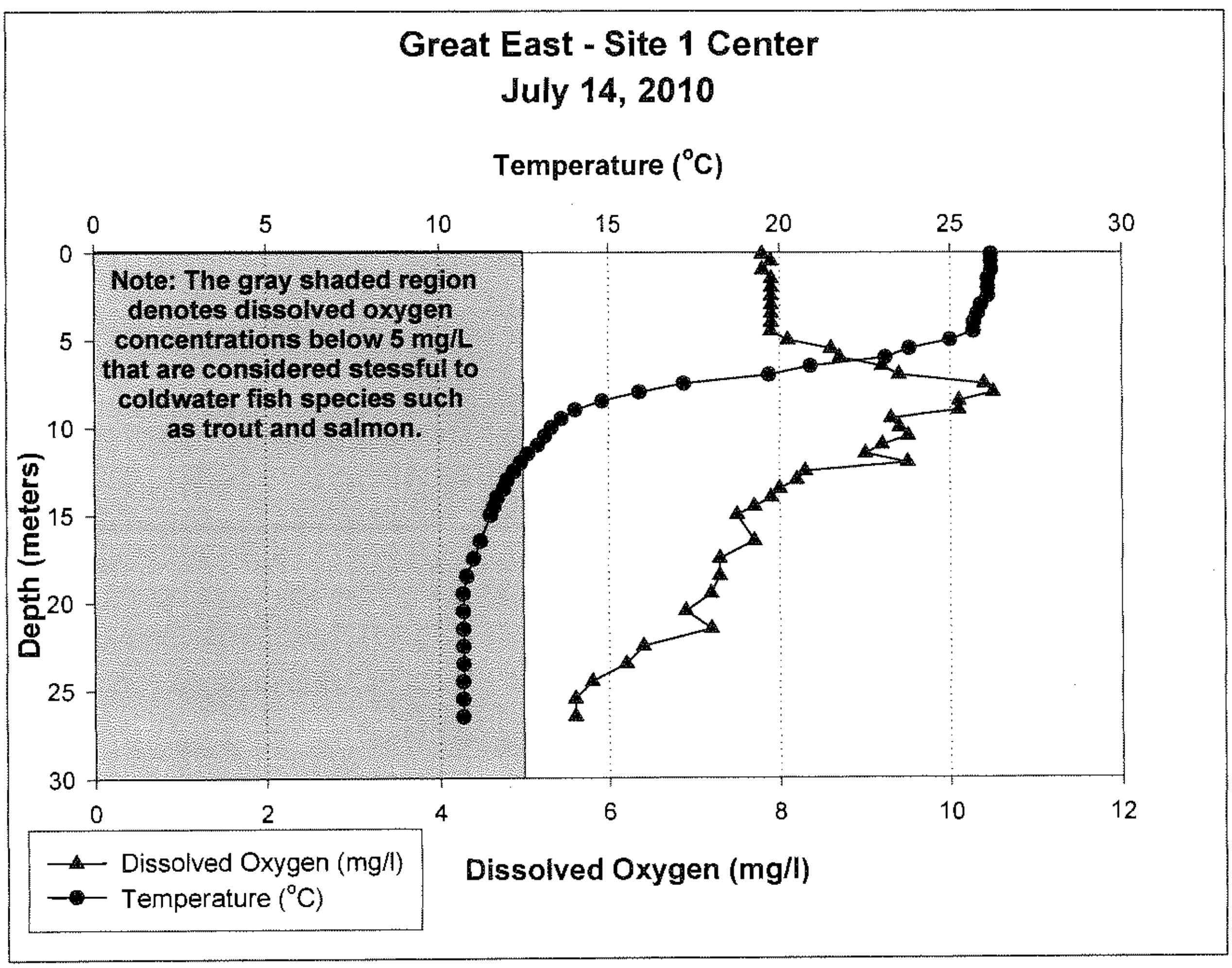


# APPENDIX C

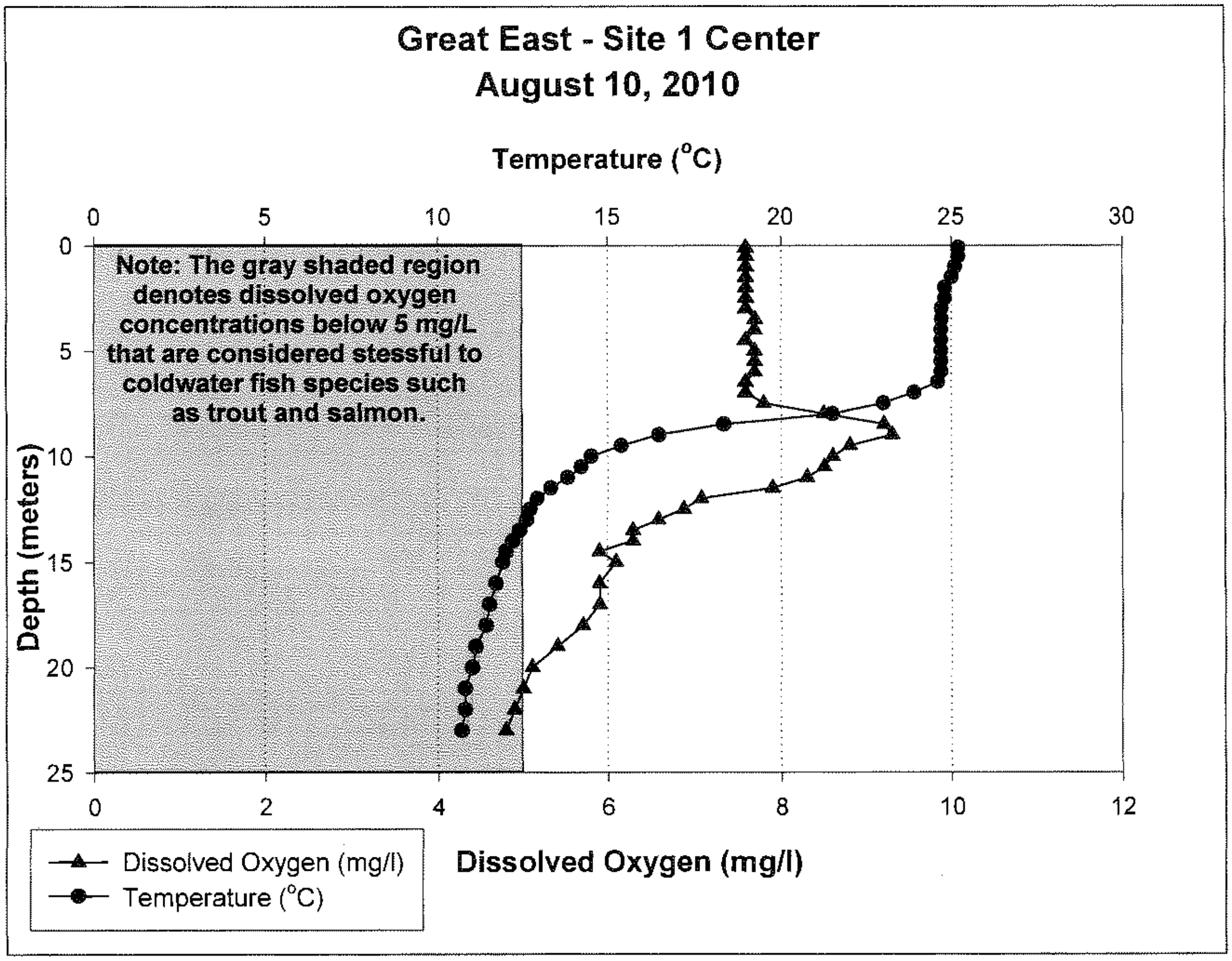
The following graphs illustrate the dissolved oxygen and temperature data collected at the Great East Lake deep sampling stations, Sites 1 Center, 2 Canal, 3 Maine Mann and 2$^{nd}$ Basin, between June 4 and September 23, 2010. Temperature and dissolved oxygen data were generally collected at one-half meter intervals from the surface down to the lake bottom. The temperature units are degrees Celsius ($^{o}$C) while the dissolved oxygen units are milligrams per liter (mg/l). The gray shaded region on the graphs represents dissolved oxygen concentrations stressful to coldwater fish species (dissolved oxygen concentrations less than 5 parts per million). *Notice the low dissolved oxygen concentrations near the lake bottom.*



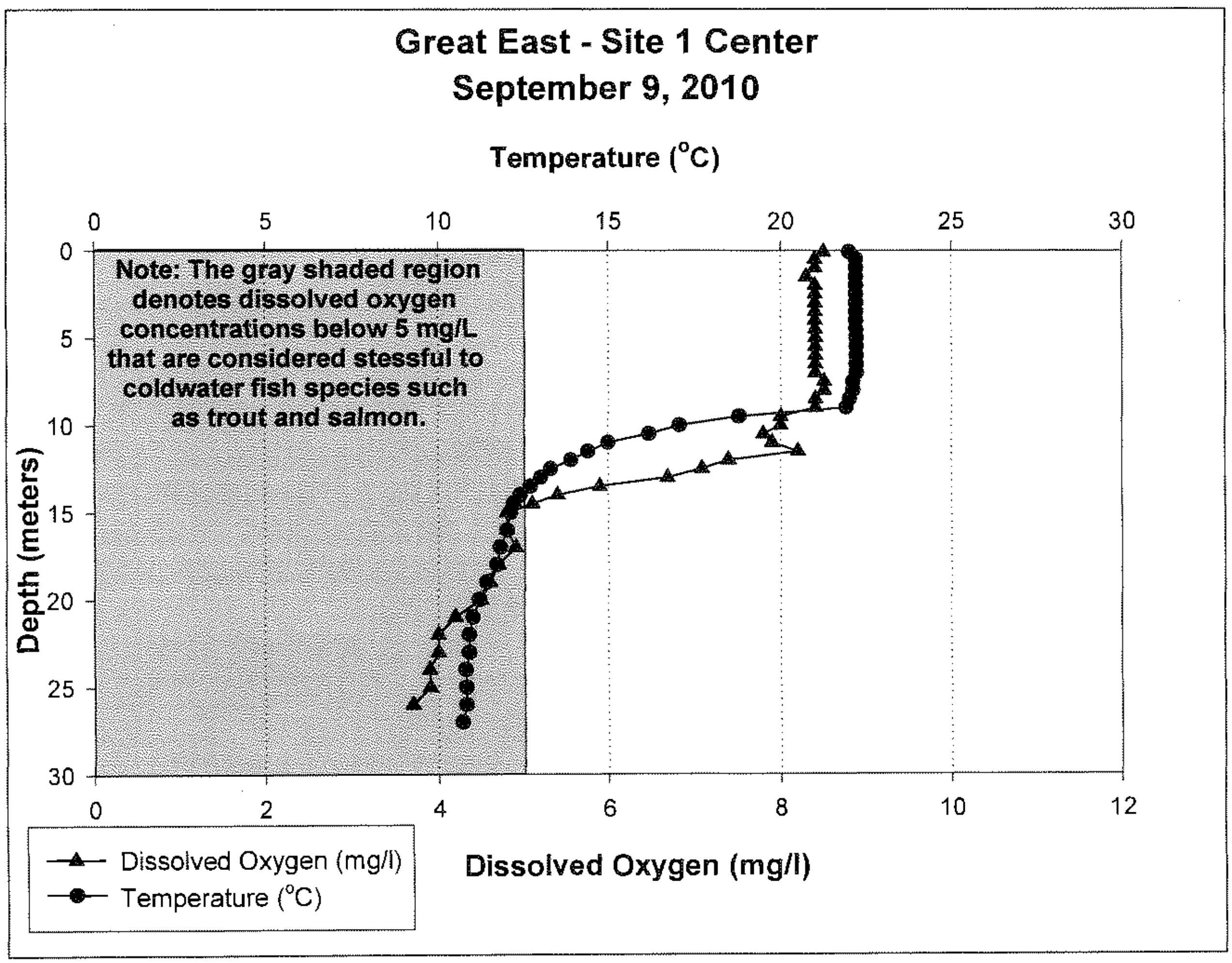
Great East - Site 1 Center
June 18, 2010
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
5
10
15
20
25
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

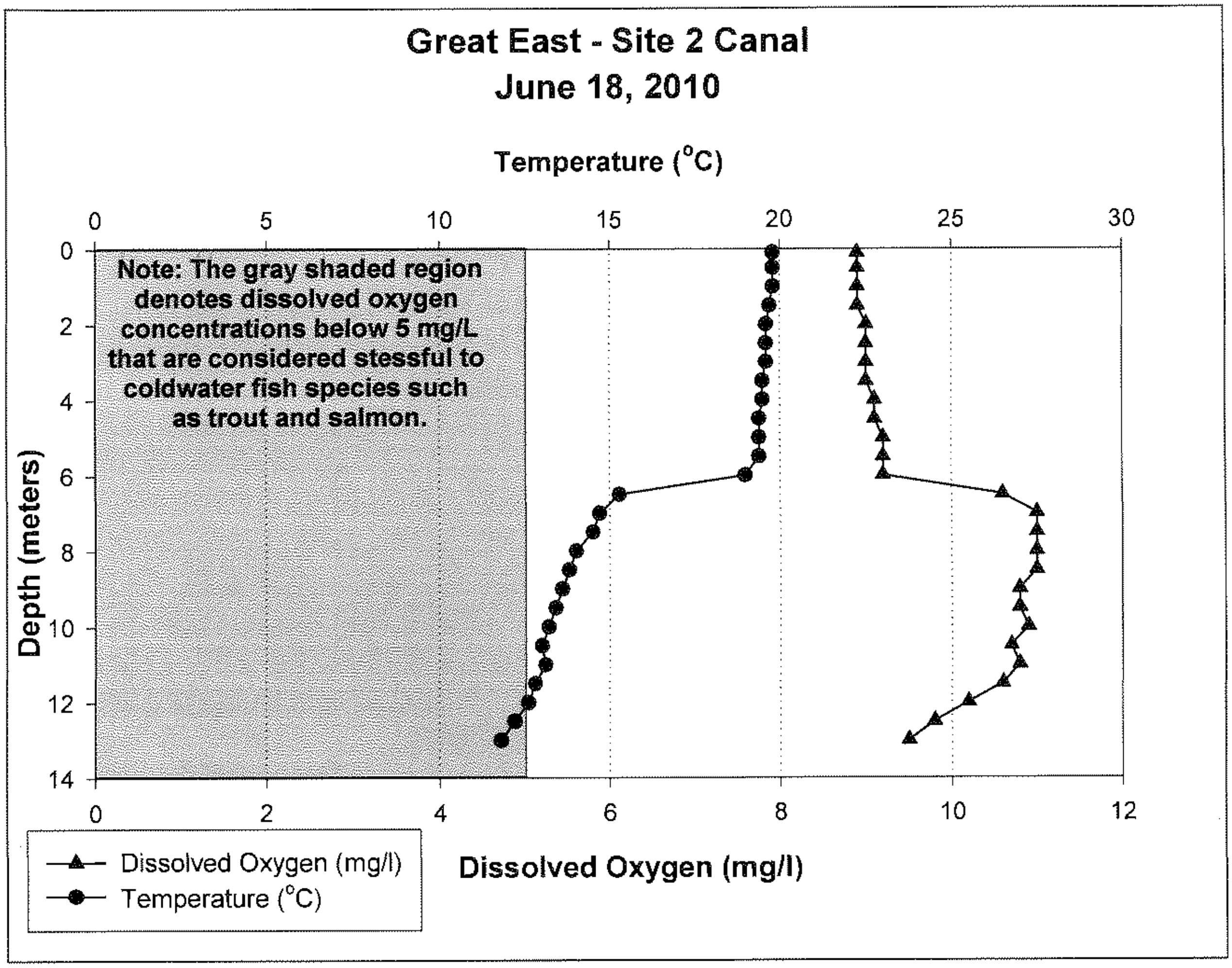
Great East - Site 1 Center
July 14, 2010
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
5
10
15
20
25
30
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

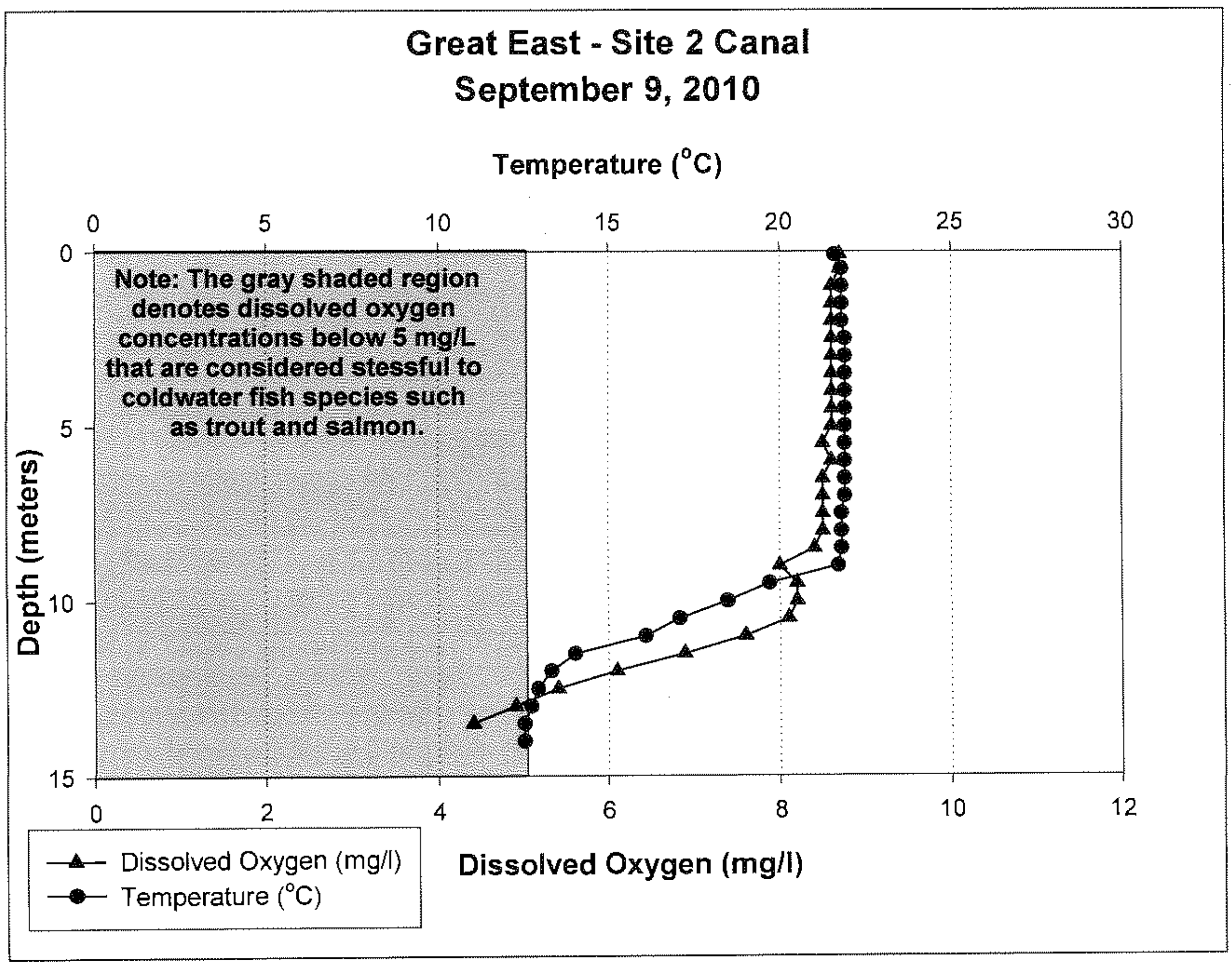


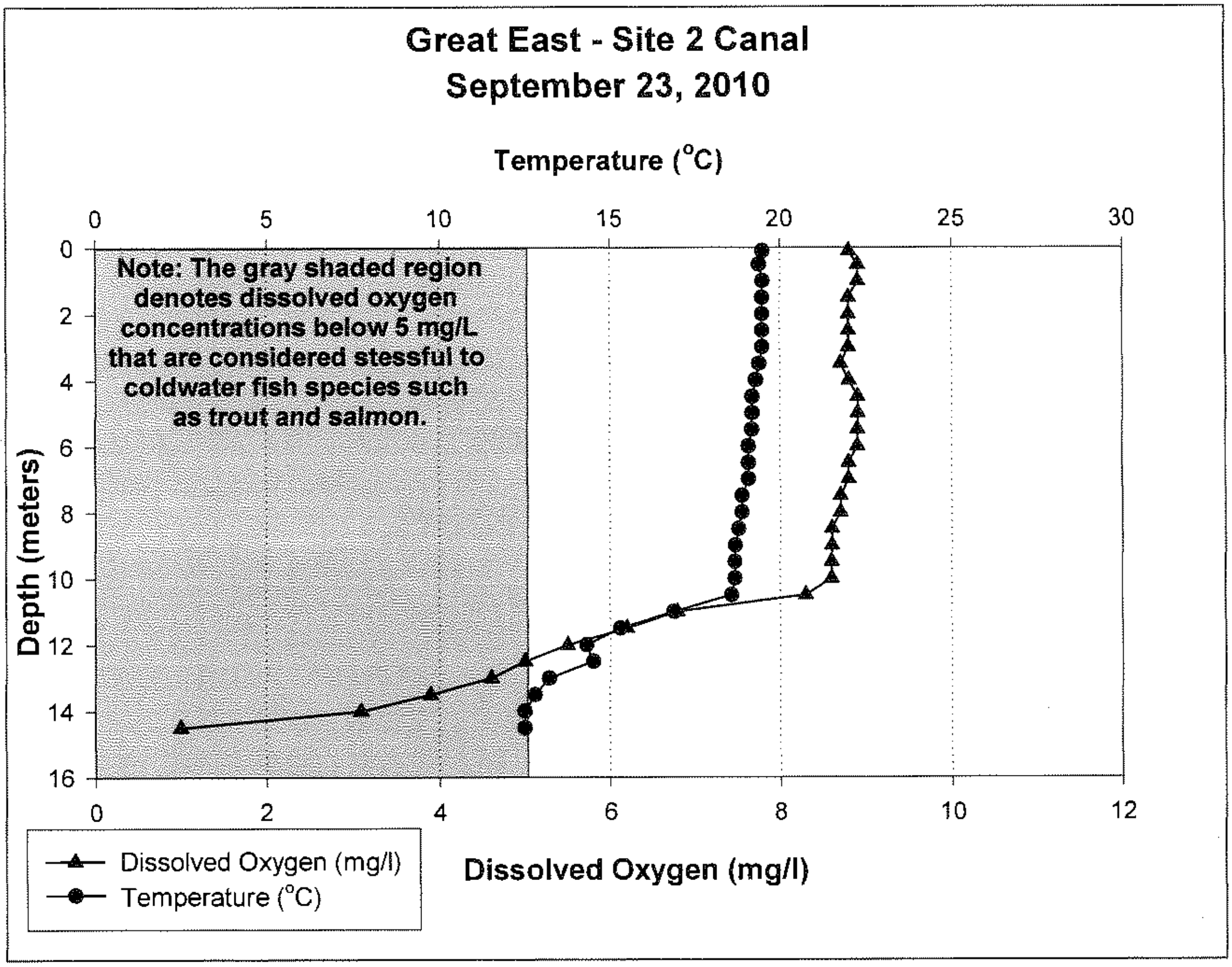
Great East - Site 1 Center
August 10, 2010
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
5
10
15
20
25
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

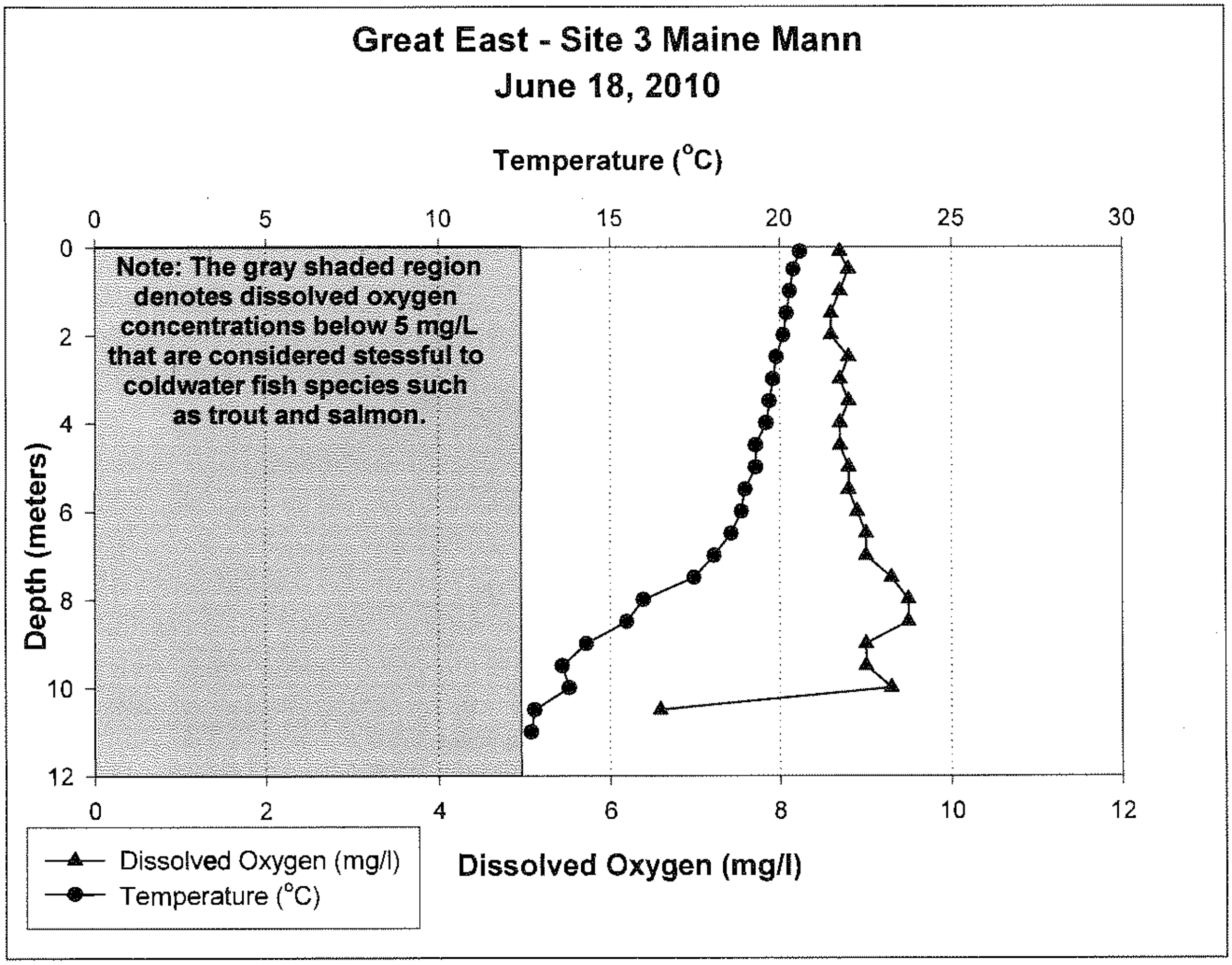



Great East - Site 1 Center
September 9, 2010
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
5
10
15
20
25
30
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

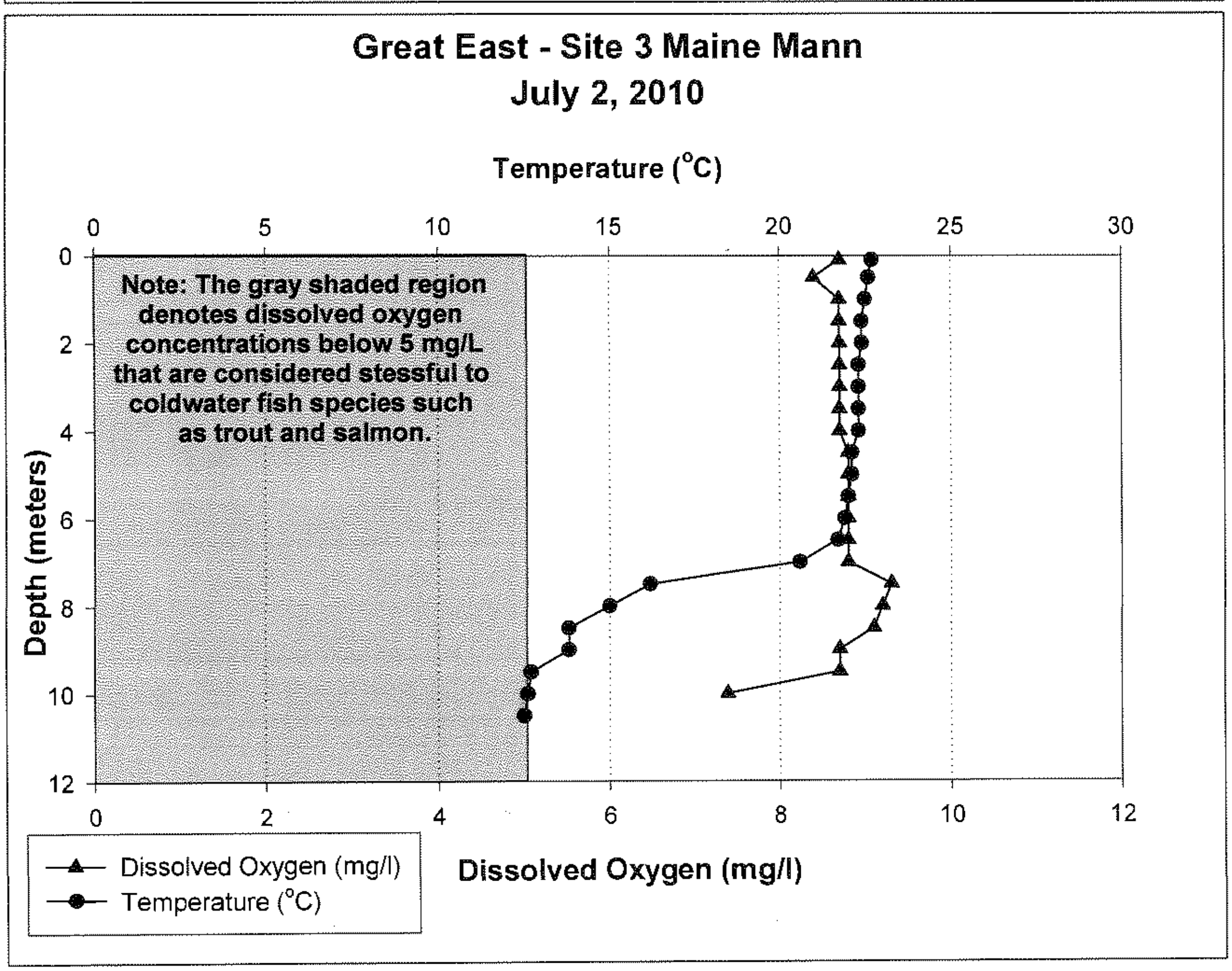

Great East - Site 2 Canal
June 18, 2010
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
2
4
6
8
10
12
14
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)


Great East - Site 2 Canal
September 9, 2010
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
5
10
15
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

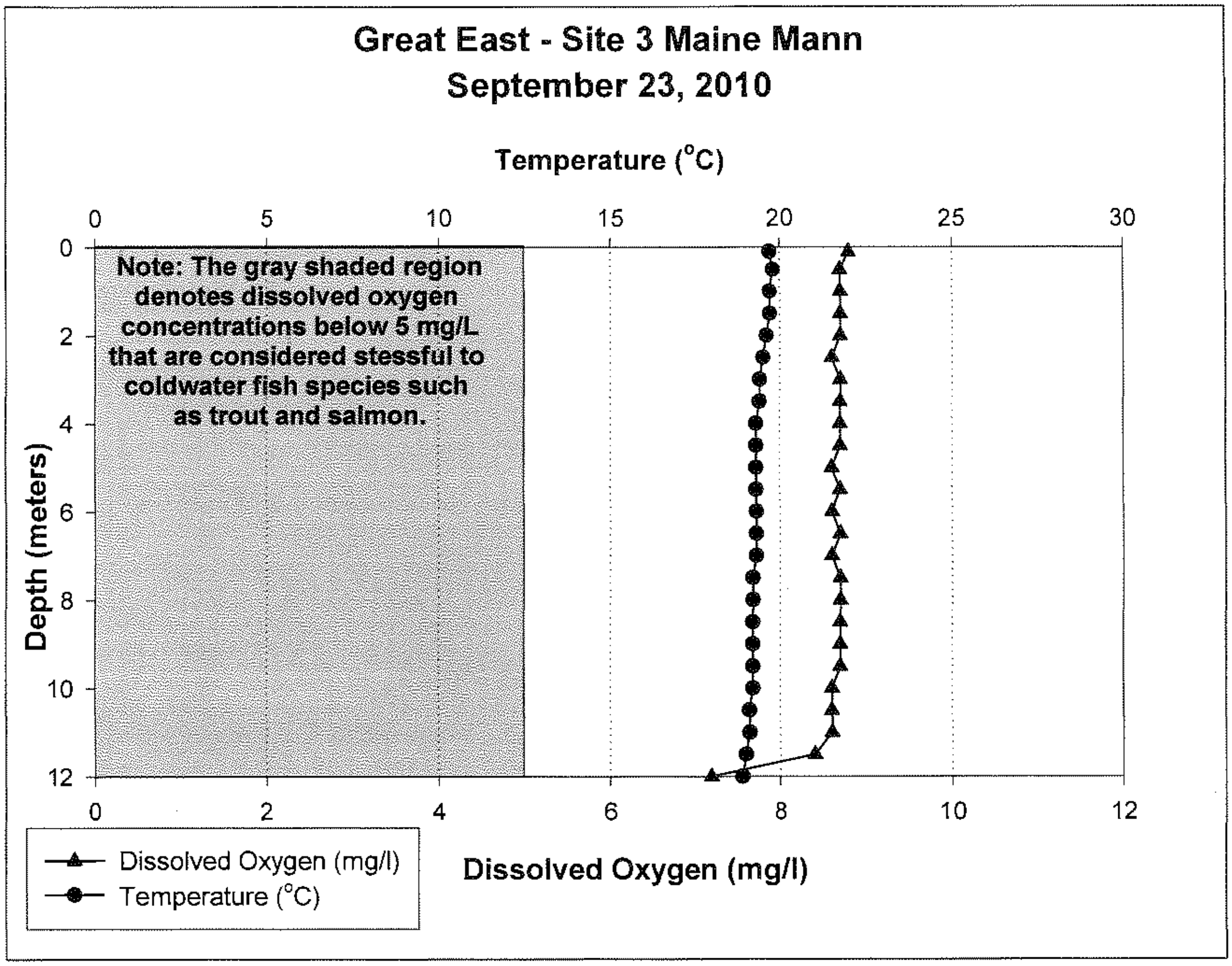

Great East - Site 2 Canal
September 23, 2010
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
2
4
6
8
10
12
14
16
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)



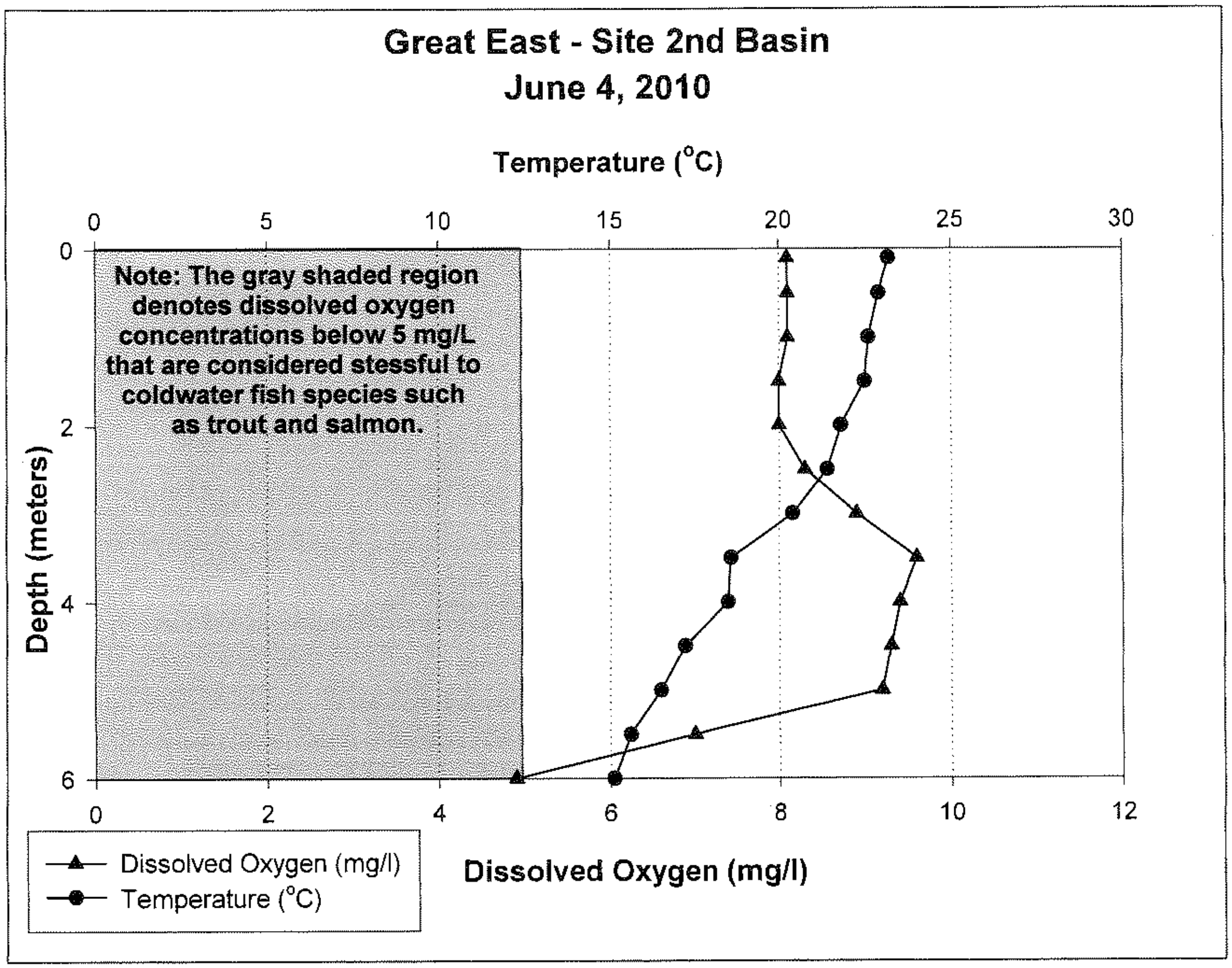
Great East - Site 3 Maine Mann
June 18, 2010
Temperature (°C)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
Dissolved Oxygen (mg/l)
Dissolved Oxygen (mg/l)
Temperature (°C)

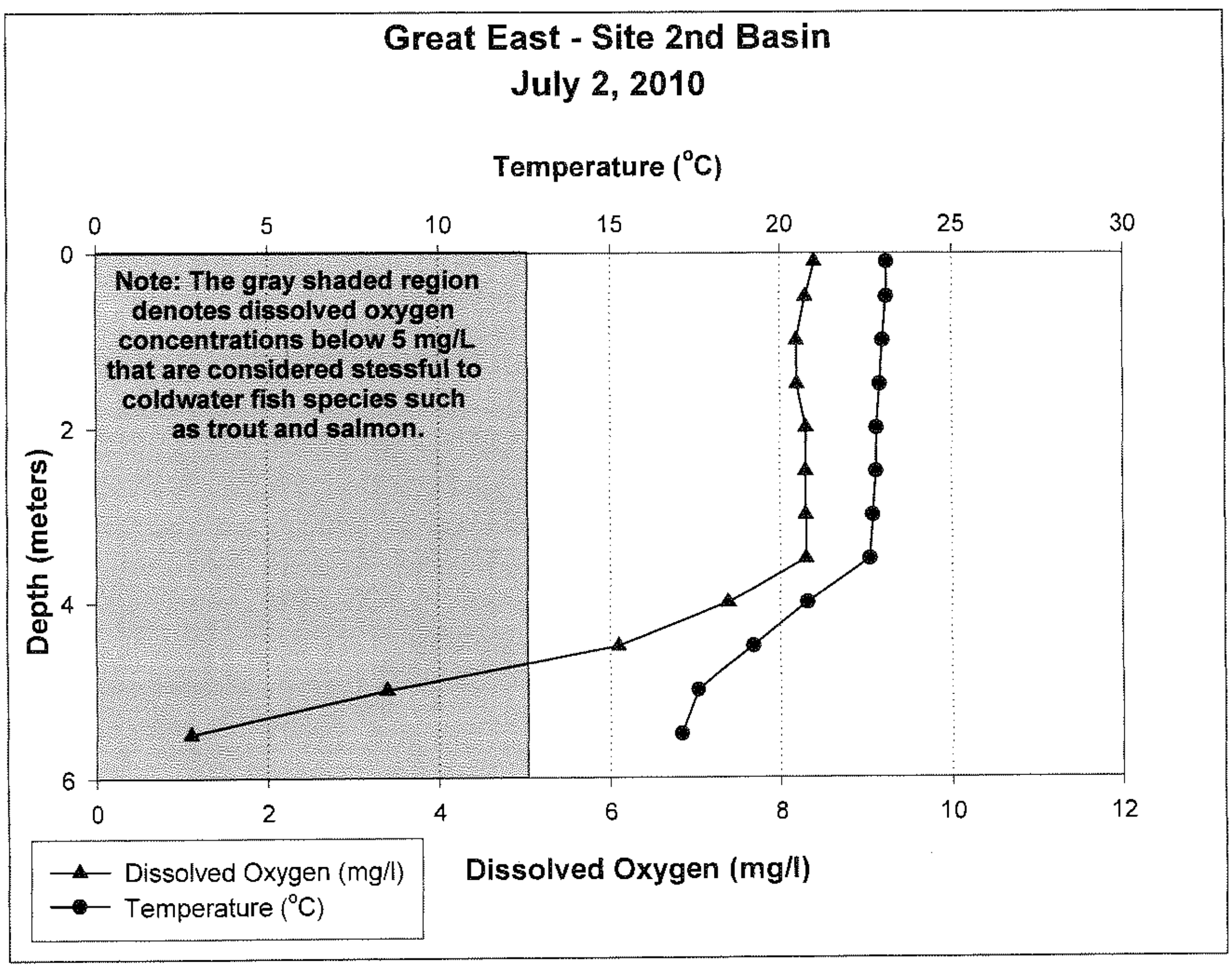
Great East - Site 3 Maine Mann
July 2, 2010
Temperature (°C)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
Dissolved Oxygen (mg/l)
Dissolved Oxygen (mg/l)
Temperature (°C)



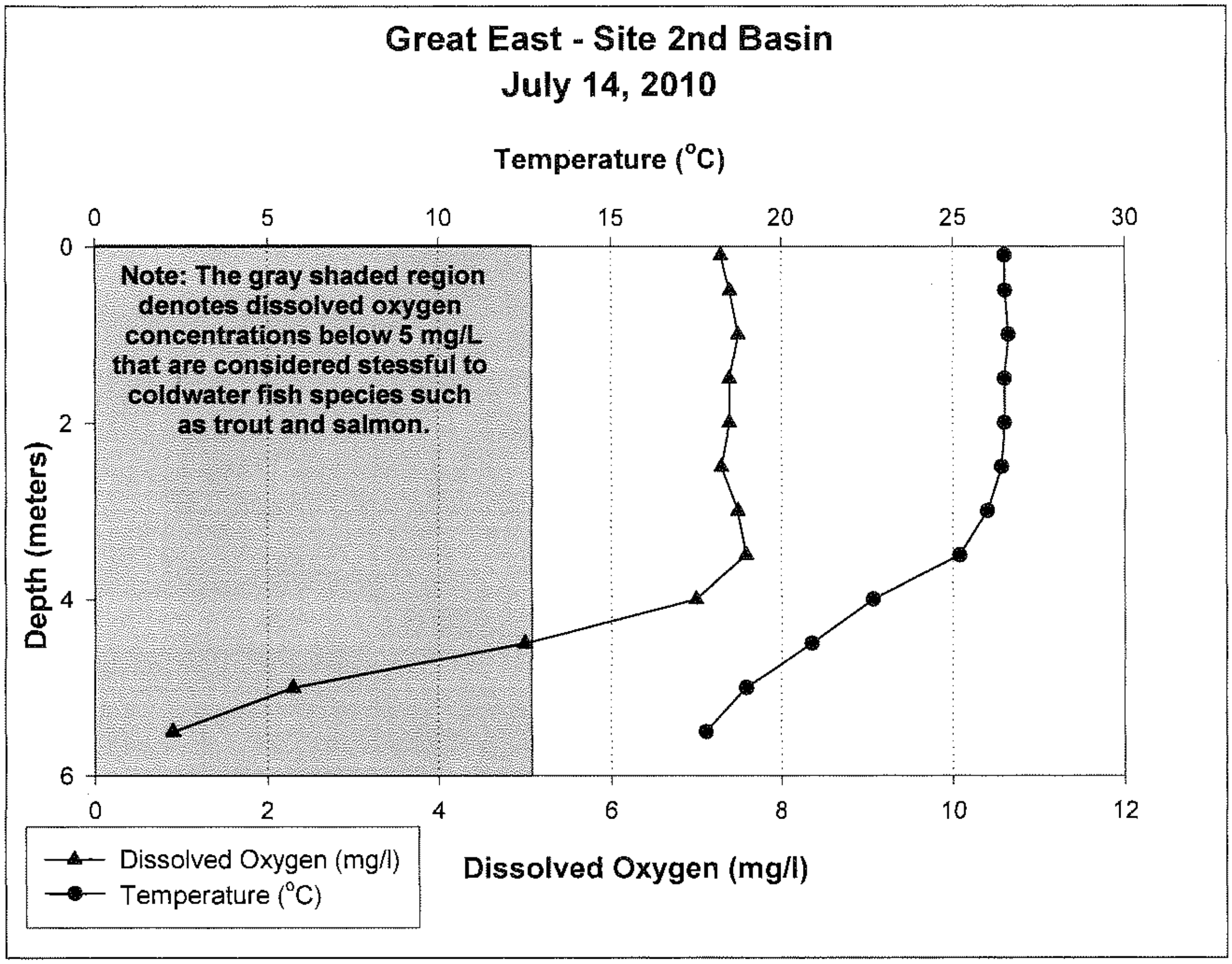
Great East - Site 3 Maine Mann
September 23, 2010
Temperature (°C)
0
5
10
15
20
25
30
Depth (meters)
0
2
4
6
8
10
12
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

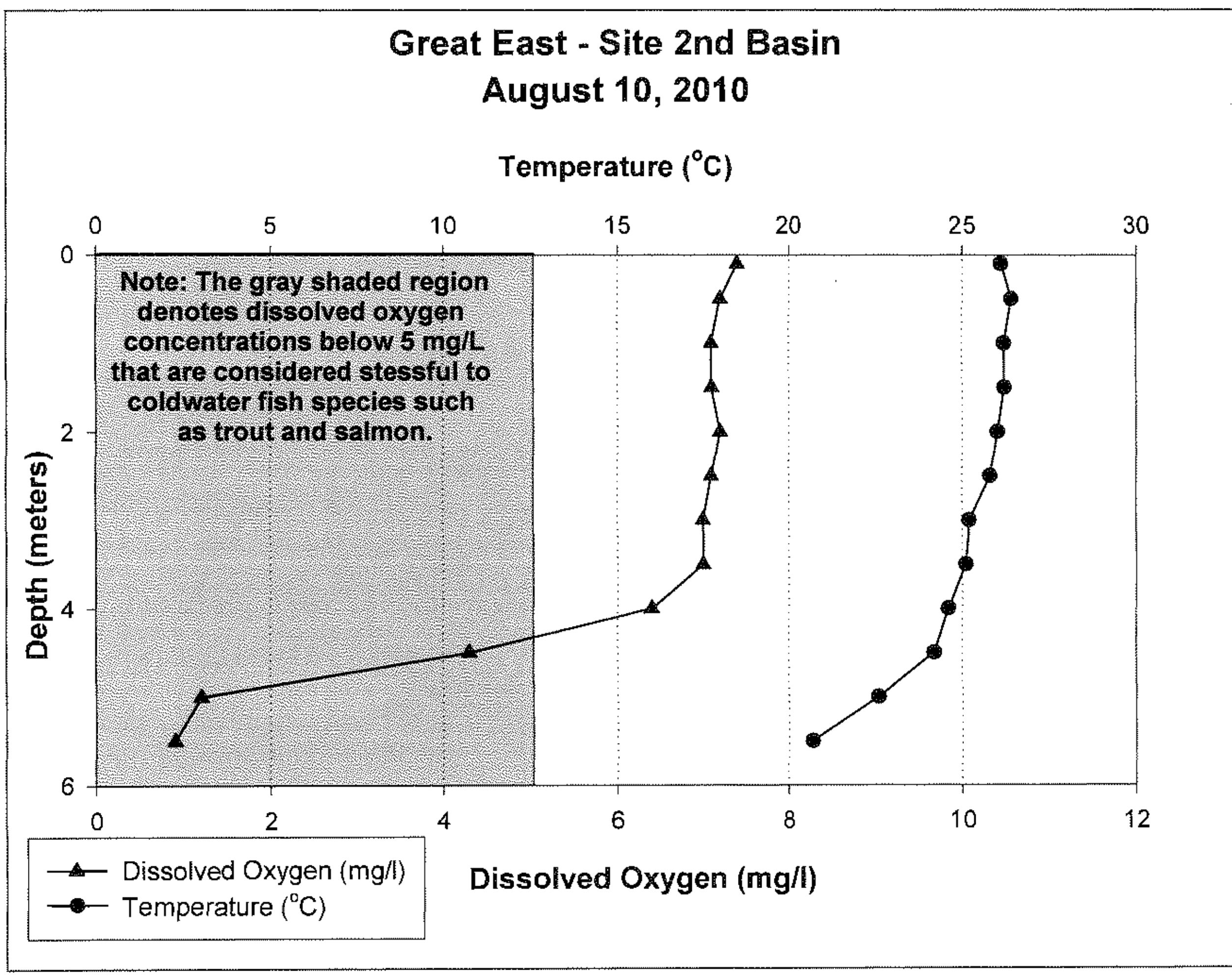


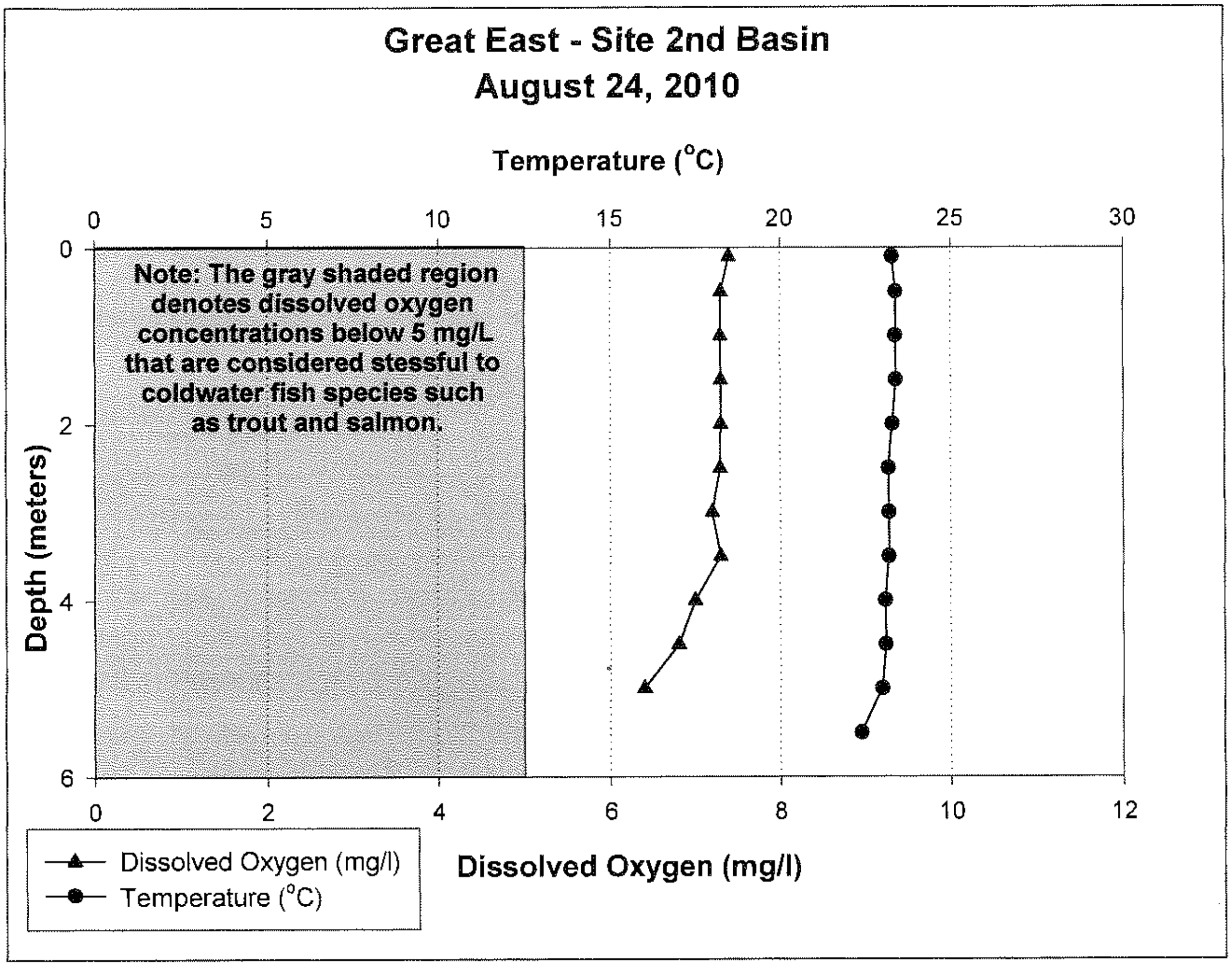
Great East - Site 2nd Basin
June 4, 2010
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
2
4
6
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

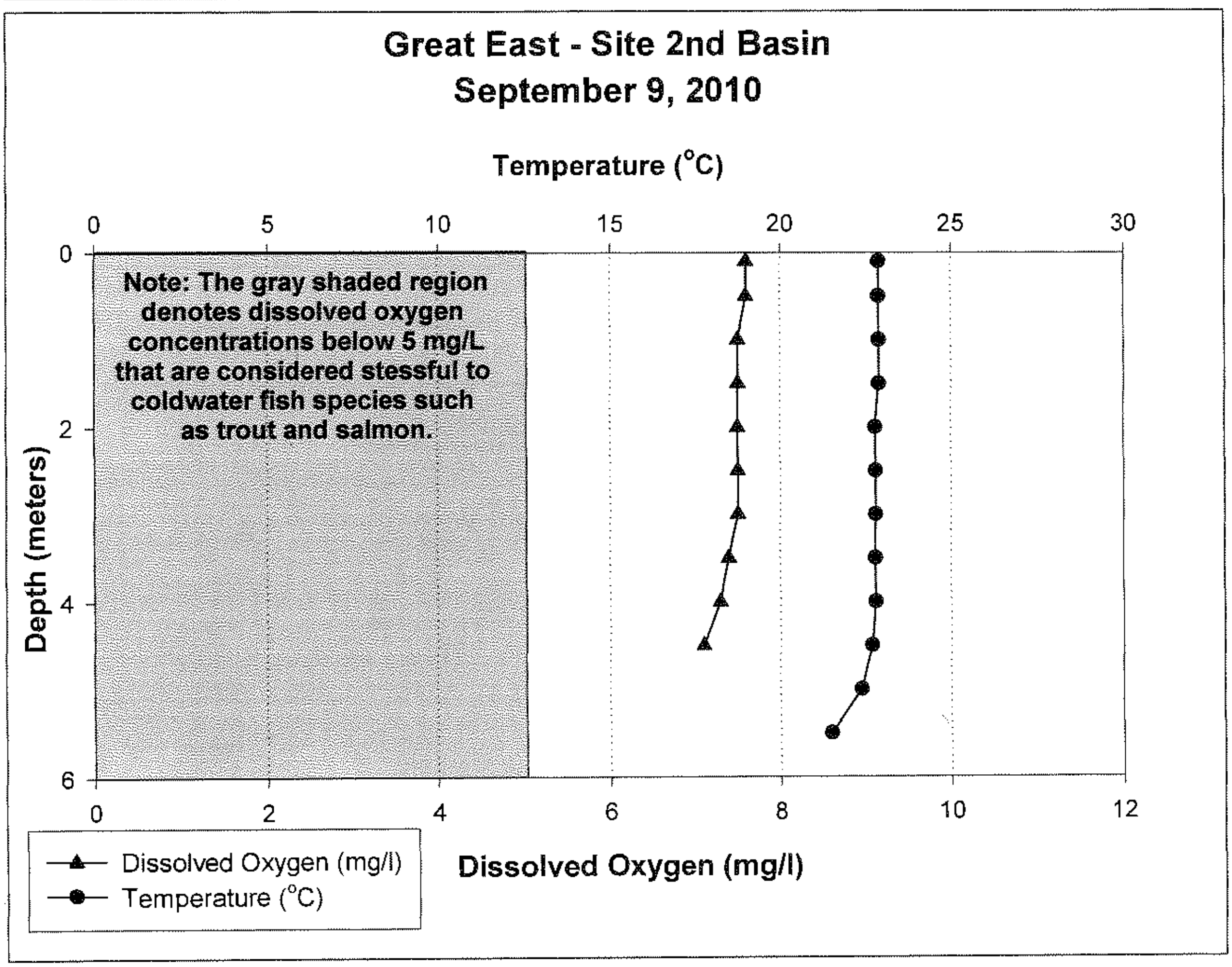



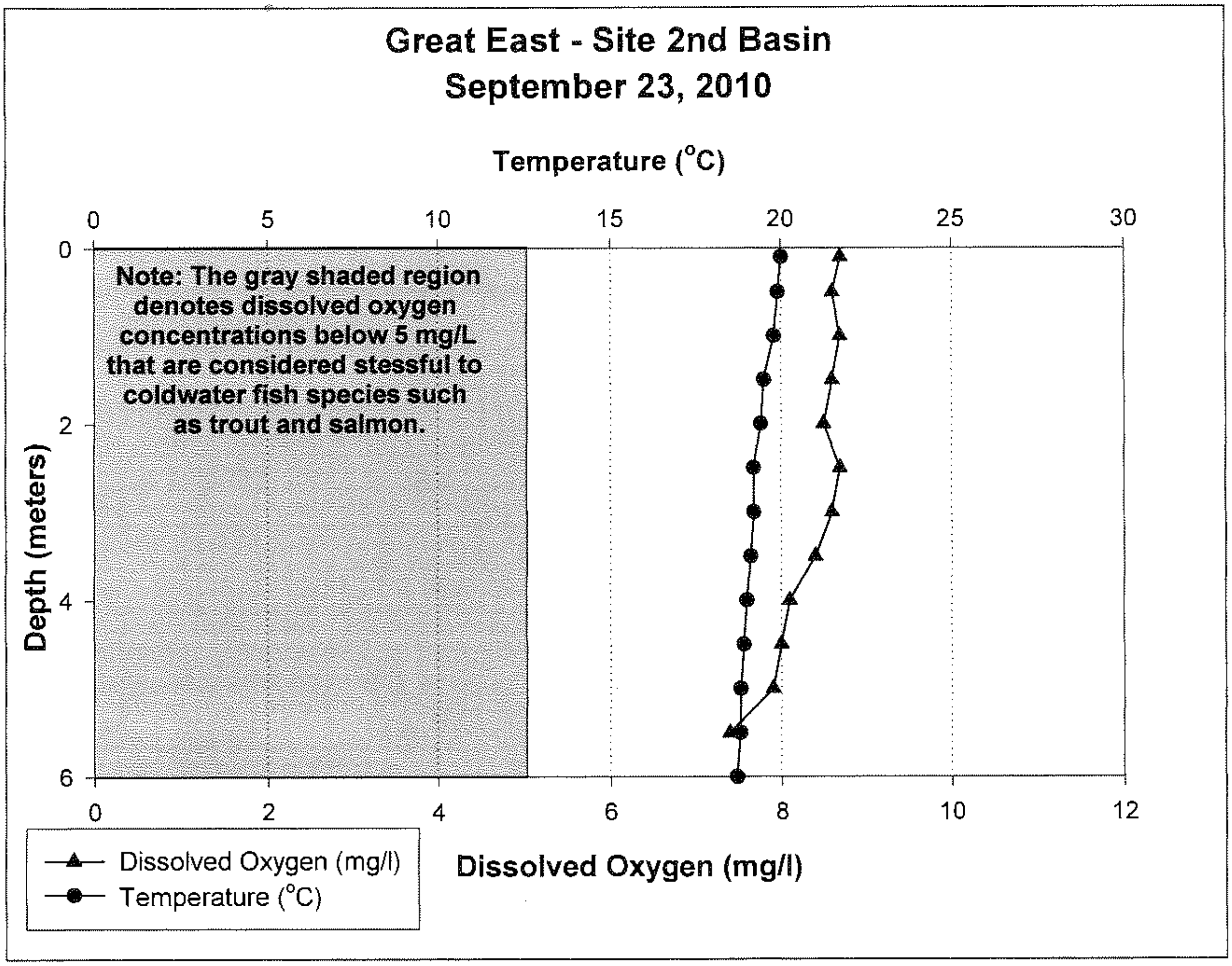
Great East - Site 2nd Basin
July 2, 2010
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
2
4
6
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)


Great East - Site 2nd Basin
July 14, 2010
Temperature (°C)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

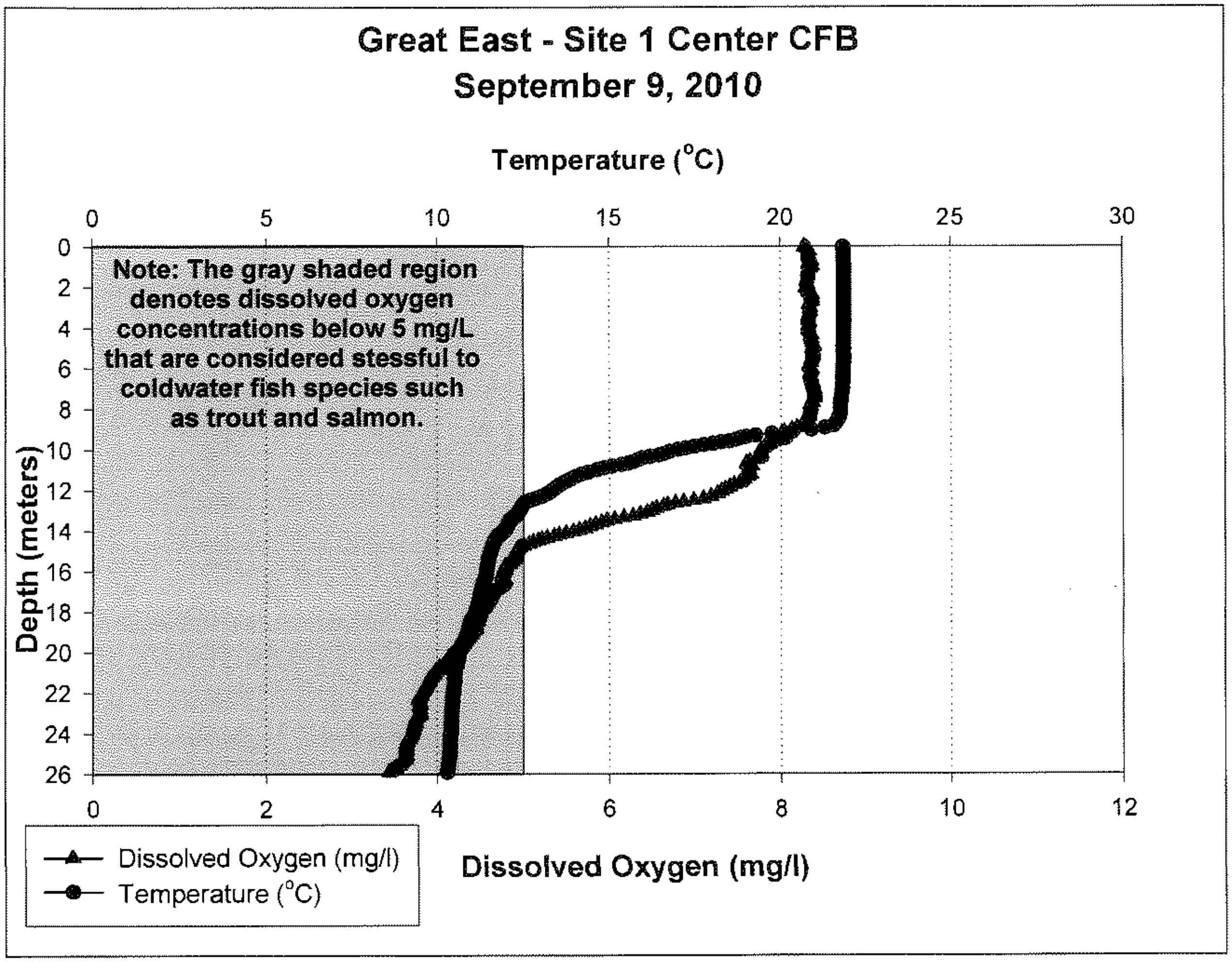

Great East - Site 2nd Basin
August 10, 2010
Temperature (°C)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

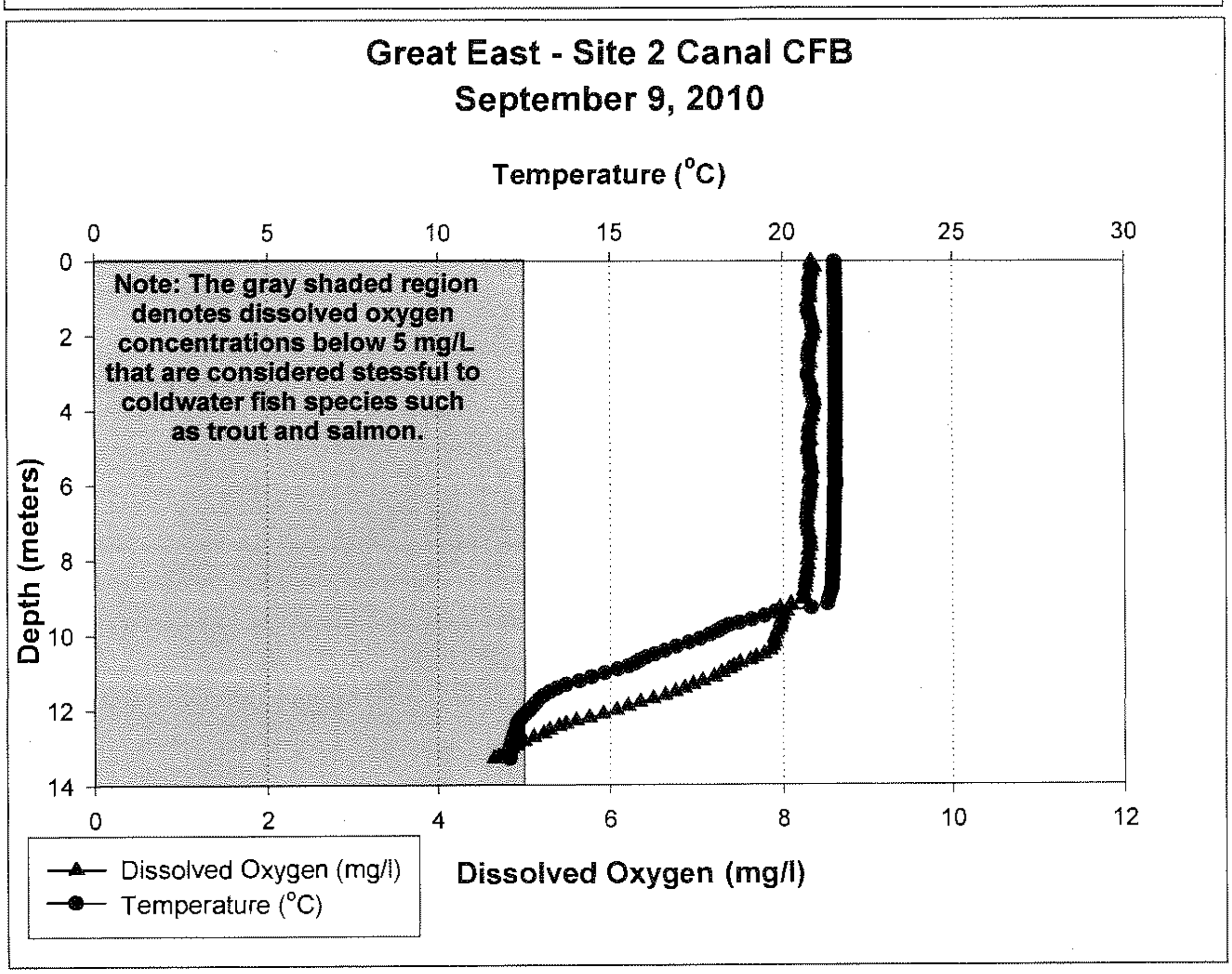

Great East - Site 2nd Basin
August 24, 2010
Temperature (°C)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

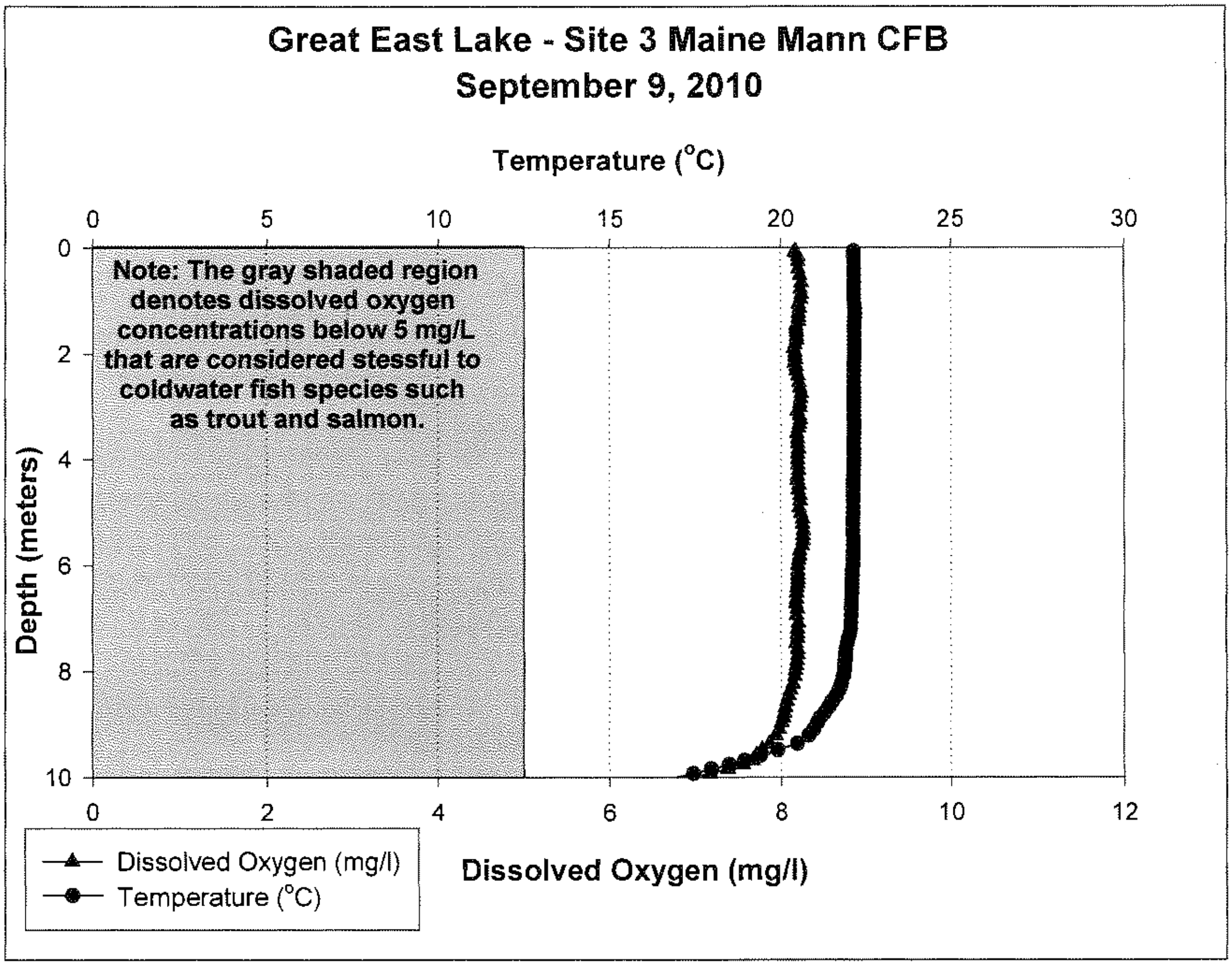

Great East - Site 2nd Basin
September 9, 2010
Temperature (°C)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)



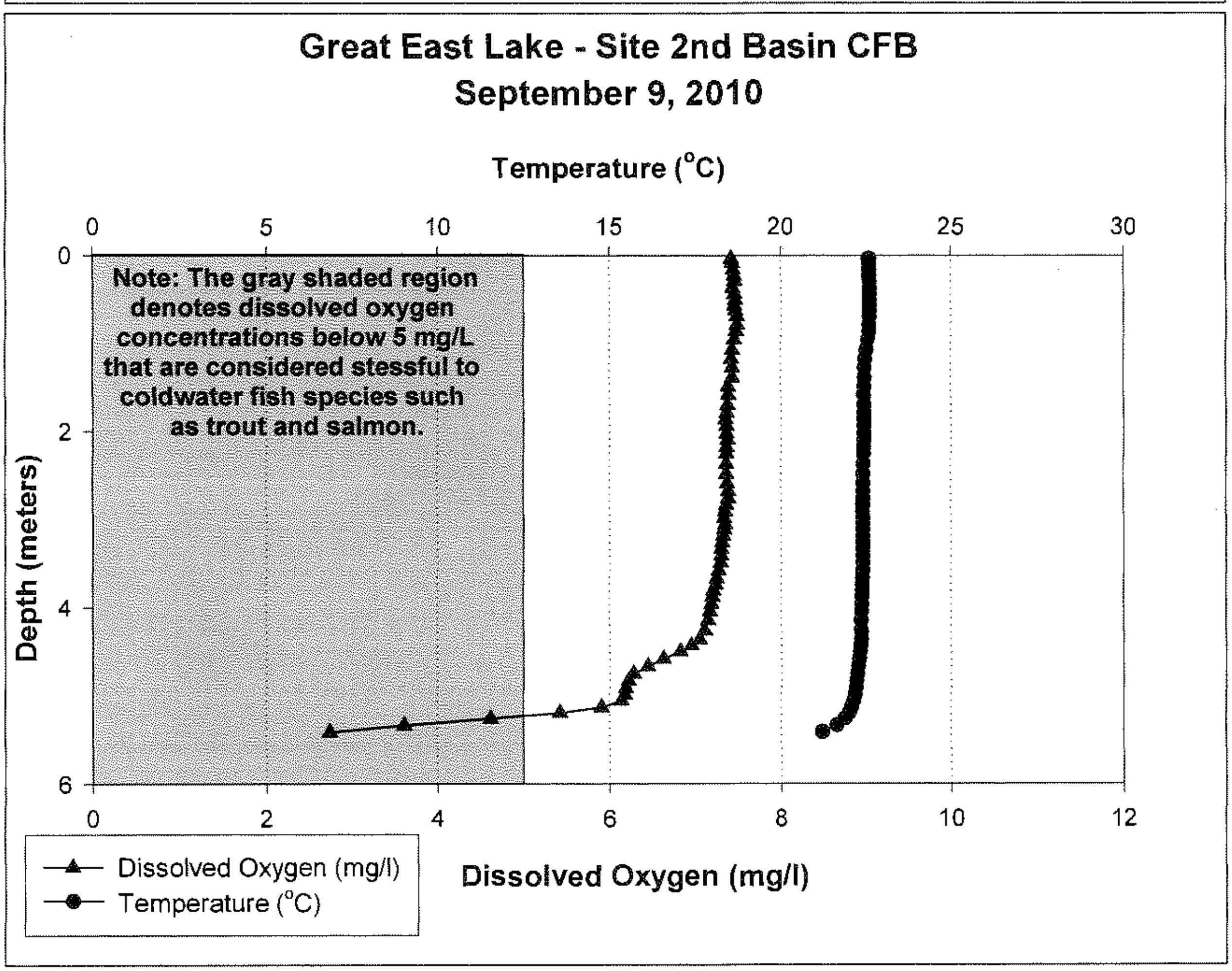
Great East - Site 2nd Basin
September 23, 2010
Temperature (°C)
0 5 10 15 20 25 30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0 2 4 6
0 2 4 6 8 10 12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)


Great East - Site 1 Center CFB
September 9, 2010
Temperature (°C)
0
5
10
15
20
25
30
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Depth (meters)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)


Great East - Site 2 Canal CFB
September 9, 2010
Temperature (°C)
0
5
10
15
20
25
30
0
2
4
6
8
10
12
14
Depth (meters)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)



Great East Lake - Site 3 Maine Mann CFB
September 9, 2010
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
2
4
6
8
10
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

Great East Lake - Site 2nd Basin CFB
September 9, 2010
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
2
4
6
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

# APPENDIX D

**Lakes Lay Monitoring Program, U.N.H.**
**[Lay Monitor Data]**

Great East Lake, Wakefield NH
-- subset of trophic indicators, all sites, 2010

| | | | | | |
|---|---|---|---|---|---|
| Average Transparency: | 8.8 (2010: | 38 values; | 4.5 | - | 11.8 range) |
| Average Chlorophyll: | 1.4 (2010: | 40 values; | 0.4 | - | 4.2 range) |
| Average Color: | 13.8 (2010: | 38 values; | 7.2 | - | 22.5 range) |
| Average Alkalinity (gray): | 6.7 (2010: | 36 values; | 5.8 | - | 8.8 range) |
| Average Alkalinity (pink): | 7.8 (2010: | 36 values; | 7.0 | - | 9.7 range) |
| Total Phosphorus (ug/L): | 7.0 (2010: | 40 values; | 3.2 | - | 14.1 range) |

| Site | Date | Secchi Disk Transparency (meters) | Chl *a* (ug/L) | Dissolved Color (CPU) | Alkalinity Gray end pt. @ pH 5.1 (mg/L) | Alkalinity pink end pt. @ pH 4.6 (mg/L) | Total Phosphorus (ug/L) |
|---|---|---|---|---|---|---|---|
| 1 Center | 5/2/10 | 9.9 | 0.9 | ----- | ----- | ----- | 5.6 |
| 1 Center | 5/20/10 | 10.9 | 1.6 | 17.1 | 7.1 | 7.6 | 4.7 |
| 1 Center | 6/4/10 | 9.1 | 1.0 | 18.9 | 6.1 | 7.2 | 6.8 |
| 1 Center | 6/18/10 | 9.9 | 1.6 | 11.7 | 7.4 | 8.2 | 7.4 |
| 1 Center | 7/2/10 | 9.7 | 0.4 | 10.8 | 6.9 | 8.4 | 5.5 |
| 1 Center | 7/14/10 | 9.9 | 0.9 | 9.9 | 6.4 | 7.2 | 5.6 |
| 1 Center | 8/10/10 | 10.1 | 1.1 | 9.0 | 6.6 | 7.1 | 6.1 |
| 1 Center | 8/24/10 | 10.4 | 0.9 | 8.1 | 6.1 | 7.5 | 4.8 |
| 1 Center | 9/9/10 | 11.2 | 0.9 | 8.1 | 6.4 | 7.4 | 4.3 |
| 1 Center | 9/23/10 | 11.8 | 1.4 | 7.2 | 6.6 | 8.3 | 6.3 |
| 2 Canal | 5/2/10 | 9.5 | 0.7 | 14.4 | ----- | ----- | 6.1 |
| 2 Canal | 5/20/10 | 10.5 | 1.1 | 15.3 | 6.4 | 7.1 | 5.0 |
| 2 Canal | 6/4/10 | 8.0 | 1.2 | 8.1 | 6.8 | 7.6 | 8.0 |
| 2 Canal | 6/18/10 | 9.4 | 1.6 | 12.6 | 6.9 | 7.7 | 4.3 |
| 2 Canal | 7/2/10 | 10.1 | 1.6 | 13.5 | 6.5 | 7.5 | 6.6 |
| 2 Canal | 7/14/10 | 9.6 | 1.0 | 11.7 | 6.5 | 7.5 | 5.7 |
| 2 Canal | 8/10/10 | 10.5 | 0.6 | 9.0 | 6.7 | 7.2 | 7.0 |
| 2 Canal | 8/24/10 | 10.4 | 0.9 | ----- | 6.5 | 7.7 | 7.9 |
| 2 Canal | 9/9/10 | 11.5 | 0.8 | 8.1 | 6.4 | 7.5 | 5.2 |
| 2 Canal | 9/23/10 | ----- | 0.9 | 10.8 | 6.9 | 8.0 | 9.4 |
| 2nd Basin | 5/2/10 | 5.6 | 0.5 | 19.8 | ----- | ----- | 10.0 |
| 2nd Basin | 5/20/10 | 5.5 | 2.3 | 22.5 | 7.0 | 7.7 | 9.3 |
| 2nd Basin | 6/4/10 | 5.5 | 1.2 | 20.7 | 6.8 | 8.8 | 11.7 |
| 2nd Basin | 6/18/10 | 5.1 | 2.7 | 17.1 | 7.3 | 8.1 | 9.6 |
| 2nd Basin | 7/2/10 | 5.8 | 1.1 | 20.7 | 6.2 | 7.8 | 8.4 |
| 2nd Basin | 7/14/10 | 5.7 | 2.1 | 19.8 | 6.9 | 8.1 | 9.8 |
| 2nd Basin | 8/10/10 | 5.1 | 0.9 | 22.5 | 6.3 | 7.0 | 10.2 |
| 2nd Basin | 8/24/10 | 4.5 | 4.2 | 22.5 | 6.3 | 8.6 | 14.1 |

| Site | Date | Secchi Disk Transparency (meters) | Chl *a* (*ug*/L) | Dissolved Color (CPU) | Alkalinity Gray end pt. @ pH 5.1 (mg/L) | Alkalinity pink end pt. @ pH 4.6 (mg/L) | Total Phosphorus (*ug*/L) |
|---|---|---|---|---|---|---|---|
| 2nd Basin | 9/9/10 | 5.5 | 3.6 | 21.6 | 6.7 | 8.6 | 6.5 |
| 2nd Basin | 9/23/10 | 5.4 | 2.4 | 9.9 | 8.8 | 9.1 | 12.2 |
| 3 MMann | 5/2/10 | 10.1 | 0.8 | 14.4 | ----- | ----- | 5.9 |
| 3 MMann | 5/20/10 | 10.8 | 1.4 | 16.2 | 6.6 | 7.2 | 3.2 |
| 3 MMann | 6/4/10 | 9.6 | 1.0 | 22.5 | 7.2 | 9.7 | 6.8 |
| 3 MMann | 6/18/10 | 8.9 | 2.4 | 12.6 | 7.1 | 7.9 | 8.0 |
| 3 MMann | 7/2/10 | ----- | 1.1 | 11.7 | 6.9 | 7.9 | 5.9 |
| 3 MMann | 7/14/10 | 8.9 | 1.0 | 11.7 | 6.6 | 7.5 | 4.1 |
| 3 MMann | 8/10/10 | 9.9 | 0.9 | 9.9 | 6.3 | 7.1 | 7.0 |
| 3 MMann | 8/24/10 | 8.5 | 1.4 | 8.1 | 5.8 | 7.1 | 5.7 |
| 3 MMann | 9/9/10 | 10.3 | 1.1 | 8.1 | 7.0 | 7.6 | 5.0 |
| 3 MMann | 9/23/10 | 9.8 | 1.7 | 9.0 | 6.4 | 7.9 | 6.1 |

<< End of 2010 data listing; 40 records >>

## Lakes Lay Monitoring Program
## [CFB Data – September 9, 2010]

| Site | Depth (meters) | Chlorophyll (ug/l) | Alkalinity gray end @ pH 5.1 (mg/l) | Alkalinity pink end pt. @ pH 4.6 (mg/l) | Total Phosphorus (ug/l) |
|---|---|---|---|---|---|
| 1 Center | 0.5 | 1.0 | 7.1 | 7.6 | ----- |
| 1 Center | 11.5 | 1.6 | 7.0 | 7.6 | 3.7 |
| 1 Center | 25.0 | ----- | 7.2 | 7.8 | 8.3 |
| 1 Center | 0-8.0 | 0.8 | 7.1 | 7.6 | 2.9 |
| 2 Canal | 0.5 | 1.4 | 7.1 | 2.6 | ----- |
| 2 Canal | 10.0 | 2.8 | 7.3 | 7.8 | 4.5 |
| 2 Canal | 12.5 | ----- | 7.2 | 7.7 | 5.2 |
| 2 Canal | 0-8.0 | 2.0 | 7.2 | 7.7 | 3.9 |
| 2nd Basin | 0.5 | 3.6 | 10.2 | 11.0 | ----- |
| 2nd Basin | 0-5.0 | 4.7 | 9.5 | 10.1 | 12.0 |
| 3 Mmann | 0.5 | 1.0 | 7.2 | 8.0 | ----- |
| 3 Mmann | 9.5 | 1.6 | 7.0 | 7.5 | 4.0 |
| 3 Mmann | 0-8 | 1.7 | 7.1 | 7.6 | 6.3 |

| Site | Secchi Disk Transparency (meters) |
|---|---|
| 1 Center | 10.2 meters |
| 2 Canal | 10.4 meters |
| 2nd Basin | 5.2 meters |
| 3 MMann | 9.9 meters |

| Site | Depth (meters) | Temperature (°C) | Dissolved Oxygen (mg/l) | Dissolved Oxygen (% saturation) | Specific Conductivity @ 25°C (uS/cm) |
|---|---|---|---|---|---|
| 1 Deep | 0.03 | 21.9 | 8.28 | 94.5 | 66.0 |
| 1 Deep | 0.02 | 21.9 | 8.29 | 94.6 | 66.0 |
| 1 Deep | 0.08 | 21.9 | 8.31 | 94.9 | 66.0 |
| 1 Deep | 0.15 | 21.9 | 8.33 | 95.1 | 66.0 |
| 1 Deep | 0.24 | 21.9 | 8.35 | 95.2 | 66.0 |
| 1 Deep | 0.32 | 21.9 | 8.33 | 95.0 | 66.0 |
| 1 Deep | 0.41 | 21.9 | 8.34 | 95.1 | 66.0 |
| 1 Deep | 0.49 | 21.9 | 8.34 | 95.2 | 66.0 |
| 1 Deep | 0.58 | 21.9 | 8.35 | 95.2 | 66.0 |
| 1 Deep | 0.66 | 21.9 | 8.37 | 95.5 | 66.0 |
| 1 Deep | 0.74 | 21.9 | 8.37 | 95.5 | 66.0 |
| 1 Deep | 0.81 | 21.9 | 8.34 | 95.2 | 66.0 |
| 1 Deep | 0.89 | 21.9 | 8.33 | 95.0 | 66.0 |
| 1 Deep | 0.98 | 21.9 | 8.38 | 95.6 | 66.0 |
| 1 Deep | 1.07 | 21.9 | 8.36 | 95.4 | 66.0 |
| 1 Deep | 1.15 | 21.9 | 8.33 | 95.0 | 66.0 |
| 1 Deep | 1.25 | 21.9 | 8.33 | 95.0 | 66.0 |
| 1 Deep | 1.34 | 21.9 | 8.33 | 95.0 | 66.0 |

| Site | Depth (meters) | Temperature (°C) | Dissolved Oxygeu (mg/l) | Dissolved Oxygen (% saturation) | Specific Conductivity @ 25°C (uS/cm) |
|---|---|---|---|---|---|
| 1 Deep | 1.47 | 21.9 | 8.33 | 95.1 | 66.0 |
| 1 Deep | 1.60 | 21.9 | 8.32 | 95.0 | 66.0 |
| 1 Deep | 1.71 | 21.9 | 8.31 | 94.8 | 66.0 |
| 1 Deep | 1.82 | 21.9 | 8.32 | 95.0 | 66.0 |
| 1 Deep | 1.91 | 21.9 | 8.33 | 95.0 | 66.0 |
| 1 Deep | 1.98 | 21.9 | 8.31 | 94.8 | 66.0 |
| 1 Deep | 2.06 | 21.9 | 8.30 | 94.7 | 66.0 |
| 1 Deep | 2.12 | 21.9 | 8.33 | 95.1 | 66.0 |
| 1 Deep | 2.19 | 21.9 | 8.33 | 95.1 | 66.0 |
| 1 Deep | 2.26 | 21.9 | 8.34 | 95.2 | 66.0 |
| 1 Deep | 2.32 | 21.9 | 8.35 | 95.3 | 66.0 |
| 1 Deep | 2.38 | 21.9 | 8.38 | 95.6 | 66.0 |
| 1 Deep | 2.43 | 21.9 | 8.37 | 95.5 | 66.0 |
| 1 Deep | 2.49 | 21.9 | 8.37 | 95.5 | 66.0 |
| 1 Deep | 2.55 | 21.9 | 8.38 | 95.6 | 66.0 |
| 1 Deep | 2.62 | 21.9 | 8.37 | 95.5 | 66.0 |
| 1 Deep | 2.69 | 21.9 | 8.38 | 95.6 | 66.0 |
| 1 Deep | 2.77 | 21.9 | 8.36 | 95.4 | 66.0 |
| 1 Deep | 2.85 | 21.9 | 8.34 | 95.2 | 66.0 |
| 1 Deep | 2.94 | 21.9 | 8.35 | 95.3 | 66.0 |
| 1 Deep | 3.02 | 21.9 | 8.36 | 95.4 | 66.0 |
| 1 Deep | 3.11 | 21.9 | 8.35 | 95.3 | 66.0 |
| 1 Deep | 3.20 | 21.9 | 8.36 | 95.4 | 66.0 |
| 1 Deep | 3.27 | 21.9 | 8.35 | 95.3 | 66.0 |
| 1 Deep | 3.37 | 21.9 | 8.34 | 95.2 | 66.0 |
| 1 Deep | 3.47 | 21.9 | 8.33 | 95.1 | 66.0 |
| 1 Deep | 3.57 | 21.9 | 8.33 | 95.1 | 66.0 |
| 1 Deep | 3.66 | 21.9 | 8.33 | 95.1 | 66.0 |
| 1 Deep | 3.76 | 21.9 | 8.35 | 95.3 | 66.0 |
| 1 Deep | 3.85 | 21.9 | 8.34 | 95.2 | 66.0 |
| 1 Deep | 3.94 | 21.9 | 8.33 | 95.1 | 66.0 |
| 1 Deep | 4.03 | 21.9 | 8.34 | 95.1 | 66.0 |
| 1 Deep | 4.11 | 21.9 | 8.33 | 95.0 | 66.0 |
| 1 Deep | 4.18 | 21.9 | 8.34 | 95.2 | 66.0 |
| 1 Deep | 4.28 | 21.9 | 8.36 | 95.4 | 66.0 |
| 1 Deep | 4.37 | 21.9 | 8.37 | 95.4 | 66.0 |
| 1 Deep | 4.46 | 21.9 | 8.36 | 95.3 | 66.0 |
| 1 Deep | 4.55 | 21.9 | 8.37 | 95.5 | 66.0 |
| 1 Deep | 4.65 | 21.9 | 8.37 | 95.5 | 66.0 |
| 1 Deep | 4.74 | 21.9 | 8.38 | 95.6 | 66.0 |
| 1 Deep | 4.84 | 21.9 | 8.39 | 95.8 | 66.0 |
| 1 Deep | 4.94 | 21.9 | 8.40 | 95.9 | 66.0 |
| 1 Deep | 5.03 | 21.9 | 8.37 | 95.5 | 66.0 |
| 1 Deep | 5.12 | 21.9 | 8.38 | 95.5 | 66.0 |
| 1 Deep | 5.22 | 21.9 | 8.38 | 95.5 | 66.0 |

| Site | Depth (meters) | Temperature (°C) | Dissolved Oxygen (mg/l) | Dissolved Oxygen (% saturation) | Specific Conductivity @ 25°C (*u*S/cm) |
|---|---|---|---|---|---|
| 1 Deep | 5.32 | 21.9 | 8.38 | 95.6 | 66.0 |
| 1 Deep | 5.41 | 21.9 | 8.38 | 95.6 | 66.0 |
| 1 Deep | 5.51 | 21.9 | 8.37 | 95.5 | 66.0 |
| 1 Deep | 5.61 | 21.9 | 8.36 | 95.4 | 66.0 |
| 1 Deep | 5.73 | 21.9 | 8.36 | 95.4 | 66.0 |
| 1 Deep | 5.82 | 21.9 | 8.34 | 95.1 | 66.0 |
| 1 Deep | 5.92 | 21.9 | 8.34 | 95.1 | 66.0 |
| 1 Deep | 6.00 | 21.9 | 8.35 | 95.2 | 66.0 |
| 1 Deep | 6.07 | 21.9 | 8.37 | 95.4 | 66.0 |
| 1 Deep | 6.15 | 21.9 | 8.36 | 95.4 | 66.0 |
| 1 Deep | 6.23 | 21.9 | 8.35 | 95.2 | 66.0 |
| 1 Deep | 6.33 | 21.8 | 8.35 | 95.2 | 66.0 |
| 1 Deep | 6.42 | 21.8 | 8.36 | 95.3 | 66.0 |
| 1 Deep | 6.53 | 21.8 | 8.36 | 95.3 | 66.0 |
| 1 Deep | 6.64 | 21.8 | 8.37 | 95.4 | 66.0 |
| 1 Deep | 6.73 | 21.8 | 8.38 | 95.6 | 66.0 |
| 1 Deep | 6.83 | 21.8 | 8.38 | 95.6 | 66.0 |
| 1 Deep | 6.93 | 21.8 | 8.39 | 95.6 | 66.0 |
| 1 Deep | 7.01 | 21.8 | 8.40 | 95.7 | 66.0 |
| 1 Deep | 7.09 | 21.8 | 8.40 | 95.8 | 66.0 |
| 1 Deep | 7.19 | 21.8 | 8.40 | 95.7 | 66.0 |
| 1 Deep | 7.26 | 21.8 | 8.40 | 95.8 | 66.0 |
| 1 Deep | 7.36 | 21.8 | 8.41 | 95.8 | 66.0 |
| 1 Deep | 7.47 | 21.8 | 8.41 | 95.7 | 66.0 |
| 1 Deep | 7.61 | 21.8 | 8.37 | 95.4 | 66.0 |
| 1 Deep | 7.71 | 21.8 | 8.38 | 95.4 | 66.0 |
| 1 Deep | 7.80 | 21.8 | 8.35 | 95.1 | 66.0 |
| 1 Deep | 7.89 | 21.8 | 8.36 | 95.2 | 66.0 |
| 1 Deep | 7.99 | 21.8 | 8.35 | 95.1 | 66.0 |
| 1 Deep | 8.09 | 21.8 | 8.35 | 95.0 | 66.0 |
| 1 Deep | 8.18 | 21.8 | 8.34 | 94.9 | 66.0 |
| 1 Deep | 8.28 | 21.8 | 8.34 | 94.9 | 66.0 |
| 1 Deep | 8.37 | 21.7 | 8.34 | 94.9 | 66.0 |
| 1 Deep | 8.43 | 21.7 | 8.32 | 94.7 | 66.0 |
| 1 Deep | 8.52 | 21.7 | 8.31 | 94.5 | 66.0 |
| 1 Deep | 8.62 | 21.7 | 8.31 | 94.4 | 65.0 |
| 1 Deep | 8.72 | 21.6 | 8.29 | 94.1 | 66.0 |
| 1 Deep | 8.83 | 21.6 | 8.25 | 93.6 | 65.0 |
| 1 Deep | 8.94 | 21.3 | 8.19 | 92.5 | 65.0 |
| 1 Deep | 9.04 | 20.9 | 8.13 | 91.1 | 65.0 |
| 1 Deep | 9.14 | 20.4 | 8.04 | 89.1 | 65.0 |
| 1 Deep | 9.23 | 19.7 | 8.01 | 87.7 | 65.0 |
| 1 Deep | 9.31 | 19.3 | 8.03 | 87.0 | 65.0 |
| 1 Deep | 9.38 | 19.0 | 8.05 | 86.8 | 65.0 |
| 1 Deep | 9.44 | 18.8 | 8.04 | 86.3 | 65.0 |

| Site | Depth<br><br><br>(meters) | Temperature<br><br><br>(°C) | Dissolved Oxygen<br><br>(mg/l) | Dissolved Oxygen<br><br>(% saturation) | Specific Conductivity @ 25°C<br>(uS/cm) |
|---|---|---|---|---|---|
| 1 Deep | 9.51 | 18.7 | 8.02 | 85.9 | 65.0 |
| 1 Deep | 9.58 | 18.5 | 7.98 | 85.2 | 65.0 |
| 1 Deep | 9.65 | 18.3 | 7.92 | 84.1 | 65.0 |
| 1 Deep | 9.71 | 18.0 | 7.87 | 83.2 | 65.0 |
| 1 Deep | 9.78 | 17.8 | 7.86 | 82.6 | 65.0 |
| 1 Deep | 9.85 | 17.5 | 7.82 | 81.7 | 65.0 |
| 1 Deep | 9.92 | 17.2 | 7.80 | 81.1 | 65.0 |
| 1 Deep | 10.01 | 17.0 | 7.76 | 80.3 | 65.0 |
| 1 Deep | 10.10 | 16.8 | 7.76 | 79.9 | 65.0 |
| 1 Deep | 10.20 | 16.6 | 7.77 | 79.7 | 65.0 |
| 1 Deep | 10.28 | 16.4 | 7.76 | 79.4 | 65.0 |
| 1 Deep | 10.35 | 16.2 | 7.76 | 79.0 | 65.0 |
| 1 Deep | 10.41 | 16.0 | 7.75 | 78.4 | 65.0 |
| 1 Deep | 10.51 | 15.8 | 7.71 | 77.8 | 65.0 |
| 1 Deep | 10.59 | 15.7 | 7.63 | 76.8 | 65.0 |
| 1 Deep | 10.66 | 15.6 | 7.59 | 76.2 | 65.0 |
| 1 Deep | 10.74 | 15.4 | 7.60 | 76.0 | 65.0 |
| 1 Deep | 10.82 | 15.1 | 7.66 | 76.1 | 65.0 |
| 1 Deep | 10.90 | 14.8 | 7.62 | 75.3 | 65.0 |
| 1 Deep | 11.00 | 14.6 | 7.62 | 75.0 | 65.0 |
| 1 Deep | 11.12 | 14.4 | 7.62 | 74.6 | 65.0 |
| 1 Deep | 11.22 | 14.2 | 7.65 | 74.5 | 65.0 |
| 1 Deep | 11.33 | 14.0 | 7.62 | 73.9 | 65.0 |
| 1 Deep | 11.45 | 13.9 | 7.57 | 73.3 | 65.0 |
| 1 Deep | 11.56 | 13.8 | 7.54 | 72.8 | 65.0 |
| 1 Deep | 11.65 | 13.7 | 7.51 | 72.3 | 65.0 |
| 1 Deep | 11.74 | 13.6 | 7.45 | 71.6 | 65.0 |
| 1 Deep | 11.84 | 13.5 | 7.40 | 71.0 | 65.0 |
| 1 Deep | 11.95 | 13.4 | 7.35 | 70.4 | 65.0 |
| 1 Deep | 12.06 | 13.3 | 7.31 | 69.9 | 65.0 |
| 1 Deep | 12.18 | 13.2 | 7.26 | 69.3 | 65.0 |
| 1 Deep | 12.31 | 13.0 | 7.19 | 68.3 | 65.0 |
| 1 Deep | 12.42 | 12.9 | 7.10 | 67.2 | 65.0 |
| 1 Deep | 12.50 | 12.7 | 6.99 | 65.9 | 65.0 |
| 1 Deep | 12.57 | 12.6 | 6.87 | 64.6 | 65.0 |
| 1 Deep | 12.63 | 12.6 | 6.77 | 63.6 | 65.0 |
| 1 Deep | 12.70 | 12.5 | 6.68 | 62.7 | 65.0 |
| 1 Deep | 12.78 | 12.5 | 6.63 | 62.2 | 65.0 |
| 1 Deep | 12.87 | 12.5 | 6.55 | 61.4 | 65.0 |
| 1 Deep | 12.98 | 12.4 | 6.50 | 60.9 | 65.0 |
| 1 Deep | 13.09 | 12.4 | 6.44 | 60.3 | 65.0 |
| 1 Deep | 13.17 | 12.4 | 6.36 | 59.5 | 65.0 |
| 1 Deep | 13.26 | 12.3 | 6.28 | 58.6 | 65.0 |
| 1 Deep | 13.34 | 12.2 | 6.17 | 57.5 | 65.0 |
| 1 Deep | 13.42 | 12.2 | 6.06 | 56.5 | 65.0 |

| Site | Depth (meters) | Temperature (°C) | Dissolved Oxygen (mg/l) | Dissolved Oxygen (% saturation) | Specific Conductivity @ 25°C (uS/cm) |
|---|---|---|---|---|---|
| 1 Deep | 13.50 | 12.1 | 5.97 | 55.6 | 65.0 |
| 1 Deep | 13.59 | 12.1 | 5.91 | 55.0 | 65.0 |
| 1 Deep | 13.68 | 12.1 | 5.84 | 54.3 | 65.0 |
| 1 Deep | 13.78 | 12.1 | 5.78 | 53.7 | 65.0 |
| 1 Deep | 13.88 | 12.0 | 5.72 | 53.1 | 65.0 |
| 1 Deep | 13.96 | 12.0 | 5.65 | 52.4 | 65.0 |
| 1 Deep | 14.03 | 11.9 | 5.58 | 51.8 | 65.0 |
| 1 Deep | 14.11 | 11.9 | 5.50 | 50.9 | 65.0 |
| 1 Deep | 14.19 | 11.8 | 5.42 | 50.1 | 65.0 |
| 1 Deep | 14.27 | 11.8 | 5.36 | 49.5 | 65.0 |
| 1 Deep | 14.34 | 11.7 | 5.28 | 48.7 | 65.0 |
| 1 Deep | 14.42 | 11.7 | 5.22 | 48.2 | 65.0 |
| 1 Deep | 14.49 | 11.7 | 5.18 | 47.8 | 65.0 |
| 1 Deep | 14.56 | 11.7 | 5.12 | 47.1 | 65.0 |
| 1 Deep | 14.64 | 11.7 | 5.07 | 46.7 | 65.0 |
| 1 Deep | 14.73 | 11.6 | 5.01 | 46.1 | 65.0 |
| 1 Deep | 14.81 | 11.6 | 4.97 | 45.7 | 65.0 |
| 1 Deep | 14.89 | 11.6 | 4.94 | 45.4 | 65.0 |
| 1 Deep | 14.99 | 11.6 | 4.93 | 45.3 | 65.0 |
| 1 Deep | 15.14 | 11.6 | 4.92 | 45.2 | 65.0 |
| 1 Deep | 15.29 | 11.5 | 4.91 | 45.1 | 65.0 |
| 1 Deep | 15.41 | 11.5 | 4.90 | 45.0 | 65.0 |
| 1 Deep | 15.52 | 11.5 | 4.87 | 44.7 | 65.0 |
| 1 Deep | 15.64 | 11.5 | 4.84 | 44.4 | 65.0 |
| 1 Deep | 15.72 | 11.5 | 4.80 | 44.0 | 65.0 |
| 1 Deep | 15.80 | 11.5 | 4.80 | 44.0 | 65.0 |
| 1 Deep | 15.88 | 11.5 | 4.78 | 43.9 | 65.0 |
| 1 Deep | 15.96 | 11.5 | 4.79 | 43.9 | 65.0 |
| 1 Deep | 16.05 | 11.5 | 4.77 | 43.7 | 65.0 |
| 1 Deep | 16.14 | 11.4 | 4.76 | 43.6 | 65.0 |
| 1 Deep | 16.22 | 11.4 | 4.76 | 43.6 | 65.0 |
| 1 Deep | 16.31 | 11.4 | 4.78 | 43.8 | 65.0 |
| 1 Deep | 16.42 | 11.4 | 4.79 | 43.9 | 65.0 |
| 1 Deep | 16.51 | 11.4 | 4.78 | 43.7 | 65.0 |
| 1 Deep | 16.61 | 11.3 | 4.77 | 43.6 | 65.0 |
| 1 Deep | 16.72 | 11.3 | 4.75 | 43.4 | 65.0 |
| 1 Deep | 16.82 | 11.3 | 4.72 | 43.1 | 65.0 |
| 1 Deep | 16.90 | 11.3 | 4.69 | 42.8 | 65.0 |
| 1 Deep | 17.01 | 11.3 | 4.65 | 42.5 | 65.0 |
| 1 Deep | 17.10 | 11.3 | 4.64 | 42.4 | 65.0 |
| 1 Deep | 17.20 | 11.3 | 4.62 | 42.2 | 65.0 |
| 1 Deep | 17.31 | 11.3 | 4.62 | 42.1 | 65.0 |
| 1 Deep | 17.41 | 11.2 | 4.60 | 42.0 | 65.0 |
| 1 Deep | 17.53 | 11.2 | 4.59 | 41.8 | 65.0 |
| 1 Deep | 17.64 | 11.2 | 4.57 | 41.6 | 65.0 |

| Site | Depth<br>(meters) | Temperature<br>(°C) | Dissolved Oxygen<br>(mg/l) | Dissolved Oxygen<br>(% saturation) | Specific Conductivity @ 25°C<br>(uS/cm) |
|---|---|---|---|---|---|
| 1 Deep | 17.73 | 11.2 | 4.56 | 41.6 | 65.0 |
| 1 Deep | 17.82 | 11.2 | 4.54 | 41.3 | 65.0 |
| 1 Deep | 17.90 | 11.2 | 4.52 | 41.1 | 65.0 |
| 1 Deep | 17.98 | 11.2 | 4.51 | 41.0 | 65.0 |
| 1 Deep | 18.08 | 11.1 | 4.51 | 41.0 | 65.0 |
| 1 Deep | 18.16 | 11.1 | 4.49 | 40.8 | 65.0 |
| 1 Deep | 18.25 | 11.1 | 4.49 | 40.8 | 65.0 |
| 1 Deep | 18.33 | 11.0 | 4.48 | 40.7 | 65.0 |
| 1 Deep | 18.41 | 11.0 | 4.48 | 40.7 | 65.0 |
| 1 Deep | 18.49 | 11.0 | 4.47 | 40.5 | 65.0 |
| 1 Deep | 18.58 | 11.0 | 4.45 | 40.4 | 65.0 |
| 1 Deep | 18.66 | 11.0 | 4.46 | 40.4 | 65.0 |
| 1 Deep | 18.75 | 11.0 | 4.45 | 40.3 | 65.0 |
| 1 Deep | 18.84 | 11.0 | 4.46 | 40.4 | 65.0 |
| 1 Deep | 18.92 | 10.9 | 4.44 | 40.2 | 65.0 |
| 1 Deep | 19.02 | 10.9 | 4.41 | 39.9 | 65.0 |
| 1 Deep | 19.12 | 10.9 | 4.40 | 39.8 | 65.0 |
| 1 Deep | 19.22 | 10.9 | 4.38 | 39.6 | 65.0 |
| 1 Deep | 19.32 | 10.8 | 4.36 | 39.4 | 65.0 |
| 1 Deep | 19.41 | 10.8 | 4.34 | 39.2 | 65.0 |
| 1 Deep | 19.50 | 10.8 | 4.32 | 39.0 | 65.0 |
| 1 Deep | 19.59 | 10.7 | 4.31 | 38.8 | 65.0 |
| 1 Deep | 19.72 | 10.7 | 4.29 | 38.6 | 65.0 |
| 1 Deep | 19.81 | 10.7 | 4.27 | 38.5 | 65.0 |
| 1 Deep | 19.89 | 10.7 | 4.25 | 38.2 | 65.0 |
| 1 Deep | 19.98 | 10.7 | 4.22 | 38.0 | 65.0 |
| 1 Deep | 20.08 | 10.7 | 4.19 | 37.7 | 65.0 |
| 1 Deep | 20.18 | 10.6 | 4.16 | 37.4 | 65.0 |
| 1 Deep | 20.28 | 10.6 | 4.14 | 37.2 | 65.0 |
| 1 Deep | 20.39 | 10.6 | 4.13 | 37.1 | 65.0 |
| 1 Deep | 20.49 | 10.6 | 4.12 | 37.0 | 65.0 |
| 1 Deep | 20.58 | 10.6 | 4.11 | 36.9 | 65.0 |
| 1 Deep | 20.64 | 10.6 | 4.10 | 36.8 | 65.0 |
| 1 Deep | 20.69 | 10.6 | 4.07 | 36.5 | 65.0 |
| 1 Deep | 20.76 | 10.6 | 4.03 | 36.2 | 65.0 |
| 1 Deep | 20.84 | 10.5 | 4.02 | 36.0 | 65.0 |
| 1 Deep | 20.94 | 10.5 | 3.99 | 35.8 | 65.0 |
| 1 Deep | 21.04 | 10.5 | 3.97 | 35.7 | 65.0 |
| 1 Deep | 21.12 | 10.5 | 3.97 | 35.6 | 65.0 |
| 1 Deep | 21.20 | 10.5 | 3.94 | 35.3 | 65.0 |
| 1 Deep | 21.25 | 10.5 | 3.93 | 35.2 | 65.0 |
| 1 Deep | 21.32 | 10.5 | 3.91 | 35.0 | 65.0 |
| 1 Deep | 21.39 | 10.5 | 3.91 | 35.0 | 65.0 |
| 1 Deep | 21.46 | 10.5 | 3.91 | 35.0 | 65.0 |
| 1 Deep | 21.54 | 10.5 | 3.89 | 34.9 | 65.0 |

| Site | Depth<br><br>(meters) | Temperature<br><br>(°C) | Dissolved Oxygen<br><br>(mg/l) | Dissolved Oxygen<br><br>(% saturation) | Specific Conductivity @ 25°C<br>(uS/cm) |
|---|---|---|---|---|---|
| 1 Deep | 21.62 | 10.5 | 3.88 | 34.8 | 65.0 |
| 1 Deep | 21.71 | 10.5 | 3.87 | 34.7 | 65.0 |
| 1 Deep | 21.78 | 10.5 | 3.86 | 34.6 | 65.0 |
| 1 Deep | 21.84 | 10.5 | 3.85 | 34.5 | 65.0 |
| 1 Deep | 21.93 | 10.5 | 3.84 | 34.4 | 65.0 |
| 1 Deep | 22.00 | 10.5 | 3.82 | 34.3 | 65.0 |
| 1 Deep | 22.08 | 10.5 | 3.81 | 34.1 | 65.0 |
| 1 Deep | 22.15 | 10.5 | 3.81 | 34.1 | 65.0 |
| 1 Deep | 22.24 | 10.5 | 3.79 | 33.9 | 65.0 |
| 1 Deep | 22.30 | 10.5 | 3.78 | 33.9 | 65.0 |
| 1 Deep | 22.35 | 10.5 | 3.79 | 34.0 | 65.0 |
| 1 Deep | 22.42 | 10.5 | 3.80 | 34.1 | 65.0 |
| 1 Deep | 22.50 | 10.5 | 3.80 | 34.1 | 65.0 |
| 1 Deep | 22.57 | 10.5 | 3.81 | 34.1 | 65.0 |
| 1 Deep | 22.68 | 10.5 | 3.79 | 34.0 | 65.0 |
| 1 Deep | 22.81 | 10.4 | 3.80 | 34.0 | 65.0 |
| 1 Deep | 22.92 | 10.4 | 3.80 | 34.0 | 65.0 |
| 1 Deep | 23.03 | 10.4 | 3.81 | 34.1 | 65.0 |
| 1 Deep | 23.11 | 10.4 | 3.80 | 34.0 | 65.0 |
| 1 Deep | 23.19 | 10.4 | 3.77 | 33.7 | 65.0 |
| 1 Deep | 23.27 | 10.4 | 3.75 | 33.6 | 65.0 |
| 1 Deep | 23.37 | 10.4 | 3.74 | 33.5 | 65.0 |
| 1 Deep | 23.47 | 10.4 | 3.75 | 33.6 | 65.0 |
| 1 Deep | 23.56 | 10.4 | 3.73 | 33.4 | 65.0 |
| 1 Deep | 23.66 | 10.4 | 3.73 | 33.4 | 65.0 |
| 1 Deep | 23.79 | 10.4 | 3.72 | 33.3 | 65.0 |
| 1 Deep | 23.91 | 10.4 | 3.71 | 33.2 | 65.0 |
| 1 Deep | 24.02 | 10.4 | 3.70 | 33.1 | 65.0 |
| 1 Deep | 24.10 | 10.4 | 3.69 | 33.0 | 65.0 |
| 1 Deep | 24.17 | 10.4 | 3.68 | 32.9 | 65.0 |
| 1 Deep | 24.27 | 10.4 | 3.67 | 32.8 | 65.0 |
| 1 Deep | 24.35 | 10.4 | 3.65 | 32.7 | 65.0 |
| 1 Deep | 24.44 | 10.4 | 3.65 | 32.6 | 65.0 |
| 1 Deep | 24.52 | 10.4 | 3.64 | 32.5 | 65.0 |
| 1 Deep | 24.61 | 10.4 | 3.64 | 32.5 | 65.0 |
| 1 Deep | 24.70 | 10.4 | 3.63 | 32.5 | 65.0 |
| 1 Deep | 24.77 | 10.4 | 3.64 | 32.6 | 65.0 |
| 1 Deep | 24.85 | 10.4 | 3.64 | 32.5 | 65.0 |
| 1 Deep | 24.95 | 10.4 | 3.63 | 32.5 | 65.0 |
| 1 Deep | 25.03 | 10.4 | 3.64 | 32.5 | 65.0 |
| 1 Deep | 25.11 | 10.4 | 3.64 | 32.5 | 65.0 |
| 1 Deep | 25.17 | 10.4 | 3.63 | 32.5 | 65.0 |
| 1 Deep | 25.24 | 10.4 | 3.63 | 32.4 | 65.0 |
| 1 Deep | 25.31 | 10.4 | 3.61 | 32.3 | 65.0 |
| 1 Deep | 25.39 | 10.4 | 3.59 | 32.0 | 65.0 |

| Site | Depth (meters) | Temperature (°C) | Dissolved Oxygen (mg/l) | Dissolved Oxygen (% saturation) | Specific Conductivity @ 25°C (uS/cm) |
|---|---|---|---|---|---|
| 1 Deep | 25.47 | 10.3 | 3.57 | 31.9 | 65.0 |
| 1 Deep | 25.57 | 10.3 | 3.55 | 31.7 | 65.0 |
| 1 Deep | 25.68 | 10.3 | 3.52 | 31.4 | 65.0 |
| 1 Deep | 25.76 | 10.3 | 3.49 | 31.1 | 65.0 |
| 1 Deep | 25.84 | 10.3 | 3.46 | 30.9 | 65.0 |
| 2 Canal | 0.02 | 21.6 | 8.34 | 94.6 | 66.0 |
| 2 Canal | 0.04 | 21.6 | 8.35 | 94.7 | 66.0 |
| 2 Canal | 0.11 | 21.6 | 8.34 | 94.5 | 66.0 |
| 2 Canal | 0.17 | 21.6 | 8.39 | 95.2 | 66.0 |
| 2 Canal | 0.22 | 21.6 | 8.35 | 94.7 | 66.0 |
| 2 Canal | 0.26 | 21.6 | 8.35 | 94.7 | 66.0 |
| 2 Canal | 0.29 | 21.6 | 8.36 | 94.8 | 66.0 |
| 2 Canal | 0.34 | 21.6 | 8.33 | 94.4 | 66.0 |
| 2 Canal | 0.38 | 21.6 | 8.33 | 94.5 | 66.0 |
| 2 Canal | 0.42 | 21.6 | 8.32 | 94.4 | 66.0 |
| 2 Canal | 0.49 | 21.6 | 8.33 | 94.5 | 66.0 |
| 2 Canal | 0.57 | 21.6 | 8.33 | 94.5 | 66.0 |
| 2 Canal | 0.66 | 21.6 | 8.33 | 94.4 | 66.0 |
| 2 Canal | 0.73 | 21.6 | 8.32 | 94.4 | 66.0 |
| 2 Canal | 0.81 | 21.6 | 8.32 | 94.3 | 66.0 |
| 2 Canal | 0.90 | 21.6 | 8.33 | 94.5 | 66.0 |
| 2 Canal | 1.00 | 21.6 | 8.33 | 94.5 | 66.0 |
| 2 Canal | 1.09 | 21.6 | 8.30 | 94.1 | 66.0 |
| 2 Canal | 1.16 | 21.6 | 8.31 | 94.2 | 66.0 |
| 2 Canal | 1.22 | 21.6 | 8.31 | 94.2 | 66.0 |
| 2 Canal | 1.27 | 21.6 | 8.30 | 94.2 | 66.0 |
| 2 Canal | 1.30 | 21.6 | 8.32 | 94.4 | 66.0 |
| 2 Canal | 1.35 | 21.6 | 8.32 | 94.3 | 66.0 |
| 2 Canal | 1.38 | 21.6 | 8.33 | 94.4 | 66.0 |
| 2 Canal | 1.44 | 21.6 | 8.32 | 94.4 | 66.0 |
| 2 Canal | 1.51 | 21.6 | 8.35 | 94.7 | 66.0 |
| 2 Canal | 1.57 | 21.6 | 8.35 | 94.7 | 66.0 |
| 2 Canal | 1.65 | 21.6 | 8.36 | 94.8 | 66.0 |
| 2 Canal | 1.73 | 21.6 | 8.36 | 94.8 | 66.0 |
| 2 Canal | 1.82 | 21.6 | 8.39 | 95.1 | 66.0 |
| 2 Canal | 1.88 | 21.6 | 8.36 | 94.8 | 66.0 |
| 2 Canal | 1.96 | 21.6 | 8.37 | 94.9 | 66.0 |
| 2 Canal | 2.03 | 21.6 | 8.36 | 94.8 | 66.0 |
| 2 Canal | 2.11 | 21.6 | 8.33 | 94.4 | 66.0 |
| 2 Canal | 2.18 | 21.6 | 8.34 | 94.6 | 66.0 |
| 2 Canal | 2.24 | 21.6 | 8.32 | 94.4 | 66.0 |
| 2 Canal | 2.30 | 21.6 | 8.32 | 94.4 | 66.0 |
| 2 Canal | 2.35 | 21.6 | 8.32 | 94.4 | 66.0 |
| 2 Canal | 2.42 | 21.6 | 8.31 | 94.3 | 66.0 |

| Site | Depth (meters) | Temperature (°C) | Dissolved Oxygen (mg/l) | Dissolved Oxygen (% saturation) | Specific Conductivity @ 25°C (*u*S/cm) |
|---|---|---|---|---|---|
| 2 Canal | 2.49 | 21.6 | 8.31 | 94.2 | 66.0 |
| 2 Canal | 2.57 | 21.6 | 8.31 | 94.3 | 66.0 |
| 2 Canal | 2.65 | 21.6 | 8.32 | 94.3 | 66.0 |
| 2 Canal | 2.75 | 21.6 | 8.33 | 94.5 | 66.0 |
| 2 Canal | 2.83 | 21.6 | 8.31 | 94.3 | 66.0 |
| 2 Canal | 2.91 | 21.6 | 8.30 | 94.1 | 66.0 |
| 2 Canal | 3.00 | 21.6 | 8.30 | 94.2 | 66.0 |
| 2 Canal | 3.07 | 21.6 | 8.31 | 94.3 | 66.0 |
| 2 Canal | 3.14 | 21.6 | 8.32 | 94.4 | 66.0 |
| 2 Canal | 3.30 | 21.6 | 8.34 | 94.6 | 66.0 |
| 2 Canal | 3.39 | 21.6 | 8.34 | 94.5 | 66.0 |
| 2 Canal | 3.46 | 21.6 | 8.34 | 94.6 | 66.0 |
| 2 Canal | 3.55 | 21.6 | 8.35 | 94.7 | 66.0 |
| 2 Canal | 3.61 | 21.6 | 8.37 | 95.0 | 66.0 |
| 2 Canal | 3.69 | 21.6 | 8.37 | 94.9 | 66.0 |
| 2 Canal | 3.77 | 21.6 | 8.38 | 95.1 | 66.0 |
| 2 Canal | 3.86 | 21.6 | 8.37 | 95.0 | 66.0 |
| 2 Canal | 3.94 | 21.6 | 8.36 | 94.9 | 66.0 |
| 2 Canal | 4.01 | 21.6 | 8.35 | 94.7 | 66.0 |
| 2 Canal | 4.10 | 21.6 | 8.34 | 94.6 | 66.0 |
| 2 Canal | 4.19 | 21.6 | 8.36 | 94.8 | 66.0 |
| 2 Canal | 4.28 | 21.6 | 8.33 | 94.4 | 66.0 |
| 2 Canal | 4.38 | 21.6 | 8.32 | 94.4 | 66.0 |
| 2 Canal | 4.47 | 21.6 | 8.31 | 94.3 | 66.0 |
| 2 Canal | 4.56 | 21.6 | 8.32 | 94.4 | 66.0 |
| 2 Canal | 4.63 | 21.6 | 8.31 | 94.2 | 66.0 |
| 2 Canal | 4.71 | 21.6 | 8.31 | 94.3 | 66.0 |
| 2 Canal | 4.77 | 21.6 | 8.32 | 94.4 | 66.0 |
| 2 Canal | 4.82 | 21.6 | 8.33 | 94.4 | 66.0 |
| 2 Canal | 4.88 | 21.6 | 8.31 | 94.2 | 66.0 |
| 2 Canal | 4.94 | 21.6 | 8.30 | 94.1 | 66.0 |
| 2 Canal | 5.00 | 21.6 | 8.30 | 94.1 | 66.0 |
| 2 Canal | 5.07 | 21.6 | 8.30 | 94.2 | 66.0 |
| 2 Canal | 5.16 | 21.6 | 8.32 | 94.3 | 66.0 |
| 2 Canal | 5.25 | 21.5 | 8.32 | 94.3 | 66.0 |
| 2 Canal | 5.32 | 21.5 | 8.32 | 94.4 | 66.0 |
| 2 Canal | 5.39 | 21.5 | 8.33 | 94.5 | 66.0 |
| 2 Canal | 5.45 | 21.6 | 8.33 | 94.5 | 66.0 |
| 2 Canal | 5.52 | 21.6 | 8.34 | 94.6 | 66.0 |
| 2 Canal | 5.59 | 21.5 | 8.35 | 94.7 | 66.0 |
| 2 Canal | 5.67 | 21.6 | 8.33 | 94.4 | 66.0 |
| 2 Canal | 5.73 | 21.6 | 8.33 | 94.5 | 66.0 |
| 2 Canal | 5.80 | 21.6 | 8.31 | 94.3 | 66.0 |
| 2 Canal | 5.85 | 21.6 | 8.32 | 94.4 | 66.0 |

| Site | Depth (meters) | Temperature (°C) | Dissolved Oxygen (mg/l) | Dissolved Oxygen (% saturation) | Specific Conductivity @ 25°C (*u*S/cm) |
|---|---|---|---|---|---|
| 2 Canal | 5.91 | 21.6 | 8.34 | 94.6 | 66.0 |
| 2 Canal | 5.97 | 21.6 | 8.33 | 94.4 | 66.0 |
| 2 Canal | 6.03 | 21.6 | 8.32 | 94.4 | 66.0 |
| 2 Canal | 6.09 | 21.5 | 8.32 | 94.3 | 66.0 |
| 2 Canal | 6.16 | 21.5 | 8.32 | 94.3 | 66.0 |
| 2 Canal | 6.23 | 21.5 | 8.32 | 94.3 | 66.0 |
| 2 Canal | 6.31 | 21.5 | 8.31 | 94.2 | 66.0 |
| 2 Canal | 6.39 | 21.5 | 8.30 | 94.1 | 66.0 |
| 2 Canal | 6.47 | 21.5 | 8.30 | 94.1 | 66.0 |
| 2 Canal | 6.56 | 21.5 | 8.30 | 94.0 | 66.0 |
| 2 Canal | 6.66 | 21.5 | 8.29 | 93.9 | 66.0 |
| 2 Canal | 6.76 | 21.5 | 8.28 | 93.8 | 66.0 |
| 2 Canal | 6.86 | 21.5 | 8.29 | 93.9 | 66.0 |
| 2 Canal | 6.95 | 21.5 | 8.28 | 93.8 | 66.0 |
| 2 Canal | 7.05 | 21.5 | 8.29 | 94.0 | 66.0 |
| 2 Canal | 7.15 | 21.5 | 8.30 | 94.1 | 66.0 |
| 2 Canal | 7.24 | 21.5 | 8.30 | 94.0 | 66.0 |
| 2 Canal | 7.33 | 21.5 | 8.32 | 94.3 | 66.0 |
| 2 Canal | 7.45 | 21.5 | 8.32 | 94.3 | 66.0 |
| 2 Canal | 7.56 | 21.5 | 8.32 | 94.2 | 66.0 |
| 2 Canal | 7.66 | 21.5 | 8.33 | 94.4 | 66.0 |
| 2 Canal | 7.76 | 21.5 | 8.30 | 94.0 | 66.0 |
| 2 Canal | 7.89 | 21.5 | 8.31 | 94.1 | 66.0 |
| 2 Canal | 8.01 | 21.5 | 8.29 | 93.9 | 66.0 |
| 2 Canal | 8.14 | 21.5 | 8.30 | 94.0 | 66.0 |
| 2 Canal | 8.25 | 21.5 | 8.28 | 93.8 | 66.0 |
| 2 Canal | 8.35 | 21.5 | 8.29 | 93.9 | 66.0 |
| 2 Canal | 8.44 | 21.5 | 8.27 | 93.6 | 66.0 |
| 2 Canal | 8.54 | 21.5 | 8.27 | 93.6 | 66.0 |
| 2 Canal | 8.63 | 21.5 | 8.26 | 93.4 | 66.0 |
| 2 Canal | 8.74 | 21.5 | 8.26 | 93.5 | 66.0 |
| 2 Canal | 8.85 | 21.4 | 8.24 | 93.2 | 66.0 |
| 2 Canal | 8.96 | 21.4 | 8.25 | 93.2 | 66.0 |
| 2 Canal | 9.07 | 21.4 | 8.22 | 92.9 | 66.0 |
| 2 Canal | 9.17 | 21.3 | 8.09 | 91.4 | 66.0 |
| 2 Canal | 9.28 | 20.8 | 7.96 | 89.0 | 64.0 |
| 2 Canal | 9.38 | 19.8 | 8.04 | 88.1 | 65.0 |
| 2 Canal | 9.50 | 19.4 | 8.00 | 87.0 | 65.0 |
| 2 Canal | 9.60 | 19.1 | 7.98 | 86.1 | 65.0 |
| 2 Canal | 9.68 | 18.7 | 7.97 | 85.4 | 65.0 |
| 2 Canal | 9.74 | 18.4 | 7.97 | 85.0 | 65.0 |
| 2 Canal | 9.81 | 18.3 | 7.96 | 84.5 | 65.0 |
| 2 Canal | 9.89 | 18.1 | 7.93 | 84.0 | 65.0 |
| 2 Canal | 9.99 | 17.9 | 7.92 | 83.6 | 65.0 |

| Site | Depth (meters) | Temperature (°C) | Dissolved Oxygen (mg/l) | Dissolved Oxygen (% saturation) | Specific Conductivity @ 25°C (uS/cm) |
|---|---|---|---|---|---|
| 2 Canal | 10.10 | 17.6 | 7.89 | 82.7 | 65.0 |
| 2 Canal | 10.20 | 17.3 | 7.90 | 82.3 | 65.0 |
| 2 Canal | 10.31 | 16.9 | 7.88 | 81.4 | 65.0 |
| 2 Canal | 10.42 | 16.6 | 7.85 | 80.6 | 65.0 |
| 2 Canal | 10.52 | 16.3 | 7.77 | 79.3 | 65.0 |
| 2 Canal | 10.60 | 16.0 | 7.68 | 77.9 | 65.0 |
| 2 Canal | 10.68 | 15.9 | 7.61 | 76.9 | 65.0 |
| 2 Canal | 10.76 | 15.7 | 7.49 | 75.4 | 65.0 |
| 2 Canal | 10.83 | 15.5 | 7.42 | 74.4 | 65.0 |
| 2 Canal | 10.92 | 15.2 | 7.37 | 73.4 | 65.0 |
| 2 Canal | 11.01 | 14.8 | 7.29 | 72.0 | 65.0 |
| 2 Canal | 11.12 | 14.5 | 7.21 | 70.7 | 66.0 |
| 2 Canal | 11.23 | 14.1 | 7.08 | 68.9 | 66.0 |
| 2 Canal | 11.32 | 13.7 | 6.97 | 67.2 | 65.0 |
| 2 Canal | 11.42 | 13.4 | 6.87 | 65.9 | 65.0 |
| 2 Canal | 11.52 | 13.2 | 6.76 | 64.5 | 65.0 |
| 2 Canal | 11.62 | 13.1 | 6.64 | 63.1 | 65.0 |
| 2 Canal | 11.71 | 12.9 | 6.50 | 61.6 | 65.0 |
| 2 Canal | 11.80 | 12.9 | 6.35 | 60.1 | 65.0 |
| 2 Canal | 11.90 | 12.8 | 6.21 | 58.6 | 65.0 |
| 2 Canal | 12.01 | 12.7 | 6.08 | 57.2 | 65.0 |
| 2 Canal | 12.10 | 12.6 | 5.92 | 55.7 | 65.0 |
| 2 Canal | 12.20 | 12.4 | 5.76 | 54.0 | 65.0 |
| 2 Canal | 12.29 | 12.4 | 5.61 | 52.5 | 65.0 |
| 2 Canal | 12.37 | 12.3 | 5.49 | 51.3 | 65.0 |
| 2 Canal | 12.44 | 12.3 | 5.41 | 50.5 | 65.0 |
| 2 Canal | 12.54 | 12.3 | 5.30 | 49.5 | 65.0 |
| 2 Canal | 12.64 | 12.2 | 5.23 | 48.8 | 65.0 |
| 2 Canal | 12.73 | 12.2 | 5.12 | 47.7 | 65.0 |
| 2 Canal | 12.84 | 12.2 | 5.01 | 46.7 | 65.0 |
| 2 Canal | 12.94 | 12.1 | 4.92 | 45.8 | 65.0 |
| 2 Canal | 13.03 | 12.1 | 4.86 | 45.2 | 65.0 |
| 2 Canal | 13.11 | 12.1 | 4.80 | 44.6 | 65.0 |
| 2 Canal | 13.21 | 12.1 | 4.76 | 44.2 | 65.0 |
| 2nd Basin | 0.04 | 22.6 | 7.43 | 86.0 | 65.0 |
| 2nd Basin | 0.04 | 22.6 | 7.43 | 86.0 | 65.0 |
| 2nd Basin | 0.09 | 22.6 | 7.44 | 86.1 | 65.0 |
| 2nd Basin | 0.16 | 22.6 | 7.45 | 86.3 | 65.0 |
| 2nd Basin | 0.23 | 22.6 | 7.46 | 86.3 | 65.0 |
| 2nd Basin | 0.30 | 22.6 | 7.46 | 86.3 | 65.0 |
| 2nd Basin | 0.37 | 22.6 | 7.44 | 86.1 | 65.0 |
| 2nd Basin | 0.44 | 22.6 | 7.46 | 86.4 | 65.0 |
| 2nd Basin | 0.51 | 22.6 | 7.47 | 86.4 | 65.0 |
| 2nd Basin | 0.57 | 22.6 | 7.46 | 86.4 | 65.0 |

| Site | Depth (meters) | Temperature (°C) | Dissolved Oxygen (mg/l) | Dissolved Oxygen (% saturation) | Specific Conductivity @ 25°C (*u*S/cm) |
|---|---|---|---|---|---|
| 2nd Basin | 0.63 | 22.6 | 7.47 | 86.5 | 65.0 |
| 2nd Basin | 0.70 | 22.6 | 7.49 | 86.7 | 65.0 |
| 2nd Basin | 0.79 | 22.6 | 7.49 | 86.7 | 65.0 |
| 2nd Basin | 0.86 | 22.6 | 7.48 | 86.5 | 65.0 |
| 2nd Basin | 0.96 | 22.6 | 7.46 | 86.3 | 65.0 |
| 2nd Basin | 1.08 | 22.5 | 7.44 | 86.0 | 65.0 |
| 2nd Basin | 1.18 | 22.5 | 7.43 | 85.8 | 65.0 |
| 2nd Basin | 1.28 | 22.5 | 7.44 | 85.8 | 65.0 |
| 2nd Basin | 1.39 | 22.5 | 7.44 | 85.8 | 65.0 |
| 2nd Basin | 1.50 | 22.5 | 7.39 | 85.3 | 65.0 |
| 2nd Basin | 1.59 | 22.5 | 7.39 | 85.3 | 65.0 |
| 2nd Basin | 1.71 | 22.5 | 7.38 | 85.2 | 65.0 |
| 2nd Basin | 1.80 | 22.5 | 7.37 | 85.0 | 65.0 |
| 2nd Basin | 1.87 | 22.5 | 7.36 | 85.0 | 65.0 |
| 2nd Basin | 1.95 | 22.5 | 7.37 | 85.0 | 65.0 |
| 2nd Basin | 2.03 | 22.5 | 7.37 | 85.0 | 65.0 |
| 2nd Basin | 2.10 | 22.5 | 7.38 | 85.1 | 65.0 |
| 2nd Basin | 2.19 | 22.5 | 7.37 | 85.1 | 65.0 |
| 2nd Basin | 2.26 | 22.5 | 7.37 | 85.0 | 65.0 |
| 2nd Basin | 2.38 | 22.5 | 7.37 | 85.0 | 65.0 |
| 2nd Basin | 2.49 | 22.4 | 7.37 | 85.1 | 65.0 |
| 2nd Basin | 2.60 | 22.4 | 7.38 | 85.1 | 65.0 |
| 2nd Basin | 2.69 | 22.4 | 7.39 | 85.3 | 65.0 |
| 2nd Basin | 2.77 | 22.4 | 7.39 | 85.2 | 65.0 |
| 2nd Basin | 2.84 | 22.4 | 7.37 | 84.9 | 65.0 |
| 2nd Basin | 2.92 | 22.4 | 7.35 | 84.8 | 65.0 |
| 2nd Basin | 2.99 | 22.4 | 7.34 | 84.7 | 65.0 |
| 2nd Basin | 3.06 | 22.4 | 7.35 | 84.8 | 65.0 |
| 2nd Basin | 3.12 | 22.4 | 7.34 | 84.7 | 65.0 |
| 2nd Basin | 3.19 | 22.4 | 7.33 | 84.5 | 65.0 |
| 2nd Basin | 3.27 | 22.4 | 7.32 | 84.3 | 65.0 |
| 2nd Basin | 3.34 | 22.4 | 7.31 | 84.2 | 65.0 |
| 2nd Basin | 3.42 | 22.4 | 7.31 | 84.3 | 65.0 |
| 2nd Basin | 3.49 | 22.4 | 7.30 | 84.1 | 65.0 |
| 2nd Basin | 3.59 | 22.4 | 7.28 | 84.0 | 65.0 |
| 2nd Basin | 3.67 | 22.4 | 7.26 | 83.7 | 65.0 |
| 2nd Basin | 3.75 | 22.4 | 7.25 | 83.5 | 65.0 |
| 2nd Basin | 3.81 | 22.4 | 7.22 | 83.3 | 65.0 |
| 2nd Basin | 3.88 | 22.4 | 7.21 | 83.1 | 65.0 |
| 2nd Basin | 3.96 | 22.4 | 7.20 | 82.9 | 65.0 |
| 2nd Basin | 4.05 | 22.4 | 7.18 | 82.7 | 65.0 |
| 2nd Basin | 4.15 | 22.4 | 7.16 | 82.5 | 65.0 |
| 2nd Basin | 4.27 | 22.4 | 7.12 | 82.0 | 65.0 |
| 2nd Basin | 4.36 | 22.4 | 7.06 | 81.3 | 65.0 |

| Site | Depth (meters) | Temperature (°C) | Dissolved Oxygen (mg/l) | Dissolved Oxygen (% saturation) | Specific Conductivity @ 25°C (uS/cm) |
|---|---|---|---|---|---|
| 2nd Basin | 4.43 | 22.4 | 6.96 | 80.1 | 65.0 |
| 2nd Basin | 4.50 | 22.3 | 6.83 | 78.7 | 65.0 |
| 2nd Basin | 4.58 | 22.3 | 6.63 | 76.3 | 65.0 |
| 2nd Basin | 4.67 | 22.3 | 6.45 | 74.2 | 66.0 |
| 2nd Basin | 4.75 | 22.3 | 6.28 | 72.1 | 66.0 |
| 2nd Basin | 4.84 | 22.2 | 6.22 | 71.4 | 66.0 |
| 2nd Basin | 4.92 | 22.2 | 6.19 | 71.1 | 66.0 |
| 2nd Basin | 4.99 | 22.2 | 6.18 | 70.9 | 66.0 |
| 2nd Basin | 5.06 | 22.2 | 6.14 | 70.4 | 66.0 |
| 2nd Basin | 5.14 | 22.1 | 5.91 | 67.7 | 66.0 |
| 2nd Basin | 5.20 | 22.0 | 5.43 | 62.2 | 66.0 |
| 2nd Basin | 5.26 | 21.9 | 4.63 | 52.9 | 67.0 |
| 3 Mmann | 0.07 | 22.2 | 8.17 | 93.7 | 66.0 |
| 3 Mmann | 0.09 | 22.2 | 8.19 | 94.0 | 66.0 |
| 3 Mmann | 0.17 | 22.2 | 8.21 | 94.2 | 66.0 |
| 3 Mmann | 0.26 | 22.2 | 8.21 | 94.2 | 66.0 |
| 3 Mmann | 0.40 | 22.2 | 8.21 | 94.2 | 66.0 |
| 3 Mmann | 0.52 | 22.2 | 8.23 | 94.4 | 66.0 |
| 3 Mmann | 0.65 | 22.2 | 8.25 | 94.7 | 66.0 |
| 3 Mmann | 0.78 | 22.2 | 8.24 | 94.6 | 66.0 |
| 3 Mmann | 0.88 | 22.2 | 8.25 | 94.7 | 66.0 |
| 3 Mmann | 0.97 | 22.2 | 8.24 | 94.5 | 66.0 |
| 3 Mmann | 1.06 | 22.2 | 8.21 | 94.3 | 66.0 |
| 3 Mmann | 1.14 | 22.2 | 8.22 | 94.4 | 66.0 |
| 3 Mmann | 1.23 | 22.2 | 8.21 | 94.2 | 66.0 |
| 3 Mmann | 1.32 | 22.2 | 8.21 | 94.2 | 66.0 |
| 3 Mmann | 1.39 | 22.2 | 8.21 | 94.2 | 66.0 |
| 3 Mmann | 1.47 | 22.2 | 8.18 | 93.9 | 66.0 |
| 3 Mmann | 1.53 | 22.2 | 8.18 | 93.9 | 66.0 |
| 3 Mmann | 1.59 | 22.2 | 8.19 | 93.9 | 66.0 |
| 3 Mmann | 1.67 | 22.2 | 8.19 | 94.0 | 66.0 |
| 3 Mmann | 1.75 | 22.2 | 8.19 | 93.9 | 66.0 |
| 3 Mmann | 1.83 | 22.2 | 8.17 | 93.8 | 66.0 |
| 3 Mmann | 1.91 | 22.2 | 8.15 | 93.5 | 66.0 |
| 3 Mmann | 1.98 | 22.2 | 8.17 | 93.7 | 66.0 |
| 3 Mmann | 2.05 | 22.2 | 8.17 | 93.7 | 66.0 |
| 3 Mmann | 2.12 | 22.2 | 8.18 | 93.9 | 66.0 |
| 3 Mmann | 2.18 | 22.2 | 8.17 | 93.8 | 66.0 |
| 3 Mmann | 2.25 | 22.2 | 8.19 | 94.0 | 66.0 |
| 3 Mmann | 2.33 | 22.2 | 8.19 | 94.0 | 66.0 |
| 3 Mmann | 2.42 | 22.2 | 8.21 | 94.2 | 66.0 |
| 3 Mmann | 2.54 | 22.2 | 8.22 | 94.3 | 66.0 |
| 3 Mmann | 2.65 | 22.2 | 8.23 | 94.4 | 66.0 |
| 3 Mmann | 2.75 | 22.2 | 8.25 | 94.7 | 66.0 |

| Site | Depth<br><br><br>(meters) | Temperature<br><br><br>(°C) | Dissolved Oxygen<br><br>(mg/l) | Dissolved Oxygen<br><br>(% saturation) | Specific Conductivity @ 25°C<br>(uS/cm) |
|---|---|---|---|---|---|
| 3 Mmann | 2.85 | 22.2 | 8.24 | 94.6 | 66.0 |
| 3 Mmann | 2.94 | 22.2 | 8.23 | 94.4 | 66.0 |
| 3 Mmann | 3.02 | 22.2 | 8.23 | 94.4 | 66.0 |
| 3 Mmann | 3.09 | 22.2 | 8.20 | 94.1 | 66.0 |
| 3 Mmann | 3.18 | 22.2 | 8.22 | 94.3 | 66.0 |
| 3 Mmann | 3.25 | 22.2 | 8.23 | 94.5 | 66.0 |
| 3 Mmann | 3.34 | 22.2 | 8.22 | 94.3 | 66.0 |
| 3 Mmann | 3.41 | 22.2 | 8.21 | 94.2 | 66.0 |
| 3 Mmann | 3.51 | 22.2 | 8.19 | 93.9 | 66.0 |
| 3 Mmann | 3.61 | 22.2 | 8.20 | 94.0 | 66.0 |
| 3 Mmann | 3.70 | 22.2 | 8.20 | 94.1 | 66.0 |
| 3 Mmann | 3.81 | 22.2 | 8.21 | 94.1 | 66.0 |
| 3 Mmann | 3.90 | 22.2 | 8.20 | 94.1 | 66.0 |
| 3 Mmann | 4.01 | 22.2 | 8.20 | 94.1 | 66.0 |
| 3 Mmann | 4.11 | 22.2 | 8.20 | 94.1 | 66.0 |
| 3 Mmann | 4.21 | 22.1 | 8.21 | 94.2 | 66.0 |
| 3 Mmann | 4.31 | 22.1 | 8.20 | 94.1 | 66.0 |
| 3 Mmann | 4.40 | 22.1 | 8.20 | 94.0 | 66.0 |
| 3 Mmann | 4.49 | 22.1 | 8.22 | 94.3 | 66.0 |
| 3 Mmann | 4.58 | 22.1 | 8.21 | 94.1 | 66.0 |
| 3 Mmann | 4.68 | 22.1 | 8.23 | 94.3 | 66.0 |
| 3 Mmann | 4.78 | 22.1 | 8.23 | 94.4 | 66.0 |
| 3 Mmann | 4.91 | 22.1 | 8.22 | 94.3 | 66.0 |
| 3 Mmann | 5.02 | 22.1 | 8.24 | 94.5 | 66.0 |
| 3 Mmann | 5.12 | 22.1 | 8.26 | 94.7 | 66.0 |
| 3 Mmann | 5.23 | 22.1 | 8.26 | 94.7 | 66.0 |
| 3 Mmann | 5.35 | 22.1 | 8.27 | 94.8 | 66.0 |
| 3 Mmann | 5.44 | 22.1 | 8.26 | 94.7 | 66.0 |
| 3 Mmann | 5.54 | 22.1 | 8.26 | 94.7 | 66.0 |
| 3 Mmann | 5.63 | 22.1 | 8.25 | 94.6 | 66.0 |
| 3 Mmann | 5.73 | 22.1 | 8.22 | 94.2 | 66.0 |
| 3 Mmann | 5.82 | 22.1 | 8.22 | 94.3 | 66.0 |
| 3 Mmann | 5.91 | 22.1 | 8.21 | 94.1 | 66.0 |
| 3 Mmann | 6.00 | 22.1 | 8.20 | 94.1 | 66.0 |
| 3 Mmann | 6.11 | 22.1 | 8.20 | 94.0 | 66.0 |
| 3 Mmann | 6.19 | 22.1 | 8.20 | 94.0 | 66.0 |
| 3 Mmann | 6.27 | 22.1 | 8.20 | 93.9 | 66.0 |
| 3 Mmann | 6.35 | 22.1 | 8.20 | 93.9 | 66.0 |
| 3 Mmann | 6.43 | 22.1 | 8.19 | 93.9 | 66.0 |
| 3 Mmann | 6.52 | 22.1 | 8.19 | 93.9 | 66.0 |
| 3 Mmann | 6.64 | 22.1 | 8.19 | 93.8 | 66.0 |
| 3 Mmann | 6.73 | 22.1 | 8.18 | 93.7 | 66.0 |
| 3 Mmann | 6.82 | 22.1 | 8.20 | 93.9 | 66.0 |
| 3 Mmann | 6.95 | 22.1 | 8.19 | 93.9 | 66.0 |

| Site | Depth (meters) | Temperature (°C) | Dissolved Oxygen (mg/l) | Dissolved Oxygen (% saturation) | Specific Conductivity @ 25°C (uS/cm) |
|---|---|---|---|---|---|
| 3 Mmann | 7.08 | 22.1 | 8.21 | 94.0 | 66.0 |
| 3 Mmann | 7.20 | 22.1 | 8.20 | 93.9 | 66.0 |
| 3 Mmann | 7.30 | 22.0 | 8.20 | 93.8 | 66.0 |
| 3 Mmann | 7.38 | 22.0 | 8.20 | 93.8 | 66.0 |
| 3 Mmann | 7.47 | 22.0 | 8.18 | 93.5 | 66.0 |
| 3 Mmann | 7.58 | 21.9 | 8.20 | 93.6 | 66.0 |
| 3 Mmann | 7.69 | 21.9 | 8.20 | 93.6 | 66.0 |
| 3 Mmann | 7.79 | 21.9 | 8.19 | 93.4 | 66.0 |
| 3 Mmann | 7.89 | 21.9 | 8.18 | 93.3 | 66.0 |
| 3 Mmann | 7.98 | 21.9 | 8.17 | 93.2 | 66.0 |
| 3 Mmann | 8.10 | 21.8 | 8.16 | 93.0 | 66.0 |
| 3 Mmann | 8.24 | 21.8 | 8.14 | 92.7 | 65.0 |
| 3 Mmann | 8.36 | 21.7 | 8.11 | 92.2 | 65.0 |
| 3 Mmann | 8.46 | 21.6 | 8.09 | 91.8 | 65.0 |
| 3 Mmann | 8.57 | 21.5 | 8.07 | 91.4 | 65.0 |
| 3 Mmann | 8.68 | 21.4 | 8.05 | 91.0 | 65.0 |
| 3 Mmann | 8.79 | 21.3 | 8.04 | 90.8 | 65.0 |
| 3 Mmann | 8.88 | 21.2 | 8.03 | 90.4 | 65.0 |
| 3 Mmann | 8.97 | 21.1 | 8.01 | 90.0 | 65.0 |
| 3 Mmann | 9.09 | 21.0 | 7.98 | 89.5 | 65.0 |
| 3 Mmann | 9.21 | 20.8 | 7.94 | 88.8 | 65.0 |
| 3 Mmann | 9.37 | 20.5 | 7.87 | 87.4 | 65.0 |
| 3 Mmann | 9.48 | 19.9 | 7.78 | 85.4 | 65.0 |
| 3 Mmann | 9.59 | 19.4 | 7.72 | 83.8 | 65.0 |
| 3 Mmann | 9.68 | 19.0 | 7.67 | 82.6 | 65.0 |
| 3 Mmann | 9.76 | 18.5 | 7.56 | 80.7 | 65.0 |
| 3 Mmann | 9.84 | 18.0 | 7.38 | 77.9 | 66.0 |
| 3 Mmann | 9.93 | 17.4 | 7.17 | 74.9 | 66.0 |
| 3 Mmann | 10.02 | 16.8 | 6.93 | 71.4 | 66.0 |

# APPENDIX E

## DETERMINING WATER QUALITY CHANGES AND TRENDS

**Box and Whisker Plots**

**Quick Overview:**

The 2010 summary **New Hampshire Lakes Lay Monitoring Program (NH LLMP)** reports include *box-and-whisker* plots that provide a visual representation of how the data are spread out and how much variation exists. Thus, the *box-and-whisker* plots provide a summary of how your data are distributed and provide a visual summary of how the data have varied among years and, when multiple sampling locations are monitored, provide a summary of how the data vary among sampling sites.

These plots show how the data group together for a given year. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. An algae bloom event may cause this type of outlier to occur in the chlorophyll data (high point) or Secchi disk clarity (low point).

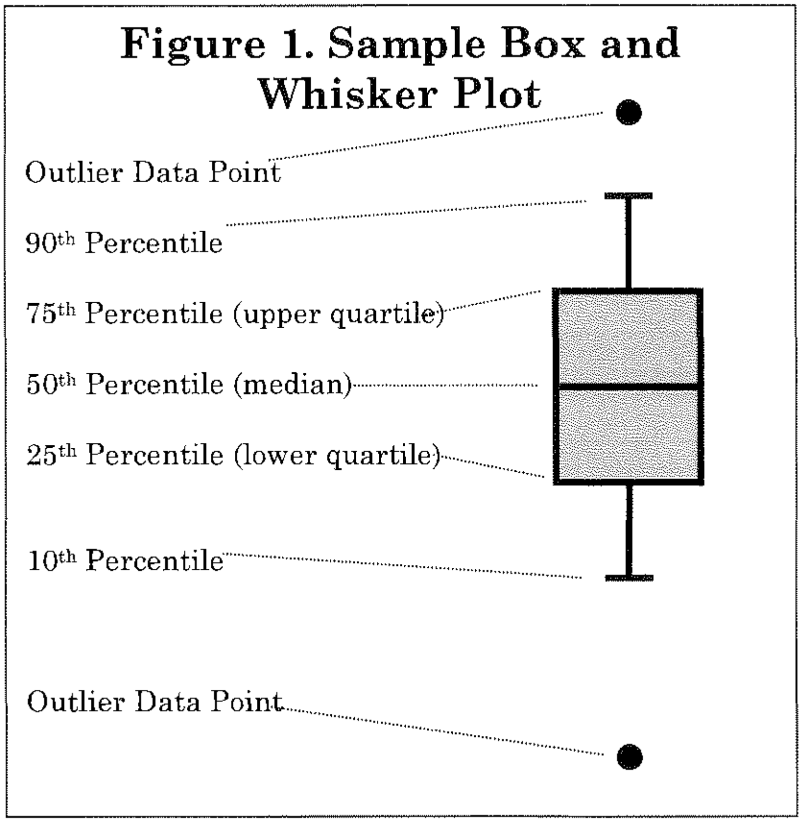
We recommend that each **NH LLMP** participating group plan on collecting weekly or biweekly measurements throughout the sampling season to ensure that enough data are available for this type of statistical analysis. We suggest that at least 8 data collections per year occur and generally set 10 measurements per year as a sampling effort goal per site.

We can employ the appropriate statistical techniques for detecting the extent that change is occurring when the sampling effort recommendations are followed. Your report summary should include box and whisker plots as well as a basic interpretation for your lake. If you have additional questions on interpreting your results feel free to call the Educational Program Coordinator (Bob Craycraft) at 603-862-3696.

**The Details:**

In the sections below we further describe the use of the box and whisker plot for those that are interested on how they are determined and how they are interpreted:

The **box-and-whisker plot** is good at showing the **extreme values** and the range of middle values of your data (Figure 1). The box depicts the middle values of a variable, while the **whiskers** stretch to demonstrate the values between which 80% of the data points will fall. The filled circles then reflect the "outlier" data points that fall outside of the whiskers and reflect values that are atypically high or atypically low relative to the other data measured for a given year.




The box-and-whisker plots can be summarized as a graphic that displays the following important features of the data when they are arranged in order from least to greatest:

- Median ($50^{th}$ percentile) – the middle of the data
- Lower Quartile ($25^{th}$ percentile) – the point below which 25% of the data points are located.
- Upper Quartile ($75^{th}$ percentile) – the point below which 75% of the data points are located.
- $90^{th}$ Percentile – the point below which 90% of the data points are located.
- $10^{th}$ Percentile – the point below which 10% of the data points are located.
- Outlier Data points – data points that represent the upper 10% or the lowest 10% of the data collected for a specific year.

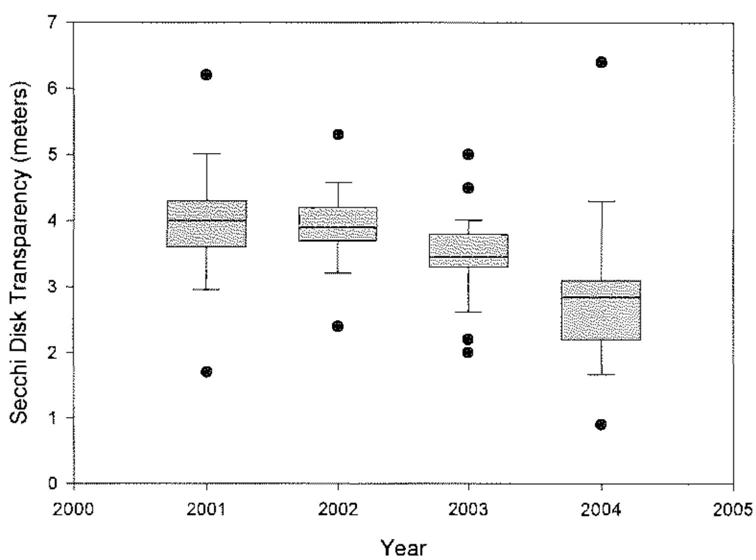
*Note: A minimum number of data points is required to compute each feature documented above. At least three points are required to compute the Lower and the Upper Quartiles, five points are needed to compute the $10^{th}$ percentile, and six points are needed to compute the $90^{th}$ percentile. In the event that insufficient data points have been collected features will not be graphed due to the inability to reliably calculate the respective attribute.*

**Sample box-and-whisker plot interpretation:**

A sample *box-and-whisker* plot is depicted in Figure 2 and it provides an opportunity to assess the usefulness of this type of plot at interpreting water quality monitoring data. The imaginary data depicted in Figure 2 reflect the annual water transparency measurements between the years 2001 and 2004. As you can glean from Figure 2, the distribution of the water clarity measurements have shifted to less clear conditions between 2001 and 2004. The median values, as well as the upper and lower quartiles (what is represented by the gray shaded box) have gradually shifted to less clear conditions over the four year span. The data points that lie between the upper and lower quartiles reflect 50% of the data collected for a given year and can provide insight into whether or not the water quality data are varying significantly between or among years. In extreme cases, when the gray shaded regions do not overlap between successive years or among years, one can quickly determine that the data distribution is significantly different for those years where the middle data (gray shading) does not overlap. Such differences can reflect long-term trends or can be a reflection of extreme climatic conditions for a given year such as atypically wet or atypically dry conditions that can have a profound impact on water quality.

**Figure 2.**

**Sample Lake - Site 1 Deep**
**Annual Secchi Disk Transparency Comparisions**
**Box and Whisker Plots: 2001-2004**




***Note: The number of outlier data points is dependant on the size of the dataset.***

Additional evaluation of the data can include a review of the $10^{th}$ and the $90^{th}$ percentiles (the whiskers) that provide additional insight into the distribution of the data. In this case, the trends exhibited by the $10^{th}$ and the $90^{th}$ percentiles are following the pattern of decreasing Secchi Disk Transparency as is exhibited by boxes (gray shaded regions). Outlier data points that fall outside of the "whiskers" can also be insightful. Such extreme values can be an early indicator of coming trends or can be an early warning sign of potential water quality problems. For instance, when Secchi Disk transparency measurements occasionally become significantly reduced (i.e. shallower water) such phenomenon can be an indication of short-term water quality problems such as excessive sediment or an algal bloom. If such problems are not contended with, but are instead left unattended, the longer-term impact could result in an increase in the magnitude and frequency of the water transparency reductions that, in turn, would result in a decreasing trend as evidenced by a shift of the "Boxes" to shallower water transparencies. There might also be occasions when the Secchi Disk transparency outliers reflect atypically clear water clarity. Such outliers can be a sign that conditions are improving or, as is often the case, the water quality is responding to short-term climatic variations that can have a profound impact on the water quality data. For instance, the outlier data point of 6.4 meters that was documented in 2004 (Figure 2) is counter intuitive to the long term trend of decreasing water quality. Plausible explanations for such an anomaly could be due to short term overgrazing of algae by zooplankton (typical for moderate to highly productive lakes), an abrupt shift in climate that might have favored clearer water (cloudy days or cooler water) or perhaps there was some sort of human intervention, such as a fish stocking or lake treatment that would have resulted in clearer water claries.

Your 2010 executive summary in this report includes a basic interpretation of the box-and whisker plots that are specific to your lake. However, since you have personal knowledge of the conditions of your lake and local events that might influence the water quality measurements, you might have additional insight into the cause of the water quality fluctuations that have not been discussed in the report. Should you want to discuss the water quality results further, or provide additional information that you feel is important, please contact Bob Craycraft by phone, (603) 862-3696, or by email, bob.craycraft@unh.edu.

# APPENDIX F

## GLOSSARY OF LIMNOLOGICAL TERMS

**Aerobe**- Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.

**Algae**- See phytoplankton.

**Alkalinity**- Total concentration of bicarbonate and hydroxide ions (in most lakes).

**Anaerobe**- Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.

**Anoxic**- A system lacking oxygen, therefore incapable of supporting the most common kind of biological respiration, or of supporting oxygen-demanding chemical reactions. The deeper waters of a lake may become anoxic if there are many organisms depleting oxygen via respiration, and there is little or no replenishment of oxygen from photosynthesis or from the atmosphere.

**Benthic**- Referring to the bottom sediments.

**Bacterioplankton**- Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.

**Bicarbonate**- The most important ion (chemical) involved in the buffering system of New Hampshire lakes.

**Buffering**- The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the chemical responsible for buffering is the bicarbonate ion. (See pH.)

**Chloride**- One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.

**Chlorophyll *a***- The main green pigment in plants. The concentration of chlorophyll *a* in lakewater is often used as an indicator of algal abundance.

**Circulation**- The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.

**Density**- The weight per volume of a substance. The more dense an object, the heavier it feels. Low-density liquids will float on higher-density liquids.

**Dimictic**- The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).

**Dystrophy**- The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity. Chlorophyll *a* concentration may be low or high.

**Epilimnion**- The uppermost layer of water during periods of thermal stratification. (See lake diagram).

**Eutrophy**- The lake trophic state in which algal production is high. Associated with eutrophy is low Secchi Disk depth, high chlorophyll *a*, and high total phosphorus. From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present. A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.

**Free CO2**- Carbon dioxide that is not combined chemically with lake water or any other substances. It is produced by respiration, and is used by plants and bacteria for photosynthesis.

**Holomixis**- The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)

**Humic Acids**- Dissolved organic compounds released from decomposition of plant leaves and stems. Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire. Humic acids are consumed only by fungi, and thus are relatively resistant to biological decomposition.

**Hydrogen Ion**- The "acid" ion, present in small amounts even in distilled water, but contributed to rain-water by atmospheric processes, to ground-water by soils, and to lakewater by biological organisms and sediments. The active component of "acid rain". See also "pH" the symbolic value inversely and exponentially related to the hydrogen ion.

**Hypolimnion**- The deepest layer of lakewater during periods of thermal stratification. (See lake diagram)

**Lake**- Any "inland" body of relatively "standing" water. Includes many synonyms such as ponds, tarns, loches, billabongs, bogs, marshes, etc.

**Lake Morphology**- The shape and size of a lake and its basin.

**Littoral**- The area of a lake shallow enough for submerged aquatic plants to grow.

**Meromixis**- The condition where the entire lake fails to circulate to its deepest points; caused by a high concentration of salt in the deeper waters, and by peculiar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)

**Mesotrophy**- The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll *a*, Secchi Disk depth, and total phosphorus are also moderate. These lakes are esthetically "fair" but not as good as oligotrophic lakes.

**Metalimnion**- The "middle" layer of the lake during periods of summer thermal stratification. Usually defined as the region where the water temperature changes at least one degree per meter depth. Also called the thermocline.

**Mixis**- Periods of lakewater mixing or circulation.

**Mixotrophy**- The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll *a* values are also high.

**Oligotrophy**- The lake trophic state where algal production is low, Secchi Disk depth is deep, and chlorophyll *a* and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

**Overturn**- See circulation or mixis

**pH**- A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times. Symbolically, the pH value is the "negative logarithm" of the hydrogen ion concentration. For example, a pH of 5 represents a hydrogen ion concentration of $10^{-5}$ molar. [Please thank the chemists for this lovely symbolism -- and ask them to explain it in lay terms!] In any event, the higher the pH value, the lower the hydrogen ion concentration. The range is 0 to 14, with 7 being neutral 1 denoting high acid condition and 14 denoting very basic condition.

**Photosynthesis**- The process by which plants convert the inorganic substances carbon dioxide and water into organic glucose (sugar) and oxygen using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance of almost all life forms.

**Phytoplankton**- Microscopic algae which are suspended in the "open water" zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.

**Parts per million**- Also known as "ppm". This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 ppm of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water. Domestic sewage usually contains from 2 to 10 ppm phosphorus.

**Parts per billion**- Also known as "ppb". This is only 1/1000 of ppm, therefore much less concentrated. As little as 1 ppb of phosphorus will sustain growth of algae. As little as 10 ppb phosphorus will cause algal blooms! Think of the ratio as 1 milligram (1/28000 of an ounce) of phosphorus in 25 barrels of water (55 gallon drums)! Or, 1 gallon of septic waste diluted into 10,000 gallons of lakewater. It adds up fast!

**Plankton**- Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants. See also "bacterioplankton" (bacteria), "phytoplankton" (algae) and "zooplankton" (microcrustaceans and rotifers).

**Saturated**- When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater, gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen if exposed sufficiently long to the atmosphere or another source of oxygen.

**Specific Conductivity**- A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

**Stratum**- A layer or "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

**Thermal Stratification**- The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind.

**Thermocline**- Region of temperature change. (See metalimnion.)

**Total Phosphorus**- A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

**Trophic Status**- A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories)

**Z**- A symbol used by limnologists as an abbreviation for depth.

**Zooplankton**- Microscopic animals in the planktonic community. Some are called "water fleas", but most are known by their scientific names. Scientific names include: *Daphnia, Cyclops, Bosmina,* and *Kellicottia.*

# LOVELL LAKE

## Water Quality Monitoring: 2010
## Summary and Recommendations
## NH LAKES LAY MONITORING PROGRAM




By: Robert Craycraft & Jeffrey Schloss

**Center for Freshwater Biology**
**University of New Hampshire**

UNIVERSITY of NEW HAMPSHIRE
COOPERATIVE EXTENSION

**To obtain additional information on the NH Lakes Lay Monitoring Program (NH LLMP) contact the Coordinator (Jeff Schloss) at 603-862-3848 or Assistant Coordinator (Bob Craycraft) at 603-862-3696.**

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# PREFACE

This report contains the findings of a water quality survey of Lovell Lake, Sanbornville, New Hampshire, conducted in the summer of 2010 by the University of New Hampshire **Center for Freshwater Biology (CFB)** in conjunction with the Lovell Lake Association.

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of the 2010 results as well as more detailed "Introduction" and "Discussion" sections. Graphic display of data is included, in addition to listings of data in appendices, to aid visual perspective.

# ACKNOWLEDGMENTS

2010 was the twenty-second year the Lovell Lake Association participated in the **New Hampshire Lakes Lay Monitoring Program (LLMP)**. The volunteer monitors involved in the water quality monitoring effort are highlighted in Table 1 while Gil and Barbara Binette coordinated the volunteer monitoring activities on Lovell Lake and acted as liaisons to the **Center for Freshwater Biology (CFB)**. The **CFB** congratulates the volunteer monitors on the quality of their work, and the time and effort put forth. We invite other interested residents to join the Lovell Lake water quality monitoring effort in 2011 and expand upon the current database. Funding for the water quality monitoring program was provided by the Lovell Lake Association.

**Table 1: Lovell Lake Volunteer Monitors (2010)**

| |
|---|
| Gil and Barbara Binette |
| Richard and Judy Desroches |
| John and Carolyn Gilpatrick |
| Glen Rowley |
| Glenn and Stephanie Thornton |

The **New Hampshire Lakes Lay Monitoring Program** is a not-for-profit citizen based research program coordinated by Robert Craycraft and directed by Jeff Schloss, Associate Director of the UNH CFB. Members of the **CFB-LLMP** summer field team included Gabrielle Hodgman, Lejla Kadic and Andrew Middleton while Elizabeth Adejuyigbe, Emma Carroll, Emma Leslie, Emily Ramlow, Choe Shannon and Jessica Waller provided additional assistance in the fall analyzing, compiling and organizing the water quality data.

The **LLMP** acknowledges the University of New Hampshire Cooperative Extension for funding and furnishing office and storage space while the College of Life Sciences and Agriculture provided laboratory facilities and additional storage space. The **LLMP** would like to thank the **Caswell Family Foundation** for their continued generosity in providing long-term support for undergraduate assistantships while additional support for administering the **NH LLMP** comes from the **United States Department of Agriculture Cooperative State Research, Education and Extension Service** through support from the New England Regional Water Quality Program,
(http://www.usawaterquality.org/newengland/).

Participating groups in the **LLMP** include: Acton-Wakefield Watershed Alliance, Green Mountain Conservation Group, North River Lake Monitors, the associations of Baboosic Lake, Bow Lake Camp Owners, Chocorua Lake, Conway Lake Conservation, Crystal Lake, Goose Pond, Great East Lake, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Lovell Lake, Mendums Pond, Merrymeeting Lake, Milton Three Ponds Lake Lay Monitoring, Mirror Lake (Tuftonboro), Moultonborough Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake Region, Nippo Lake, Silver Lake (Madison), Squam Lakes, Sunset Lake, Swains Lake, Lake Wentworth, Winnisquam Drive, and the

towns of Alton, Amherst, Enfield, Madison, Meredith, Merrimack, Milton, Strafford and Wolfeboro.

Major collaborators with the UNH CFB in 2010 included the NH Water Resources Research Center, New Hampshire Lakes Association, New Hampshire Department of Environmental Services, Lakes Regional Planning Commission, Dartmouth Hitchcock Medical Center, Sandy Point Discovery Center (NH Fish and Game and Great Bay National Estuary Research Reserve), EPA New England, the Volunteer Monitoring National Facilitation Project (USDA) and the Northeastern States and Caribbean Islands Regional Water Center (USDA National Institute of Food and Agriculture).

# Lovell Lake
# Water Quality Monitoring 2010

Lovell Lake remains one of Wakefield's natural resource assets providing recreational opportunities to the lakefront property owners, town residents and out of town visitors. Long-term water quality monitoring was instituted on Lovell Lake to generate a database to which future water quality data could be compared, to identify potential problems around the lake and to proactively address water quality threats to the lake which will help ensure that Lovell Lake remains a natural resource for future generations.

### 2010 Water Quality Data

Water quality monitoring continued in Lovell Lake and included the collection of bi-weekly water quality data during the "summer growing season" that spanned from June 2 through September 19. Water quality monitoring focused on the collection of water quality data at two deep sampling locations that provide insight into the overall condition of Lovell Lake.

Water transparency measurements are collected with a standardized eight inch diameter black and white disk that is lowered into the water column until it can no longer be seen. The Lovell Lake water transparency measurements remained high throughout the summer months and included a maximum visibility of 24.0 feet on July 5, 2010.

The amount of microscopic plant growth (visually detectible as golden or green water) remained low during the summer months and remained well below nuisance levels. The corresponding phosphorus (nutrient) concentrations remained low at each of the deep sampling locations and corresponded to the low levels of algal growth documented in Lovell Lake.

Dissolved oxygen concentrations, required for a healthy fishery, were decreasing near the lakebottom on July 13, 2010 and suggest the oxygen concentrations in the deep, cold waters, may not be sufficient to support a self sustaining cold water fishery.

Lake acidity, measured as pH, was near neutrality in the surface waters and remained within the tolerable range for most aquatic organisms.

### Common Concerns among New Hampshire Lakes

Many lakeshore property owners throughout New Hampshire express concerns that increased aquatic plant "weed" growth and the amount of slime that coats the lake bottom in the shallows has been steadily increasing over the years. While sufficient data have not been generated to scientifically support these assertions, communications from Wakefield residents indicate these are also common concerns for lakes and ponds located within the town of Wakefield. As the lakeshore and the surrounding uplands are converted from a well forested landscape to a more suburbanized setting, more nutrients oftentimes enter the lake and in turn promote plant growth. Keep in mind, the same nutrients that stimulate growth of our lawns will also stimulate growth in our lakes. Nutrients can originate from a number of sources within the Lovell Lake watershed that include septic system effluent, lawn fertilizer runoff and sediment washout. While some nutrient loading will occur naturally even in our most remote New Hampshire lakes, there are steps you can take to minimize nutrient runoff, that increases microscopic plant growth (greenness), contributes to the slimy coatings we find on rocks along our beaches and allows for new, or the expansion of, existing weed beds in the shallows of Lovell Lake.

**10 Recommendations for Healthy Lakeshore and Streamside Living**

Given the concerns discussed above make sure you consider the following recommendations and spread the word to your lake association and neighbors.

1. <u>Encourage shoreside vegetation and protect wetlands</u> - Shoreside vegetation (also known as **riparian vegetation**) and wetlands provide a protective buffer that "traps" pollutants before reaching the lake. These buffers remove materials both chemically (through biological uptake) and physically (settling materials out). As riparian buffers are removed and wetlands lost, pollutant materials are more likely to enter the lake and in turn, favor declining water quality. Shoreline vegetation grown tall will also discourage geese invasions and shade the water reducing the possibility of aquatic weed recruitment including the dreaded invasive milfoil.
2. <u>Limit fertilizer applications</u> - Fertilizers entering the lake can stimulate aquatic plant and algal growth and in extreme cases result in noxious algal blooms. Increases in algal growth tend to diminish water transparency and under extreme cases culminate in surface "scums" that can wash up on the shoreline and can also produce unpleasant smells as the material decomposes. Excessive nutrient concentrations also favor algal forms known to produce toxins which irritate the skin and under extreme conditions, are dangerous when ingested. Use low maintenance grasses such as fescues that require less nutrients and water to grow. Do not apply any fertilizers until you have had your soils tested. Oftentimes a simple pH adjustment will do more good and release nutrients already in the soils. After a lawn is established a single application of fertilizer in the late fall is generally more than adequate to maintain a healthy growth from year to year.
3. <u>Prevent organic matter loading</u> - Excessive organic matter (leaves, grass clippings, etc.) are a major source of nutrients in the aquatic environment. As the vegetative matter decomposes nutrients are "freed up" and can become available for aquatic plant and algal growth. In general, we are not concerned with this material entering the lake naturally (leaf senescence in the fall) but rather excessive loading of this material as occurs when residents dump or rake leaf litter and grass clippings into the lake. This material not only provides large nutrient reserves which can stimulate

aquatic plant and algal growth but also makes great habitat for leaches and other potentially undesirable organisms in swimming areas.

4. Limit the loss of vegetative cover and the creation of impervious surfaces - A forested watershed offers the best protection against pollutant runoff. Trees and tall vegetation intercept heavy rains that can erode soils and surface materials. The roots of these plants keep the soils in place, process nutrients and absorb moisture so the soils do not wash out. Impervious surfaces (paved roads, parking lots, building roofs, etc.) reduce the water's capacity to infiltrate into the ground, and in turn, go through nature's water purification system, our soils. As water seeps into the soil, pollutants are removed from the runoff through absorption onto soil particles. Biological processes detoxify substances and/or immobilize substances. Surface water runoff over impervious surfaces also increases water velocities which favor the transport of a greater load of suspended and dissolved pollutants into your lake.

5. Follow the Flow - Try to landscape and re-develop with consideration of how water flows on and off your property. Divert runoff from driveways, roofs and gutters to a level vegetated area or a rain garden so the water can be slowed, filtered and hopefully absorbed as recharge.

6. Discourage the feeding ducks and geese - Ducks and geese that are locally fed tend to concentrate in higher densities around the known food source and can result in localized water quality problems. Waterfowl quickly process food into nutrients that are capable of stimulate microscopic plant ("algal") growth. Ducks and geese are also host to the parasite responsible for swimmers itch. While not a serious health threat, swimmers itch is very uncomfortable especially for young children.

7. Maintain septic systems - Faulty septic systems are a big concern as they can be a primary source of water pollution around our lakes in the summer. Septic systems are loaded with nutrients and can also be a health threat when not functioning properly. Inspect your system on a timely basis and pump out the septic tank every three to five years depending on tank capacity and household water use. Since the septic system is such an expensive investment often costing a minimum of $10,000 for a complete overhaul, it is advantageous to assure proper care is taken to prolong the system's life. Additionally, following proper maintenance practices will reduce water quality degradation.

8. Take care when using and storing pesticides, toxic substances and fuels as it only takes a small amount to pollute lake, stream and ground water. Store, handle and use with attention paid to the label instructions.

9. Stabilize access areas and beaches - Perched beaches (cribbed areas) that keep sand and rocks in-place are preferred if you have to have that type of access. Do not create or enhance beach areas with sand (contains phosphorus, smothers aquatic habitat, fills in the lake as it gets transported

away by currents and wind and encourages invasive plants and algal blooms).

10. Review the updated New Hampshire Comprehensive Shoreland Protection Act (CSPA) if you have shoreland property. The CSPA sets legal regulations aimed at protecting water quality. If you have any questions regarding the act or need further information contact the Shoreline Protection Act Coordinator at (603) 271-3503.

**Note: Consult materials such as those listed below, for further guidance on assessing and implementing corrective actions that can maintain or improve the quality of surface and subsurface (septic) runoff that may otherwise impact water quality.**

- Pipeline: Summer 2008. Vol. 19, No. 1. Septic Systems and Source Water Protection: Homeowners can help improved community water quality.
  http://www.nesc.wvu.edu/pdf/WW/publications/pipline/PL_SU08.pdf
- Landscaping at the Water's Edge: an Ecological Approach. $20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824.
  http://extension.unh.edu/resources/ to order a bound copy.
  http://extension.unh.edu/resources/files/Resource001799_Rep2518.pdf -to download a PDF copy of the manual.
- Integrated Landscaping: Following Nature's Lead. $20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824.
  http://extension.unh.edu/resources/
- The Best Plants for New Hampshire Gardens and Landscapes - How to Choose Annuals, Perennials, Small Trees & Shrubs to Thrive in Your Garden. University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824.
  http://extension.unh.edu/resources/
- Buffers for Wetlands and Surface Waters: A Guidebook for New Hampshire Municipalities. Audubon Society of New Hampshire. 1997.
  http://www.nh.gov/oep/resourcelibrary/referencelibrary/b/buffers/documents/handbook.pdf
- New Hampshire Homeowner's Guide to Stormwater Management: Do-It-Yourself Stormwater Solutions for Your Home. March 2011. New Hampshire Department of Environmental Services. 29 Hazen Drive. Concord NH 03301.
  http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/wd-11-11.pdf

# Lovell Lake
# 2010 Executive Summary

Water quality data were collected by the Lovell Lake volunteer monitors between June 2 and September 19, 2010 while a more in-depth water quality survey of the Lovell Lake deep sampling stations (Sites 1 North and 2 South) was conducted by the **Center for Freshwater Biology (CFB)** on July 13, 2010 to augment the volunteer monitoring data. Generally speaking, the 2010 Lovell Lake water quality remained high as summarized in Table 2; the seasonal average Secchi Disk transparency measured 19.4 (5.9 meters) while the amount of microscopic plant growth and the total phosphorus (nutrient) concentrations were low to moderate and remained below nuisance concentrations.

**Table 2: 2010 Lovell Lake Seasonal Average Water Quality Readings and Water Quality Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.**

| **Parameter** | Oligotrophic "Pristine" | Mesotrophic "Transitional" | Eutrophic "Enriched" | Lovell Lake Average (range) | Lovell Lake Classification |
|---|---|---|---|---|---|
| **Water Clarity (meters)** | > 4.0 | 2.5 - 4.0 | < 2.5 | 5.9 (range: 5.1 – 7.3) | Oligotrophic |
| **Chlorophyll a (ppb)** | < 3.0 | 3.0 - 7.0 | > 7.0 | 2.2 (range: 0.8 – 3.3) | Oligo/Mesotrophic |
| **Phosphorus (ppb)** | < 15.0 | 15.0 - 25.0 | > 25.0 | 8.4 (range: 6.3 – 10.1 | Oligotrophic |

** Total Phosphorus data were collected in the surface waters (epilimnion) by the volunteer monitors.*

The following section reviews the 2010 Lovell Lake water quality data and when applicable incorporates historical data into the discussion. *Refer to Appendix D for a complete listing of the 2010 Lovell Lake water quality data and refer to Appendix E for a primer on interpreting the box and whisker plots that are included in the 2010 Lovell Lake summary report.*

**1) Water Clarity (measured as Secchi Disk transparency)** – The 2010 Lovell Lake Secchi Disk transparency measurements consistently exceeded the visibility of 13.2 feet (4.0 meters) that is considered the boundary between an unproductive "pristine" and more nutrient enriched "transitional" New Hampshire lake (Tables 2 & 3 and Appendix A). The 2010 Secchi Disk transparency measurements varied slightly between the two sampling locations and the seasonal average water transparency was slightly shallower at the northwesterly sampling station, Site 1 North (Table 3).

**Table 3: 2010 Water Clarity data summary for the Lovell Lake deep sampling stations.**

| Site | **Seasonal Average Water Transparency (meters)** |
|---|---|
| 1 North | 5.8 meters (range: 5.2 – 7.3) |
| 2 South | 6.0 meters (range: 5.1 – 7.1) |

The 2010 median Secchi Disk transparency, documented at Sites 1 North and 2 South, remained well within the range of historical values documented since 1989 (Appendix B). No new water transparency minimum or maximum values were documented in 2010 and the long-term Lovell Lake water transparency measurements do not exhibit any clear water quality trends (Appendix B).

**2) Microscopic plant abundance "greenness" (measured as chlorophyll *a*)** – The 2010 Lovell Lake seasonal chlorophyll *a* measurements remained below the concentration of 3 parts per billion (ppb) that is considered the boundary between an unproductive and more nutrient enriched "transitional" New Hampshire lake (Tables 2 & 4 and Appendix A). The chlorophyll *a* concentrations were similar between the two deep sampling stations, Sites 1 North and 2 South, during the 2010 sampling season (Table 4).

**Table 4: 2010 Chlorophyll *a* data summary for the Lovell Lake deep sampling stations.**

| Site | Seasonal Average Chlorophyll *a* (ppb) |
|---|---|
| 1 North | 2.1 ppb (range: 0.8 – 2.7) |
| 2 South | 2.3 ppb (range: 1.1 – 3.3) |

The median Lovell Lake chlorophyll *a* concentrations documented at Sites 1 North and 2 South increased (i.e. greener water) between 1998 and 2006 (Appendix B) while the median chlorophyll a concentrations documented between 2007 and 2010 have been significantly lower. Data collected in participating New Hampshire Lakes Lay Monitoring Program lakes since 1979 have indicated that some lakes undergo cycles of increasing and decreasing chlorphyll *a* concentrations that appear to be naturally occuring. However, other lakes have exhibited definative trends of increasing chlorophyll *a* concentrations that have coincided with a marked decline in water quality. The Lovell Lake Association should continue to educate the lakeshore and the watershed residents of strategies that can help preserve the high water quality that is characteristic of Lovell Lake (refer to the section Understanding Lake Aging).

**3) Background (dissolved) water color: often perceived as a "tea" color in more highly stained lakes** – The 2010 Lovell Lake dissolved color concentration averaged 11.2 chloroplatinate units (cpu) and fell within the classification of a slightly "tea" colored lake (Table 5). Dissolved color, or true color as it is sometimes called, is indicative of dissolved organic carbon levels in the water (a by-product of microbial decomposition). Small increases in water color from the natural breakdown of plant materials in and around a lake are not considered to be detrimental to water quality. However, increased color can lower water transparency, and hence, change the public perception of water quality.

**Table 5. Dissolved Color Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.**

| Range | Classification |
|---|---|
| 0 - 10 | Clear |
| 10 - 20 | Slightly colored |
| 20 - 40 | Light tea color |
| 40 - 80 | Tea colored |
| > 80 | Highly tea colored |

**4) Total Phosphorus: the nutrient considered most responsible for elevated microscopic plant growth in our New Hampshire Lakes.** - Total phosphorus concentrations, measured in the surface waters (epilimnion), were low during the 2010 sampling season and ranged from 6.3 to 10.1 parts per billion, ppb (Table 6). The epilimnetic total phosphorus concentrations remained near or below the concentration of 10 parts per billion that is considered sufficient to stimulate an algal bloom.

**Table 6: 2010 Total Phosphorus data summary for the Lovell Lake deep and near-shore sampling stations.**

| Site | Seasonal Average Total Phosphorus (ppb) |
|---|---|
| 1 North | * 8.9 ppb (range: 7.6 – 10.1 ppb) |
| 2 South | * 7.7 ppb (range: 6.3 – 9.1 ppb) |

* Indicates volunteer monitor data collected in the surface waters (epilimnion).

**5) Resistance against acid precipitation (measured as total alkalinity)** – The 2010 seasonal average Lovell Lake alkalinity, 12.9 milligrams per liter (mg/l), is characteristic of a lake with a low vulnerability to acid precipitation according to the standards developed by the New Hampshire Department of Environmental Services (Table 7). Generally speaking, the geology of the region does not contain the mineral content (e.g. limestone) that increases the buffering capacity in our surface waters. However, local mineral deposits within the Lovell Lake watershed are contributing to elevated alkalinity levels in Lovell Lake, relative to other lakes in the region. Thus, the Lovell Lake alkalinity levels are near/in excess of two times higher than other nearby lakes (e.g. Great East Lake, Lake Wentworth and Northeast Pond) and are capable of neutralizing acid inputs.

**Table 7. Alkalinity Classification Criteria used by the New Hampshire Department of Environmental Services**

| Range | Classification |
|---|---|
| < 0 | Acidified |
| 0 -2 | Extremely Vulnerable |
| 2.1 - 10.0 | Moderately Vulnerable |
| 10.1 - 25.0 | Low Vulnerability |
| > 25.0 | Not Vulnerable |

**Lake acidity (measured as pH)** - The Lovell Lake pH data, collected in the surface waters by the **Center for Freshwater Biology** on July 13, 2010, ranged from 7.5 to 7.6 units and remained well within the tolerable range for most aquatic organisms.

**6) Dissolved salts: measured as specific conductivity** – Specific Conductivity levels, documented in Lovell Lake, were moderate to high and ranged from 99.0 to 107.0 micro-Siemans (*u*S) when measured at the deep, open water, sampling stations. High specific conductivity values can occur naturally and are often associated with natural geological deposits (i.e. limestone) that contribute dissolved substances into the water column. However, high specific conductivity values can also be an indication of problem areas around a lake where failing septic systems, heavy fertilizer applications and shoreland erosion contribute "excessive" nutrients that make their way into the lake. The Lovell Lake specific conductivity measurements were relatively consistent between the two sampling locations (Site 1 North and Site 2 South) and did not suggest any significant water quality problems on the July 13, 2010 sampling date.

7) **Temperature and dissolved oxygen profiles** – Temperature profiles collected by the volunteer monitors indicate Lovell Lake becomes stratified into three distinct thermal layers during the summer months; a warm upper water layer, the **epilimnion**, overlies a layer of rapidly decreasing temperatures, the **thermocline**. A third layer, the **hypolimnion**, has also been observed at the deep southern sampling location, Site 1 South, and consists of relatively uniform cold water. The formation of thermal stratification limits the replenishment of oxygen in the deeper waters and under adverse conditions can be associated with oxygen depletion near the lake-bottom.

**Dissolved oxygen concentrations required for a healthy fishery** – The Lovell Lake dissolved oxygen concentrations, measured at Site 1 North, remained high down to the lake bottom on July 13, 2010; the dissolved oxygen concentrations remained above 5 milligrams per liter (mg/L) that is considered the minimum dissolved oxygen concentration required for the successful growth and reproduction of most coldwater fish that include trout and salmon. On the other hand, the dissolved oxygen concentrations measured at Site 2 South measured on July 13, 2010 became reduced below 5 milligrams per liter at a depth of approximately 9.5 meters. The low dissolved oxygen concentrations near the lake bottom (in the deep, cold, waters) are inhibitive to the establishment of a self sustaining cold water fishery in Lovell Lake. However, the dissolved oxygen concentrations remained high in the surface waters and were capable of supporting a healthy warm water fishery.

8) Based on the current and historical water quality data, Lovell Lake would be considered an unproductive "pristine" lake that borders the conditions characteristic of a moderately nutrient enriched (i.e. greener and less clear water) New Hampshire Lake. A first step towards maintaining and possibly improving water quality in Lovell Lake is to take action at the local level and do your part to minimize the number of pollutants (particularly sediment and the nutrient phosphorus) that enter the lake. Refer to the sections, "10 Recommendations for Healthy Lakeshore and Streamside Living," "Go with the Flow: Understanding how water moves onto, through and away from your house site" and "Lake Friendly Lawn Care," that discuss measures landowners can take to improve water quality.

# COMMENTS AND RECOMMENDATIONS

1) We recommend that each participating lake association, including the Lovell Lake Association, continue to develop its database on lake water quality through continuation of the long-term monitoring program. The database currently provides information on the short-term and long-term cyclic variability that occurs in Lovell Lake while continued monitoring would enable more reliable predictions of both short-term and long-term water quality trends.

2) We recommend initiating lake sampling early in the season (April/May) to document Lovell Lake's reaction to the nutrient and acid loadings that typically occur during and after spring thaw. Sampling should include alkalinity, chlorophyll *a*, dissolved color and Secchi Disk transparency measurements. Phosphorus samples are also recommended from both the in-lake and the tributary sampling sites.

3) Frequent "weekly" or "bi-weekly" water quality samples, necessary to assess the current condition of Lovell Lake, should continue to be collected whenever possible. Continued sampling of chlorophyll *a*, Secchi Disk transparency, dissolved color, alkalinity and total phosphorus samples will be useful to track variations in nutrient loading during the summer months.

4) We suggest interested residents and public officials review the Salmon Falls Headwater Lakes Watershed Management Plan, http://www.awwatersheds.org/images/stories/SFHeadwaterLakesWMP_April2010.pdf. The document includes a summary of the Lovell Lake water quality, identifies threats to Lovell Lake and provides suggestions aimed at minimizing future water quality degradation through a watershed management approach that encompases the entire Lovell Lake drainage basin.

5) Some lake associations have become increasingly interested in conducting supplemental near-shore sampling and/or stream sampling to better assess whether localized water quality variations exist. The supplemental near-shore and tributary sampling would facilitate the targeting of resources (i.e. money and volunteer hours) to the most critical areas within the watershed where future monitoring and corrective efforts should be directed. Expanded water quality monitoring could be as simple as collecting additional near-shore/tributary total phosphorus or chlorophyll *a* samples or could involve the expansion of additional water quality parameters such as dissolved oxygen and specific conductivity measurements. Advanced water quality monitoring efforts might also include more in-depth shoreline/watershed surveys aimed at visually identifying the land-use patterns and potential problem areas within the drainage basin. If you

are interested in discussing additional water quality monitoring options that would meet your needs please contact Bob Craycraft @ 862-3696 or via email, bob.craycraft@unh.edu.

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# INTRODUCTION

## *The New Hampshire Lakes Lay Monitoring Program*

The 2010 sampling season marked the thirty-second anniversary for the **NH Lakes Lay Monitoring Program (LLMP).** The **LLMP** has grown from a university class project on Chocorua Lake and pilot study on the Squam Lakes to a comprehensive state-wide program with over 500 volunteer monitors and more than 100 lakes participating. Originally developed to establish a database for determining long-term trends of lake water quality for science and management, the program has expanded by taking advantage of the many resources that citizen monitors can provide (Figure 1).

**Figure 1. LLMP Objectives**

**LLMP OBJECTIVES:**

***Baseline Lake Water Quality Info- for Change and Trends***

***Lake Volunteer Monitoring Training***

***Shoreline & Watershed Surveys***

***Survey for Non-Native Species***

***Tie-In with Youth & Adult Education***

The **NH LLMP** has gained an international reputation as a successful cooperative monitoring, education and research program. Current projects include: the use of volunteer generated data for non-point pollution studies using high tech analysis system (Geographic Information Systems and Satellite Remote Sensing), and intensive watershed monitoring for the development of watershed nutrient budgets, investigations of water quality impacts, including the formation of blue green bacteria blooms, associated with land use changes.

The key ingredients responsible for the success of the program include innovative cost share funding and cost reduction, assurance of credible data, practical sampling protocols and, most importantly, the interest and motivation of our volunteer monitors.

The 2010 sampling season was another exciting year for the **New Hamp-**

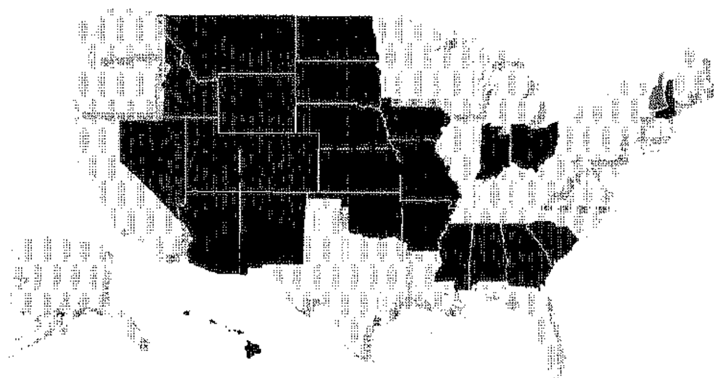
**Table 8. Awards & Recognition**

| | |
|---|---|
| 1983- | NH Environmental Law Council Award |
| 1984- | Governor's Volunteer Award |
| 1985- | CNN Science & Technology Today |
| 1988- | Governor's "Gift" award funded |
| 1990- | NH Journal TV coverage NHPTV |
| 1991- | Renew America Award<br>Environmental Success Index<br>White House Reception / Briefing |
| 1992- | EPA Administrators Award |
| 1993- | NH Lakes Association Award |
| 1994- | EPA Office of Watersheds Award |
| 1995- | Winnipesaukee Watershed Project |
| 1998- | Governor's Proclamation for 20th Anniversary |
| 1999- | EPA Watershed Academy Host |
| 2001- | Lake Chocorua Project highlighted at national conferences (invited presentations) |
| 2002- | Chocorua Project receives Technical Excellence Award from the North American Lake Management Society |
| 2003- | UNH CE Maynard and Audrey Heckel Extension Fellowship awarded to LLMP |
| 2004- | Participatory Research Model of NH LLMP highlighted at National Water Quality Monitoring Conference |
| 2005- | LLMP Coordinator J. Schloss receives the prestigious Secchi Disk Award from the North American Lakes Management Society |
| 2007- | Lake friendly landscaping manual introduced receives praise from New Hampshire agencies and waterfront landowners. |
| 2008- | NH LLMP's 30th year of sampling NH lakes! |
| 2009- | EPA Equipment support grant to the NH LLMP. |
| 2010- | NH LLMP becomes first citizen program to monitor cyanotoxins |

**shire Lakes Lay Monitoring Program.** National recognition for the high quality of work by you, the volunteer monitors, culminated with program awards, requests for program information and invitations to speak at national conferences (Table 5).

**Figure 2. National LLMP Support to Volunteer Monitoring Programs**

NH LLMP Directly inolved with the Initiation, Expansion or Support of Volunteer Programs in 24 States.



Light gray shading denotes LLMP assisted states

The NH LLMP and its long-term database has been instrumental in supporting the efforts of NH DES and lake communities across New Hampshire in setting nutrient goals for various lake watersheds. Besides our continued worked with the Newfound Lakes Region Association (highlighted in last year's reports) we have been heavily involved with work on the Winnipesaukee Watershed Project, collaborating with the Lake Winnipesaukee Association and the Lakes Region Planning Commission, as well as the communities of Meredith, Laconia and Gilford (see http://winnipesaukeegateway.org/about/ ) We are also excited by the continued results of teaming up students, educators and local lake residents through our Multidisciplinary Lakes Management course and our summer Watershed Ecology course that are held annually (the course for educators, community leaders and other interested persons). Some of the lake management recommendations made as part of the student coursework requirements have been successfully implemented by lake associations.

Our active collaboration with the UNH Center for Freshwater Biology continues to drive relevant applied research: The CFB was involved in supporting the zooplankton analysis for regional and national lake surveys.

We continue the research initiated by collaborators Dr. John Sasner and Dr. Jim Haney focusing on how watershed development and our activities on the landscape play a role in creating potentially toxic plankton blooms. Analogous to the 'red tide" of estuaries, certain blue-green bacteria (microscopic bacteria that are very much like algae) can produce toxins that are heath risks to animals and humans.

Additional ongoing research is focusing on the use of satellite and aerial imagery as well as on-lake optical devices as a means of determining the water transparency and amount of microscopic plant "algal" growth in our New Hampshire Lakes, particularly blue green algae. Water quality data, collected by the volunteer monitors, have served as ground truthed data to assess whether or not the satellite imagery shows promise. Data generated through this project have been presented at national conferences and are testament to the high quality data generated by our volunteer monitors.

Recent interest in the success of our NH LLMP participatory science research model has resulted in invited presentations at national conferences and provided the basis of a series of articles in the Volunteer Monitor, the national newsletter with a distribution of over 10,000. We continue to be listed as a model citizen-monitoring program on the Environmental Success Index of Renew America, the Environmental Network Clearinghouse and the National Awards Council for Environmental Sustainability. To date, the approach and methods of the **NH LLMP** have been adopted by new or existing programs in twenty-four states and eleven countries (Figure 2)!

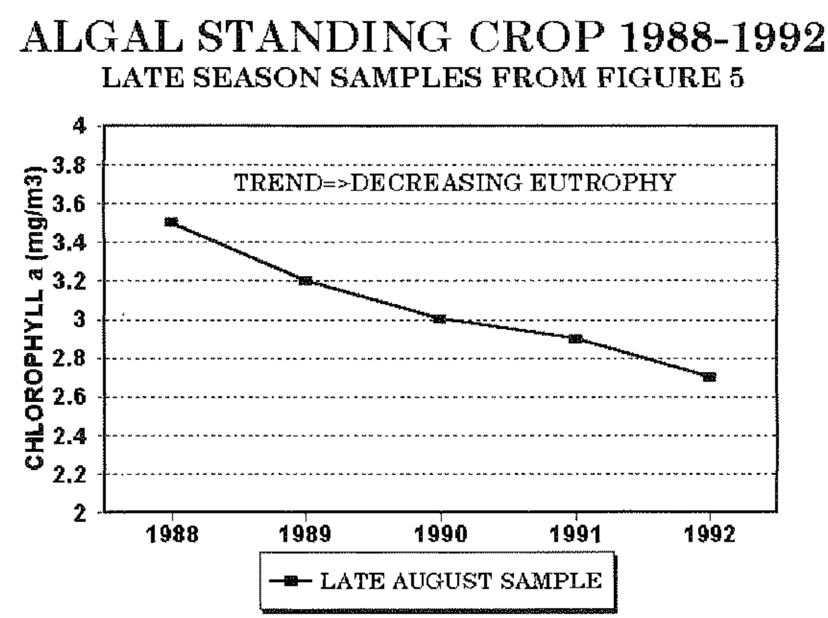
## *Importance of Long-term Monitoring*

A major goal of our monitoring program is to identify any short or long-term changes in the water quality of the lake. Of major concern is the detection of cultural eutrophication: increases in the productivity of the lake, the amount of algae and plant growth, due to the addition of nutrients from human activities. Changes in the natural buffering capacity of the lakes in the program is also a topic of great concern, as New Hampshire receives large amounts of acid precipitation, yet most of our lakes contain little mineral content to neutralize this type of pollution.

For over two decades, weekly data collected from lakes participating in the **New Hampshire Lakes Lay Monitoring Program** have indicated there is quite a variation in water quality indicators through the open water season (April through November) on the majority of lakes. Short-term differences may be due to variations in weather, lake use, or other chance events. Monthly sampling of a lake during a single summer provides some useful information, but there is a greater chance that important short-term events such as algal blooms or the lake's response to storm run-off will be missed. These short-term fluctuations may be unrelated to the actual long-term trend of a lake or they may be indicative of the changing status or "health" of a lake.

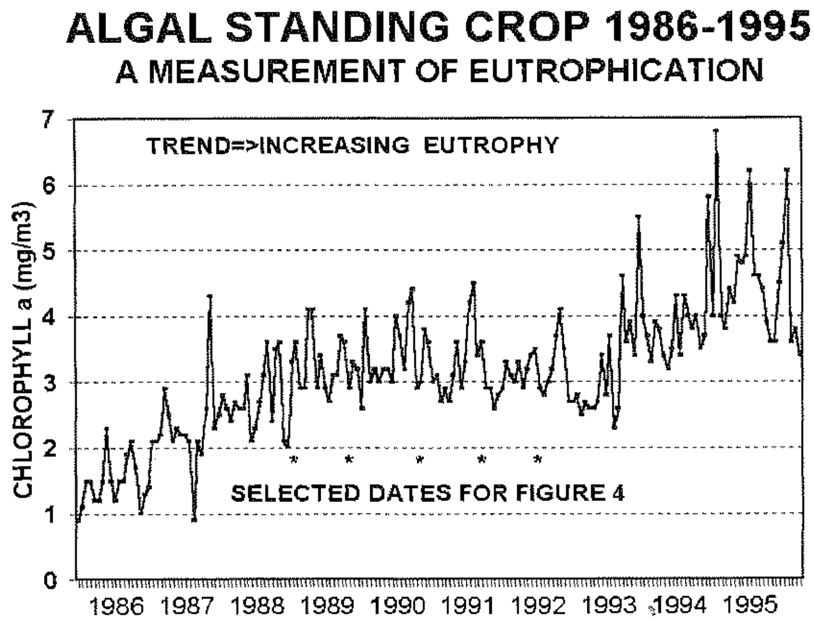
Consider the hypothetical data depicted in Figure 3. Limiting sampling of only once a year during August, from 1988 to 1992, produced a plot suggesting a decrease in eutrophication. However, the actual long-term term trend of the lake, increasing eutrophication, can only be clearly discerned by frequent sampling over a ten-year period (Figure 4). In this instance, the information necessary to distinguish between short-term fluctuations, the "noise", and long-term trends, the actual "signal", could only be accomplished through the frequent collection of water quality data over many years. To that end, the establishment of a long-term database was essential to determining trends in water quality.

**Figure 3.**




The number of seasons it takes to distinguish between the "noise" and the signal is not the same for each lake. Evaluation and interpretation of a long-term database will indicate that the water quality of the lake has worsened, improved, or remained the same. In addition, different areas of a lake may show a different response. As more data are collected, predictions of current and future trends can be made. No matter what the outcome, this information is essential for the intelligent management of your lake.

Figure 4




There are also short-term uses for lay monitoring data. The examination of different stations in a lake can disclose the location of specific problems and corrective action can be initiated to handle the situation before it becomes more serious. On a lighter note, some associations post their weekly data for use in determining the best depths for finding fish!

It takes a considerable amount of effort as well as a deep concern for one's lake to be a volunteer in the **NH Lakes Lay Monitoring Program**. Many times a monitor has to brave inclement weather or heavy boat traffic to collect samples. Sometimes it seems that one week's data does not differ from the next week's data, but every sampling provides important information on the variability of the lake.

We are pleased with the interest and commitment of our Lay Monitors and are proud that their work is what makes the **NH LLMP** the most extensive, and we believe, the best volunteer program of its kind.

## *Purpose and Scope of This Effort*

The primary purpose of annual lake reporting is to discuss results of the current monitoring season with emphasis on current conditions of New Hampshire lakes including the extent of eutrophication and the lakes' susceptibility to increasing acid precipitation. If you have additional water quality concerns, we advise the lake association to contact our program staff to discuss additional monitoring options. When applicable we also strive to place the recent results into a historical context using past NH LLMP data as well as historical data from other sources. This information is part of a large data base of historical and more recent data compiled and entered onto our computer files for New Hampshire lakes that include New Hampshire Fish and Game surveys of the 1930's through the 1950's, the surveys conducted by the New Hampshire Water Supply and Pollution Control Commission and the **UNH CFB/FBG** surveys. However, care must be taken when comparing current results with early studies. Many complications arise due to methodological differences of the various analytical facilities and technological improvements in testing.

# Climatic Summary - 2010

### *Water Quality and the Weather*

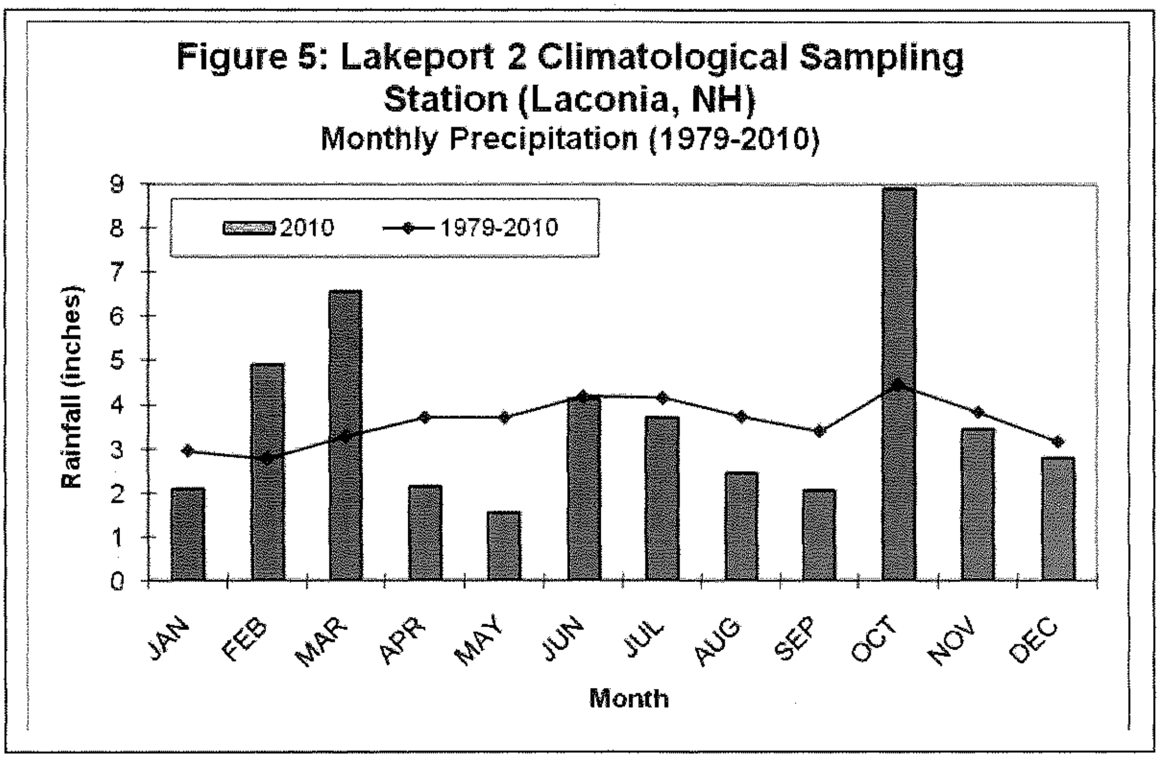
Water quality variations are commonly observed over the course of the year and among years in our New Hampshire lakes, ponds, wetlands and streams. The most commonly noticed changes are those associated with decreasing water clarities, increasing algal growth (greenness), and increasing plant growth around the lake's periphery. Over the long haul, changes such as these are attributed to a lake's natural aging process that is referred to as **eutrophication**. However, short-term water quality changes such as those mentioned above are often encountered even in our most pristine lakes and ponds. These water quality changes often coincide with variations in weather patterns such as precipitation and temperature fluctuations, and even variations in the sunlight intensity which can accelerate or suppress the photosynthetic process.

Climatic "swings" can have a profound effect on water quality, sometimes positive and other times negative. For instance, 1996 was a wet year relative to other years of LLMP water quality monitoring. The wet conditions translated into reduced water clarities, elevated microscopic plant "algal" growth and increased total phosphorus concentrations for most participating LLMP lakes. "Excessive" runoff associated with wet periods often facilitates the transport of pollutants such as nutrients (including phosphorus), sediment, dissolved colored compounds, as well as toxic materials such as herbicides, automotive oils, etc. into water bodies. As a result, lakes often respond with shallower water clarities and elevated algal abundance (greenness) during these periods as evidence by historical monitoring through the NH LLMP. Similarly, short-term storm events can have a profound effect on the water quality. Take for instance the "100 year storm" (October 21-22, 1996) that blanketed southern New Hampshire with approximately 6 inches of rain over a 30-hour period. This storm resulted in increased sedimentation and organic matter loading into our lakes as materials were flushed into the water bodies from the adjacent uplands. More recently, an August 11, 2008 precipitation event (1.91") included turbidity (particulate debris) and total phosphorus (nutrient) concentrations that were elevated nearly two orders of magnitude (100x) above baseline concentrations in Newfound Lake tributary inlets. While events such as the October 1996 and the August 2008 storms are short lived, they can have a profound effect on our water quality in the weeks to months that follow, particularly when nutrients that stimulate plant growth are retained in the lake. They also highlight the importance of low impact development practices to minimize the storm water loadings that occur after significant storms.

**NH LLMP** data collected during dry years such as 1985 and 2001, on the other hand, have coincided with improved water quality for many New Hampshire lakes. Reduced pollutant transport into the lake often results in higher water quality measured as deeper water transparencies, lower microscopic plant "algae" concentrations and lower nutrient concentrations. Do all lakes experience poorer water quality as a result of heavy precipitation events? Simply stated, the answer is no. While most New Hampshire lakes are characterized by reduced water clarities, increased nutrients and elevated plant "algal" concentrations following periods, or years, of heavy precipitation, a handful of lakes actually benefit from these types of events. The water bodies that improve during wet periods are generally lakes characterized by high nutrient concentrations and high "algal" concentrations that are diluted by watershed runoff and thus benefit during periods, or years, of heavy rainfall. However, these more nutrient enriched lakes remain susceptible to nutrients entering the lake from seepage sources such as poorly functioning septic systems.

**Precipitation (2010)**

The 2010 annual precipitation (reported as "rainfall" water equivalent) measured 44.81 inches and was slightly higher than the 32 year, 1979-2010,




average of 43.42 inches (note: precipitation data are reported for the Lakeport 2 Climatological sampling station located in Laconia New Hampshire: 43°33'N and 71°28'W). 2010 began with below average January rainfall that was followed by atypically wet conditions in February and March (Figure 5). The spring and summer weather pattern was characterized by below average precipitation with greater than one-inch below average rainfall in April, May, August and September and near-average precipitation during the months of June and July. Wet conditions returned in September when the monthly rainfall of 8.91" was nearly double the long term-average of 4.46" (1979-2010). The year closed out with near to slightly below above average rainfall during the months of November and December.

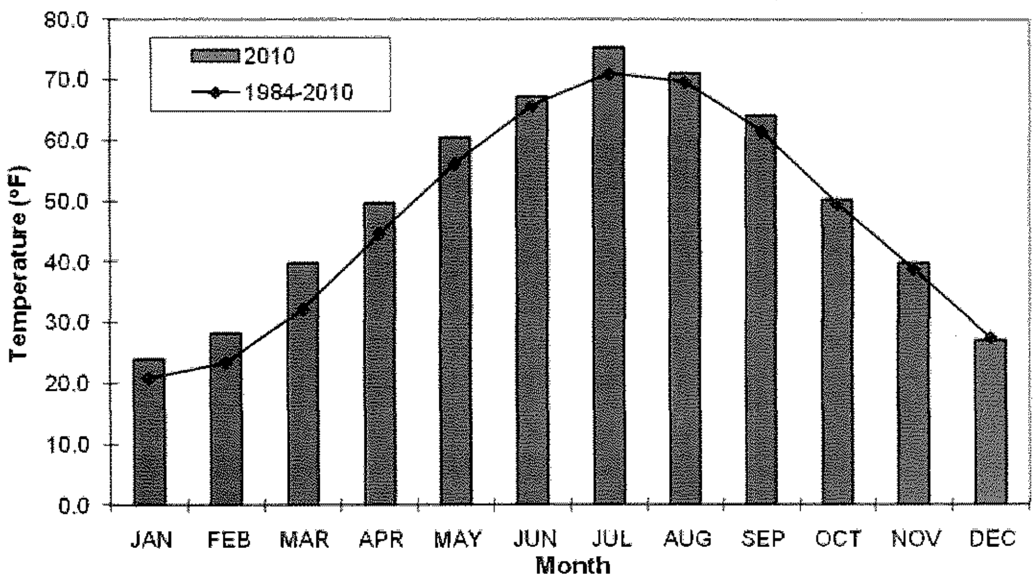
**Temperature (2010)**

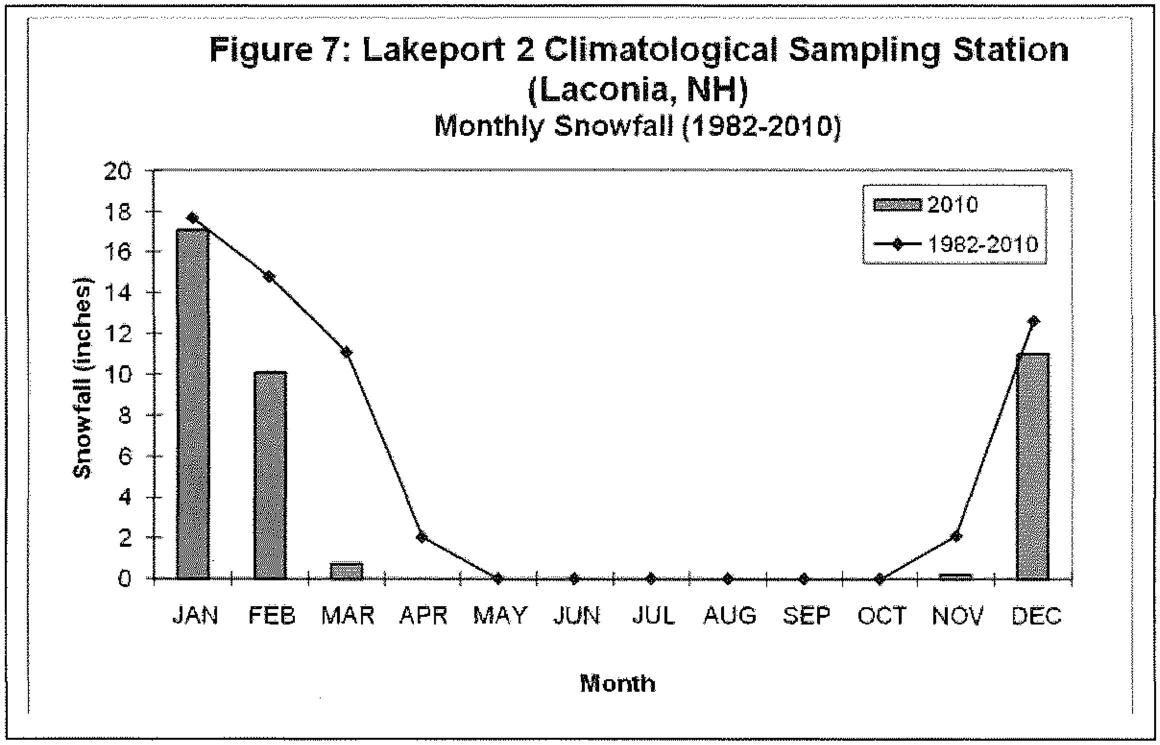
Similar to the impact of precipitation extremes, temperature extremes can have far reaching effects on the water quality, particularly early in the year and during the summer months. Atypically cold winter periods can promote the accumulation of snowpack while atypically warm periods can account for a rapid snowpack melt resulting in flooding and a massive influx of materials (e.g. nutrients, sediments) into our lakes during the late winter and early spring months. Early spring runoff periods coincide with minimal vegetative cover (that acts as a pollutant filter and soil stabilizer) and thus leaves the landscape highly susceptible to erosion. As we progress into the summer months, atypically warm periods can enhance both microscopic "algal" and macroscopic aquatic "weed" plant growth. During the summer growing season, above average temperatures often result in algal blooms that can reach nuisance proportions under optimal conditions. These nuisance blooms can include surface algal "scums" that cover the lake and wash up on the windward lakeshores.

During years such as 1994 and 1995, when above average temperatures exemplified the summer months, participating **NH LLMP** lakes were generally characterized by increased algal concentrations, particularly in the shallows, where filamentous cotton-candy-like clouds of algae (i.e. Mougeotia) flourished. Other **NH LLMP** lakes had increased algal growth (greenness) and shallower water transparencies during these "hot" periods.

The average January, February and March, 2010 monthly temperatures

**Figure 6: Lakeport 2 Climatological Sampling Station (Laconia, NH)**
Monthly Temperature (1984-2010)






were over five degrees warmer than the twenty-seven year (1984-2010) monthly average at the Lakeport 2 Climatological sampling station (Figure 6). The lack of significant snowpack accumulation during the winter months, partially associated with the above average temperature (Figures 6 & 7), resulted in short-term periods of heavy watershed runoff during the months of February, March and April. Above average temperatures continued into the months of April through September and contributed to elevated in-lake water temperatures during the summer months that can be conductive to microscopic plant "algal" growth.

## *Water Quality Impacts*

### Water Transparency and Dissolved "tea" Colored Water

As previously mentioned, shallower water transparency readings are characteristic of most New Hampshire lakes during wet years and following short term precipitation events. Wet periods often coincide with greater concentrations of dissolved "tea" colored compounds (dissolved organic matter resulting from the breakdown of vegetation and soils) washed in from surrounding forests and wetlands. Dissolved water color is not indicative of water quality problems (although large increases in dissolved color sometimes follow large land clearing operations) but in some of our more pristine program lakes, it nevertheless has a large effect on water clarity changes. Data collected by the **Center for Freshwater Biology (CFB)** since 1985 indicate most lakes are characterized by higher dissolved "tea" colored water during wet years relative to years more typical in terms of annual precipitation levels. In some of our more highly "tea" colored lakes the early spring months are also characterized by higher dissolved color concentrations, relative to mid-summer levels, due to the heavy runoff periods that flush highly colored water into our lakes during the period of spring snowmelt and following heavy spring rains.

**Sediment Loading**

Sediments are continuously flushed into our lakes and ponds during periods of heavy watershed runoff, particularly during snowmelt and again during and following sporadic storm events during the summer and fall months. Many New Hampshire lakes experience water clarity decreases following storm events such as those described above. Lakes, ponds and rivers are particularly susceptible to sediment loadings in the early spring months when vegetated shoreline buffers, often referred to as riparian buffers, are reduced. With limited vegetation to trap sediments and suspended materials, a high percentage of the particulate debris and dissolved materials are flushed into the lake. Human activities such as logging, agriculture, construction and land clearing can also increase sediment displacement during and following heavy storm events throughout the year. As sediment is transported into surface waters it can degrade water quality in a number of ways. When fine sediments (silt) enter a lake they tend to remain in the water column for relatively long periods of time. These suspended sediments can be abrasive to fish gills, ultimately leading to fish kills. Suspended sediments also reduce the available light necessary for plant growth that can result in plant die-offs and the subsequent oxygen depletion under extreme conditions.

As sediments settle out of the water column they can smother bottom dwelling aquatic organisms and fish spawning habitat. As the dead materials begin to decay the result can be noxious odors as well as stimulation of nuisance plant growth (i.e. scums along the lake-bottom; new macroscopic plant growth). Note: one should keep in mind that nuisance plants such as water milfoil (Myriophyllum heterophyllum) will generally regenerate more rapidly than more favorable plant forms. This can result in more problematic weed beds than those present before the disturbance. Habitat changes associated with the accumulation of fine sediments and associated "muck" might also favor increased nuisance plant growth in the future. Another unfavorable attribute of sediment loading is that the sediments tend to carry with them other forms of contaminants such as pathogens, nutrients and toxic chemicals (i.e. herbicides and pesticides).

Early symptoms of excessive sediment runoff include deposits of fine material along the lake-bottom, particularly in close proximity to tributary inlets and disturbed regions previously discussed (i.e. construction sites, logging sites, etc.). Silt may be visible covering rocks or aquatic vegetation along the lake-bottom. During periods of heavy overland runoff the water might appear brown and turbid which reflects the sediment load. As material collects along the lake-bottom you might notice a change in the weed composition reflecting a change in the substrate type (note: aquatic plants will display natural changes in abundance and distribution, so be careful not to jump to hasty conclusions). If excessive sediment loading is suspected, take a closer look in these areas and assess whether or not the change is associated with sediment loading (look for the warning signs discussed above) or whether the changes might be attributable to other factors.

**Nutrient Loading**

Nutrient loading is often greatest during heavy precipitation events, particularly during the periods of heavy watershed runoff. Phosphorus is generally considered the limiting nutrient for excessive plant and algal growth in New Hampshire lakes. Elevated phosphorus concentrations are generally most visible when documented in our tributary inlets where nutrients are concentrated in a relatively small volume of water. Much of the phosphorus entering our lakes is attached to particulate matter (i.e. sediments, vegetative debris), but may also include dissolved phosphorus associated with fertilizer applications and septic system discharge.

**Microscopic "Algal" and Macroscopic "Weed" Plant Growth**

Historical **Lakes Lay Monitoring Program** data indicate most lakes experience "algal blooms" during years with above average summer temperatures (June, July and August) while years with heavy precipitation are also associated with an increased frequency and occurrence of "algal blooms." Algal blooms are often green water events associated with decreases in water clarity due to their ability to absorb and scatter light within the water column, but can also accumulate near the lake bottom in shallow areas as "mats" or on the water surface as "scums" and "clouds." During some years, such as 1996, the "algal blooms" are predominantly green water events composed of algae distributed within the water column. New Hampshire lakes were particularly susceptible to algal blooms in 1996 as a function of the heavy runoff associated with an atypically wet year. Wet years such as 1996 can be particularly hard on lakes where excessive fertilizer applications, agricultural practices and construction activities favor the displacement of nutrients into surface waters. The occasional formation of certain algal blooms is a naturally occurring phenomenon and is not necessarily associated with changes in lake productivity. However, increases in the occurrence of bloom conditions can be a sign of eutrophication (the "greening" of a lake). Shifts from benign (clean water) forms to nuisance (polluted water) cyanobacterial forms such as Anabaena, Aphanizomenon and Oscillatoria, can also be a warning sign that improper land use practices are contributing excessive nutrients into the lake.

Filamentous cotton-candy-like "clouds" of the nuisance green algae, Mougeotia and related species, have been well documented in 1994 and 1995 when the temperatures during the months of June and July were well above normal. These algal "clouds" often develop within nearshore weed beds where they can be seen along the lake-bottom and tend to flourish during warm periods. During cooler years, this type of algal growth is kept "in check" and generally does not reach nuisance proportions. In other lakes, metalimnetic algae, algae which tend to grow in a thin layer along the thermocline gradient in a lake's middle depths, sometimes migrate up towards the lake surface causing a "bloom" event. If these algae are predominantly "nuisance" forms, like certain green or blue-green algae, they can be an early indication of nutrient loading.

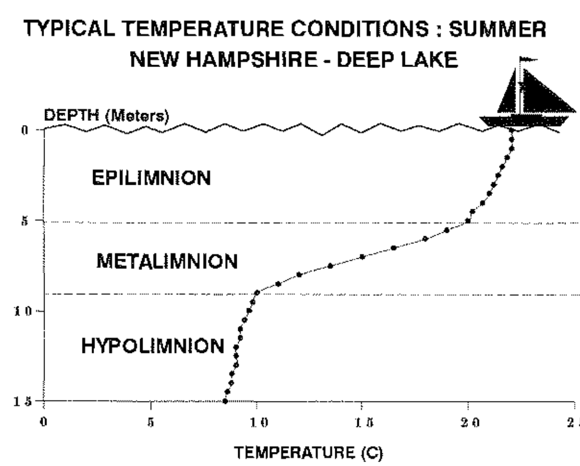
# DISCUSSION OF LAKE AND STREAM MONITORING MEASUREMENTS

The section below details the important concepts involved for the various testing procedures used in the **New Hampshire Lakes Lay Monitoring Program**. Certain tests or sampling performed at the time of the optional **Center for Freshwater Biology** field trip are indicated by an asterisk (*).

## *Thermal Stratification in the Deep Water Sites*

Lakes in New Hampshire display distinct patterns of temperature stratification, that develop as the summer months progress, where a layer of warmer water (the **epilimnion**) overlies a deeper layer of cold water (**hypolimnion**). The layer that separates the two regions characterized by a sharp drop in temperature with depth is called the **thermocline** or **metalimnion** (Figure 8). Some shallow lakes may be continually mixed by wind action and will never stratify. Other lakes may only contain a developed epilimnion and metalimnion.

**Figure 8**




## *Water Transparency*

Secchi Disk depth is a measure of the water transparency. The deeper the depth of Secchi Disk disappearance, the more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and non-living particles) to absorb and scatter it.

In the shallow areas of many lakes, the Secchi Disk will hit bottom before it is able to disappear from view (what is referred to as a "Bottom Out" condition). Thus, Secchi Disk measurements are generally taken over the deepest sites of a lake. Transparency values greater than 4 meters are typical of clear, unproductive lakes while transparency values less than 2.5 meters are generally an indication of highly productive lakes. Water transparency values between 2.5 meters and 4 meters are generally considered indicative of moderately productive lakes.

## *Chlorophyll a*

The chlorophyll *a* concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. **Eutrophic** lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Characteristics include accumulated organic matter in the lake basin and lower dissolved oxygen in the bottom waters. Summer chlorophyll *a* concentrations average above 7 mg $m^3$ (7 milligrams per cubic meter; 7 parts per billion). **Oligotrophic** lakes have low productivity and low nutrient levels and average summer chlorophyll *a* concentrations that are generally less than 3 mg $m^3$. These lakes generally have cleaner bottoms and high dissolved oxygen levels throughout. **Mesotrophic** lakes are intermediate in productivity with concentrations of chlorophyll *a* generally between 3 mg $m^3$ and 7 mg $m^3$. Testing is sometimes done to check for **metalimnetic algal populations**, algae that layer out at the thermocline and generally go undetected if only epilimnetic (point or integrated) sampling is undertaken. Chlorophyll concentrations of a water sample collected in the thermocline is compared to the integrated epilimnetic sample. Greater chlorophyll levels of the point sample, in conjunction with microscopic examination of the samples (see Phytoplankton section below), confirm the presence of such a population of algae. These populations should be monitored as they may be an early indication of increased nutrient loading into the lake.

## *Turbidity **

Turbidity is a measure of suspended material in the water column such as sediments and planktonic organisms. The greater the turbidity of a given water body the lower the Secchi Disk transparency and the greater the amount of particulate matter present. Turbidity is measured as nephelometric turbidity units (NTU), a standardized method among researchers. Turbidity levels are generally low in New Hampshire reflecting the pristine condition of the majority of our lakes and ponds. Increasing turbidity values can be an indication of increasing lake productivity or can reflect improper land use practices within the watershed which destabilize the surrounding landscape and allow sediment runoff into the lake.

While Secchi Disk measurements will integrate the clarity of the water column from the surface waters down to the depth of disappearance, turbidity measurements are collected at discrete depths from the surface down to the lake bottom. Such discrete sampling can identify layering algal populations (previously discussed) that are undetectable when measuring Secchi Disk transparency alone.

## *Dissolved Color*

The dissolved color of lakes is generally due to dissolved organic matter from **humic substances**, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters. Increases in dissolved watercolor can be an indication of increased development within the watershed as many land clearing activities (construction, deforestation, and the resulting increased run-off) add additional organic material to lakes. Natural fluctuations of dissolved color occur when storm events increase drainage from wetlands areas within the watershed. As suspended sediment is a difficult and expensive test to undertake, both dissolved color and chlorophyll information are important when interpreting the Secchi Disk transparency

Dissolved color is measured on a comparative scale that uses standard chloroplatinate dyes and is designated as a color unit or ptu. Lakes with color below 10 ptu are very clear, 10 to 20 ptu are slightly colored, 20 to 40 ptu are lightly tea colored, 40 to 80 ptu are tea colored and greater than 80 ptu indicates highly colored waters. Generally the majority of New Hampshire lakes have color between 20 to 30 ptu.

## *Total Phosphorus*

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources arise primarily through human related activity in a watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton. As little as 10 parts per billion of phosphorus in a lake can cause an algal bloom.

Generally, in the more pristine lakes, phosphorus values are higher after spring melt when the lake receives the majority of runoff from its surrounding watershed. The nutrient is used by the algae and plants which in turn die and sink to the lake bottom causing surface water phosphorus concentrations to decrease as the summer progresses. Lakes with nutrient loading from human activities and sources (agriculture, logging, sediment erosion, septic systems, etc.) will show greater concentrations of nutrients as the summer progresses or after major storm events.

## *Soluble Reactive Phosphorus **

Soluble reactive phosphorus is a fraction of the (total) phosphorus that consists largely of orthophosphate, the form of phosphorus that is directly taken up by algae and that stimulates growth. Soluble reactive phosphorus is obtained by filtering a water sample through a fine mesh filter, generally a 0.45 micron membrane filter, which effectively removes the particulate matter from the sample. Soluble reactive phosphorus concentrations are thus less than, or equal to, the measured total phosphorus concentrations for a water sample.

Soluble reactive phosphorus typically occurs in trace concentrations while applications of fertilizers as well as septic system effluent can be associated with elevated concentrations. Knowledge of both the total phosphorus and the soluble reactive phosphorus is important to understanding the sources of phosphorus into a lake and to understanding the lake's response to the phosphorus loading. For instance, a lake experiencing soluble reactive phosphorus runoff from a fertilized field may exhibit immediate water quality decline (i.e. increased algal growth) while lakes experiencing elevated total phosphorus concentrations associated with sediment washout may not exhibit clear symptoms of increased nutrient loading for years.

## *Streamflow*

Streamflow, when collected in conjunction with stream channel information, is a measure of the volume of water traversing a given stream stretch over a period of time and is often expressed as cubic meters per second. Knowledge of the streamflow is important when determining the amount of nutrients and other pollutants that enter a lake. Knowledge of the streamflow in conjunction with nutrient concentrations, for instance, will provide the information necessary to calculate phosphorus loading values and will in turn be useful in discerning the more impacted areas within a watershed.

## *pH **

The pH is a way of expressing the acidic level of lake water, and is generally measured with an electrical probe sensitive to hydrogen ion activity. The pH scale has a range of 1 (very acidic) to 14 (very "basic" or alkaline) and is logarithmic (i.e.: changes in 1 pH unit reflect a ten times difference in hydrogen ion concentration). Most aquatic organisms tolerate a limited range of pH and most fish species require a pH of 5.5 or higher for successful growth and reproduction.

## *Alkalinity*

Alkalinity is a measure of the buffering capacity of the lake water. The higher the alkalinity value, the more acid that can be neutralized. Typically lakes in New Hampshire have low alkalinities due to the absence of carbonates and other natural buffering minerals in the bedrock and soils of lake watersheds.

Decreasing alkalinity over a period of a few years can have serious effects on the lake ecosystem. In a study on an experimental acidified lake in Canada by Schindler, gradual lowering of the pH from 6.8 to 5.0 in an 8-year period resulted in the disappearance of some aquatic species, an increase in nuisance species of algae and a decline in the condition and reproduction rate of fish. During the first year of Schindler's study the pH remained unchanged while the alkalinity declined to 20 percent of the pretreatment value. The decline in alkalinity was sufficient to trigger the disappearance of zooplankton species, which in turn caused a decline in the "condition" of fish species that fed on the zooplankton.

The analysis of alkalinity employed by the **Center for Freshwater Biology** includes use of a dilute titrant allowing an order of magnitude greater sensitivity and precision than the standard method. Two endpoints are recorded during each analysis. The first endpoint (gray color of dye; pH endpoint of 5.1 ) approximates low level alkalinity values, while the second endpoint (pink dye color; pH endpoint of 4.6) approximates the alkalinity values recorded historically, such as NH Fish and Game data, with the methyl-orange endpoint method.

The average alkalinity of lakes throughout New Hampshire is low, approximately 6.5 mg per liter (calcium carbonate alkalinity). When alkalinity falls below 2 mg per liter the pH of waters can greatly fluctuate. Alkalinity levels are most critical in the spring when acid loadings from snowmelt and run-off are high, and many aquatic species are in their early, and most susceptible, stages of their life cycle.

## *Specific Conductivity* *

The specific conductance of a water sample indicates concentrations of dissolved salts. Leaking septic systems and deicing salt runoff from highways can cause high conductivity values. Fertilizers and other pollutants can also increase the conductivity of the water. Conductivity is measured in **micromhos** (the opposite of the measurement of resistance **ohms**) per centimeter, more commonly referred to as micro-Siemans (υS). Specific conductivity implies the measurements are standardizes to the equivalent room temperature reading as conductivity will increase with increasing temperature.

## *Sodium and Chloride* *

Low levels of sodium and chloride are found naturally in some freshwater and groundwater systems while high sodium and chloride concentrations are characteristic of the open ocean and are elevated in estuarine systems as well. Elevated sodium and chloride concentrations in freshwater or groundwater systems, that exceed the natural baseline concentrations, are commonly associated with the application of road salt. Sodium and particularly chloride are highly mobile and, relatively speaking, move into the surface and groundwater relatively unimpeded. Sodium and chloride concentrations can become elevated during periods of heavy snow pack melt when the salts are flushed into surface waters and have also been observed in elevated concentrations during the summer months when low flow conditions concentrate the sodium and chloride.

Road salt runoff is known to adversely impact roadside vegetation as is oftentimes evidenced by bleached (discolored) leaves and needles and in more extreme instances dead trees and shrubs. The United States Environmental Protection Agency (EPA) has set the standard for protection of aquatic life, both plants and animals, at 230 milligrams per liter (mg/l). The EPA has also established a secondary maximum contaminant level of 250 mg/l for both sodium and chloride, predominantly for taste, while the sodium advisory limit for persons with hypertention is 20 mg/l

## *Dissolved Oxygen and Free Carbon Dioxide* *

Oxygen is an essential component for the survival of aquatic life. Submergent plants and algae take in carbon dioxide and create oxygen through **photosynthesis** by day. **Respiration** by both animals and plants uses up oxygen continually and creates **carbon dioxide**. Dissolved oxygen profiles determine the extent of declining oxygen concentrations in the lower waters. High carbon dioxide values are indicative of low oxygen conditions and accumulating organic matter. For both gases, as the temperature of the water decreases, more gas can be dissolved in the water.

The typical pattern of clear, unproductive lakes is a slight decline in hypolimnetic oxygen as the summer progresses. Oxygen in the lower waters is important for maintaining a fit, reproducing, cold water fishery. Trout and salmon generally require oxygen concentrations above 5 mg per liter (parts per million) in the cool deep waters. On the other hand, carp and catfish can survive very low oxygen conditions. Oxygen above the lake bottom is important in limiting the release of nutrients from the sediments and minimizing the collection of undecomposed organic matter.

Bacteria, fungi and other **decomposers** in the bottom waters break down organic matter originating from the watershed or generated by the lake. This process uses up oxygen and produces carbon dioxide. In lakes where organic matter accumulation is high, oxygen depletion can occur. In highly stratified eutrophic lakes the entire hypolimnion can remain unoxygenated or **anaerobic** until fall mixing occurs.

The oxygen peaks occurring at surface and mid-lake depths during the day are quite common in many lakes. These characteristic **heterograde oxygen curves** are the result of the large amounts of oxygen, the by-product of photosynthesis, collecting in regions of high algal concentrations. If the peak occurs in the thermocline of the lake, metalimnetic algal populations (discussed above) may be present.

## *Underwater Light* *

Underwater light available to photosynthetic organisms is measured with an **underwater photometer** which is much like the light meter of a camera (only waterproofed!). The **photic zone** of a lake is the volume of water capable of supporting photosynthesis. It is generally considered to be delineated by the water's surface and the depth that light is reduced to one percent surface iridescence by the absorption and scattering properties of the lake water. The one percent depth is sometimes termed the **compensation depth**. Knowledge of light penetration is important when considering lake productivity and in studies of submerged vegetation. Discontinuity (abrupt changes in the slope) of the profiles could be due to metalimnetic layering of algae or other particulates (discussed above). The underwater photometer allows the investigator to measure light at depths below the Secchi Disk depth to supplement the water clarity information.

## *Indicator Bacteria* *

Certain disease causing organisms, pathogenic bacteria, viruses and parasites, can be spread through contact with polluted waters. Faulty septic systems, sewer leaks, combined sewer overflows and the illegal dumping of wastes from boats can contribute fecal material containing these pathogens. Typical water testing for pathogens involves the use of detecting coliform bacteria. These bacteria are not usually considered harmful themselves but they are relatively easy to detect and can be screened for quickly. Thus, they make good surrogates for the more difficult to detect pathogens.

**Total coliform** includes all coliform bacteria that arise from the gut of animals or from vegetative materials. **Fecal coliform** are those specific organisms that inhabit the gut of warm blooded animals. Another indicator organism **Fecal streptococcus** (sometimes referred to as **enterococcus**) also can be monitored. The ratio of fecal coliform to fecal strep may be useful in suggesting the type of animal source responsible for the contamination. In 1991, the State of New Hampshire changed the indicator organism of preference to *E. coli* which is a specific type of fecal coliform bacteria thought to be a better indicator of human contamination. The new state standard requires Class A "bathing waters" to be under 88 organisms (referred to as colony forming units; cfu) per 100 milliliters of lakewater.

Ducks and geese are often a common cause of high coliform concentrations at specific lake sites. While waterfowl are important components to the natural and aesthetic qualities of lakes that we all enjoy, it is poor management practice to encourage these birds by feeding them. The lake and surrounding area provides enough healthy and natural food for the birds and feeding them stale bread or crackers does nothing more than import additional nutrients into the lake and allows for increased plant growth. As birds also are a host to the parasite that causes "swimmers itch", waterfowl roosting areas offer a greater chance for infestation to occur. Thus while leaving offerings for our feathered friends is enticing, the results can prove to be detrimental to the lake system and to human health.

## *Phytoplankton* *

The planktonic community includes microbial organisms that represent diverse life forms, containing photosynthetic as well as non-photosynthetic types, and including bacteria, algae, crustaceans and insect larvae (the insect larvae and zooplankton are discussed below in separate sections). Because planktonic algae or "phytoplankton" tend to undergo rapid seasonal cycles on a time scale of days and weeks, the levels of populations found should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

The composition and concentration of phytoplankton can be indicative of the trophic status of a lake. Seasonal patterns do occur and must be considered. For example **diatoms**, tend to be most abundant in April-June and October-November, in the surface or epilimnetic layers of New Hampshire lakes. As the summer progresses, the dominant types might shift to **green algae** or **golden algae**. By late season **Blue-green bacteria** generally dominate. In nutrient rich lakes, nuisance green algae and/or bluegreen bacteria might dominate continually. After fall mixing diatoms might again be found to bloom.

## *Zooplankton* *

There are three groups of zooplankton that are generally prevalent in lakes: the **protozoa**, **rotifers** and **crustaceans**. Most research has been devoted to the last two groups although protozoa may be found in substantial amounts. Of the rotifers and the crustaceans, time and budgetary constraints usually make it necessary to sample only the larger zooplankton (macrozooplankton; larger than 80 or 150 microns; 1 million microns make up a meter). Thus, zooplankton analysis is generally restricted only to the larger crustaceans. Crustacean zooplankton are very sensitive to pollutants and are commonly used to indicate the presence of toxic substances in water. The crustaceans can be divided into two groups, the **cladocerans** (which include the "water fleas") and the **copepods**.

Macrozooplankton are an important component in the lake system. The filter feeding of the herbivorous ("grazing") species may control the population size of selected species of phytoplankton. The larger zooplankton can be an important food source for juvenile and adult planktivorous fish. All zooplankton play a part in the recycling of nutrients within the lake. Like the phytoplankton, zooplankton, tend to undergo rapid seasonal cycles. Thus, the zooplankton population density and diversity should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

## *Macroinvertebrates* *

Macroinvertebrates generally refer to the aquatic insect community living near the bottom substrate (i.e. sediments) while other invertebrate groups such as the crayfish, leeches and the aquatic worms are also included. Like the phytoplankton and zooplankton, previously discussed, the macroinvertebrates undergo seasonal cycles and are most representative of conditions for particular periods of the year. The mayflies are probably the most well known example of a seasonal aquatic macroinvertebrate as mayfly populations metamorphosize into adults as the water temperatures increase in the spring and thus giving rise to the name "mayflies". Macroinvertebrates are also sensitive to environmental conditions such as streamflow, temperature and food availability and are most representative of particular habitats along the stream continuum (i.e. some organisms prefer slower moving stream reaches while others prefer rapidly flowing waters).

Macroinvertebrates are an essential component to a healthy aquatic habitat. Macroinvertebrates help decompose organic matter entering the system such as leaves and twigs and also serve as a food source for many fish species.

While some macroinvertebrates are capable of breathing air as we do, others have gills and utilize oxygen dissolved in the water much as fish do. Macroinvertebrates also vary in their tolerance to depleting dissolved oxygen concentrations making them a good indicator of pollutants coming into the water body. The caddis flies (Trichop-tera), the mayflies (Ephemeroptera) and the stoneflies (Plecoptera) are often considered highly sensitive to pollution while the "true" flies (Diptera) are often considered highly tolerant to pollution. However, exceptions to the above categorizations are often encountered.

A variety of indices have been proposed to characterize water bodies over a gradient of pollution levels ranging from least polluted to most polluted scenarios and often designated by assigning a numerical delineator (i.e. 1 is least polluted while 10 is most polluted). Such an index, the Hilsenhoff Biotic Index (HBI), or a modification thereof, is commonly used by stream monitoring programs around the country. Macroinvertebrate data are useful in discerning the more impacted areas within the watershed where corrective efforts should be directed. Unlike chemical measurements that represent ambient conditions in the water body, the macroinvertebrate community composition integrates the water quality conditions over a longer period (months to years) and can identify "hot" spots missed by chemical sampling. If you are interested in more information regarding macroinvertebrate monitoring contact the **LLMP** coordinator.

## *Fish Condition*

The assessment of fish species "health" is another biological indicator of water quality. Because fish are at the top of the food chain, their condition should reflect not only water quality changes that affect them directly but also those changes that affect their food supply. The fish condition index utilized by the **New Hampshire Fish Condition Program** is based on two components; fish scale analysis and a fish condition index.

Like tree trunks, fish scales have annual growth rings (annuli) that reflect their growth history and hence, provide a long-term record of past conditions in the lake. The fish condition index, based upon length and weight measurements, is a good indicator of the fish's health at the time of collection.

The resulting fish condition data can be compared among different lakes or among different years, or the index for a particular species can be compared to standard length-to-weight relationships that have been developed by fisheries biologists for many important fish species. In the end, the "health" of the various fish species reflects the overall water quality in the respective lake or pond.

UNIVERSITY of NEW HAMPSHIRE
COOPERATIVE EXTENSION

# Understanding Lake Aging (Eutrophication)

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A common concern among **New Hampshire Lakes Lay Monitoring Program (NH LLMP)** participants is a perceived increase in the density and abundance of aquatic plants in the shallows, increases in the amount of microscopic plant "algae" growth (detected as greener water), and water transparency decreases; what is known as **eutrophication**. Eutrophication is a natural process by which all lakes age and progress from clear pristine lakes to green, nutrient enriched lakes on a geological time frame of thousands of years. Much like the fertilizers applied to our lawns, nutrients that enter our lakes stimulate plant growth and culminate in greener (and in turn less clear) waters. Some lakes age at a faster rate than others due to naturally occurring attributes: watershed area relative to lake area, slope of the land surrounding the lake, soil type, mean lake depth, etc. Since our New Hampshire lakes were created during the last ice-age, which ended about 10,000 years ago, we should have a natural continuum of lakes ranging from extremely pristine to very enriched.

Classification criteria are often used to categorize lakes into what are known as **trophic states**, in other words, levels of lake plant and algae productivity or "greenness" Refer to Table 8 below for a summary of commonly used eutrophication parameters.

**Table 9: Eutrophication Parameters and Categorization**

| Parameter | Oligotrophic "pristine" | Mesotrophic "transitional" | Eutrophic "enriched" |
|---|---|---|---|
| **Chlorophyll a (*ug*/l) *** | <3.0 | 3.0-7.0 | >7.0 |
| **Water Transparency (meters) *** | >4.0 | 2.5-4.0 | <2.5 |
| **Total Phosphorus (*ug*/l) *** | <15.0 | 15.0-25.0 | >25.0 |
| **Dissolved Oxygen (saturation) #** | high to moderate | moderate to low | low to zero |
| **Macroscopic Plant (Weed) Abundance** | low | moderate | high |

*** Denotes classification criteria employed by Forsberg and Ryding (1980).**
**# Denotes dissolved oxygen concentrations near the lakebottom.**

**Oligotrophic** lakes are considered "unproductive" pristine systems and are characterized by high water clarities, low nutrient concentrations, low algae concentrations, minimal levels of aquatic plant "weed" growth, and high dissolved oxygen concentrations near the lake bottom. **Eutrophic** lakes are considered "highly productive" enriched systems characterized by low water transparencies, high nutrient concentrations, high algae concentrations, large stands of aquatic plants and very low dissolved oxygen concentrations near the lake bottom. **Mesotrophic** lakes have qualities between those of oligotrophic and eutrophic lakes and are characterized by moderate water transparencies, moderate nutrient concentrations, moderate algae growth, moderate aquatic plant "weed" growth and decreasing dissolved oxygen concentrations near the lake bottom.

Is a pristine, oligotrophic, lake "better than" an enriched, eutrophic, lake? Not necessarily! As indicated above, lakes will naturally exhibit varying degrees of productivity. Some lakes will naturally be more susceptible to eutrophication than others due to their natural attributes and in turn have aged more rapidly. This is not necessarily a bad thing as our best bass fishing lakes tend to be more mesotrophic to eutrophic than oligotrophic; an ultra-oligotrophic lake (extremely pristine) will not support a very healthy cold water fishery. However, human related activities can augment the aging process (what is known as cultural eutrophication) and result in a transition from a pristine system to an enriched system in tens of years rather than the natural transitional period that should take thousands of years. Cultural eutrophication is particularly a concern for northern New England lakes where large tracts of once forested or agricultural lands are being developed, with the potential for increased sediment and nutrient loadings into our lakes, which augment the eutrophication process.

Additionally, other pollutants such as heavy metals, herbicides, insecticides and petroleum products might also affect your lake's "health". A "healthy" lake, as far as eutrophication is concerned, is one in which the various aquatic plants and animals are minimally impacted so that nutrients and other materials are processed efficiently. We can liken this process to a well-managed pasture: nutrients stimulate the growth of grasses and other plants that are eaten by grazers like cows and sheep. As long as producers and grazers are balanced, a good amount of nutrients can be processed through the system. Impact the grazers and the grass will overgrow and nuisance weeds will appear, even if nutrients remain the same. In a lake, the producers are the algae and aquatic weeds while the grazers are the microscopic animals (**zooplankton**) and aquatic insects. These organisms can be very susceptible to a wide range of pollutants at very low concentrations. If impacted, the lake can become much more productive and the fishery will be impacted as well since these same organisms are an important food source for most fish at some stage of their life.

Development upon the landscape can negatively affect water quality in a number of ways:

- <u>Removal of shore side vegetation and loss of wetlands</u> - Shore side vegetation (what is known as **riparian vegetation**) and wetlands provide a protective buffer that "traps" pollutants before reaching the lake. These buffers remove materials both chemically (through biological uptake) and physically (settling materials out). As riparian buffers are removed and wetlands lost, pollutant materials are more likely to enter the lake and in turn, favor declining water quality.

- Excessive fertilizer applications - Fertilizers entering the lake can stimulate aquatic plant and algal growth and in extreme cases result in noxious algal blooms. Increases in algal growth tend to diminish water transparency and under extreme cases culminate in surface "scums" that can wash up on the shoreline producing unpleasant smells as the material decomposes. Excessive nutrient concentrations also favor algal forms known to produce toxins, which irritate the skin and under extreme conditions, are dangerous when ingested.

- Increased organic matter loading - Organic matter (leaves, grass clippings, etc.) is a major source of nutrients in the aquatic environment. As the vegetative matter decomposes nutrients are "freed up" and can become available for aquatic plant and algal growth. In general, we are not concerned with this material entering the lake naturally (leaf senescence in the fall) but rather excessive loading of this material as occurs when residents dump or rake leaf litter and grass clippings into the lake. This material not only provides large nutrient reserves which can stimulate aquatic plant and algal growth but also makes great habitat for leaches and other potentially undesirable organisms in swimming areas.

- Septic problems - Faulty septic systems are a big concern as they can be a primary source of water pollution around our lakes. Septic systems are loaded with nutrients and can also be a health threat when not functioning properly.

- Loss of vegetative cover and the creation of impervious surfaces - A forested watershed offers the best protection against pollutant runoff. Trees and tall vegetation intercept heavy rains that can erode soils and surface materials. The roots of these plants keep the soils in place, process nutrients and absorb moisture so the soils do not wash out. Impervious surfaces (paved roads, parking lots, building roofs, etc.) reduce the water's capacity to infiltrate into the ground, and in turn, go through nature's water purification system. As water seeps into the soil, pollutants are removed from the runoff through absorption onto soil particles. Biological processes detoxify pollutants and/or immobilize substances. Surface water runoff over impervious surfaces also increases water velocities that favor the transport of a greater load of suspended and dissolved pollutants into your lake.

## *How can you minimize your water quality impacts?*

- Minimize fertilizer applications whenever possible. Most people apply far more fertilizers than necessary, with the excess eventually draining into your lake. This not only applies to those immediately adjacent to the lake but to everybody within the watershed. Pollutants in all areas of the watershed will ultimately make their way into your lake. Have your soil tested for a nominal fee (contact your county UNH Cooperative Extension Office for further information) to find out how much fertilizer and soil amendments are really needed. Sometimes just an application of crushed lime will release enough nutrients to fit the bill. If you do use fertilizer try to use low phosphorus, slow release nitrogen varieties. And remember that under the current NH Comprehensive Shoreline Protection Act (CSPA) you cannot apply any fertilizers or amendments within 25 feet of the shore.

- Don't dump leaf litter or leaves into the lake. Compost the material or take it to a proper waste disposal center. Do not fill in wetland areas. Do not create or enhance beach areas with sand (contains phosphorus, smothers aquatic habitat, fills in lake as it gets transported away by currents and wind).
- Septic systems will not function efficiently without the proper precautionary maintenance. Have your septic system inspected every two to four years and pumped out when necessary. Since the septic system is such an expensive investment often costing around $10,000 for a complete overhaul, it is advantageous to assure proper care is taken to prolong the system's life. Additionally, following proper maintenance practices will reduce water quality degradation. Refer to:

  *Pipeline: Summer 2008 Vol. 19, No. 1. Septic Systems and Source Water Protection: Homeowners can help improved community water quality.*

  http://www.nesc.wvu.edu/pdf/WW/publications/pipline/PL_SU08.pdf
- Try to landscape and re-develop with consideration of how water flows on and off your property. Divert runoff from driveways, roofs and gutters to a level vegetated area or a rain garden so the water can be slowed, filtered and hopefully absorbed as recharge. Refer to:

  *Landscaping at the Water's Edge: an Ecological Approach 2nd Edition. $20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824.*

  *Integrated Landscaping: Following Nature's Lead. $20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824.*
- Maintain shore side (riparian) vegetative cover when new construction is undertaken. For those who have pre-existing houses but lack vegetative buffers, consider shoreline plantings aimed at diminishing the pollution load into your lake. Refer to:

  *Landscaping at the Water's Edge: an Ecological Approach 2nd Edition. $20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824.*

  *Buffers for Wetlands and Surface Waters: A Guidebook for New Hampshire Municipalities.* Audubon Society of New Hampshire.

  http://www.nh.gov/oep/resourcelibrary/documents/buffershandbook.pdf

# Lake Friendly Lawn Care

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Below is an expanded version of an article written by the author and published in the Spring 2009 "Lakeside", the newsletter of the NH Lakes Association.

The recent publication, "**Landscaping at the Water's Edge: An ecological approach, 2nd edition**" from UNH Cooperative Extension covers the importance of considering how you may landscape your shoreline property for both the improvement of water quality as well as the enhancement of your property. Lawns and lawn care, specifically for shoreline properties, are among the most popular requests for information. While the publication goes into much greater and more specific detail, the information below is a good start when considering lawns and their potential impacts to water quality.

There is often controversy and confusion regarding lawns on shoreland properties. Some consider lawns inconsistent with the natural shoreland ecology while others want to bring to their shoreland home the same look and feel as the neighborhoods in surburbia that they have grown up with. As all vegetation provides at least some water quality functions, a lawn managed in the proper way can still allow for stabilized soils, filtered water infiltration into the ground and some nutrient and pollutant capture. And as with all vegetation, lawns sequester carbon dioxide, produce oxygen and, by doing so, cool the planet. Thus, lawns still make a better alternative to pavement or patios which create greater runoff conditions and impede groundwater recharge. Of course, if managed improperly and located too close to the water, lawns and their care can add to pollutant and nutrient loading to our surface and ground waters, attract nuisance weeds and insect pests (and even big pests like Canadian Geese!), impact important plant and wildlife species, as well as greatly reduce the available potable water supply with their potential need for irrigation. So how might you maintain a lawn area to enjoy on your shoreland property (or any property for that matter) while minimizing your impacts to the water quality and natural ecology?

- <u>Everything in moderation</u> - We often hear from our health providers that moderation is the key to healthy living and the same holds true for natural systems. Questions to ask yourself here include: How much lawn or open space do we really need for our intended use? Do we need to have all of our open space as a monoculture of a single type of grass or can we live with a combination of grasses and groundcovers that match our use? There are many varieties of grasses depending on the type and frequency of use (ie: occasionally picnicking to kids playing ball everyday) and site conditions (soils, sun exposure and slope). Recently developed fescues, for example, require less maintenance (water, mowing and fertilizing) and can even be obtained with symbiotic fungi in their roots that make the grass better resistant to pests and diseases. The best approach is a mix of grass species with even some other groundcovers and white clover (or another low growing legume to naturally supply nitrogen to the soil). Talk to your county Extension educator, landscaper, or garden center expert about your options.

- **Location, location, location** - Yes, the mantra of real estate agents also works well for lawns. Additional maintenance of a lawn, even when not excessive, can still threaten water quality. To make up for this residents might consider locating the lawn as away from the shore as possible and maintaining a significant buffer area downslope from the lawn with a mix of shrubs and woody plants. A lawn right down to the water is the worst thing for the water and it will serve to attract nuisance geese. It's a known fact that keeping the vegetation high at the water's edge will discourage geese from coming onto a property. It also provides many water quality and wildlife (aquatic and near shore) related benefits.
- **Test first, apply later** - It is most important to test your soil before even thinking about applying fertilizers. Once a lawn is established, fertilizing more than once a year (unless the yearly dosage is applied in fractions) is generally excessive and can lead to excess nitrogen loading to surface and groundwater. Lawns tend to need more basic soils so sometimes even applying crushed limestone to raise the pH can release enough nutrients that were bound to the soil to maintain the lawn. A soil test will let you know exactly what you need to maintain a healthy lawn. If the test informs you that only nitrogen is needed, look for low to no phosphorus fertilizer blends (middle number of the N-P-K rating on the bag is zero) as phosphorous causes algae blooms in lakes and ponds. Generally, a well established lawn can survive adequately with no more than 1 to 2 pounds of nitrogen per 1000 square feet. The best time to apply fertilizer on an established lawn is around mid September when the grass is still active enough to incorporate the fertilizer into the plants, the summer draught is over and the surrounding vegetation is well established to capture any runoff from your lawn. Choose slow release fertilizers only, to insure less polluted runoff. Many residents apply crushed limestone in the spring and fertilize in the fall. Some residents have never felt the need to fertilize and others have had their best results just using lake water (which usually contains small amounts of N and low P) for irrigation. It is really up to you to balance the results you are looking for with the minimum applications needed. Remember the NH Comprehensive Shoreline Protection Act prohibits applying anything except limestone in areas within 25 feet of the high water line except in some circumstances like initially establishing a ground cover.
- **Read the fine print!** - A recent survey in Maine indicated that many consumers did not realize that "Weed & Feed" products contain both fertilizers and pesticides. Why pay for and put down something that can potentially threaten the health of pets, children and water quality when you may not need it in the first place? If you do have weed or insect problems consult with your county Exten-

sion educator, landscaper or garden center expert to learn of safer alternative controls. No matter what you choose always read the application directions and never over apply. Many of the plants and animals that form the foundation of the aquatic food web are extremely sensitive to pesticides so your impacts can have serious repercussions. Also be sure to apply only what you need - just because you bought a whole bag does not mean you have to apply all of it. Over-fertilization will cause more pest problems and will threaten surface and ground water supplies.

- **Conserve every drop** - If you are on a public water supply it is best to choose grass species with low watering requirements or use alternative irrigation supplies like rain barrels, cisterns or even the water directly from the shore. Summer water demand for lawns can be very significant in many communities. Depending on the species and soil conditions you should water, only when needed, no more than a half inch to an inch total weekly. You can use a rain gauge or a can to measure rainfall and irrigation amounts. Early morning watering is preferable to minimize evaporation loss but give the water enough time to infiltrate and to allow the leaf blades to completely dry before night so as not to encourage disease problems. Keeping the lawn height at least 3 inches or higher will also encourage deeper roots which require less water (and a mulching mower blade will allow for those grass clippings to recycle nutrients back into the soil). Remember that in times of draught and hot summer lawns are supposed to go dormant. Letting this happen is the most environmentally friendly thing you can do.

So, the choices are yours, you can have a lawn on your property with minimum impact to our waters if you can restrict its size, locate it properly, provide adequate vegetative buffer areas down-slope and use low input design and maintenance methods. To learn more about how informed landscaping can actually improve the water coming off of your property refer to "**Landscaping at the Water's Edge: An ecological approach, 2nd edition**" and/or request a presentation from your Cooperative Extension county Master Gardeners. Jeff Schloss can also be contacted to schedule a talk or workshop for your lake association.

# Go with the Flow:
## Understanding How Water Moves Onto, Through and Away from Your House Site

Water travels through a watershed (the catchment area) in two ways, across the land surface and down through the ground. As water traveling on the land surface moves along, following the path of least resistance, it passes across various types of land and land uses. In a state as geographically diverse as New Hampshire, a drop of water from irrigation, rain or snowmelt might travel across neighborhood roads and your driveway, through a wooded area or an open field. Unless it infiltrates down into the ground, gets intercepted by a plant or evaporates into the atmosphere, the drop will end up in a lake, pond, stream, wetland or estuary. As water travels downhill on the landscape it picks up small particles and soluble materials and carries them along to the waterbody at the end of its journey. It might pick up pesticides or fertilizers from a backyard garden or salts and oils from a driveway or patio. In times of heavy rain, fast moving waters can pick up large particles of soils and sediments and deliver large pollutant loads to our surface waters. This flow of water and materials from a given location across the land surface and into our water is called "runoff".

Controlling water runoff should be a major objective of any shoreland landscape design. As water collects and flows through channels, it gathers energy and increases its erosive force. The faster water flows, the greater the particle size and quantity of pollutants it can carry along to the receiving water body (pond, lake, stream, river, wetland or coastal water). Modifying the landscape with any type of development has the potential to degrade soil and water, resulting in changes in water flow, nutrient- and pollutant-loading, and groundwater recharge. However, if you start with a plan that takes into consideration the specific water runoff situation on your house site, your new landscape design could even improve the quality of water coming off it.

This overview will guide you through the process of assessing your current runoff situation and offer various strategies you can use to minimize the runoff from your house site. Combining these approaches with appropriate choices of plants and horticultural products is key to ensuring a healthy shoreland environment. More detail and instructions on how to map out your site assessment and design an integrated landscaping plan can be found in the UNH Cooperative Extension publication: **Landscaping at the Water's Edge: An ecological approach (2nd edition)** which can be ordered from the publications office : www.extension.unh.edu/publications.

### *Common Runoff Control Strategies*

**Infiltration** - allowing water to percolate into the ground where it can be filtered by soils rather than running across the land surface where it can cause erosion and collect pollutants.

**Detention** - holding back or "ponding" a volume of water to slow the speed of its outflow. In some cases water detention may also allow for infiltration and evaporation to reduce the resulting outflow volume.

**Diversion** - preventing water from traveling over the area of concern, thereby reducing surface runoff damage and minimizing the potential for erosion and the transport of nonpoint source pollutants.

**Flow Spreading** - allowing a concentrated flow to spread out over a wide, gently sloping area to reduce the water velocity and encourage infiltration.

**Plant absorption and transpiration** - the movement of water from the shallow soil into the plant roots, up through the stems and leaves and the release of water vapor through the leaf stomates (under-leaf openings) to the atmosphere.

## *Typical Techniques used to control runoff*

**Berm** – A stabilized mound of dirt or stone to create a diversion and/or redirect water flow

**Check dam** – A small mound of stabilized dirt or stone that breaks up the flow of water in a drainage ditch or trench to slow down velocity and allow for the settling of heavier materials.

**Cut-in (or Cut-out)** – A small trench that diverts water flow away from the direction of the major flow stream to prevent a significant volume of water from collecting as it runs down a driveway, walkway, or path. Multiple cut-ins may be required for long distances or high slopes.

**Infiltration trench** – A dug-in trench commonly used for roof runoff that allows for storage of runoff and encourages infiltration into the ground.

**Plunge Pool** – A dug-in hole stabilized by stone, typically placed adjacent to a drainage ditch or trench. This allows water to fall below the level of the surface to slow the runoff velocity and capture heavy particle. These are often constructed in a series along a sloped route.

**Rain Garden** – A shallow infiltration basin planted with water tolerant plant species, designed to capture concentrated runoff. Rain gardens are designed to pond water for just a few hours at a time, allowing it to be taken up and transpired by plants or infiltrate into the ground.

**Swale** – A stabilized trench that can act to store water (detention), sometimes also engineered to enhance infiltration.

**Vegetated buffer** – A relatively flat area stabilized with vegetation that allows water flow to spread out, slow down, infiltrate and be filtered by the soil, and/or be intercepted and transpired by plants.

**Waterbar** – A diversion device that diagonally crosses a sloped trail, path or road to capture and divert runoff to the side. Commonly made of a log, a stone, a small reinforced drainage channel, or a partially buried flexible material, a waterbar is most useful for small contributing areas (watersheds less than one acre) that receive light foot and vehicle traffic. Waterbars are spaced according to the slop of the land.

## *Following the flow*

Paying attention to how water flows (or will flow) into, over and through your home site before, during and after development or landscaping, is critical in determining current and potential negative impacts. Some questions you'll want to answer before proceeding:

- What is the extent of lands and roads above the site that contribute runoff water, and where does the runoff enter your property?
- Where does the water run off impervious surfaces (paved driveways and walkways, roofs, patios, compacted soils, etc) and piped sources (sumps, gutters, etc.) go?
- Where does that water, along with the additional runoff generated in your new design, run over the site? Is it treated by vegetation and infiltrated or does it accumulate?
- Where will that water flow off your site? Does it enter the water body directly?
- Most importantly, how might you modify your design to take advantage of these factors in creating diversions, detention and infiltration areas?

## *Investigate the drainageways*

Since water moves downhill, you need to walk your property boundary and note where the major water flows occur after a heavy rainstorm. Does the runoff from abutting roads or a neighbor's driveway flow onto your property? Are there any adjacent steeply sloped lands that rise above the level of your property? Are they extensive enough to contribute water flows during rains and snow melts? Make note of all of these off-site contributors to flow. Also note any occasional or perennial wet areas or streams at your property boundary that encroach on your site.

## *Investigate onsite runoff generation*

**Note any wet areas or seeps on your property.** Now consider how your house and current landscaping features generate runoff. It is always easy to point uphill and blame runoff on other properties, but many people are surprised at how much runoff their own site creates, even in low-density development. Also note whether areas on your land divert runoff onto neighboring properties.

**Take inventory of all paved and compacted areas,** such as driveways, patios and walkways. Can you find evidence of water flow moving off these areas and heading downhill? You may see just a small area of sheet erosion, indicated by the appearance of worn-down gravelly areas with small stones and roots showing because finer soil particles have been washed away. Or you may see rill, visible channels where water has eroded away materials a fraction of an inch to a few inches deep. In the worst cases, you'll find gullies where water flows through channels deep enough for you to step into them.

The potential for erosion and runoff increases with site steepness, area of impervious surfaces, and size of contributing watershed area (land above your site).

**Investigate the point sources of flows on your property** from culverts, drain pipes, and hoses, as well as rain gutters, sump pumps, and tile drainage outlets. Culverts, drain pipes, etc. concentrate diffuse flows that need treatment and diversion to ensure they don't contribute to runoff. If the house doesn't have gutters, look for areas where the roof design intercepts and dumps rainwater onto the property. As you develop your landscape plan, consider ways you might reduce the impacts of those flows.

**Account for any paths, trails and cleared areas that lead to the water.** Shoreland properties almost always have pathways and cleared areas which runoff follows directly into the water body. In the worst cases, a driveway at the top of the property allows water from the road above and the gutter runoff to collect and concentrate. Runoff flowing down a pathway directly into a cleared beach area and into the water often takes a lot of sand with it.

Note how the paths follow the slope of the land. Meandering paths may function to break up runoff before it concentrates, but straight downhill paths encourage flow directly to the water. Also, note the flow-contributing areas that lie above the access area or beach. Do swaths of vegetation above help break up the flow, or does the water pretty much flow straight down and onto the area below?

**Finally, look for areas where water tends to pond** after it rains. Even flat areas may pond water if the soils don't drain well or if there is a lot or shallow ledge or hardpan present. Be sure to keep track of these areas and prevent additional water from reaching these locations.

## *Minimize and divert runoff*

Significant flows coming onto your site may create runoff and erosion problems. Your design should take into account all flows that will come in contact with your newly landscaped area, as well as those flows that may cause runoff concerns in other areas on your property (or your neighbor's).

Of all the methods that can help deal with these situations, diversion and flow-spreading are the most reliable. If you can treat all of the incoming runoff by diverting it and spreading it out over a stable vegetated area before it leaves the properly, then by all means do so. However, in situations of high runoff flow coming from off-property sites such as roads, diverting some of the flow may be warranted to keep it from entering your property. The sources of offsite runoff can be diverse and you may not be able to take action without involving neighbors, road associations and municipalities, since road-drainage diversions and treatment systems require professional design and installation.

Use what you have (or can design) to break up, slow down and spread out the flow over or into a vegetated area. The goal is to prevent offsite and onsite flows from accumulating and divert them from impervious areas. You may be able to break up the flow by using shallow channels, stone check dams, small vegetated berms, or alternating areas of low and high vegetation.

Simple drainage cut-ins can break the flow and move the water from long driveways and pathways. In more challenging situations, for example, when sites are very steep or narrow you may need to hire a professional to install a waterbar or similar diversion.

If you can't divert the flows coming onto your site and can't find ways to prevent the flow from concentrating to a significant volume, then consider diverting the water into your existing vegetated areas. Or, create additional vegetated areas to allow the water to slow down, spread out and infiltrate the ground, thus losing most of its destructive force and most of its pollutant load. For this to work, you need an adequately sized vegetated area with minimal slope.

The denser the root systems of the plants in vegetated areas, the greater the volume of water the area can process. Mixed types of vegetation with different root depths will have the greatest impact, as contrasted with lawn like monocultures, which grow a single type of plant. However any type of vegetation is better than a bare, cleared, compacted, or impervious area.

The same holds true for dealing with runoff from pavement, roots, tile drainage, sump flows, and existing drainageways: capture the water and/or divert it by any means possible (plunge pools, waterbars, berms, swales and drainage trenches) to prevent it from running directly down to the shore. Conditions such as lack or space, steep slopes, and/or proximity to the shore create special challenges to diverting the water from a rain gutter or other concentrated flow. In these situations, consider alternative controls such as rain barrels, storage cisterns and infiltration trenches.

You may be able to cut down runoff generation at the source by replacing impervious areas with porous alternatives. For problematic and excessive stormwater volumes you may need to have something engineered to capture water and pump it into other areas for treatment.

If you have enough space, consider installing a rain garden, a shallow, dug-in area planted with water-tolerant plant species. Rain gardens can collect a significant volume of water during a storm, allowing the water that doesn't get used by plants to infiltrate the ground quickly and prevents it from becoming runoff. When designed and constructed correctly, the surface of a well-designed rain garden will not flood, eliminating concerns about standing water. The publication, **Landscaping at the Water's Edge**, includes resources for more information on rain garden design and appropriate plants. Or call your county Cooperative Extension office for more information.

Properly designed pathways and trails should meander across the slope and allow each segment to throw water off the trail, rather than letting it flow in a straight path, accumulating velocity and pollutants as it moves downhill. The best trails are those that follow the ridges and contours of the property. Some low vegetation planted at the corners of the meanders or staggered alternately on the sides of steeper pathways will help break up, capture, and slow down the flow of water as it moves downhill.

To maximize water quality protection as you consider the ways you want to use and enjoy your waterfront property, the key is to remove as little vegetation as possible. For all lake shores and large rivers, the state's Comprehensive Shoreland Protection Act requires that in the "waterfront buffer" (0-50 feet from shore) natural ground cover and duff (forest litter) shall remain intact. No cutting or removal of vegetation under 3 feet in height (excluding lawns) is allowed. Stumps, roots and rocks must remain intact in and on the ground. In addition, within the waterfront buffer, tree coverage is managed with a 50 foot by 50 foot grid and point system that ensures adequate forest cover and prevents new clear cutting. Within the "natural woodland buffer" (50-150 feet from shore) there are additional protections where 25 to 50 percent of that buffer must remain undisturbed dependent on lot size. See the NH DES Comprehensive Shoreline Protection Act web site for more detailed information (http://des.nh. gov/ organization/divisions/water/wetlands/cspa/index.htm).

Plan to stabilize a major portion of the shoreline area with a good mix of plants. The more protective vegetation you remove from near the shore, the more you increase the area's potential for transporting pollutants to the lake or stream. Removing taller plants also opens the shore area to receive more sunlight. Exposure to more sun heats up the water, making it less desirable for aquatic organisms and more conducive to submerged and emergent weed growth including exotic invasive species.

Where you locate your water access area is also important. Areas that don't receive significant runoff from the land above make the best locations for minimizing potential impacts. Water access areas that lie directly below a runoff flow may allow the runoff to reach the water without any reduction in impact. If you have no choice of access location, try to create a diversion of the flow away from the shoreline opening and into a more vegetated area using one or more or the approaches discussed above.
**Note**: State wetland laws forbid dumping sand or other materials on the shoreline to make a beach. Wetland permits are required for any beach construction. Sand beaches not naturally present are discouraged as they tend to get washed away. In locations where a small opening, with stable groundcover and perhaps a few flat stones or steps will not do, you can apply for a permit for a small perched beach located just above the shoreline. Contact the Department of Environmental Services Wetlands Bureau for more information, (http://des.nh.gov/organization/divisions/water/wetlands/index.htm).

## *Structural approaches*

Most structural modifications for dealing with flow and runoff require professional design and installation. However, homeowners might try one or more of these simpler approaches before calling in the pros:

- Clear existing drainage-ways of accumulated materials, including loose sediments and litter, before the snow melts and the spring rains arrive. Encourage vegetative growth in these drainageways however, as the vegetation removes sediments and pollutants from the water as it passes through.
- If possible, divert other flows into your existing drainageways (as long as they themselves don't directly flow into the water body) by some shallow channeling, the use of check dams of stone or gravel, or by using small berms.

- Break up the water flow by alternating small berms down a sloped area, diverting water off into vegetated areas before it can accumulate in significant volume.

In general, anything you can do by hand or using hand tools doesn't require a permit, as long as you stay at least 25 feet away from the shoreline. Any time you have to use a power tool, vehicle or power equipment, or your project requires significant earth-moving within the 250 foot Shoreland Protection Zone, you will probably need a state permit, and possibly one or more local permits as well.

## *Making a Difference*

A typical small shorefront lot on a moderate slope with conventional development (house, paved driveway, vegetation cleared for lawn) can increase water runoff, phosphorus pollution and sediment erosion about 5, 7, and 18 times, respectively, compared to an undisturbed, forested lot. By re-growing out a shoreland buffer of 50 feet and infiltrating the roof runoff through trenching or a rain garden, the impacts can be reduced significantly: to only 1.5 times the runoff, 2 times the phosphorus loading and less than 3 times the sediment erosion compared to the undisturbed lot.

With the knowledge of how water flows over and currently runs off your site, you now may want to consider adding water diversions, as well as vegetated buffers and infiltration areas into your landscape design to take advantage of the water-treatment properties of vegetation. The full publication: **Landscaping at the Water's Edge** contains further information on how to maintain and establish shoreline buffers, choose the appropriate plant systems for low impact and low maintenance, and how to plant and maintain lawn areas in an environmentally-friendly way.

Adapted by Jeff Schloss, UNH Extension Professor of Biological Sciences and Cooperative Extension Water Resources Specialist from his contributed chapter in: **Landscaping at the Water's Edge: An ecological approach, 2nd edition**
www.extension.unh.edu/resources to order a bound copy of the manual.
http://extension.unh.edu/resources/files/Resource001799_Rep2518.pdf to download and electric copy of the manual.

JAS 3/15/10

# Toxic Cyanobacteria - what's the story?

Spring and summer "blooms" (rapid increase in concentrations) of a primitive group of organisms, the cyanobacteria (sometimes mistakenly referred to as "blue-green algae"), have been documented in New Hampshire lakes these past years, focusing attention on the potential health threats from the toxins they produce. The N.H. Department of Environmental Services (NHDES) posted beach advisories warning of cyanobacterial contamination in at least 21 lakes in 2009--a substantial increase over the 14 advisories posted the previous year.

## *Beneficial algae differ from toxin-producing cyanobacteria*

Algae occur in all New Hampshire waters, providing oxygen and serving as an important food source that forms the base of the aquatic food chain. Occasional spring, summer and fall "blooms" (rapid increase in concentrations) of algae have been known to occur but are historically rare on all but a small percentage of New Hampshire lakes. It is also common during sunny, quiet summers to see cotton-candy-like green to almost white "clouds" of green filamentous algae floating in the shallows of the many lakes with aquatic plant beds. But cyanobacteria, which used to be called "blue-green algae," produce a range of compounds toxic to humans, pets and wildlife. When present in large-enough concentrations, as are found typically during bloom events and when the surface populations are concentrated due to wind and water currents, toxin concentrations can reach levels of concern.

## *Potential human health effects from exposure to cyanotoxins*

Long-term exposure to these toxins is suspected to cause chronic symptoms and ingestion of the toxins over long periods may possibly damage the liver, kidney and nervous system. Short-term exposure to cyanotoxins through activities such as swimming and boating in cyanobacteria-contaminated water or showering in water drawn directly from contaminated lakes, may produce symptoms such as skin rashes, muscle pain, eye and ear inflammation or infection, nausea, disorientation, diarrhea and flu-like symptoms. Cyanobacteria don't always produce significant quantities of toxin capable of producing symptoms like those described above. Only five of the common cyanobacteria in New Hampshire waters have been shown to produce at least one toxin.

## *Stay vigilant*

While there have been no documented cases of negative human health effects from cyanotoxin exposure in New Hampshire, it is best to be vigilant and cautious. Keep pets and children (who are at greatest risk) away from any surface scums, "blooms" or underwater "mats" that are green, yellow-green or bluish green. Other states have reported dog illnesses and deaths from cyanotoxins when dogs drank small volumes of heavily-contaminated water or licked contaminated water from their coats. Everyone should heed the posted warning signs and keep aware of cyanobacteria beach advisories by checking the NHDES beach program Web site. Current advisories are posted based on the amount of potentially toxin-producing cyanobacteria, rather than on any measured amount of toxins. Researchers are currently investigating additional methods to predict toxin concentrations, but as any cyanobacteria bloom may produce more than one toxin and not all toxins are easily and quickly identified, the microscopic analysis, as is done for the advisories, is still the best option.

## *Learn more*

NHDES Beach Program Lots of information on cyanobacteria, current beach advisories, and presentations from recent informational workshops.
http://des.nh.gov/organization/divisions/water/wmb/beaches/index.htm

NH Lakes Association Information on algal and cyanobacteria blooms. http://www.nhlakes.org/algae.htm

UNH biotoxins lab Ongoing research to understand the role of biotoxins in aquatic systems and their importance as a threat to public health and water quality.
http://www.cfb.unh.edu/programs/Biotoxins/biotoxins.htm

Cyanobacteria under the microscope Click on fourth picture down in the far right column. http://cfb.unh.edu/phycokey/phycokey.htm

Cyanotoxins and the health of domestic animals and humans presentation (Microsoft Powerpoint) by Dr. Jim Haney of the UNH Center for Freshwater Biology. http://des.nh.gov/organization/divisions/water/wmb/beaches/documents/20090515wkshp_haney.pdf

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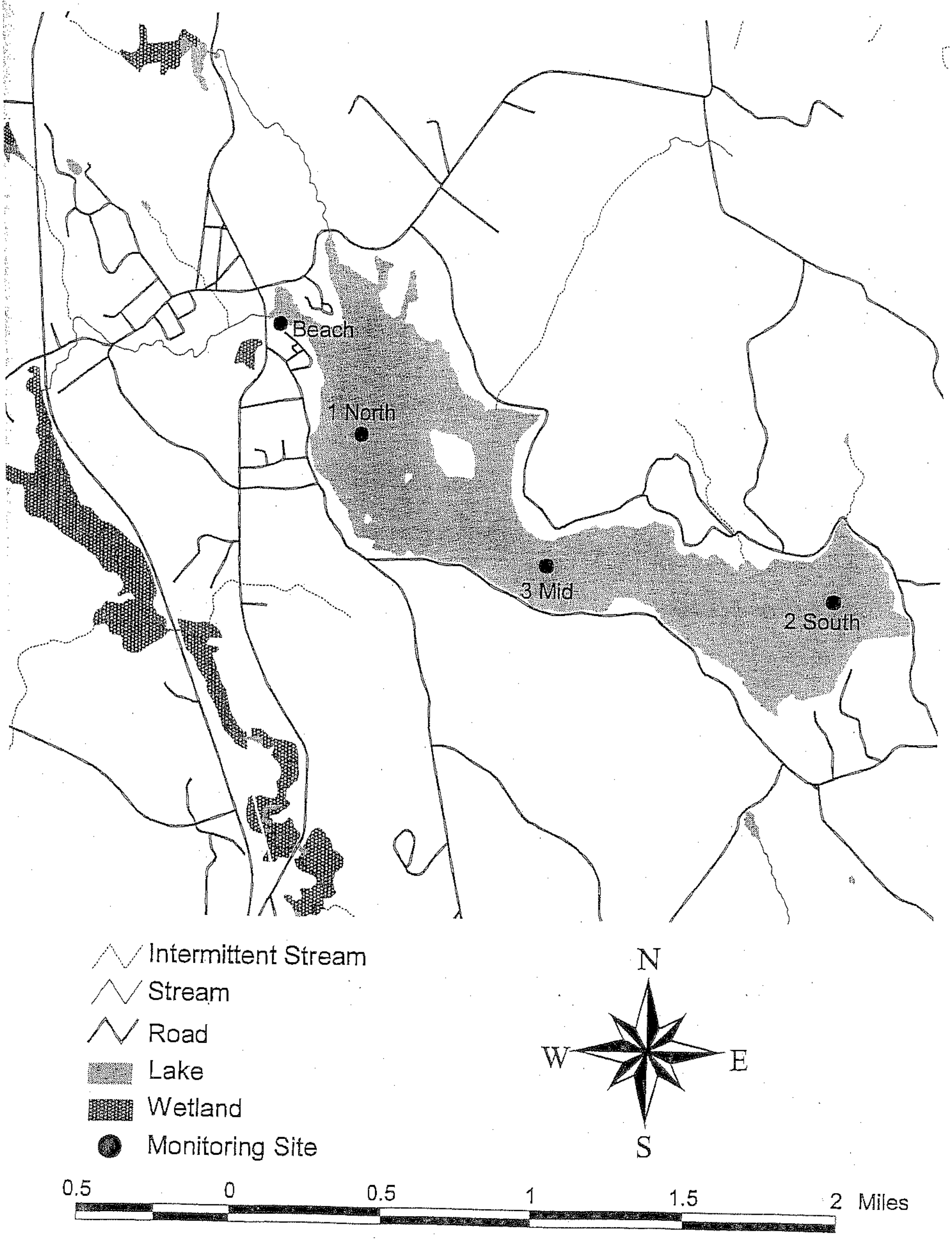
# REPORT FIGURES

**Figure 9.** Location of the 2010 Lovell Lake deep and near-shore sampling stations, Sanbornville New Hampshire.

# Lovell Lake

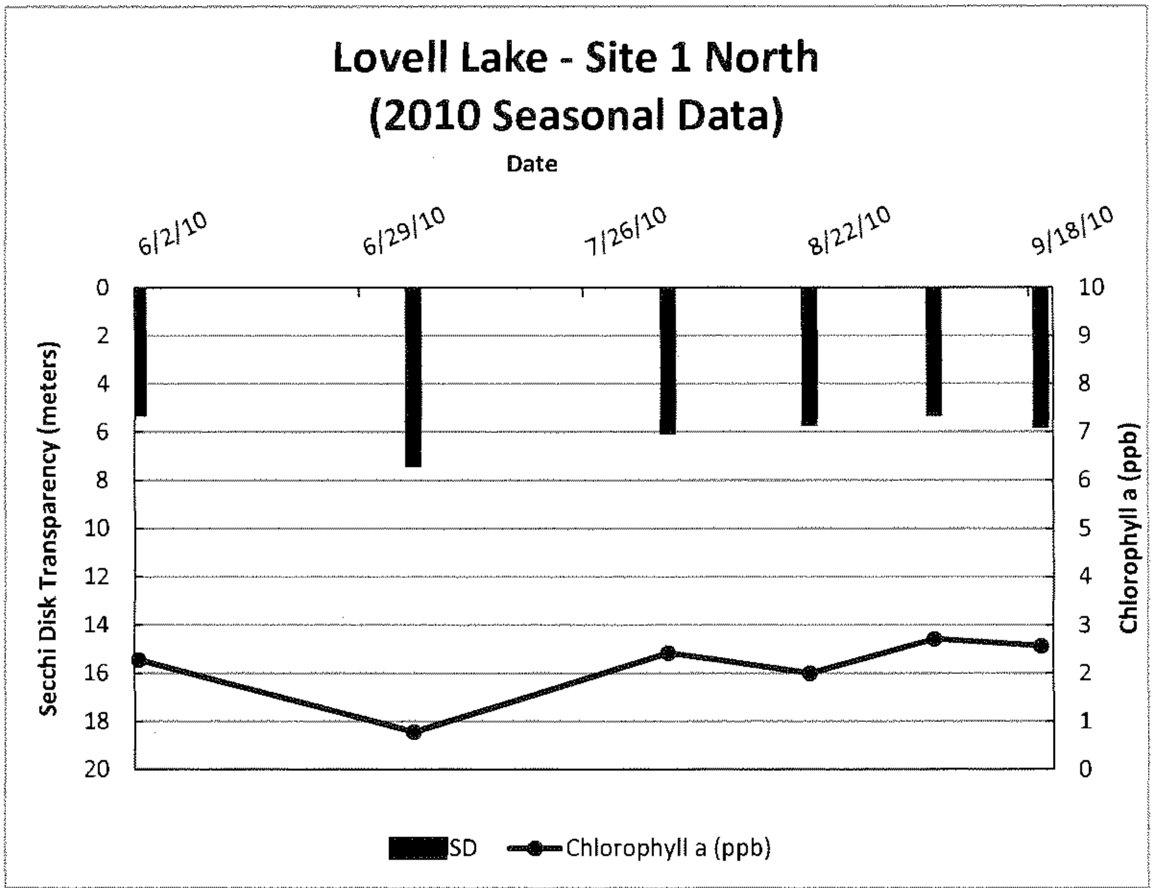

Beach
1 North
3 Mid
2 South
Intermittent Stream
Stream
Road
Lake
Wetland
Monitoring Site
N
W
E
S
0.5
0
0.5
1
1.5
2 Miles

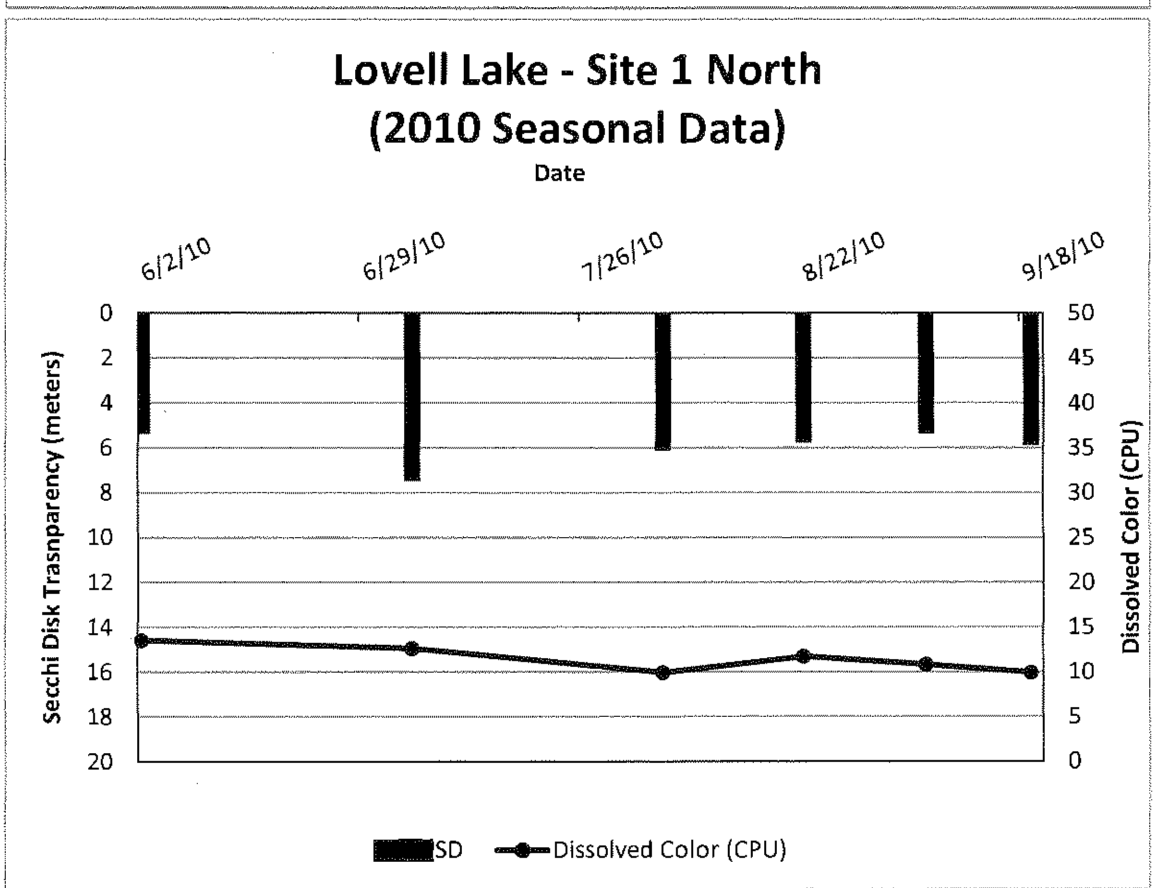
# APPENDIX A

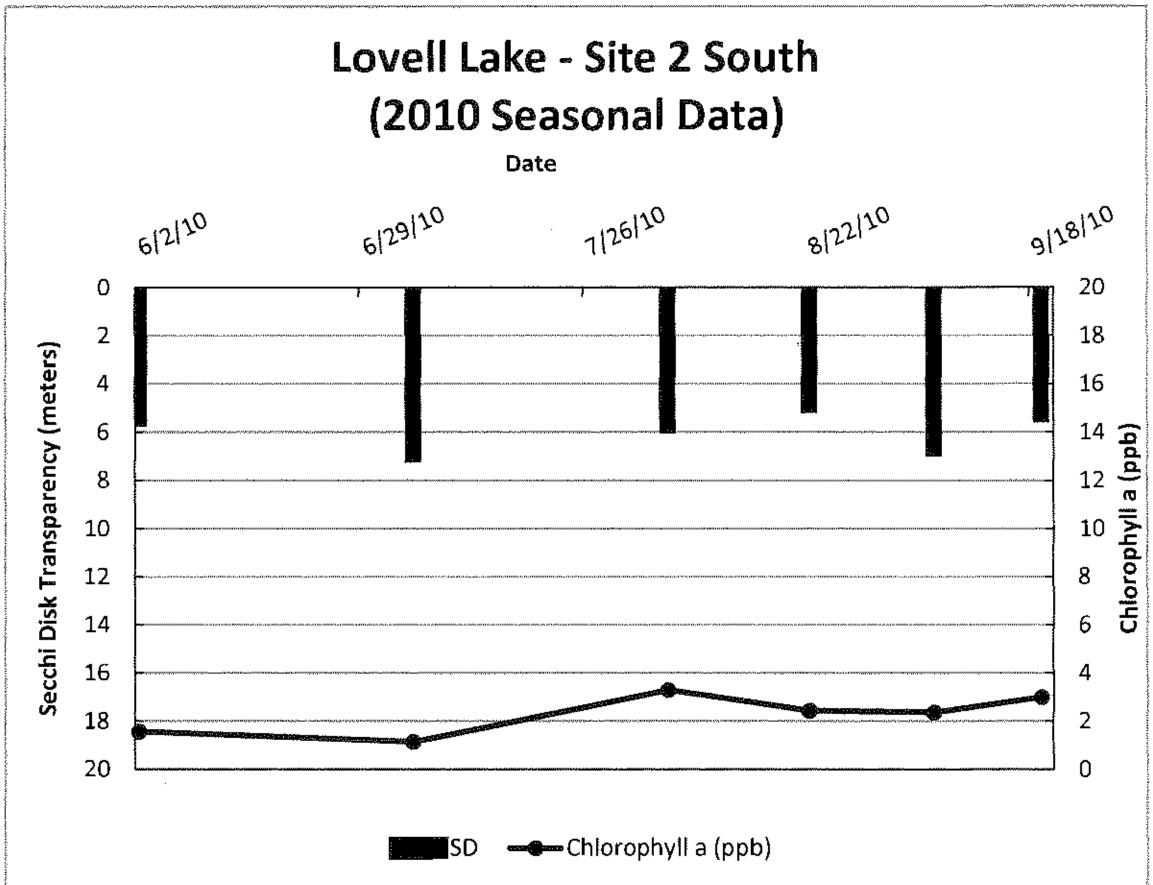
Lovell Lake, 2010. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Sites 1 North and 2 South. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

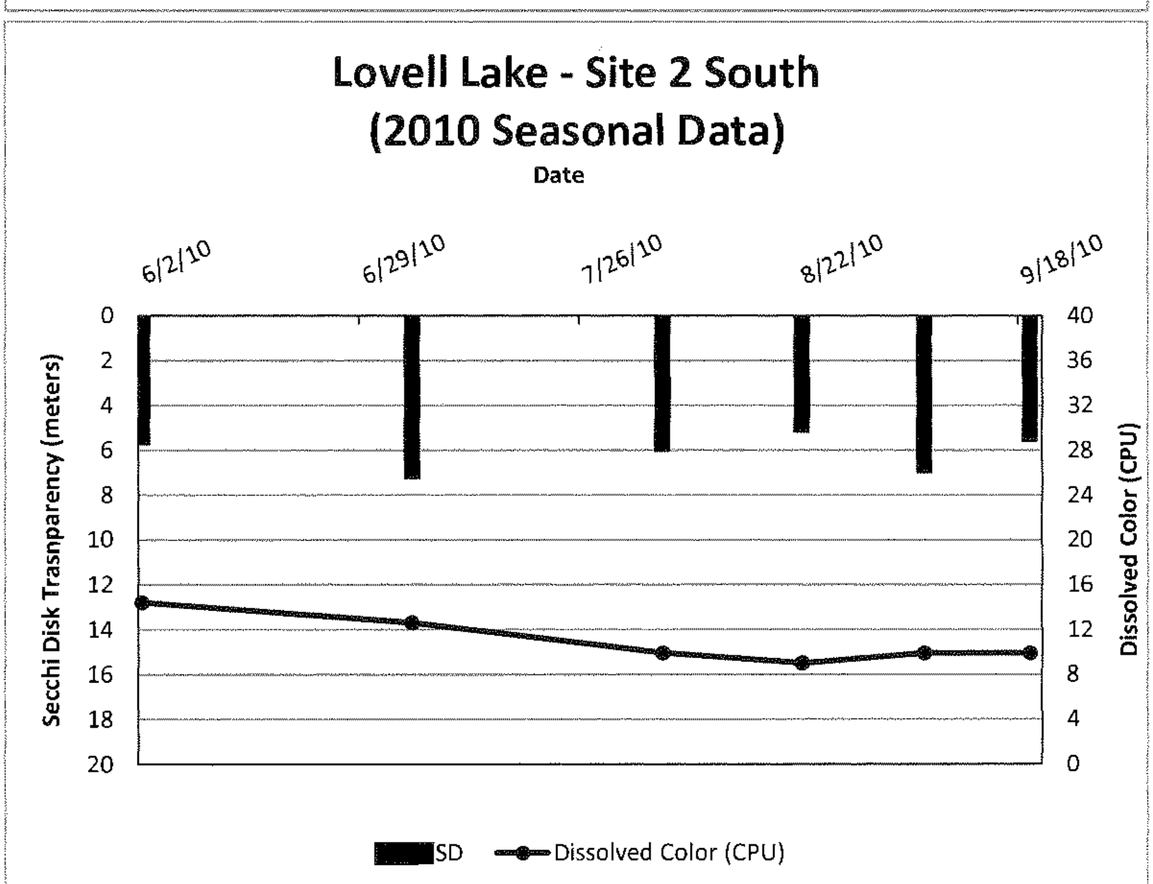
Lovell Lake, 2010. Seasonal Secchi Disk (water transparency) and dissolved color trends for Sites 1 North and 2 South. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).


Lovell Lake - Site 1 North
(2010 Seasonal Data)
Date
6/2/10
6/29/10
7/26/10
8/22/10
9/18/10
Secchi Disk Transparency (meters)
Chlorophyll a (ppb)
SD
Chlorophyll a (ppb)


Lovell Lake - Site 1 North
(2010 Seasonal Data)
Date
6/2/10
6/29/10
7/26/10
8/22/10
9/18/10
Secchi Disk Trasnparency (meters)
Dissolved Color (CPU)
SD
Dissolved Color (CPU)


Lovell Lake - Site 2 South
(2010 Seasonal Data)
Date
6/2/10
6/29/10
7/26/10
8/22/10
9/18/10
Secchi Disk Transparency (meters)
0
2
4
6
8
10
12
14
16
18
20
Chlorophyll a (ppb)
20
18
16
14
12
10
8
6
4
2
0
SD
Chlorophyll a (ppb)

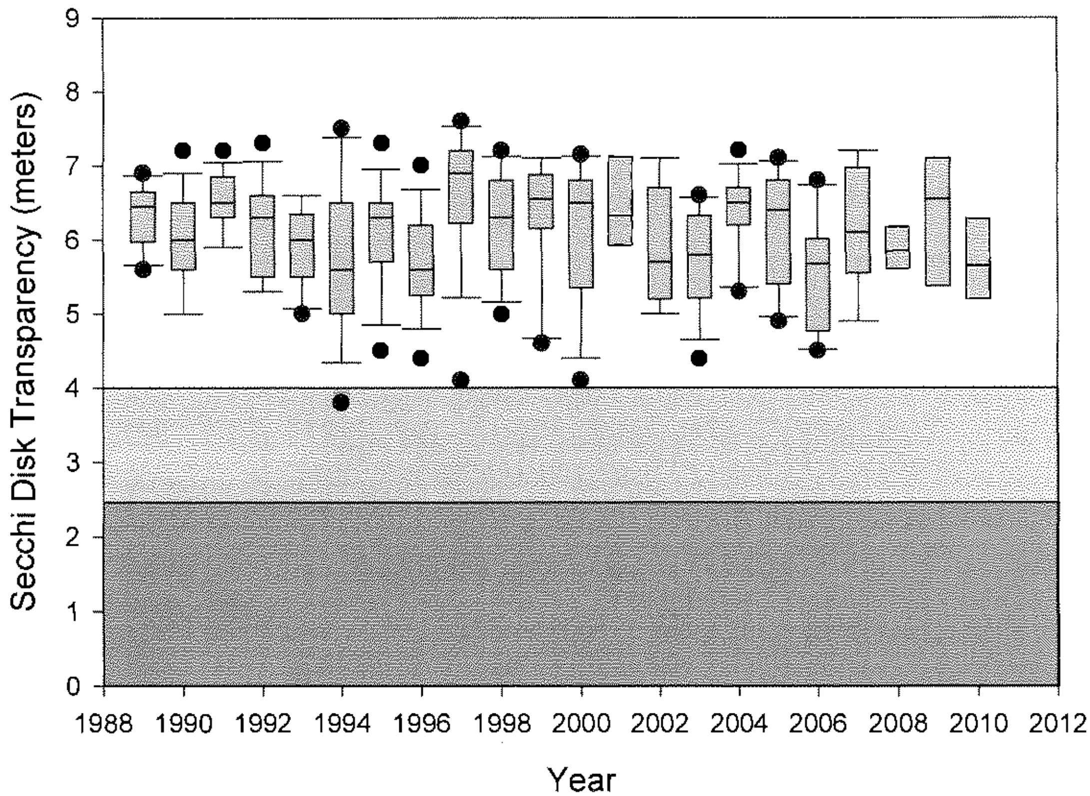

Lovell Lake - Site 2 South
(2010 Seasonal Data)
Date
6/2/10
6/29/10
7/26/10
8/22/10
9/18/10
Secchi Disk Trasnparency (meters)
0
2
4
6
8
10
12
14
16
18
20
Dissolved Color (CPU)
40
36
32
28
24
20
16
12
8
4
0
SD
Dissolved Color (CPU)

# APPENDIX B

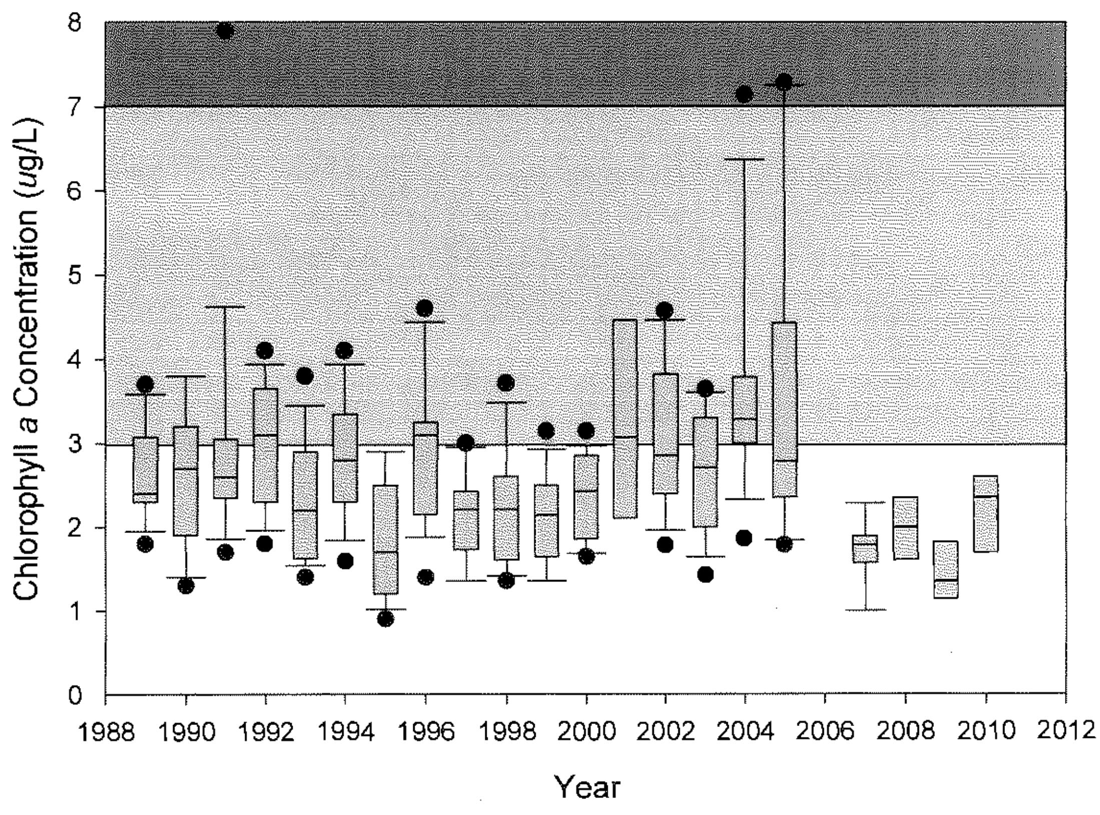
Comparison of the annual Lovell Lake, lay monitor Secchi Disk transparency data that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Comparison of the annual Lovell Lake, lay monitor chlorophyll *a* data that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

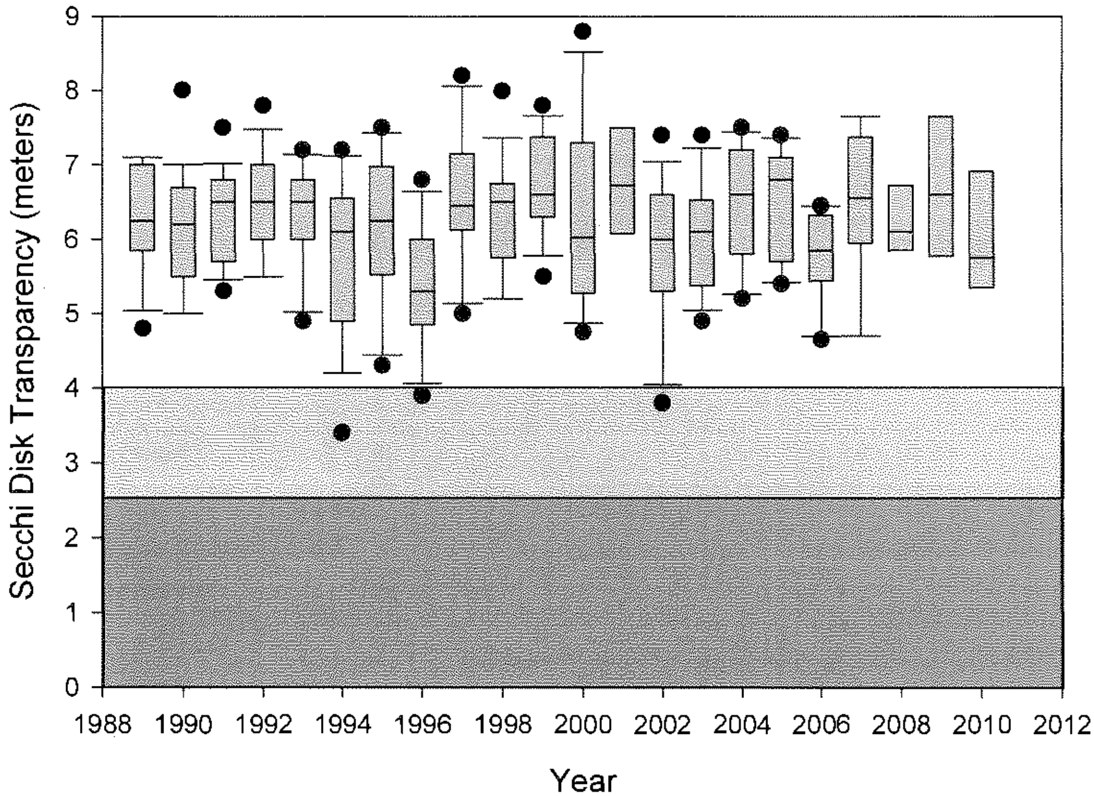
## Lovell Lake - Site 1 North
## Annual Secchi Disk Transparency Comparisons
## Box and Whisker Plots: 1989-2010



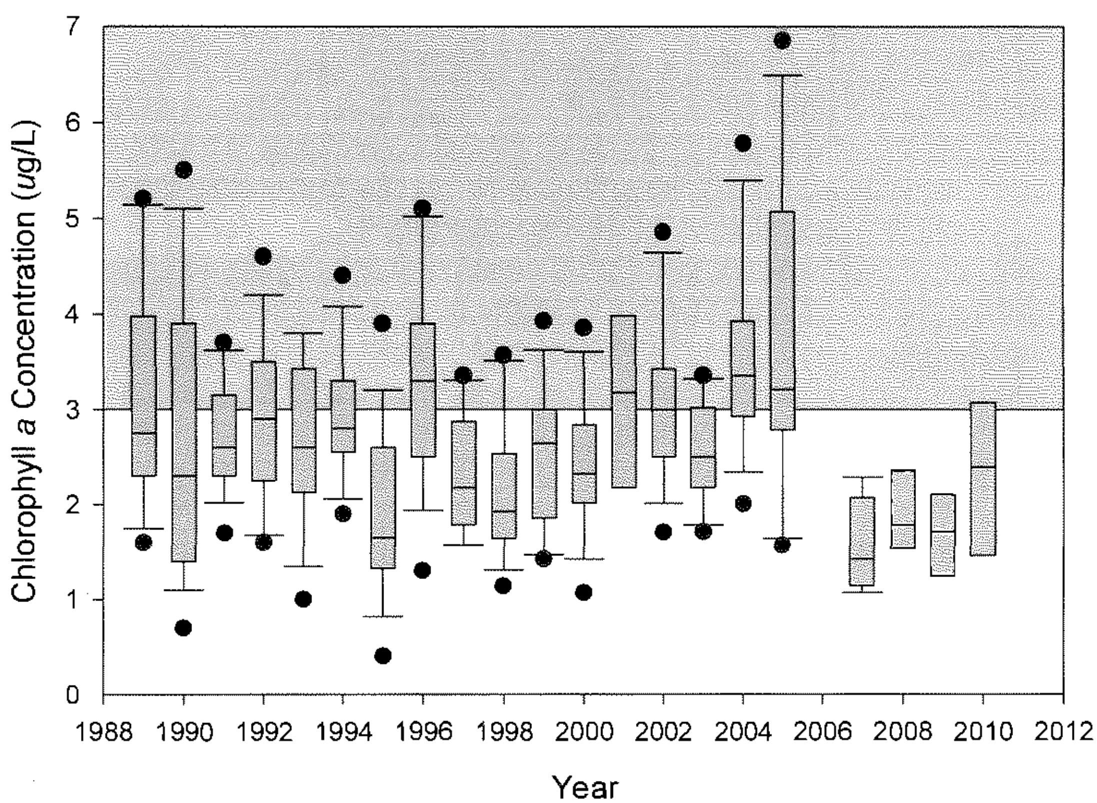

## Lovell Lake -- Site 1 North
## Annual Chlorophyll *a* Comparisons
## Box and Whisker Plots: 1989-2010



## Lovell Lake - Site 2 South
## Annual Secchi Disk Transparency Comparisons
## Box and Whisker Plots: 1989-2010

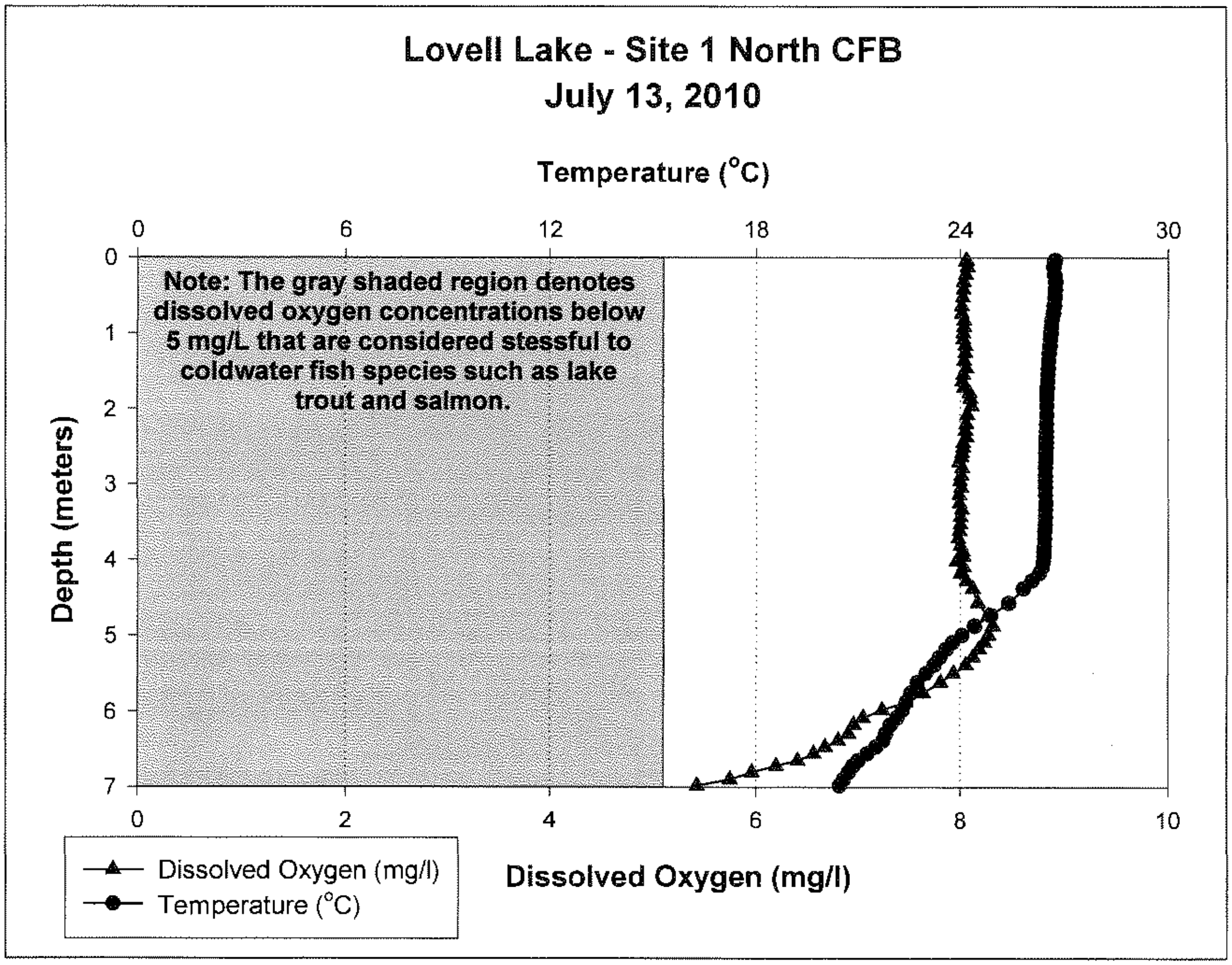


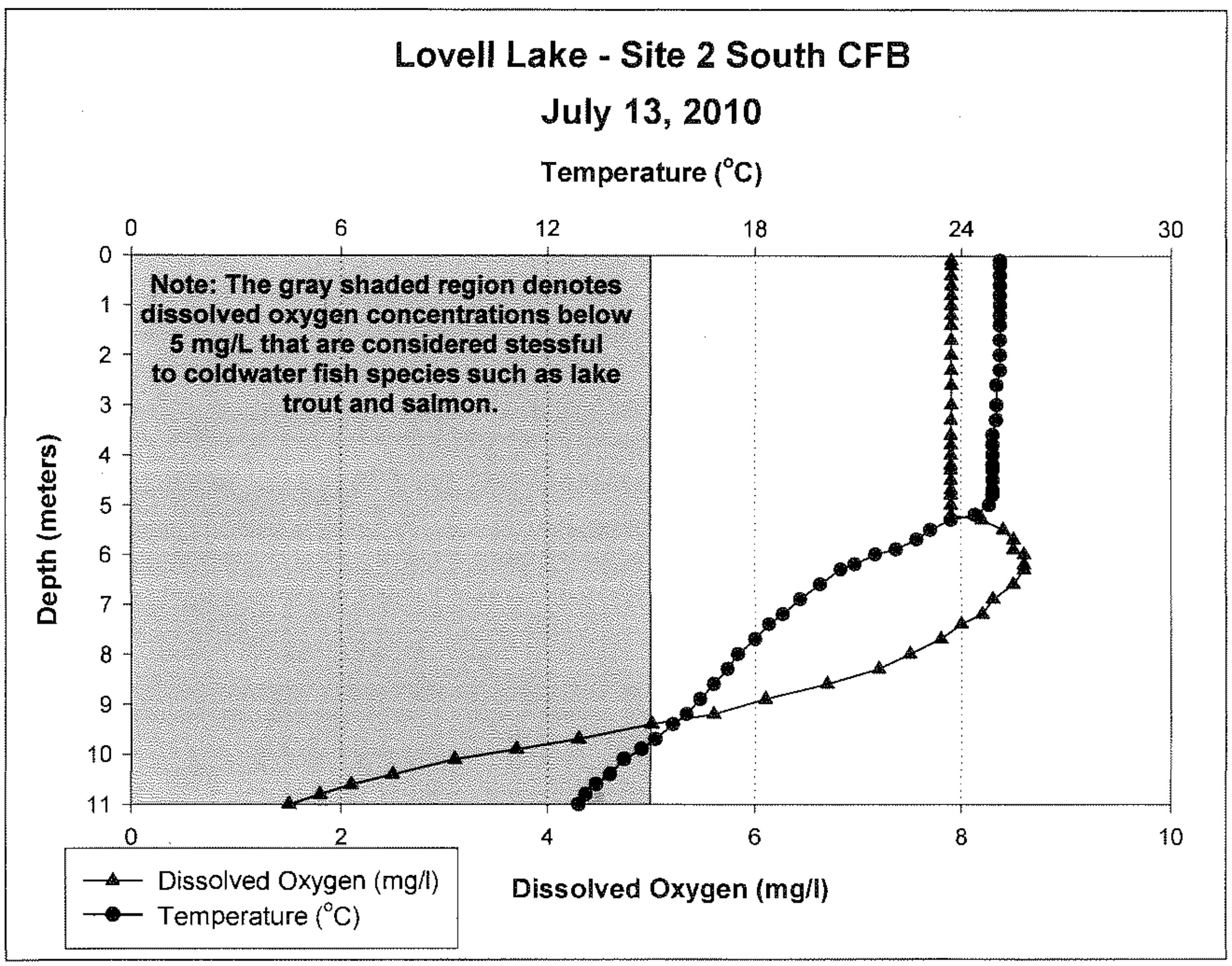

## Lovell Lake -- Site 2 South
## Annual Chlorophyll *a* Comparisons
## Box and Whisker Plots: 1989-2010



# APPENDIX C

The following graphs illustrate the dissolved oxygen and temperature data collected at the Lovell Lake deep sampling stations, Sites 1 Ledges and 3 Bennett, between July 13, 2010. Temperature and dissolved oxygen data were generally collected at one-half meter intervals from the surface down to the lake bottom. The temperature units are degrees Celsius ($^{o}$C) while the dissolved oxygen units are milligrams per liter (mg/l). The gray shaded region on the graphs represents dissolved oxygen concentrations stressful to coldwater fish species (dissolved oxygen concentrations less than 5 parts per million). *Notice the low dissolved oxygen concentrations near the lake bottom.*


Lovell Lake - Site 1 North CFB
July 13, 2010
Temperature (°C)
0
6
12
18
24
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as lake trout and salmon.
Depth (meters)
0
1
2
3
4
5
6
7
0
2
4
6
8
10
Dissolved Oxygen (mg/l)
Dissolved Oxygen (mg/l)
Temperature (°C)


Lovell Lake - Site 2 South CFB
July 13, 2010
Temperature (°C)
0
6
12
18
24
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as lake trout and salmon.
Depth (meters)
0
1
2
3
4
5
6
7
8
9
10
11
0
2
4
6
8
10
Dissolved Oxygen (mg/l)
Dissolved Oxygen (mg/l)
Temperature (°C)

# APPENDIX D

**Lakes Lay Monitoring Program, U.N.H.**
**[Lay Monitor Data]**

Lovell Lake, Sanbornville, NH
-- subset of trophic indicators, all sites, 2010

| | | | | | |
|---|---|---|---|---|---|
| Average Transparency: | 5.9 (2010: | 12 values; | 5.1 | - | 7.3 range) |
| Average Chlorophyll: | 2.2 (2010: | 12 values; | 0.8 | - | 3.3 range) |
| Average Color: | 11.2 (2010: | 12 values; | 9.0 | - | 14.4 range) |
| Average Alkalinity (gray): | 12.9 (2010: | 12 values; | 12.2 | - | 13.7 range) |
| Average Alkalinity (pink): | 14.4 (2010: | 12 values; | 13.0 | - | 15.6 range) |
| Total Phosphorus (ug/L): | 8.4 (2010: | 6 values; | 6.3 | - | 10.1 range) |

| Site | Date | Secchi Disk Transparency (meters) | Chl *a* (*ug*/L) | Dissolved Color (CPU) | Total Phosphorus (*ug*/L) | Alkalinity gray end pt. @ pH 5.1 (mg/L) | Alkalinity pink end pt. @ pH 4.6 (mg/L) |
|---|---|---|---|---|---|---|---|
| 1 North | 6/2/10 | 5.2 | 22.8 | 13.5 | 10.1 | 12.4 | 13.0 |
| 1 North | 7/5/10 | 7.3 | 0.8 | 12.6 | ----- | 12.6 | 14.7 |
| 1 North | 8/5/10 | 6.0 | 2.4 | 9.9 | ----- | 13.3 | 14.0 |
| 1 North | 8/22/10 | 5.6 | 2.0 | 11.7 | 7.6 | 12.2 | 14.4 |
| 1 North | 9/6/10 | 5.2 | 2.7 | 10.8 | ----- | 12.9 | 14.5 |
| 1 North | 9/19/10 | 5.7 | 2.6 | 9.9 | ----- | 13.6 | 14.8 |
| 2 South | 6/2/10 | 5.6 | 15.7 | 14.4 | 6.3 | 12.5 | 13.2 |
| 2 South | 7/5/10 | 7.1 | 1.1 | 12.6 | ----- | 12.8 | 15.6 |
| 2 South | 8/5/10 | 5.9 | 3.3 | 9.9 | ----- | 12.6 | 14.2 |
| 2 South | 8/22/10 | 5.1 | 2.4 | 9.0 | 9.1 | 13.7 | 15.0 |
| 2 South | 9/6/10 | 6.9 | 2.4 | 9.9 | ----- | 12.9 | 14.3 |
| 2 South | 9/19/10 | 5.5 | 3.0 | 9.9 | ----- | 13.0 | 15.5 |
| 3 Middle | 6/2/10 | ----- | ----- | ----- | 9.8 | ----- | ----- |
| 3 Middle | 8/22/10 | ----- | ----- | ----- | 7.3 | ----- | ----- |

<< end of 2010 data listing; 14 records >>

## Lakes Lay Monitoring Program
## [CFB Data – July 13, 2010]

| Site | Depth (meters) | Chlorophyll *a* (*u*g/l) | Dissolved Color (CPU) | Carbon Dioxide (mg/l) | Alkalinity gray end pt. @ pH 5.1 (mg/l) | Alkalinity pink end pt. @ pH 4.6 (mg/l) | Total Phosphorus (*u*g/l) | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|---|
| 1 North | 0.5 | 1.4 | 8.6 | 0.7 | 12.6 | 13.3 | ----- | 0.13 |
| 1 North | 2.0 | ----- | ----- | 0.5 | 12.2 | 12.8 | ----- | 0.15 |
| 1 North | 6.3 | 7.6 | 10.3 | 1.1 | 12.6 | 13.2 | 10.1 | 0.73 |
| 1 North | 0-4.0 | 1.6 | 8.6 | ----- | 12.5 | 13.3 | 8.0 | 0.17 |
| 2 South | 0.5 | 1.3 | 8.6 | 1.3 | 12.8 | 13.4 | ----- | 0.11 |
| 2 South | 2.0 | ----- | ----- | 1.0 | 11.9 | 12.4 | ----- | 0.14 |
| 2 South | 5.0 | 3.4 | 9.4 | 0.7 | 12.4 | 12.9 | 6.9 | 0.31 |
| 2 South | 10.0 | 3.7 | 12.0 | 4.9 | 13.7 | 14.5 | 8.2 | 0.79 |
| 2 South | 0-4.0 | 2.0 | 10.3 | ----- | 12.6 | 13.2 | ----- | 0.21 |

| Site | Secchi Disk Transparency (meters) |
|---|---|
| 1 North | 7.1 meters |
| 2 South | 7.3 meters |

| Site | Depth (meters) | Temperature (°C) | Specific Conductivity @ 25°C (*u*S/cm) | Chlorophyll *a* (*u*g/l) | pH (std units) |
|---|---|---|---|---|---|
| 1 North | 0.04 | 26.7 | 100.0 | 0.9 | 7.6 |
| 1 North | 0.05 | 26.7 | 100.0 | 0.7 | 7.6 |
| 1 North | 0.12 | 26.7 | 100.0 | 0.9 | 7.6 |
| 1 North | 0.22 | 26.7 | 100.0 | 0.7 | 7.6 |
| 1 North | 0.32 | 26.8 | 100.0 | 1.3 | 7.6 |
| 1 North | 0.42 | 26.7 | 100.0 | 0.8 | 7.6 |
| 1 North | 0.52 | 26.7 | 100.0 | 0.6 | 7.6 |
| 1 North | 0.63 | 26.7 | 100.0 | 0.8 | 7.6 |
| 1 North | 0.73 | 26.7 | 100.0 | 1.0 | 7.6 |
| 1 North | 0.83 | 26.7 | 100.0 | 1.6 | 7.6 |
| 1 North | 0.91 | 26.6 | 100.0 | 1.6 | 7.6 |
| 1 North | 0.99 | 26.6 | 100.0 | 1.5 | 7.6 |
| 1 North | 1.08 | 26.6 | 100.0 | 1.5 | 7.6 |
| 1 North | 1.16 | 26.6 | 100.0 | 1.4 | 7.6 |
| 1 North | 1.26 | 26.6 | 100.0 | 1.3 | 7.6 |
| 1 North | 1.36 | 26.6 | 100.0 | 1.0 | 7.6 |
| 1 North | 1.46 | 26.6 | 100.0 | 0.8 | 7.6 |
| 1 North | 1.54 | 26.5 | 100.0 | 1.1 | 7.6 |
| 1 North | 1.63 | 26.5 | 100.0 | 0.4 | 7.6 |
| 1 North | 1.72 | 26.5 | 100.0 | 0.4 | 7.6 |
| 1 North | 1.79 | 26.5 | 100.0 | 0.1 | 7.6 |
| 1 North | 1.86 | 26.5 | 100.0 | 0.0 | 7.6 |
| 1 North | 1.96 | 26.5 | 100.0 | 0.3 | 7.6 |

| Site | Depth (meters) | Temperature (°C) | Specific Conductivity @ 25°C (*u*S/cm) | Chlorophyll *a* (*u*g/l) | pH (std units) |
|---|---|---|---|---|---|
| 1 North | 2.08 | 26.5 | 100.0 | 0.9 | 7.6 |
| 1 North | 2.20 | 26.5 | 100.0 | 1.2 | 7.6 |
| 1 North | 2.29 | 26.5 | 100.0 | 1.1 | 7.6 |
| 1 North | 2.38 | 26.5 | 100.0 | 1.2 | 7.6 |
| 1 North | 2.45 | 26.5 | 100.0 | 0.8 | 7.6 |
| 1 North | 2.51 | 26.5 | 100.0 | 0.5 | 7.6 |
| 1 North | 2.58 | 26.5 | 100.0 | 1.1 | 7.6 |
| 1 North | 2.64 | 26.5 | 100.0 | 1.1 | 7.6 |
| 1 North | 2.70 | 26.5 | 100.0 | 1.0 | 7.6 |
| 1 North | 2.78 | 26.5 | 100.0 | 1.8 | 7.6 |
| 1 North | 2.88 | 26.5 | 100.0 | 1.4 | 7.6 |
| 1 North | 2.96 | 26.5 | 100.0 | 1.7 | 7.6 |
| 1 North | 3.04 | 26.5 | 100.0 | 1.7 | 7.6 |
| 1 North | 3.14 | 26.5 | 100.0 | 1.7 | 7.5 |
| 1 North | 3.25 | 26.5 | 100.0 | 1.5 | 7.5 |
| 1 North | 3.33 | 26.5 | 100.0 | 1.7 | 7.5 |
| 1 North | 3.43 | 26.5 | 100.0 | 1.9 | 7.5 |
| 1 North | 3.53 | 26.5 | 100.0 | 1.9 | 7.5 |
| 1 North | 3.62 | 26.4 | 100.0 | 1.5 | 7.5 |
| 1 North | 3.72 | 26.4 | 100.0 | 1.8 | 7.5 |
| 1 North | 3.82 | 26.4 | 100.0 | 1.7 | 7.5 |
| 1 North | 3.89 | 26.4 | 100.0 | 1.7 | 7.5 |
| 1 North | 3.95 | 26.4 | 100.0 | 1.8 | 7.5 |
| 1 North | 4.03 | 26.4 | 100.0 | 2.1 | 7.5 |
| 1 North | 4.10 | 26.4 | 100.0 | 2.5 | 7.5 |
| 1 North | 4.18 | 26.3 | 100.0 | 2.8 | 7.5 |
| 1 North | 4.28 | 26.1 | 100.0 | 3.1 | 7.5 |
| 1 North | 4.38 | 25.8 | 100.0 | 4.4 | 7.6 |
| 1 North | 4.57 | 25.4 | 100.0 | 4.4 | 7.6 |
| 1 North | 4.73 | 24.9 | 100.0 | 5.8 | 7.6 |
| 1 North | 4.88 | 24.4 | 100.0 | 5.7 | 7.6 |
| 1 North | 5.00 | 24.1 | 100.0 | 5.6 | 7.6 |
| 1 North | 5.09 | 23.8 | 100.0 | 5.0 | 7.5 |
| 1 North | 5.18 | 23.6 | 100.0 | 4.2 | 7.5 |
| 1 North | 5.29 | 23.4 | 100.0 | 4.0 | 7.5 |
| 1 North | 5.39 | 23.2 | 100.0 | 3.6 | 7.5 |
| 1 North | 5.50 | 23.0 | 100.0 | 3.3 | 7.4 |
| 1 North | 5.62 | 22.8 | 100.0 | 2.9 | 7.4 |
| 1 North | 5.76 | 22.6 | 100.0 | 3.8 | 7.3 |
| 1 North | 5.87 | 22.4 | 100.0 | 4.4 | 7.3 |
| 1 North | 5.98 | 22.3 | 100.0 | 4.6 | 7.2 |
| 1 North | 6.08 | 22.2 | 100.0 | 4.7 | 7.2 |
| 1 North | 6.17 | 22.0 | 100.0 | 4.4 | 7.2 |
| 1 North | 6.29 | 21.8 | 100.0 | 4.0 | 7.1 |
| 1 North | 6.38 | 21.7 | 100.0 | 4.2 | 7.1 |

| Site | Depth (meters) | Temperature (°C) | Specific Conductivity @ 25°C (*u*S/cm) | Chlorophyll *a* (*ug*/l) | pH (std units) |
|---|---|---|---|---|---|
| 1 North | 6.47 | 21.5 | 100.0 | 3.5 | 7.1 |
| 1 North | 6.56 | 21.3 | 100.0 | 3.5 | 7.0 |
| 1 North | 6.65 | 21.0 | 101.0 | 3.0 | 7.0 |
| 1 North | 6.72 | 20.9 | 101.0 | 2.6 | 7.0 |
| 1 North | 6.81 | 20.7 | 100.0 | 2.7 | 6.9 |
| 1 North | 6.90 | 20.6 | 101.0 | 2.1 | 6.9 |
| 1 North | 6.98 | 20.5 | 101.0 | 11.0 | 6.8 |
| 2 South | 0.16 | 26.9 | 100.0 | 1.9 | 7.6 |
| 2 South | 0.19 | 26.9 | 100.0 | 1.5 | 7.6 |
| 2 South | 0.28 | 26.9 | 100.0 | 1.3 | 7.6 |
| 2 South | 0.42 | 26.8 | 100.0 | 1.3 | 7.6 |
| 2 South | 0.54 | 26.7 | 100.0 | 1.0 | 7.6 |
| 2 South | 0.64 | 26.6 | 100.0 | 1.0 | 7.6 |
| 2 South | 0.72 | 26.5 | 100.0 | 0.9 | 7.6 |
| 2 South | 0.80 | 26.4 | 100.0 | 1.1 | 7.6 |
| 2 South | 0.87 | 26.4 | 100.0 | 1.2 | 7.6 |
| 2 South | 0.94 | 26.4 | 100.0 | 1.4 | 7.6 |
| 2 South | 1.02 | 26.4 | 100.0 | 1.4 | 7.6 |
| 2 South | 1.10 | 26.3 | 100.0 | 1.0 | 7.6 |
| 2 South | 1.18 | 26.3 | 100.0 | 1.0 | 7.6 |
| 2 South | 1.28 | 26.3 | 100.0 | 0.9 | 7.6 |
| 2 South | 1.36 | 26.3 | 100.0 | 0.5 | 7.6 |
| 2 South | 1.44 | 26.3 | 100.0 | 0.7 | 7.6 |
| 2 South | 1.51 | 26.3 | 100.0 | 0.8 | 7.6 |
| 2 South | 1.59 | 26.3 | 100.0 | 1.1 | 7.6 |
| 2 South | 1.67 | 26.2 | 100.0 | 1.2 | 7.6 |
| 2 South | 1.77 | 26.2 | 100.0 | 1.3 | 7.6 |
| 2 South | 1.85 | 26.2 | 100.0 | 1.0 | 7.6 |
| 2 South | 1.97 | 26.2 | 100.0 | 1.8 | 7.6 |
| 2 South | 2.09 | 26.2 | 100.0 | 1.8 | 7.6 |
| 2 South | 2.22 | 26.2 | 100.0 | 1.4 | 7.6 |
| 2 South | 2.35 | 26.2 | 100.0 | 1.4 | 7.6 |
| 2 South | 2.47 | 26.2 | 100.0 | 1.4 | 7.6 |
| 2 South | 2.57 | 26.1 | 100.0 | 1.3 | 7.6 |
| 2 South | 2.64 | 26.1 | 100.0 | 0.9 | 7.6 |
| 2 South | 2.73 | 26.1 | 100.0 | 1.0 | 7.6 |
| 2 South | 2.84 | 26.1 | 100.0 | 1.3 | 7.6 |
| 2 South | 2.93 | 26.1 | 100.0 | 1.7 | 7.6 |
| 2 South | 3.01 | 26.1 | 100.0 | 1.8 | 7.6 |
| 2 South | 3.11 | 26.1 | 100.0 | 1.5 | 7.6 |
| 2 South | 3.20 | 26.0 | 100.0 | 1.5 | 7.6 |
| 2 South | 3.27 | 26.0 | 100.0 | 1.4 | 7.6 |
| 2 South | 3.37 | 26.0 | 100.0 | 1.2 | 7.6 |
| 2 South | 3.44 | 26.0 | 100.0 | 1.3 | 7.6 |
| 2 South | 3.49 | 25.9 | 100.0 | 1.5 | 7.6 |

| Site | Depth (meters) | Temperature (°C) | Specific Conductivity @ 25°C ($u$S/cm) | Chlorophyll *a* ($ug$/l) | pH (std units) |
|---|---|---|---|---|---|
| 2 South | 3.56 | 25.9 | 100.0 | 1.9 | 7.6 |
| 2 South | 3.68 | 25.9 | 100.0 | 2.6 | 7.6 |
| 2 South | 3.80 | 25.8 | 100.0 | 2.4 | 7.6 |
| 2 South | 3.90 | 25.7 | 100.0 | 2.1 | 7.6 |
| 2 South | 3.99 | 25.5 | 100.0 | 2.7 | 7.6 |
| 2 South | 4.07 | 25.3 | 100.0 | 3.1 | 7.6 |
| 2 South | 4.16 | 25.1 | 100.0 | 3.7 | 7.6 |
| 2 South | 4.26 | 25.0 | 100.0 | 3.2 | 7.6 |
| 2 South | 4.32 | 24.9 | 100.0 | 3.1 | 7.6 |
| 2 South | 4.43 | 24.8 | 100.0 | 3.0 | 7.7 |
| 2 South | 4.56 | 24.7 | 100.0 | 2.3 | 7.7 |
| 2 South | 4.71 | 24.5 | 100.0 | 2.4 | 7.7 |
| 2 South | 4.83 | 24.4 | 100.0 | 2.0 | 7.7 |
| 2 South | 4.97 | 24.3 | 100.0 | 2.1 | 7.7 |
| 2 South | 5.12 | 24.1 | 100.0 | 2.6 | 7.7 |
| 2 South | 5.27 | 23.9 | 100.0 | 2.9 | 7.7 |
| 2 South | 5.41 | 23.7 | 100.0 | 3.0 | 7.6 |
| 2 South | 5.54 | 23.5 | 100.0 | 2.8 | 7.6 |
| 2 South | 5.66 | 23.2 | 99.0 | 3.3 | 7.6 |
| 2 South | 5.76 | 22.9 | 99.0 | 2.7 | 7.5 |
| 2 South | 5.85 | 22.6 | 99.0 | 2.8 | 7.5 |
| 2 South | 5.99 | 22.4 | 99.0 | 2.3 | 7.5 |
| 2 South | 6.18 | 22.1 | 99.0 | 1.9 | 7.4 |
| 2 South | 6.34 | 21.8 | 99.0 | 1.9 | 7.4 |
| 2 South | 6.48 | 21.5 | 99.0 | 2.4 | 7.3 |
| 2 South | 6.60 | 21.2 | 99.0 | 2.5 | 7.3 |
| 2 South | 6.72 | 21.0 | 99.0 | 2.2 | 7.2 |
| 2 South | 6.84 | 20.7 | 99.0 | 2.7 | 7.2 |
| 2 South | 6.95 | 20.5 | 99.0 | 2.9 | 7.2 |
| 2 South | 7.08 | 20.3 | 99.0 | 3.6 | 7.1 |
| 2 South | 7.19 | 20.1 | 99.0 | 4.2 | 7.1 |
| 2 South | 7.29 | 19.9 | 99.0 | 3.9 | 7.1 |
| 2 South | 7.38 | 19.7 | 99.0 | 3.6 | 7.0 |
| 2 South | 7.48 | 19.6 | 99.0 | 4.1 | 7.0 |
| 2 South | 7.60 | 19.4 | 99.0 | 3.9 | 7.0 |
| 2 South | 7.70 | 19.3 | 99.0 | 3.4 | 6.9 |
| 2 South | 7.82 | 19.2 | 99.0 | 3.6 | 6.9 |
| 2 South | 7.95 | 19.0 | 99.0 | 3.3 | 6.9 |
| 2 South | 8.10 | 18.9 | 99.0 | 3.2 | 6.9 |
| 2 South | 8.22 | 18.8 | 99.0 | 2.9 | 6.8 |
| 2 South | 8.35 | 18.7 | 99.0 | 3.0 | 6.8 |
| 2 South | 8.50 | 18.6 | 99.0 | 3.3 | 6.8 |
| 2 South | 8.65 | 18.4 | 99.0 | 3.3 | 6.8 |
| 2 South | 8.79 | 18.3 | 99.0 | 3.3 | 6.7 |
| 2 South | 8.91 | 18.1 | 99.0 | 3.1 | 6.7 |

| Site | Depth (meters) | Temperature (°C) | Specific Conductivity @ 25°C (*u*S/cm) | Chlorophyll *a* (*u*g/l) | pH (std units) |
|---|---|---|---|---|---|
| 2 South | 9.03 | 17.9 | 99.0 | 2.7 | 6.7 |
| 2 South | 9.13 | 17.7 | 99.0 | 2.1 | 6.7 |
| 2 South | 9.23 | 17.6 | 99.0 | 2.1 | 6.7 |
| 2 South | 9.34 | 17.3 | 100.0 | 1.9 | 6.6 |
| 2 South | 9.45 | 17.1 | 100.0 | 2.0 | 6.6 |
| 2 South | 9.59 | 16.9 | 100.0 | 1.8 | 6.6 |
| 2 South | 9.73 | 16.6 | 100.0 | 1.4 | 6.6 |
| 2 South | 9.86 | 16.5 | 100.0 | 1.5 | 6.6 |
| 2 South | 9.99 | 16.2 | 101.0 | 1.6 | 6.6 |
| 2 South | 10.11 | 16.0 | 101.0 | 1.4 | 6.5 |
| 2 South | 10.24 | 15.8 | 101.0 | 1.4 | 6.5 |
| 2 South | 10.39 | 15.6 | 102.0 | 1.5 | 6.5 |
| 2 South | 10.55 | 15.3 | 103.0 | 1.7 | 6.5 |
| 2 South | 10.68 | 15.1 | 104.0 | 1.5 | 6.5 |
| 2 South | 10.78 | 14.9 | 107.0 | 3.5 | 6.5 |

# APPENDIX E

## DETERMINING WATER QUALITY CHANGES AND TRENDS

### Box and Whisker Plots

<u>Quick Overview:</u>

The 2010 summary **New Hampshire Lakes Lay Monitoring Program (NH LLMP)** reports include *box-and-whisker* plots that provide a visual representation of how the data are spread out and how much variation exists. Thus, the *box-and-whisker* plots provide a summary of how your data are distributed and provide a visual summary of how the data have varied among years and, when multiple sampling locations are monitored, provide a summary of how the data vary among sampling sites.

These plots show how the data group together for a given year. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. An algae bloom event may cause this type of outlier to occur in the chlorophyll data (high point) or Secchi disk clarity (low point).

We recommend that each **NH LLMP** participating group plan on collecting weekly or biweekly measurements throughout the sampling season to ensure that enough data are available for this type of statistical analysis. We suggest that at least 8 data collections per year occur and generally set 10 measurements per year as a sampling effort goal per site.

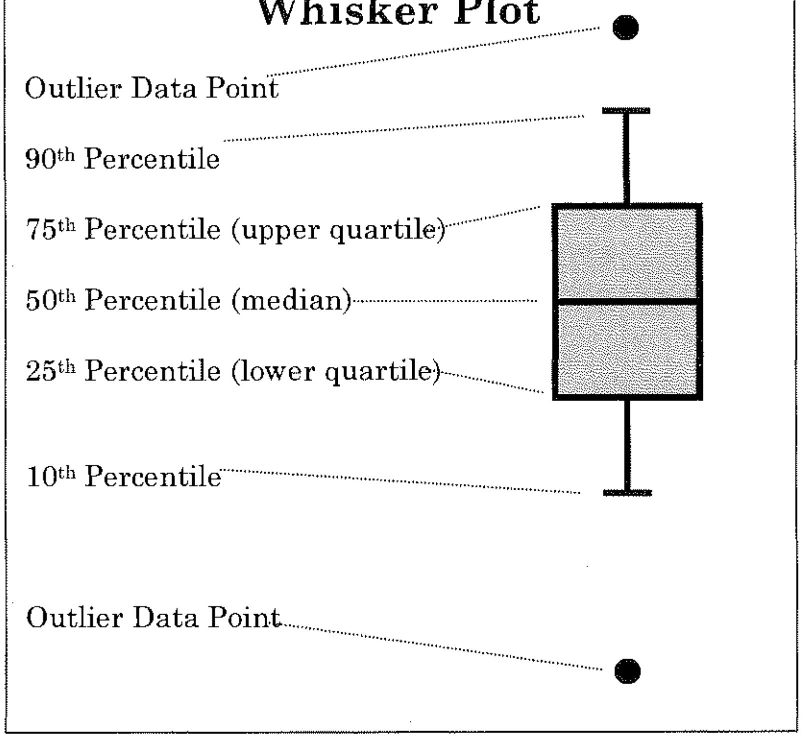
We can employ the appropriate statistical techniques for detecting the extent that change is occurring when the sampling effort recommendations are followed. Your report summary should include box and whisker plots as well as a basic interpretation for your lake. If you have additional questions on interpreting your results feel free to call the Educational Program Coordinator (Bob Craycraft) at 603-862-3696.

<u>The Details:</u>

In the sections below we further describe the use of the box and whisker plot for those that are interested on how they are determined and how they are interpreted:

The **box-and-whisker plot** is good at showing the **extreme values** and the range of middle values of your data (Figure 1). The box depicts the middle values of a variable, while the **whiskers** stretch to demonstrate the values between which 80% of the data points will fall. The filled circles then reflect the "outlier" data points that fall outside of the whiskers and reflect values that are atypically high or atypically low relative to the other data measured for a given year.

**Figure 1. Sample Box and Whisker Plot**




The box-and-whisker plots can be summarized as a graphic that displays the following important features of the data when they are arranged in order from least to greatest:

- Median ($50^{th}$ percentile) – the middle of the data
- Lower Quartile ($25^{th}$ percentile) – the point below which 25% of the data points are located.
- Upper Quartile ($75^{th}$ percentile) – the point below which 75% of the data points are located.
- $90^{th}$ Percentile – the point below which 90% of the data points are located.
- $10^{th}$ Percentile – the point below which 10% of the data points are located.
- Outlier Data points – data points that represent the upper 10% or the lowest 10% of the data collected for a specific year.

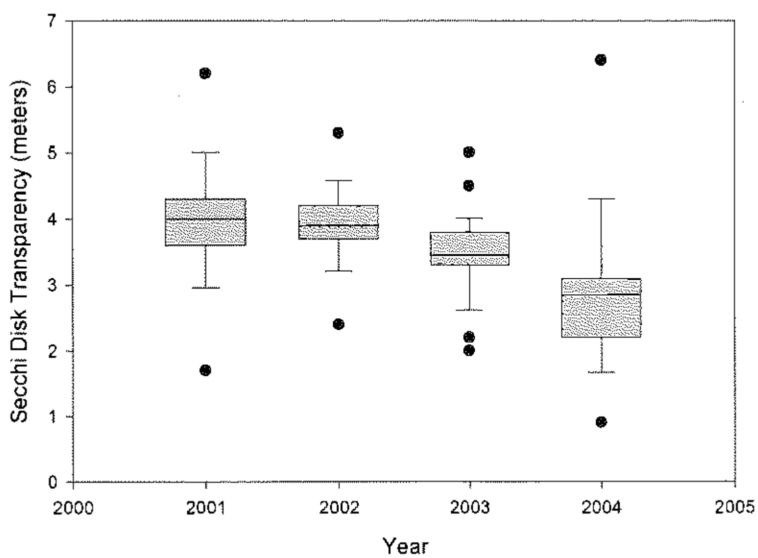
*Note: A minimum number of data points is required to compute each feature documented above. At least three points are required to compute the Lower and the Upper Quartiles, five points are needed to compute the $10^{th}$ percentile, and six points are needed to compute the $90^{th}$ percentile. In the event that insufficient data points have been collected features will not be graphed due to the inability to reliably calculate the respective attribute.*

**Sample box-and-whisker plot interpretation:**

A sample *box-and-whisker* plot is depicted in Figure 2 and it provides an opportunity to assess the usefulness of this type of plot at interpreting water quality monitoring data. The imaginary data depicted in Figure 2 reflect the annual water transparency measurements between the years 2001 and 2004. As you can glean from Figure 2, the distribution of the water clarity measurements have shifted to less clear conditions between 2001 and 2004. The median values, as well as the upper and lower quartiles (what is represented by the gray shaded box) have gradually shifted to less clear conditions over the four year span. The data points that lie between the upper and lower quartiles reflect 50% of the data collected for a given year and can provide insight into whether or not the water quality data are varying significantly between or among years. In extreme cases, when the gray shaded regions do not overlap between successive years or among years, one can quickly determine that the data distribution is significantly different for those years where the middle data (gray shading) does not overlap. Such differences can reflect long-term trends or can be a reflection of extreme climatic conditions for a given year such as atypically wet or atypically dry conditions that can have a profound impact on water quality.

**Figure 2.**

**Sample Lake - Site 1 Deep**
**Annual Secchi Disk Transparency Comparisions**
**Box and Whisker Plots: 2001-2004**




***Note: The number of outlier data points is dependant on the size of the dataset.***

Additional evaluation of the data can include a review of the 10th and the 90th percentiles (the whiskers) that provide additional insight into the distribution of the data. In this case, the trends exhibited by the 10th and the 90th percentiles are following the pattern of decreasing Secchi Disk Transparency as is exhibited by boxes (gray shaded regions). Outlier data points that fall outside of the "whiskers" can also be insightful. Such extreme values can be an early indicator of coming trends or can be an early warning sign of potential water quality problems. For instance, when Secchi Disk transparency measurements occasionally become significantly reduced (i.e. shallower water) such phenomenon can be an indication of short-term water quality problems such as excessive sediment or an algal bloom. If such problems are not contended with, but are instead left unattended, the longer-term impact could result in an increase in the magnitude and frequency of the water transparency reductions that, in turn, would result in a decreasing trend as evidenced by a shift of the "Boxes" to shallower water transparencies. There might also be occasions when the Secchi Disk transparency outliers reflect atypically clear water clarity. Such outliers can be a sign that conditions are improving or, as is often the case, the water quality is responding to short-term climatic variations that can have a profound impact on the water quality data. For instance, the outlier data point of 6.4 meters that was documented in 2004 (Figure 2) is counter intuitive to the long term trend of decreasing water quality. Plausible explanations for such an anomaly could be due to short term overgrazing of algae by zooplankton (typical for moderate to highly productive lakes), an abrupt shift in climate that might have favored clearer water (cloudy days or cooler water) or perhaps there was some sort of human intervention, such as a fish stocking or lake treatment that would have resulted in clearer water claries.

Your 2010 executive summary in this report includes a basic interpretation of the box-and whisker plots that are specific to your lake. However, since you have personal knowledge of the conditions of your lake and local events that might influence the water quality measurements, you might have additional insight into the cause of the water quality fluctuations that have not been discussed in the report. Should you want to discuss the water quality results further, or provide additional information that you feel is important, please contact Bob Craycraft by phone, (603) 862-3696, or by email, bob.craycraft@unh.edu.

# APPENDIX F

## GLOSSARY OF LIMNOLOGICAL TERMS

**Aerobe**- Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.

**Algae**- See phytoplankton.

**Alkalinity**- Total concentration of bicarbonate and hydroxide ions (in most lakes).

**Anaerobe**- Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.

**Anoxic**- A system lacking oxygen, therefore incapable of supporting the most common kind of biological respiration, or of supporting oxygen-demanding chemical reactions. The deeper waters of a lake may become anoxic if there are many organisms depleting oxygen via respiration, and there is little or no replenishment of oxygen from photosynthesis or from the atmosphere.

**Benthic**- Referring to the bottom sediments.

**Bacterioplankton**- Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.

**Bicarbonate**- The most important ion (chemical) involved in the buffering system of New Hampshire lakes.

**Buffering**- The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the chemical responsible for buffering is the bicarbonate ion. (See pH.)

**Chloride**- One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.

**Chlorophyll *a***- The main green pigment in plants. The concentration of chlorophyll *a* in lakewater is often used as an indicator of algal abundance.

**Circulation**- The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.

**Density**- The weight per volume of a substance. The more dense an object, the heavier it feels. Low-density liquids will float on higher-density liquids.

**Dimictic**- The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).

**Dystrophy**- The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity. Chlorophyll *a* concentration may be low or high.

**Epilimnion**- The uppermost layer of water during periods of thermal stratification. (See lake diagram).

**Eutrophy**- The lake trophic state in which algal production is high. Associated with eutrophy is low Secchi Disk depth, high chlorophyll *a*, and high total phosphorus. From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present. A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.

**Free CO2**- Carbon dioxide that is not combined chemically with lake water or any other substances. It is produced by respiration, and is used by plants and bacteria for photosynthesis.

**Holomixis**- The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)

**Humic Acids**- Dissolved organic compounds released from decomposition of plant leaves and stems. Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire. Humic acids are consumed only by fungi, and thus are relatively resistant to biological decomposition.

**Hydrogen Ion**- The "acid" ion, present in small amounts even in distilled water, but contributed to rain-water by atmospheric processes, to ground-water by soils, and to lakewater by biological organisms and sediments. The active component of "acid rain". See also "pH" the symbolic value inversely and exponentially related to the hydrogen ion.

**Hypolimnion**- The deepest layer of lakewater during periods of thermal stratification. (See lake diagram)

**Lake**- Any "inland" body of relatively "standing" water. Includes many synonyms such as ponds, tarns, loches, billabongs, bogs, marshes, etc.

**Lake Morphology**- The shape and size of a lake and its basin.

**Littoral**- The area of a lake shallow enough for submerged aquatic plants to grow.

**Meromixis**- The condition where the entire lake fails to circulate to its deepest points; caused by a high concentration of salt in the deeper waters, and by peculiar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)

**Mesotrophy**- The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll *a*, Secchi Disk depth, and total phosphorus are also moderate. These lakes are esthetically "fair" but not as good as oligotrophic lakes.

**Metalimnion**- The "middle" layer of the lake during periods of summer thermal stratification. Usually defined as the region where the water temperature changes at least one degree per meter depth. Also called the thermocline.

**Mixis**- Periods of lakewater mixing or circulation.

**Mixotrophy**- The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll *a* values are also high.

**Oligotrophy**- The lake trophic state where algal production is low, Secchi Disk depth is deep, and chlorophyll *a* and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

**Overturn**- See circulation or mixis

**pH**- A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times. Symbolically, the pH value is the "negative logarithm" of the hydrogen ion concentration. For example, a pH of 5 represents a hydrogen ion concentration of $10^{-5}$ molar. [Please thank the chemists for this lovely symbolism -- and ask them to explain it in lay terms!] In any event, the higher the pH value, the lower the hydrogen ion concentration. The range is 0 to 14, with 7 being neutral 1 denoting high acid condition and 14 denoting very basic condition.

**Photosynthesis**- The process by which plants convert the inorganic substances carbon dioxide and water into organic glucose (sugar) and oxygen using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance of almost all life forms.

**Phytoplankton**- Microscopic algae which are suspended in the "open water" zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.

**Parts per million**- Also known as "ppm". This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 ppm of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water. Domestic sewage usually contains from 2 to 10 ppm phosphorus.

**Parts per billion**- Also known as "ppb". This is only 1/1000 of ppm, therefore much less concentrated. As little as 1 ppb of phosphorus will sustain growth of algae. As little as 10 ppb phosphorus will cause algal blooms! Think of the ratio as 1 milligram (1/28000 of an ounce) of phosphorus in 25 barrels of water (55 gallon drums)! Or, 1 gallon of septic waste diluted into 10,000 gallons of lakewater. It adds up fast!

**Plankton**- Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants. See also "bacterioplankton" (bacteria), "phytoplankton" (algae) and "zooplankton" (microcrustaceans and rotifers).

**Saturated**- When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater, gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen if exposed sufficiently long to the atmosphere or another source of oxygen.

**Specific Conductivity**- A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

**Stratum**- A layer or "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

**Thermal Stratification**- The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind.

**Thermocline**- Region of temperature change. (See metalimnion.)

**Total Phosphorus**- A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

**Trophic Status**- A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories)

**Z**- A symbol used by limnologists as an abbreviation for depth.

**Zooplankton**- Microscopic animals in the planktonic community. Some are called "water fleas", but most are known by their scientific names. Scientific names include: *Daphnia, Cyclops, Bosmina,* and *Kellicottia.*