HALIFAX

P.O. Box 1749
Halifax, Nova Scotia
B3J 3A5 Canada

Item No. 11.3.1
Halifax Regional Council
February 24, 2015

TO:	Mayor Savage and Members of Halifax Regional Council
SUBMITTED BY:	Original Signed Councillor Jennifer Watts, Chair Environment and Sustainability Standing Committee
DATE:	February 9, 2015
SUBJECT:	Weed Growth in Lakes Banook and MicMac

ORIGIN

This report originated by motion of Regional Council, Item 12.1, July 29 2014.

Following the initial request, a motion of the Environment and Sustainability Standing Committee, Item 7.1 (b), February 5, 2015 provided recommendation to Regional Council.

LEGISLATIVE AUTHORITY

Section 3.5.1 and 3.5.3 of the Environment and Sustainability Standing Committee's Terms of Reference describes as responsibility under Water Management:

- *Involvement in policy development and oversight of policies appropriate to promote and protect water resources in HRM.*
- *Other related activities in the area of Water Resource management as identified by the Standing Committee and approved by Regional Council*

RECOMMENDATION

It is recommended that Halifax Regional Council direct staff to:

1. Seek approval from the Province to manage the weeds in Lakes Banook and MicMac
2. Implement the short-term control of weed management on Lake Banook and Lake Micmac through contracted mechanical harvesting services; and
3. Prepare recommendations for long-term options for weed control on Lake Banook and Lake MicMac.

BACKGROUND / DISCUSSION

On July 29, 2014, Regional Council requested a staff report regarding weed growth in Lakes Banook and

MicMac. On January 15, 2015, the Environment and Sustainability Standing Committee received a staff recommendation report dated December 17, 2014. The report was deferred to the Committee's February 5, 2015 meeting with a request that staff report regarding additional information received from Lake Management Services. On February 5, 2015, the Committee passed the staff recommendation.

FINANCIAL IMPLICATIONS

Financial implications are as outlined in the December 17, 2014 staff information report.

Should Council adopt the recommendations of the Environment and Sustainability Standing Committee additional actions will be required by Regional Council to address the financial implications outlined to implement the program including:

A motion, pending provincial approval, to include contracted mechanical weed control in Lakes Banook and MicMac as a new service in the 2015/2016 Operating Budget and directing staff to prepare the 2015/2016 Planning and Development Budget and Business Plan incorporating the direction from Council and the applicable costs associated with the program as outline in the December 17, 2014 staff report estimated at $182,000 annually.

COMMUNITY ENGAGEMENT

All meetings of the Environment and Sustainability Standing Committee are open to the public. The Committee is made up of six duly elected members of Regional Council and agendas and minutes are available on the Halifax.ca website.

ENVIRONMENTAL IMPLICATIONS

Environmental implications are present and outlined in the December 17, 2014 staff report.

ALTERNATIVES

Refer to alternatives section of December 17, 2014 staff report.

ATTACHMENTS

1. Staff Recommendation Report dated December 17, 2014.

A copy of this report can be obtained online at http://www.halifax.ca/council/agendasc/cagenda.php then choose the appropriate meeting date, or by contacting the Office of the Municipal Clerk at 902.490.4210, or Fax 902.490.4208.

Report Prepared by: Sherryll Murphy, Deputy Clerk, 902-490-4211

Attachment 1

HALIFAX

P.O. Box 1749
Halifax, Nova Scotia
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Item No. 9.1.1
Environment and Sustainability Standing Committee
January 8, 2015

TO:	Chair and Members of Environment and Sustainability Standing Committee
SUBMITTED BY:	Original Signed Bob Bjerke, Chief Planner & Director, Planning & Infrastructure
DATE:	December 17, 2014
SUBJECT:	**Weed Growth in Lake Banook & MicMac**

ORIGIN

Motion of Regional Council, Item 12.1, July 29 2014: That Halifax Regional Council request a staff report on the findings of the Stantec report on weed growth in Lakes Banook and Mic Mac. The report will outline all short-term and long-term options discussed in the consultant's study and provide Council some recommendations and budget implications.

LEGISLATIVE AUTHORITY

Halifax Charter Act,
Agreements, (S.75 (1))

- The Municipality may agree with any person for the provision of a service or a capital facility that the Municipality is authorized to provide.

Power to Spend Money (S.79)(1),

- (z) acquisition of equipment, materials, vehicles, machinery, apparatus, implements and plant for a municipal purpose
- (ah) playgrounds, trails, including trails developed, operated and maintained pursuant to an agreement made under clause 73(c), bicycle paths, swimming pools, ice arenas and other recreational facilities
- (av) a grant or contribution to:
  (v) any charitable, nursing, medical, athletic, educational, environmental, cultural, community, fraternal, recreational, religious, sporting or social organization within the Province

RECOMMENDATION

It is recommended that the Environment and Sustainability Standing Committee recommend to Regional Council direct staff to:

1. Implement the short-term control of weed management on Lake Banook and Lake Micmac through contracted mechanical harvesting services; and
2. Prepare recommendations for long-term options for weed control on Lake Banook and Lake MicMac.

BACKGROUND

Members of the public first began reporting complaints regarding excessive weed growth interfering with recreation in Lake Banook and Lake MicMac to the Halifax Regional Municipality (HRM) in the summer of 2009. Further complaints regarding weed growth in both lakes were reported to the municipality in summer 2010. Weed specimens were obtained by municipal staff in the summers of 2009 and 2010 for identification by local authorities. Four separate weed species were identified:

- *Potamogeton filiformis* - (Common Name: Slender-leaved pondweed) – 2009 only
- *Potamogeton perfoliatus* (Common Name: Clasping-leaf pondweed) – 2010 only
- *Potamogeton foliosus* (Common Name: Leafy pondweed) – 2010 only
- *Elodea Canadensis* (Common Name: Canada waterweed) – 2010 only

All four plants are native to Nova Scotia and are non-invasive.

Anecdotal reports suggest that the abundance (amount) and extent (area of lakes affected) by plant growth far exceeded that of previous years, with more observed in 2010 than 2009. By 2010, the excessive plant growth was reportedly affecting motorized boating, non-motorized boating and swimming on the lakes.

In September 2010, HRM convened a public meeting to address the issue of excessive plant (weed) growth. A volunteer-based, staff-assisted committee that formed through the meeting arranged for a municipal Expression of Interest to explore the costs for either the purchase of equipment or hiring of services to harvest the weeds on an annual basis. The results of the solicitation yielded offers that both cost approximately $200,000. Although external funding opportunities were pursued to cover these costs, no funds were awarded to enable further consideration at the time.

Two staff reports were presented to the Environment and Sustainability Standing Committee documenting the status of weeds in these lakes in 2011. These reports are available online at http://www.halifax.ca/boardscom/swrac/documents/7.2.3.pdf and http://www.halifax.ca/boardscom/swrac/documents/UpdateonLakesBanookandMicMac.pdf, respectively.

In fall 2013, Halifax staff contracted Stantec Consulting Ltd. (hereafter, "Stantec") to assess the causes and possible solutions to excessive growth of submerged aquatic vegetation in Lake Banook, and to present the results of the study in a final report and subsequent public presentation. The final report and slide deck that formed the basis of the public presentation are provided as Attachments 1 and 2, respectively.

Stantec attributed the excessive growth of weeds in Lake Banook to a combination of two factors: i) sediment enrichment from non-point source urban sediment loading and ii) disturbance ecology from water level manipulations. The water level of Lake Banook was substantially reduced during the winter of 2008-2009 to accommodate the construction of the North Dartmouth Trunk Sewer along the northern shoreline of Lake Banook. Stantec advised that winter drawdown of lake water levels can disrupt the ecology of the lake community by enabling some species to outcompete others under the stressed conditions.

The study proposed that both long-term and short-term solutions would be required to address the problem of excessive weed growth. Stantec noted that addressing the sources and transport of urban sediment to the lake would not likely reduce weed growth on its own due to the enduring effects of nutrient-enriched sediments already in the lake. The use of both long-term and short-term solutions is intended to prevent a worsening of the current situation and to support the long-term effectiveness of short-term solutions.

Short-term solutions assessed in detail for the municipality's consideration include:
1. Herbicide Application;
2. Sediment Dredging and Removal; and

3. Mechanical Harvesting.

Long-term solutions proposed by Stantec include:

1. Conduct additional wet weather and dry weather water quality sampling in the spring and summer to confirm the presence of substantial sources and area(s) within the watershed from which these sources originates.
2. Conduct additional and more detailed sediment sampling and characterization in areas with and without weeds to confirm sediment enrichment
3. Reduce sediment loading to the lake through control measures at the source, conveyance, and/or discharge points within the system. A variety of methods may be deployed depending on the target of control measures, such as erosion prevention, infrastructure maintenance, sediment containment options, and one or more green infrastructure solutions.

DISCUSSION

The province of Nova Scotia is responsible for lakes. Lake Banook and Lake Micmac uniquely serve as a regional recreational asset for the municipality, as the home of four boating clubs, regular site of training and demonstration events, and frequent host to regional, national, and international paddling, rowing, and other sporting events. Due to the value of these lakes to the municipality, it makes sense for Halifax to pay for weed management services here, where such services may not be contemplated elsewhere.

Short Term Solutions

Stantec's detailed assessment of short-term solutions of weeds in Lake Banook addressed three options. The assessment included a description of each option, explanation of requirements and limitations, expected effectiveness, anticipated approval requirements, costs, and risks associated with each option. Each of the options proposed as potential short-term solutions represent safe and proven technologies that have been demonstrated to work under a variety of conditions.

Although Stantec's report provided details for three different aquatic herbicides (Diquat, Endothall, and Fluridone), only Diquat is licensed for use in Canada. Therefore, only Diquat is considered further in this report.

The following table summarizes the details for each option. Costs are addressed later in the report.

Options	Herbicide Application (aquatic)	Mechanical Harvesting	Sediment Dredging and Removal
Description	• Broad-spectrum, kills portions of plants on contact (within hours) • Kills top growth only, not roots • Rarely found in water column after 10 days • Affects young weeds more strongly than mature weeds	• Uses vessel with submersed blades & collection system • Results apparent immediately after cutting • Several treatments may be required per season	• Process removes vegetation & sediment from lake bottom &/or along shoreline • Several methods available; selection should be based on site characteristics • Dredged materials must be dewatered before disposal • Disposal options include land amendment or licensed facility

Options	Herbicide Application (aquatic)	Mechanical Harvesting	Sediment Dredging and Removal
Requirements	• Apply during growing season; • Minimum water temp. (18 - 25°C); • Wind speed; • Water movement • Low to no suspended solids	• Must be done during growing season	• Sediment containment required to prevent suspension in water • Material must be dewatered before transported. • Dewatering method may require additional erosion and sedimentation controls

Limitations	• Only Diquat approved for use in Canada
	• Does not kill roots
	• Application requires use of boat
	• Minimum waiting periods post-application:
	  • Drinking: 2 weeks
	  • Swimming: 48-72 hours
	  • Fishing: 24 hours
		• Composting facility must deem harvested weeds approved material
		• Water content of harvested weeds may pose challenges to transportation and disposal at facility
		• Does not remove roots
			• Land area available for dewatering onsite is extremely limited
			• Potential for sediment contamination by petroleum hydrocarbons must be assessed

Expected Effectiveness	• Short Term: high • Long Term: high (multiple applications required)	• Short Term: high • Long Term: high (multiple applications required)	• Short Term: high • Long Term: high (one application required)
Approvals Required	**Provincial:** • Certified applicator • Certified supplier • Class II (Activities Designation Regulations, Environment Act) **Federal*:** • Fisheries Act* • Fisheries Protection Policy Statement*	**Provincial** • Water Approval **Federal** • Fisheries Act*	**Provincial** • Water Approval (Division I Category II) • (dredging & dewatering) **Federal** • Fisheries Act* (dredging only)
Risks	• Improper application may cause harm to humans, fish and other wildlife • Method non-selective: desirable vegetation will be affected along with weeds • Weed decomposition may lead to decreased oxygen levels; if low enough, may also lead to fish mortality • Dead plant matter left in water may also release nutrients, which may promote further plant growth • Vegetation along shoreline may be affected; this in turn may stimulate erosion.	• Significant financial investment • Plant may reproduce from cuttings; success depends on prompt & thorough cutting removal • Cuttings not collected may lead to decreased oxygen levels; if low enough, may also lead to fish mortality • Small fish and invertebrates may be killed inadvertently • Method non-selective; desirable vegetation will also be removed.	• Removal of benthic habitat of lakes • Human activities in/near the lake will have to pause during activity • Dramatic impact on aquatic organisms, environment & local ecosystem

* Conditional upon outcome of Fisheries and Oceans Canada staff assessment

Financial Considerations

The overall summary of cost estimates for the three short-term options to manage weeds in Lake Banook and Lake MicMac is presented in the following table. More detailed breakdowns of the individual options, including detailed assumptions pertaining to each, is provided in Attachment 3.

Overall Cost Estimate Summary

	Herbicide Application (1/3rd of Banook & MicMac, 62ha)	Mechanical Harvesting		Sediment Dredging and Removal
		Option 1 – Purchase & Operate	Option 2 – Contract Services	
One Year Estimated Costs	$46,000 - $61,000	*Purchase:* $96,000 - $295,000 *Operate:* $26,000 - $32,000	$182,000	$1,163,000 - $2,083,000
Five Year Estimated Costs	$230,000 - $305,000	*Purchase:* $96,000 - $295,000 *Operate:* $130,000 - $160,000	$910,000	$1,162,000 - $2,083,000

Long Term Solutions

Stantec's recommended long-term solution consists of three inter-related projects:

1. Conduct additional study to confirm the extent of sediment enrichment;
2. Conduct additional study to confirm areas in the combined watersheds of Lake Banook and Lake MicMac from which substantial sediment sources originate; and
3. Reduce sediment loading to the lakes through various source control measures.

In August 2014, staff contracted Stantec to complete a study to address the third project – sediment-loading reduction. This study will provide practical guidance to the municipality for reducing sediment inputs to Lake Banook with a focus on the improvement or management of existing infrastructure, rather than the prevention of erosion. The final deliverable of this project will include field inspection summary data, flow calculations, photographs, schematic figures indicating possible mitigation features, cost estimates and possible constraints to construction and long-term maintenance.

Community Considerations

Stantec's report was presented at a public meeting on June 26, 2014. Following Stantec's presentation, members of the public expressed a variety of views. Of these, the most common was disinterest in consideration of pesticide application. Reasons for this opposition varied, but many speakers identified concerns for the potential for negative impacts on the environment and human health. Contrary to the majority opinion, one or two individuals voiced an interest in hearing more about the pesticide application option. No interest was expressed in favour of sediment dredging.

The municipality received correspondence from Lake Management Services – Canada in late September 2014 proposing a pilot project for herbicide (diquat) application on Sullivan's Pond (see Attachment 4). Although Sullivan's Pond is immediately downstream of Lake Banook and also reportedly has abundant aquatic weeds, this proposal does not directly address the approved motion of Regional Council that forms the origin of this report, and the correspondence does not affect staff recommendations to Council.

Given the strong community opposition to the application of aquatic pesticides and high costs of sediment dredging, mechanical harvesting is recommended as the most acceptable option available for the short-term management of weeds in Lake Banook and Lake MicMac. This option can be carried out through either purchase/operate or contract service approaches, which may be assessed as follows:

Issue	Purchase / Operate	Contract Services
Equipment selection	Fixed – The purchase of a single harvester will constrain the options of the municipality to certain conditions within the lakes.	Flexible – contracted service providers may be able to provide a range of harvesters to meet varying conditions within the lakes.
Human Resources	Municipal staff do not have experience, knowledge or training to operate or maintain harvesters or associated equipment.	Qualified vendors have experienced, knowledgeable, and trained professionals available for equipment operation & maintenance.
Precedence	The purchase of capital equipment exclusively available for aquatic weed management may increase expectations for additional municipal investments in other lakes.	Hiring vendors for specific, limited-term services tends to limit the potential for increased service expectations.

Regardless of the option selected to address weed growth, the development of a management plan is a fundamental element in the future success of the chosen program. Essentially, a plan should define the problem, set priorities, identify program goals and objectives, develop the management strategy, and evaluate progress, including objective indicators of success or failure. A plan to address weed management should comprehensively consider efficacy, environmental impacts, impacts on other lake users, operational issues, regulatory requirements, communications and monitoring functions, and costs.

Next Steps

Implementation of the short-term weed control management by mechanical harvesting will require the municipality to:

1. Include the new service in the 2015/2016 Operational Budget,
2. Develop an overall management plan to articulate the objectives and scope of harvesting, monitoring, and communications plans,
3. Develop and issue a request for proposals to contract the mechanical harvesting of the weed growth,
4. Seek and receive all required regulatory approvals for the proposed harvesting program, and
5. Develop and issue a request for proposals to contract the monitoring of harvesting activities.

Preparing recommendations for long-term options for weed control on Lake Banook and Lake Micmac will require the municipality to:

1. Complete studies of the sediment enrichment and source identification impacting the lakes; and
2. Prepare design and/or behavioural solutions, and associated budgets, to reduce the sediment loading from identified sources.

FINANCIAL IMPLICATIONS

The current staffing time and effort required to prepare a comprehensive aquatic weed management plan and to consider future studies to address long-term solutions is available in cost centre D935 – Energy and Environment.

The implementation of short-term weed management controls is a new service, estimated to cost $210,000 annually ($182,000 harvesting, as quoted in the Stantec study), $28,000 monitoring & communications combined, staff estimate). The cost of this new service will be proposed through the 2015/2016 budget proposal.

The costs for development of long-term options will require short-term studies. These costs can be accommodated by Energy & Environment, D935. Recommended design solutions or other activities will be budgeted separately in future years, subject to approval by Regional Council.

COMMUNITY ENGAGEMENT

Halifax hosted a widely advertised public meeting on June 26 2014, at which approximately 50 members of the public attended, including representation from the Lake Banook Residents Association. A copy of Stantec's report to the municipality was posted to the municipal website in April 2014.

ENVIRONMENTAL IMPLICATIONS

This report responds to environmental implications of short-term and long-term options proposed for the management of weed growth in Lake Banook and MicMac.

ALTERNATIVES

1. Approve the recommendations provided for the reasons stated in the report.
2. Direct staff to pursue an option for short-term aquatic weed management other than mechanical harvesting. This recommendation is not recommended due to the cost implications (sediment dredging) and public opposition (aquatic herbicide application) stated in the report.
3. Direct staff not to pursue any short-term option for the management of weed growth in Lake Banook and MicMac. This alternative is not recommended as it will not address weed growth issues in the lakes or recreation concerns expressed by the community.

ATTACHMENTS

Attachment One:	Stantec Assessment Report, March 14, 2014
Attachment Two:	Stantec Presentation at Public Meeting June 26, 2014.
Attachment Three:	Detailed cost estimates for Short Term Weed Management Options
Attachment Four:	Letter to HRM Staff, Lake Management Services Canada, September 22, 2014.

A copy of this report can be obtained online at http://www.halifax.ca/council/agendasc/cagenda.php then choose the appropriate meeting date, or by contacting the Office of the Municipal Clerk at (902) 490-4210, or Fax (902) 490-4208.

Report Prepared by: Cameron Deacoff, Environmental Performance Officer, (902) 490-1926

Attachment 1

Assessment of Aquatic Vegetation Overgrowth in Lake Banook

Development of Mitigation Alternatives

Stantec

Prepared for:
Halifax Regional Municipality

Prepared by:
Stantec Consulting Ltd.
102-40 Highfield Park Drive
Dartmouth NS B3A 0A3
Ph: (902) 468-7777

March 14, 2014

Sign-off Sheet

This document entitled Assessment of Aquatic Vegetation Overgrowth in Lake Banook was prepared by Stantec Consulting Ltd. for the account of Halifax Regional Municipality. The material in it reflects Stantec's best judgment in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibilities of such third parties. Stantec Consulting Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Original Signed

Prepared by ____

(signature)

Elizabeth C. Kennedy

Original Signed

Reviewed by ____

(signature)

Lee Jamieson

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1.0 Introduction

Stantec Consulting Ltd. (Stantec) has been contracted by the Halifax Regional Municipality (HRM) to assess the causes and possible solutions to excessive growth of submerged aquatic vegetation in Lake Banook, Dartmouth, Nova Scotia. This report presents the results of a multiple component study to consider the causes of a sudden change in submersed aquatic vegetation growth in Lake Banook. Additionally, it proposes means to address these, and reviews solutions for aquatic biomass reduction that may be implemented in 2014.

1.1 BACKGROUND

Lake Banook is an urban freshwater lake and the first in the chain of water bodies that comprise the historic Shubenacadie Canal system. Since the late 19th century, Lake Banook has been a popular lake for competitive and recreational paddling sports. It is now home to four aquatic sports clubs, and has been the hosting lake for several competitive international aquatic sporting events.

Complaints of excessive plant growth interfering with recreation in Lake Banook were first made in 2009; anecdotal reports were of plants in previously bare areas, and an overall increase in the extent and abundance of aquatic vegetation (HRM 2011). By 2010 the excessive plant growth was reported to be adversely affecting motorized boating, swimming and paddling on the lake.

In September of 2010 a public meeting took place that resulted in the formation of a committee to devise and track a plan for addressing the problem of excessive aquatic plant growth. The committee was supported by HRM's former Sustainable Environment Management Office (SEMO); now Energy and Environment. The committee included representatives of regional council, provincial legislature, members of provincial and federal staff (Nova Scotia Environment; Fisheries and Oceans Canada), SEMO staff, affected paddling clubs, Shubenacadie Canal Commission and local residents. One of the first actions of the committee was to arrange the issuance of a Request for Information from HRM to seek market solutions to the excessive plant growth. The results of this solicitation were an offer to supply a weed harvester for approximately $200,000, or for a local construction company to supply and operate a weed harvester for approximately $200,000 per year. At this time, funding opportunities were considered.

The causes of the excessive weed growth had not been conclusively determined, but community members were concerned that it was a symptom of worsening water quality in the lake. Increasing phosphorus concentrations and sediment inputs from development and land use in the watershed were suspected to be the cause.

Some individuals (*e.g.,* Allan Billard, Banook Canoe Club, Chronicle Herald 2010; Dr. Mark Trevorrow, Dartmouth Lakes Advisory Board, HRM 2011) drew a parallel between the lowering of lake levels in 2009 for the construction of the Dartmouth trunk sewer and lane improvements in advance of the International Canoe Federation (ICF) World Championships, and the sudden increase in weed growth. During construction of the North Dartmouth trunk sewer, Lake Banook was lowered by approximately 2 meters (Terrain Group 2009).

Anecdotally, it was reported that the same phenomenon was observed following the lowering of lake levels for lane improvements in advance of the 1997 ICF World Championships, prompting the purchase of an aquatic weed harvester (personal communication with a long-time employee at the Northstar Rowing Club during field studies, November 2013).

This study is intended to determine the most likely causes of the sudden excessive weed growth through interpretation of historical water quality data in the context of watershed land-use in the past decade and in-field characterization of the current state of aquatic vegetation growth and water quality in Lake Banook.

1.2 GENERAL APPROACH

The overall approach to this study was to characterize existing conditions, evaluate findings to narrow down the likely causes of sudden plant growth, and use the results to inform the evaluation of available methods for reducing plant growth in the short (summer 2014) and long term (several years).

To characterize existing conditions, Stantec completed a desktop review of development in the watershed and water quality in Lake Banook over the past decade, as well as a field characterization of current water quality and mapping of excessive plant growth. These component studies are described in detail in Sections 2.0 and 3.0, respectively.

Section 4.0 presents a discussion of the potential causes of the sudden growth of aquatic vegetation in Lake Banook. Section 5.0 presents the evaluation of solutions available to reduce plant growth in the short (2014) and long term (several years). A high-level evaluation of options is presented for consideration of the range of opportunities available, their expected effectiveness in the short and long term, and the anticipated costs, risks and approval requirements associated with each. HRM identified preferred options from among those presented by Stantec, and these were evaluated in more detail to provide a basis for decision-making.

2.0 Watershed Study

2.1 LAND USE

To assess potential sources of anthropogenic inputs to Lake Banook, topographical data from HRM's Digital Elevation Model for the Lake Banook watershed were obtained to delineate watershed boundaries. Zoning information was then overlaid on the watershed boundaries.

Figure 1 presents the watershed boundary and zoning information. Results indicate that the majority of land use within the watershed is:

- industrial (I2);
- commercial (C1A, C1B, C2); and
- residential (R1, R4).

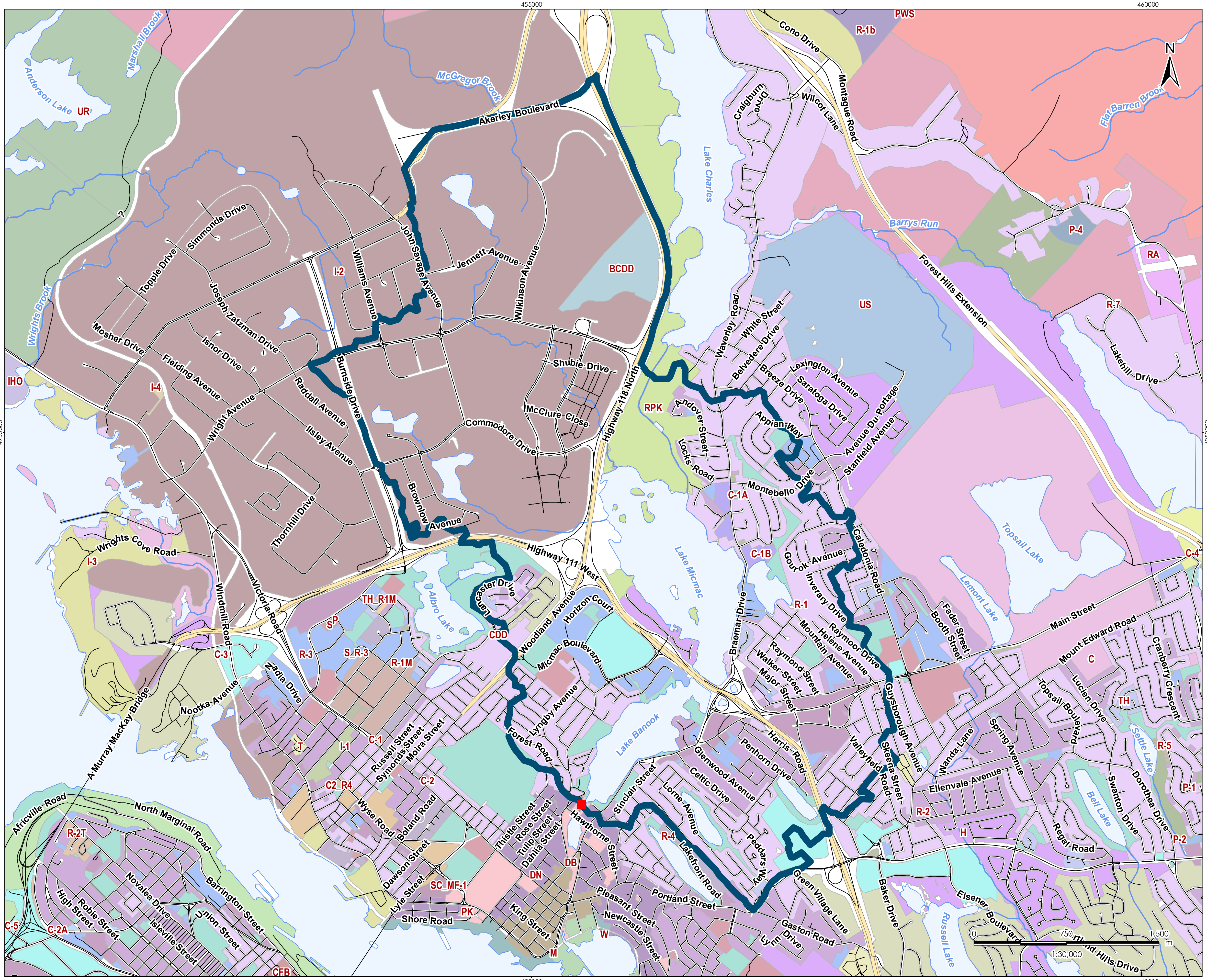
Other areas have been designated for urban development or are currently under development (*i.e.*, Urban Settlement Zone (US), Burnside Comprehensive Development District (BCDD)). The land use patterns in the watershed suggest a large and growing proportion of impervious area (*e.g.*, paved), which restricts infiltration and increases surface runoff from precipitation.

2.2 WATER QUALITY

Available water quality data for Lake Banook (Table 2.1) have consistently shown low levels of nutrients in the water column. Total phosphorus concentrations have been observed to range from non-detectable levels to a maximum concentration of 0.044 mg/L. Observed nitrate and TKN (total Kjeldahl nitrogen) concentrations have also been historically low ranging from non-detectable levels to 0.56 mg/L, and non-detectable levels to 1 mg/L, respectively. Consistent with this trend are the very low TSS (total suspended solids) concentrations, with an observed maximum of only 4 mg/L. The lake has been characterized as mesotrophic in previous studies (Stantec 2012)

In contrast, relatively high levels of total dissolved solids (TDS), specific conductivity, and chlorides have been observed. In-lake TDS concentrations have ranged from 214-675 mg/L, with specific conductivity ranging from 330-1,038 µs/cm since 2000. Since 2000, chloride concentrations have ranged from 65-210 mg/L. Generally, chloride levels in lakes of Nova Scotia should be 10-20 mg/L (McDonnell 2013). Long-term levels above 120 mg/L have been shown to be toxic to aquatic life (Canadian Council of Ministers of the Environment 2009).

The relatively high levels of dissolved constituents in the water column of Lake Banook suggest enrichment from urban non-point source inputs. However, the elevated dissolved concentrations are not accompanied by high levels of suspended parameters. This suggests that Lake Banook may be acting as a net sink for suspended particulate matter. The lack of suspended nutrients is consistent with the apparent absence of suspended algal matter in the lake and the presence of problematic species of rooted pondweeds.



Stantec

Legend

- Pour Point
- Highway
- Road
- Watercourse
- Waterbody
- Catchment

Land Use Zones

BCDD	PWS
C	R-1
C-1	R-1M
C-1A	R-1b
C-1B	R-2
C-2	R-2T
C-2A	R-3
C-3	R-4
C-4	R-5
C-5	R-7
C2_R4	RA
CDD	RPK
CFB	S
DB	SC_MF-1
DN	S_R-3
H	T
I-1	TH
I-2	TH_R1M
I-3	UR
I-4	US
IHO	W
M	
P	
P-1	
P-2	
P-4	
PK	

Notes

1. Coordinate System: NAD 1983 UTM Zone 20N
2. Base features produced under license with © CanVec, 2014; © City of Halifax, 2014.

February 2014
121511236

Client/Project
Lake Banook
Watershed Study

Figure No.
1

Title
Catchment Area & Land Use

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Revised: 2014-02-21 By: pworsell

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Revised: 2014-02-21 By: pworsell

Stantec

Legend

- Pour Point
- Highway
- Road
- Watercourse
- Waterbody
- Catchment

Notes

1. Coordinate System: NAD 1983 UTM Zone 20N
2. Base features produced under license with © CanVec, 2014.
3. Orthoimagery © First Base Solutions, 2014. Imagery taken in 2007.

February 2014
121511236

Client/Project
Lake Banook
Watershed Study

Figure No.
2

Title
Catchment Area & Airphoto

Table 2.1 Lake Banook Historical Water Quality

	Units	RDL	Historical Data													
Sample ID			**Banook Synoptic 1980**	**Banook Synoptic 1991**	**NS Lake Inventory Program 1993**	**Banook Synoptic 2000**	**HRM Sampling Program Spring 2006**	**HRM Sampling Program Fall 2006**	**HRM Sampling Program Spring 2007**	**HRM Sampling Program Summer 2007**	**HRM Sampling Program Fall 2007**	**HRM Sampling Program Spring 2008**	**HRM Sampling Program Summer 2008**	**HRM Sampling Program Fall 2008**	**HRM Sampling Program Spring 2009**	**HRM Sampling Program Summer 2009**
Sample Date and Time	DD/MM/YYYY 24hr time		14/04/1980	4/16/1991	16/07/93	28/03/2000	5/15/2006 0:00	10/11/2006 0:00	5/18/2007 12:35	8/14/2007 12:46	10/23/2007 9:25	5/2/2008 10:00	8/13/2008 7:35	10/20/2008 9:45	5/19/2009 10:30	7/28/2009 8:20
FIELD DATA																
Secchi Depth	Meters	N/A					5	3	3	4	3	3.8	3.1	6.5	2	6
Temp	Celsius	N/A	6	7.5		7.3	14.21	15.18	10.96	22.34	14.67	9.84	22.3	12.1	13.35	21.7
Dissolved Oxygen	mg/L	0.2					10.12	10.02	10.86	7.73	9.13	11.62	7.64	10.72	10.87	8.6
pH (Field)	pH	N/A	6.97	6.78	7.1	6.97	6.89	7.81	7.79	7.34	7.2	6.61	7.2	7.31	8	7.28
Specific Conductance	mS/cm	0.001	0.196	0.358	0.467	0.402	0.396	0.33	0.552	1.038	0.397	0.781	0.738	0.616	0.771	0.689
TDS	g/L	0.01						0.214	0.359	0.675	0.258	0.507	0.479	0.4	0.501	0.448
Salinity	ppt	0.01						0.16	0.27	0.51	0.19	0.38	0.36	0.3	0.38	0.34
INORGANICS																
Total Alkalinity (Total as CaCO3)	mg/L	5	9.05	9.58	15	16			29		36	22	30	34	43	34
Dissolved Chloride (Cl)	mg/L	1	55	90.8	114	92.6	92	65	140		85	210	190	160	205	190
Colour	TCU	5		10	4	5		ND	ND	ND	5	ND	7	6	ND	13
Total Kjeldahl Nitrogen (TKN)	mg/L	0.4	0.4	0.36		0.31	0.3	0.4	0.3		1	0.2	0.4	0.2	0.5	0.7
Nitrate + Nitrite	mg/L	0.05							0.25		0.08	0.3	0.08	0.07	0.2	ND
Nitrate (N)	mg/L	0.05	0.16	0.22		0.31	0.56	ND					0.08	0.07	0.2	ND
Nitrite (N)	mg/L	0.05					<0.01	ND	ND			ND	ND	ND	ND	ND
Nitrogen (Ammonia Nitrogen)	mg/L	0.05	0.02	0.007		0.007			ND		ND	ND	0.06	ND	ND	0.09
Total Organic Carbon (C)	mg/L	0.5			2.7				2		2.5	1.9	1.9	2.2	2.9	3.1
Orthophosphate (P)	mg/L	0.01	0.004	0.002	0.03	0.005			ND		ND	ND	ND	ND	ND	ND
pH (Lab)	pH	N/A							7.54		7.78	7.6	7.45	7.5	7.7	7.9
Total Phosphorus (1M depth)	mg/L	0.001	0.005	0.01		0.009	0.003	0.002	0.008	0.003	0.005	0.03	0.009	0.008	0.012	0.012
Total Phosphorus (Deep)	mg/L	0.001								0.006			0.009			0.015
Reactive Silica (SiO2)	mg/L	0.5							1.7		3.2	1.1	2.1	2.4	1.2	1.5
Total Suspended Solids	mg/L	5					3	1	3	ND	1	ND	ND	4	ND	ND
Dissolved Sulphate (SO4)	mg/L	2	6.4	5.5	18	18			21		14	25	20	19	23	21
Turbidity	NTU	0.1					0.6	1	0.7	0.5	0.8	0.6	0.8	0.5	1	0.5
Conductivity	uS/cm	1						0.33	520		410	790	740	620	803	652
METALS (ICP-MS)																
Total Aluminum (Al)	ug/L	5				0.025			22			16	ND	36		
Total Antimony (Sb)	ug/L	2							ND			ND	ND	ND		
Total Arsenic (As)	ug/L	2							2			3	5	5		
Total Barium (Ba)	ug/L	5							18			21	19	19		
Total Beryllium (Be)	ug/L	2							ND			ND	ND	ND		
Total Bismuth (Bi)	ug/L	2							ND			ND	ND	ND		
Total Boron (B)	ug/L	5							13			14	9	12		
Total Cadmium (Cd)	ug/L	0.017							ND			ND	ND	ND		
Total Calcium (Ca)	mg/L	0.1	11	10.1	14.4	13.63			23		17	22	22	21	33	18.5
Total Chromium (Cr)	ug/L	1							ND			ND	ND	ND		
Total Cobalt (Co)	ug/L	1							ND			ND	ND	ND		
Total Copper (Cu)	µg/L	2							ND		ND	ND	ND	ND	3	ND
Total Iron (Fe)	µg/L	50			0.04				57		0.03	ND	ND	ND	170	97
Total Lead (Pb)	ug/L	0.5							ND			ND	ND	ND		
Total Magnesium (Mg)	mg/L	0.1	0.2	1.4	1.8	1.74			2.6		2	3.2	2.3	2.1	2.5	2.4
Total Manganese (Mn)	µg/L	2			0.02				77		0.05	87	120	170	66	203
Total Molybdenum (Mo)	ug/L	2							ND			ND	ND	ND		
Total Nickel (Ni)	ug/L	2							ND			ND	ND	ND		
Total Phosphorus (P)	mg/L	0.1							ND			ND	ND	ND		
Total Potassium (K)	mg/L	0.1	1.2	1.3	1.3	1.1			2.1		2	2.4	2.2	2	2	2
Total Selenium (Se)	ug/L	1							ND			ND	ND	ND		
Total Silver (Ag)	ug/L	0.1							ND			ND	ND	ND		
Total Sodium (Na)	mg/L	0.1	31.5	56.2		59.2			85		58	140	120	92	99.7	97.8
Total Strontium (Sr)	ug/L	5							76			90	85	86		
Total Thallium (Tl)	ug/L	0.1							ND			ND	ND	ND		
Total Tin (Sn)	ug/L	2							ND			ND	ND	ND		
Total Titanium (Ti)	ug/L	2							ND			ND	ND	ND		
Total Uranium (U)	ug/L	0.1							0.1			ND	ND	ND		
Total Vanadium (V)	ug/L	2							ND			ND	ND	ND		
Total Zinc (Zn)	µg/L	5							8		ND	10	ND	14	256	6
MICROBIOLOGICAL																
Total Coliform Lake	MPN/100mL	2														
Total Coliform Outlet	MPN/100mL	2														
E. Coli Lake	MPN/100mL	2						ND								
E. Coli Outlet	MPN/100mL	2														
Fecal coliform Lake	CFU/100mL	2					ND	4	17	170	45	ND	110	8	6	16
Fecal coliform Outlet	CFU/100mL	2							44	320	110	ND	490	170	18	92
Fecal coliform Inlet	CFU/100mL	2									N/A	--	--	--	--	
Chlorophyll A - Acidification method	µg/L	N/A	1.54			2.01	1.42	2.15	1.96	2.66	1.42	0.84	1.23	0.73	5.53	0.48
Chlorophyll A - Welschmeyer method	µg/L	N/A						2.01	1.92	2.35	1.51	0.78	1.32	0.78	5.94	0.42

Source: Gordon et al. 1981, Keizer et al. 1993, Clement et al. 2007, and HRM Lakes Water Quality Sampling Program (2006-2011)

Table 2.1 Lake Banook Historical Water Quality

	Units	RDL	Historical Data						Fall 2013 "Dry" Data								
Sample ID			**HRM Sampling Program Fall 2009**	**HRM Sampling Program Spring 2010**	**HRM Sampling Program Summer 2010**	**HRM Sampling Program Fall 2010**	**HRM Sampling Program Summer 2011**	**HRM Sampling Program Fall 2011**	**Inlet**	**In-Lake 1**	**In-Lake 2**	**In-Lake 3**	**Outlet**	**Drainage 1**	**Drainage 2**	**Drainage 3**	**Stream**
Sample Date and Time	DD/MM/YYYY 24hr time		10/26/2009 11:00	5/19/2010 9:45	8/16/2010 10:00	11/1/2010 11:15	8/8/2011 8:55	11/8/2011 8:25	4/11/2013 11:02	4/11/2013 11:21	4/11/2013 11:29	4/11/2013 11:37	4/11/2013 11:50	4/11/2013 11:58	4/11/2013 12:07	4/11/2013 12:28	4/11/2013 12:45
FIELD DATA																	
Secchi Depth	Meters	N/A	4.3	6.9	4	7.4	3.7	5.4									
Temp	Celsius	N/A	--	14.8	22.98	10.8	21.96	--	9.25	10.57	10.56	10.41	10.33	10.81	10.36	10.4	7.04
Dissolved Oxygen	mg/L	0.2	12.15	12.09	9.16	12.47	9.34	11.22	11.78	14.21	11.91	12.63	11.27	11.2	11.65	11.54	15.29
pH (Field)	pH	N/A	7.36	7.72	8.01	7.62	7.5	7.79	9.75	8.03	7.98	8.03	7.81	7.88	7.81	7.71	5.85
Specific Conductance	mS/cm	0.001	0.493	0.679	0.669	0.607	0.63	0.402	0.504	0.554	0.558	0.556	0.554	0.557	0.556	0.553	0.003
TDS	g/L	0.01	0.32	0.442	0.434	0.395	0.41	0.261	0.328	0.36	0.363	0.362	0.36	0.385	0.362	0.359	0.002
Salinity	ppt	0.01	0.24	0.33	0.33	0.3	0.31	0.19	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0
INORGANICS																	
Total Alkalinity (Total as CaCO3)	mg/L	5	31	30	32	34	32	33									
Dissolved Chloride (Cl)	mg/L	1	123	180	173	170	168	91									
Colour	TCU	5	ND	ND	ND	ND	ND	9									
Total Kjeldahl Nitrogen (TKN)	mg/L	0.4	0.9	0.6	ND	0.7	ND	ND	0.21	0.16	0.16	0.16	0.17	0.26	0.22	0.22	0.93
Nitrate + Nitrite	mg/L	0.05	0.07	0.11	0.05	ND	ND	0.18									
Nitrate (N)	mg/L	0.05	0.07	0.11	0.05	ND	ND	0.18									
Nitrite (N)	mg/L	0.05	ND	ND	ND	ND	ND	ND									
Nitrogen (Ammonia Nitrogen)	mg/L	0.05	ND	0.08	ND	ND	ND	0.26									
Total Organic Carbon (C)	mg/L	0.5	3.4	2.5	5.2	2.7	2.9	4.6									
Orthophosphate (P)	mg/L	0.01	ND	ND	ND	ND	ND	0.07									
pH (Lab)	pH	N/A	7.8	7.9	7.8	7.7	8	7.9									
Total Phosphorus (1M depth)	mg/L	0.001	ND	0.044	0.012	0.002	0.013	0.008	ND	ND	ND	ND	ND	0.085	ND	ND	ND
Total Phosphorus (Deep)	mg/L	0.001			0.019		0.012										
Reactive Silica (SiO2)	mg/L	0.5	2.5	ND	2.1	1.8	1.1	2.8									
Total Suspended Solids	mg/L	5	ND	ND	ND	ND	ND	ND	ND	1.0	ND	ND	ND	60	ND	ND	1.0
Dissolved Sulphate (SO4)	mg/L	2	17	21	19	18	18	13									
Turbidity	NTU	0.1	0.7	0.6	1.2	0.6	0.9	0.8									
Conductivity	uS/cm	1	503	695	686	619	614	39									
METALS (ICP-MS)																	
Total Aluminum (Al)	ug/L	5	15		79		7										
Total Antimony (Sb)	ug/L	2	ND		ND		ND										
Total Arsenic (As)	ug/L	2	4		5		5										
Total Barium (Ba)	ug/L	5	16		18		15										
Total Beryllium (Be)	ug/L	2	ND		ND		ND										
Total Bismuth (Bi)	ug/L	2	ND		ND		ND										
Total Boron (B)	ug/L	5	11		9		12										
Total Cadmium (Cd)	ug/L	0.017	ND		0.054		0.045										
Total Calcium (Ca)	mg/L	0.1	18.9	25.1	31.6	23	22.7	16.3									
Total Chromium (Cr)	ug/L	1	ND		ND		ND										
Total Cobalt (Co)	ug/L	1	ND		ND		ND										
Total Copper (Cu)	µg/L	2	ND	ND	ND	ND	ND	ND									
Total Iron (Fe)	µg/L	50	95	70	76	64	55	76									
Total Lead (Pb)	ug/L	0.5	ND		1		ND										
Total Magnesium (Mg)	mg/L	0.1	2.1	2.6	3.2	2.3	2.1	2.1									
Total Manganese (Mn)	µg/L	2	45	68	41	20	52	44									
Total Molybdenum (Mo)	ug/L	2	ND		ND		ND										
Total Nickel (Ni)	ug/L	2	ND		ND		ND										
Total Phosphorus (P)	mg/L	0.1	ND		ND		ND										
Total Potassium (K)	mg/L	0.1	1.8	1.9	1.7	1.7	1.7	1.7									
Total Selenium (Se)	ug/L	1	ND		ND		ND										
Total Silver (Ag)	ug/L	0.1	ND		ND		ND										
Total Sodium (Na)	mg/L	0.1	70.5	108	125	95.6	107	66									
Total Strontium (Sr)	ug/L	5	75		123		83										
Total Thallium (Tl)	ug/L	0.1	ND		ND		ND										
Total Tin (Sn)	ug/L	2	ND		ND		ND										
Total Titanium (Ti)	ug/L	2	ND		ND		ND										
Total Uranium (U)	ug/L	0.1	ND		ND		ND										
Total Vanadium (V)	ug/L	2	ND		ND		ND										
Total Zinc (Zn)	µg/L	5	ND	ND	107	ND	ND	ND									
MICROBIOLOGICAL																	
Total Coliform Lake	MPN/100mL	2	472	83	1095	365											
Total Coliform Outlet	MPN/100mL	2	344	210	1733	345											
E. Coli Lake	MPN/100mL	2	8	2	2	11	6	10									
E. Coli Outlet	MPN/100mL	2	4	4	6	8	1	13									
Fecal coliform Lake	CFU/100mL	2	22														
Fecal coliform Outlet	CFU/100mL	2	6														
Fecal coliform Inlet	CFU/100mL	2															
Chlorophyll A - Acidification method	µg/L	N/A	2.34	1.25	1.05	1.44	5.91	1.86									
Chlorophyll A - Welschmeyer method	µg/L	N/A	2.73	1.09	0.99	1.22	5.15	1.49									

Source: Gordon et al. 1981, Keizer et al. 1993, Clement et al. 2007, an

Table 2.1 Lake Banook Historical Water Quality

	Units	RDL	Fall 2013 "Wet" Data				
Sample ID			**Inlet**	**Stream**	**Drainage 1**	**Drainage 2**	**Drainage 3**
Sample Date and Time	DD/MM/YYYY 24hr time		13/11/2013 11:00	13/11/2013 12:00	13/11/2013 11:37	13/11/2013 12:20	13/11/2013 11:11
FIELD DATA							
Secchi Depth	Meters	N/A					
Temp	Celsius	N/A	N/A	9	9.5	7.7	7.4
Dissolved Oxygen	mg/L	0.2	N/A	8.6	5.6	8	8.6
pH (Field)	pH	N/A	N/A	7.38	7.55	N/A	8.47
Specific Conductance	mS/cm	0.001	N/A	0.766	0.224	N/A	0.419
TDS	g/L	0.01	N/A	0.52	0.14	0.36	0.28
Salinity	ppt	0.01	N/A	0.5	0.1	0.3	0.3
INORGANICS							
Total Alkalinity (Total as CaCO3)	mg/L	5					
Dissolved Chloride (Cl)	mg/L	1					
Colour	TCU	5					
Total Kjeldahl Nitrogen (TKN)	mg/L	0.4	0.24	0.98	0.57	0.30	0.28
Nitrate + Nitrite	mg/L	0.05					
Nitrate (N)	mg/L	0.05					
Nitrite (N)	mg/L	0.05					
Nitrogen (Ammonia Nitrogen)	mg/L	0.05					
Total Organic Carbon (C)	mg/L	0.5					
Orthophosphate (P)	mg/L	0.01					
pH (Lab)	pH	N/A					
Total Phosphorus (1M depth)	mg/L	0.001	ND	0.021	0.021	0.023	ND
Total Phosphorus (Deep)	mg/L	0.001					
Reactive Silica (SiO2)	mg/L	0.5					
Total Suspended Solids	mg/L	5	ND	5.6	1.2	ND	ND
Dissolved Sulphate (SO4)	mg/L	2					
Turbidity	NTU	0.1					
Conductivity	uS/cm	1					
METALS (ICP-MS)							
Total Aluminum (Al)	ug/L	5					
Total Antimony (Sb)	ug/L	2					
Total Arsenic (As)	ug/L	2					
Total Barium (Ba)	ug/L	5					
Total Beryllium (Be)	ug/L	2					
Total Bismuth (Bi)	ug/L	2					
Total Boron (B)	ug/L	5					
Total Cadmium (Cd)	ug/L	0.017					
Total Calcium (Ca)	mg/L	0.1					
Total Chromium (Cr)	ug/L	1					
Total Cobalt (Co)	ug/L	1					
Total Copper (Cu)	µg/L	2					
Total Iron (Fe)	µg/L	50					
Total Lead (Pb)	ug/L	0.5					
Total Magnesium (Mg)	mg/L	0.1					
Total Manganese (Mn)	µg/L	2					
Total Molybdenum (Mo)	ug/L	2					
Total Nickel (Ni)	ug/L	2					
Total Phosphorus (P)	mg/L	0.1					
Total Potassium (K)	mg/L	0.1					
Total Selenium (Se)	ug/L	1					
Total Silver (Ag)	ug/L	0.1					
Total Sodium (Na)	mg/L	0.1					
Total Strontium (Sr)	ug/L	5					
Total Thallium (Tl)	ug/L	0.1					
Total Tin (Sn)	ug/L	2					
Total Titanium (Ti)	ug/L	2					
Total Uranium (U)	ug/L	0.1					
Total Vanadium (V)	ug/L	2					
Total Zinc (Zn)	µg/L	5					
MICROBIOLOGICAL							
Total Coliform Lake	MPN/100mL	2					
Total Coliform Outlet	MPN/100mL	2					
E. Coli Lake	MPN/100mL	2					
E. Coli Outlet	MPN/100mL	2					
Fecal coliform Lake	CFU/100mL	2					
Fecal coliform Outlet	CFU/100mL	2					
Fecal coliform Inlet	CFU/100mL	2					
Chlorophyll A - Acidification method	µg/L	N/A					
Chlorophyll A - Welschmeyer method	µg/L	N/A					
Source: Gordon et al. 1981, Keizer et al. 1993, Clement et al. 2007, an							

3.0 2013 Field Study

During November 2013, Stantec Consulting Ltd. conducted a field program with the intent of qualitatively evaluating the locations of areas with and without abundant weed growth, tributary water quality, and watershed land uses. The field program consisted of the collection of data to map out benthic vegetation cover in Lake Banook, collection of in situ water quality data (in-lake and various lake inputs), and the collection of water samples for nutrient analysis (in-lake and various lake inputs). The field work was conducted under normal "dry" conditions as well as after a rain event to capture a range of conditions. Detailed methods and results of the field studies are presented in Sections 3.1 and 3.2 below.

3.1 AQUATIC MAPPING OF LAKE BANOOK

3.1.1 Methods

On November 4th and 5th, Stantec mapped benthic vegetation growth in the lake. The purpose of this investigation was to identify and confirm areas with high levels of aquatic vegetation to help gain an understanding of conditions in the lake and to narrow down a potential cause of excessive vegetation growth.

A small vessel was used to conduct the survey throughout the lake. Transects were run across the lake and recordings were made every 50 meters to create a grid of data. At each sampling location, the abundance and species of aquatic vegetation in the area was video recorded. Geospatial coordinates of each sampling location were recorded using a handheld GPS. These points in coordination with benthic videos were used to create a map of vegetation coverage throughout the lake.

3.1.2 Results

Two species of aquatic vegetation were identified in video transects throughout Lake Banook; slender-leaf pondweed (*Potamogeton filiformis*) and clasping-leaf pondweed (*Potamogeton perfoliatus*) (Figure 3 and 4). High abundance of slender-leaf pondweed was identified in a few locations in Lake Banook including:

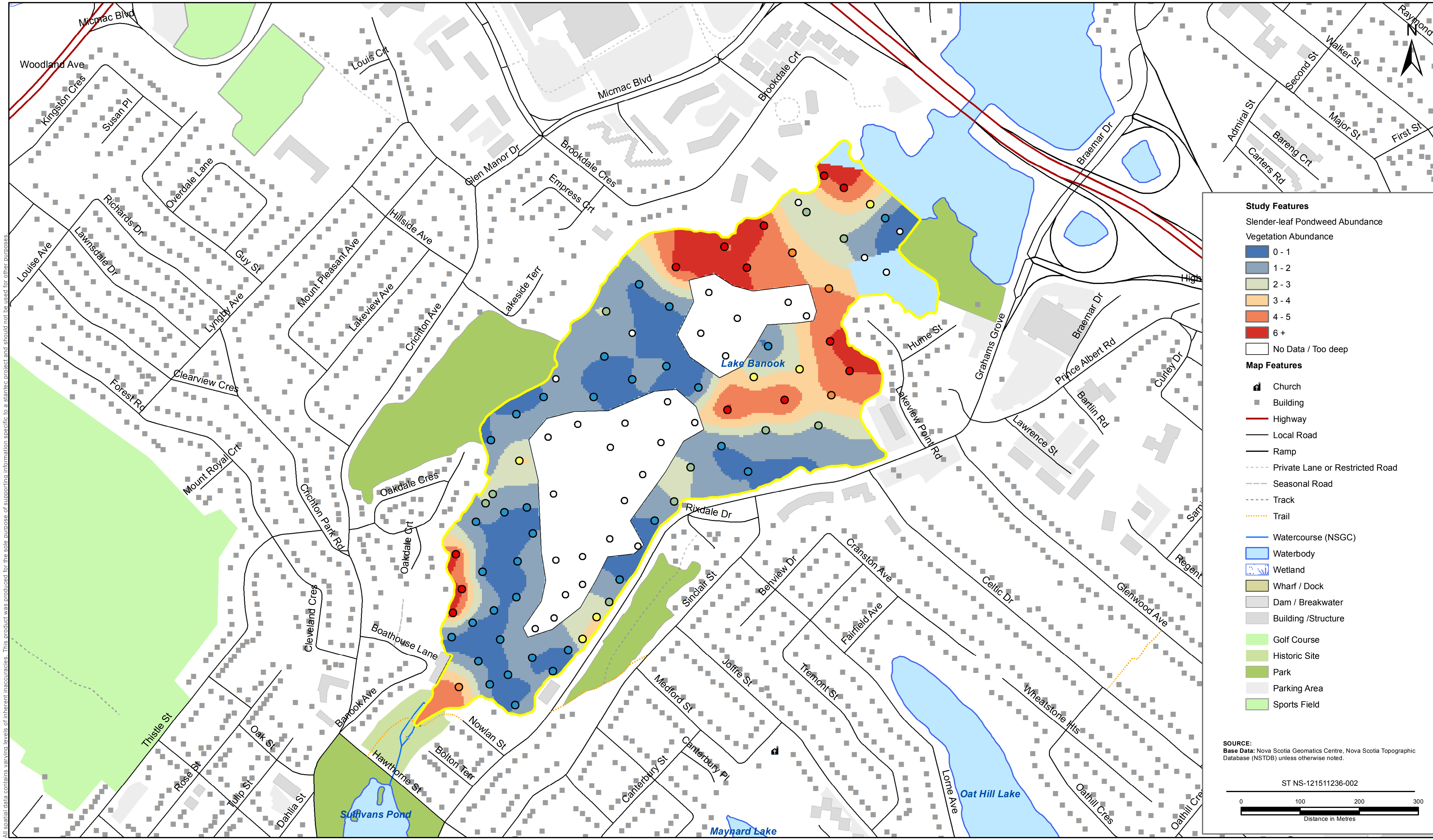
- northwest corner across from Graham's Cove Park;
- cove south of Lakeview Point Road; and
- southwest corner (nearshore) located in front of Banook Canoe Club and Northstar Rowing.

High abundance of clasping-leaf pondweed was located in the following locations of Lake Banook:

- northwest corner across from Graham's Cove Park;
- the cove south of Lakeview Point Road;

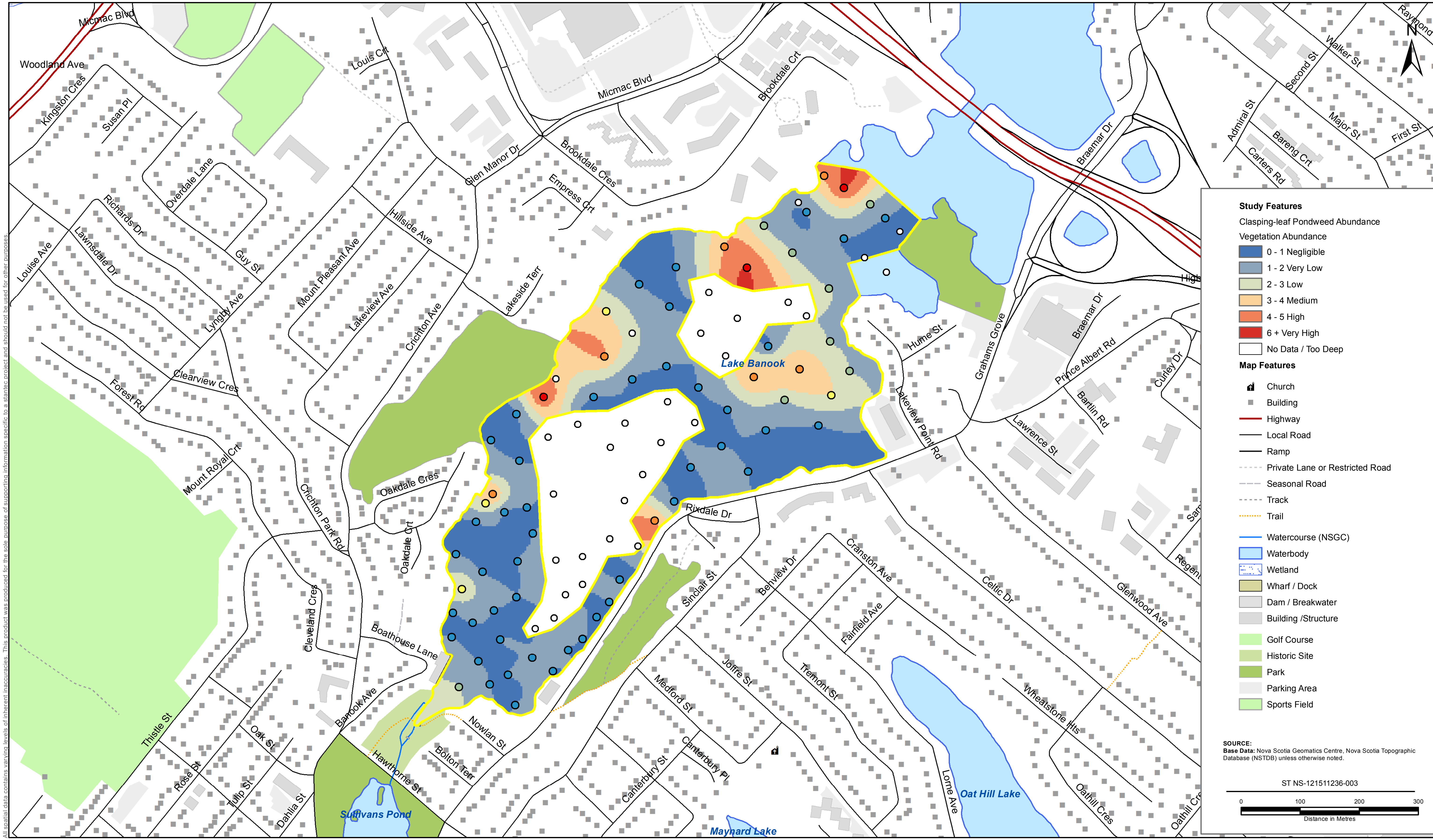
- nearshore at Birch Cove Park; and
- nearshore locations on the east and west side of southern Lake Banook.

Both species of problem aquatic vegetation were abundant in shallow and/or nearshore areas and within the photic zone. Aquatic vegetation was not observed in waters which had a depth of greater than 4 – 5 meters at the time of the study. Abundant submersed vegetation was found in soft and fine grained sediments which were suitable for root attachment. Vegetation was largely absent in areas of the lake with rocky and coarse grained sediment. Vegetation abundance was described based on the percent of substrate covered in a given survey area. Vegetation abundance was given a value of 0 – 1 (Negligible), 1 – 2 (Very Low), 2 – 3 (Low), 3 – 4 (Medium), 4 – 5 (High), and 6+ (Very High) which correspond to coverage of 0 - 20 %, 20 – 40 %, 40 – 60 %, 60 – 80 %, 80 – 95 %, and 95 – 100 % respectively.



PREPARED BY: R Sutcliffe	Banook Lake Weed Study	FIGURE NO.: 3
REVIEWED BY: C Shupe		DATE: Feb 20, 2014
CLIENT: Halifax Regional Municipality	**Lake Banook Vegetation Coverage Results - Slender-leaf Pondweed**	Stantec

File Path: V:\1215\active\121510xxx\121511236_banook_weed_study\geomatics\mapping\mxd\report\ST_NS_121511236_002_SlenderleafPondweed_20140117b.mxd



PREPARED BY: R Sutcliffe	Banook Lake Weed Study	FIGURE NO.: 4
REVIEWED BY: C Shupe		DATE: Feb 20, 2014
CLIENT: Halifax Regional Municipality	**Lake Banook Vegetation Coverage Results - Clasping-leaf Pondweed**	Stantec

File Path: V:\1215\active\121510xxx\121511236_banook_weed_study\geomatics\mapping\mxd\report\ST_NS_121511236_003_ClaspingleafPondweed_20140117b.mxd

3.2 WATER QUALITY

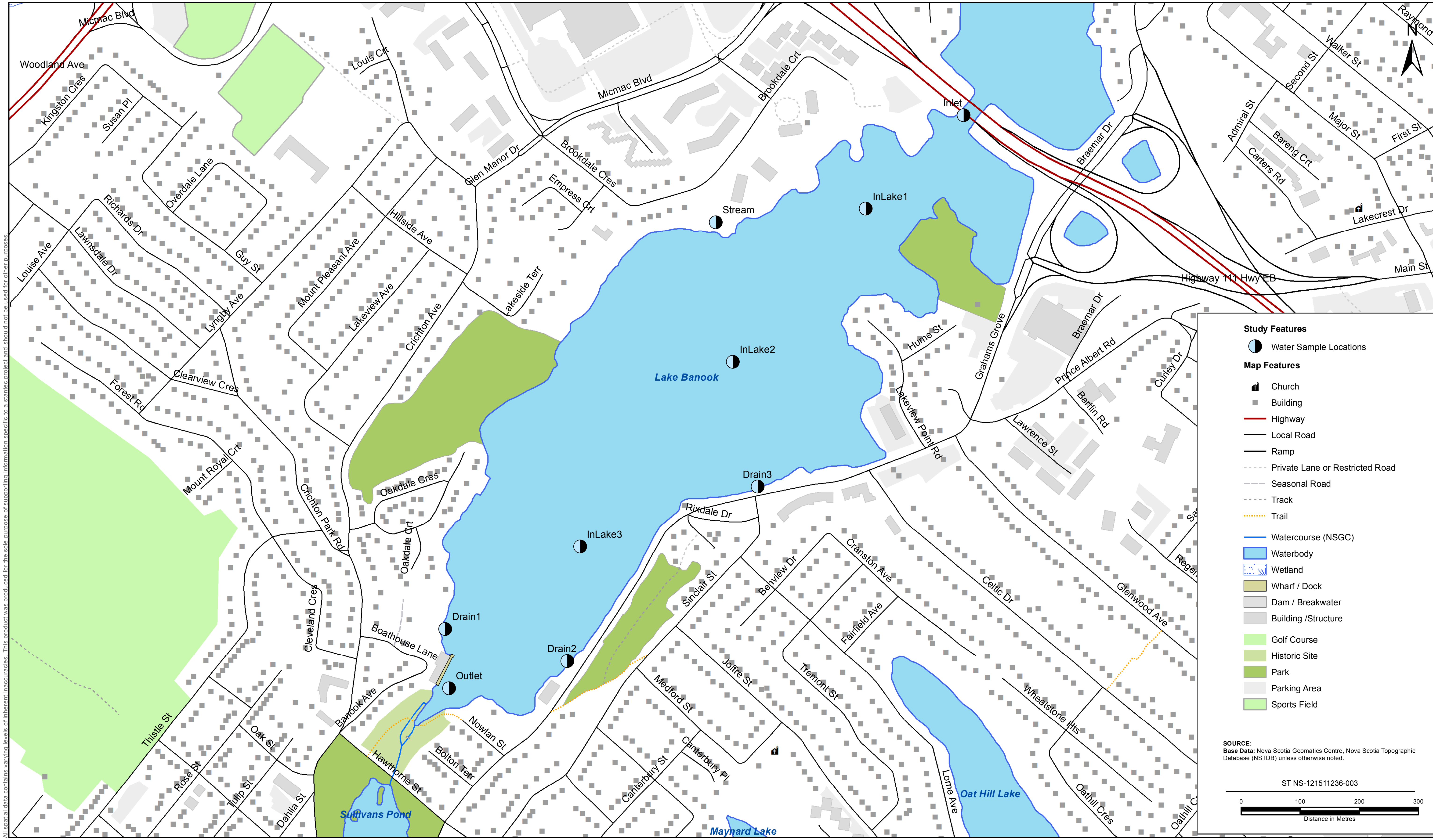
3.2.1 Methods

Water quality samples were collected under normal "dry" conditions as well as after a rain event to represent a range of conditions. Dry condition field samples were collected on November 4th, 2013 and post-rain event samples were collected on November 13th, 2013. Both in-situ water quality data and water samples were collected to characterize the water in Lake Banook. Sampling took place from a small vessel at three in-lake stations (In-Lake 1, In-Lake 2, In-Lake 3), an inlet station where Mic Mac Lake discharges to Lake Banook(Inlet), an outfall station (Outlet), three municipal drainage inputs (Drainage 1, Drainage 2, Drainage 3), and at a stream flowing into the lake (Stream: See Figure 5). Table 3.1 presents an overview of weather conditions prior to and during water quality sampling.

Table 3.1 Weather Conditions Prior to and During Sampling

November 2013						
Day	Max Temp (°C)	Min Temp (°C)	Mean Temp (°C)	Total Rain (mm)	Total Snow (cm)	Total Precipitation (mm)
November 1, 2013	16.3	13	14.7	17.6	0	17.6
November 2, 2013	13.4	9.8	11.6	0.6	0	0.6
November 3, 2013	9.8	-1.5	4.2	1.3	0	1.3
November 4, 2013	4.1	-2.6	0.8	0	0	0
November 5, 2013	5.7	-1.7	2	0	0	0
November 6, 2013	10	1	5.5	0.5	0	0.5
November 7, 2013	14.7	8.2	11.5	21.8	0	21.8
November 8, 2013	8.2	-0.2	4	0.9	0	0.9
November 9, 2013	2.2	-1.3	0.5	0	0	0
November 10, 2013	8.3	-2.8	2.8	11.5	0	11.5
November 11, 2013	5	1	3	0	0	0
November 12, 2013	6.5	-2.4	2.1	7.1	1.5	8.6
November 13, 2013	-0.7	-6.1	-3.4	0	0	0

Source: Environment Canada 2014



PREPARED BY: R Sutcliffe

REVIEWED BY: C Shupe

CLIENT: Halifax Regional Municipality

Banook Lake Weed Study

Lake Banook Water Sample Locations

FIGURE NO.: 5

DATE: Feb 20, 2014

Stantec

File Path: V:\1215\active\121510xxx\121511236_banook_weed_study\geomatics\mapping\mxd\report\ST_NS_121511236_001_FieldCollection_20140117b.mxd

A multiparameter water quality meter (YSI 600 QS) was used to collect in-situ water temperature (°C), dissolved oxygen (% and mg/L), specific conductivity (mS), pH, salinity (‰) and TDS (mg/L). The water quality meter was slowly lowered into the water column until the lake bottom was reached to log data at intervals over the entire water column. This data was then used in the field to determine if the water column was mixed or stratified. Under mixed conditions water samples were collected from one meter below the surface of the water (no stratification was observed). In-situ water parameters were recorded at all sampling stations during the dry sampling period. Wet sampling was done from the shore to assess the quality of water entering the water body from the watershed at watercourses discharging to the lake, and as a result, in situ parameters were not recorded at the in-lake stations during the wet sampling period. Water samples were collected using a stainless steel Kemmerer water sampler. Water was then transferred from the Kemmerer sampler to the appropriate sample bottle. Samples were then placed in a cooler on ice and sent to Maxxam Analytics in Bedford for analysis. Water samples were analyzed for total nitrogen (mg/L), total phosphorus (mg/L) and total suspended solids (mg/L).

3.2.2 Results

3.2.2.1 Water Sample Results

Water quality samples were collected from the Inlet, In-Lake, Outlet, Drainage and Stream sampling stations on November 4, 2013 and November 13, 2013. Data collected on November 4, 2013 represented normal flow conditions, while data collected on November 13, 2013 represented flow conditions after a precipitation event. Tables 3.2 and 3.3 below represent water quality sampling results for total nitrogen (mg/L), total phosphorus (mg/L), and total suspended solids (mg/L). It should be noted that the water column was mixed during sampling and as a result, samples were taken from 1 m below the surface.

Table 3.2 Water Quality Results from Sampling Stations on Lake Banook, November 4, 2013.

November 4, 2013											
Parameter	**Units**	**RDL**	**Inlet**	**In-Lake 1**	**In-Lake 2**	**In-Lake 3**	**Outlet**	**Drainage 1**	**Drainage 2**	**Drainage 3**	**Stream**
Total Nitrogen	mg/L		0.21	0.16	0.16	0.16	0.17	0.26	0.22	0.22	0.93
Total Phosphorus	mg/L	0.02	ND	ND	ND	ND	ND	0.085	ND	ND	ND
Total Suspended Solids	mg/L	1.0	ND	1.0	ND	ND	ND	60	ND	ND	1.0
ND = Not Detectable RDL = Reportable Detection Limit											

Table 3.3 Water Quality Results from Sampling Stations on Lake Banook, November 13, 2013.

November 13, 2013							
Parameter	**Units**	**RDL**	**Inlet**	**Stream**	**Drainage 1**	**Drainage 2**	**Drainage 3**
Total Nitrogen	mg/L		0.24	0.98	0.57	0.30	0.28
Total Phosphorus	mg/L	0.02	ND	0.021	0.021	0.023	ND
Total Suspended Solids	mg/L	1.0	ND	5.6	1.2	ND	ND
ND = Not Detectable RDL = Reportable Detection Limit					Note: In-lake measurements were not recorded as wet weather sampling was done from shore		

During normal flow conditions, total nitrogen ranged from 0.16 mg/L to 0.93 mg/L. The lowest levels were found in-lake, with moderately higher levels found in areas from municipal drainage inputs and the highest level of nitrogen found in the stream sample. Total phosphorus levels were non-detectable in all samples except for one of the municipal drainage samples, which had a total phosphorus level of 0.085 mg/L. TSS levels ranged from non-detectable to 1.0 mg/L. A level of 60 mg/L was observed at Drainage1. It is believed that this observation is an error as the same site after a rain event, showed much lower levels, when they would be expected to be higher.

Water quality results from a post rain event on Lake Banook show a very minimal increase in nutrient levels (total nitrogen and phosphorus) and TSS. The only parameter to show a large increase was the TSS levels in the Stream sample which showed over a five-fold increase from 1.0 mg/L during normal conditions to 5.6 mg/L post-rain.

3.2.2.2 In-Situ Results

Water quality profiles were recorded at each sample site on November 4, 2013. During the post-rain event, in-situ water quality was measured just below the surface, as all samples were taken from shore from the various lake inputs. In-situ measurements were analyzed against depth for temperature (°C), dissolved oxygen (% and mg/L), specific conductivity (mS/cm), salinity, TDS (mg/L), and pH. A complete list of water quality profiles for each sample location is presented in Appendix A. Water quality profiles for temperature, dissolved oxygen (%), and specific conductivity are presented in Figures 6, 7 and 8.

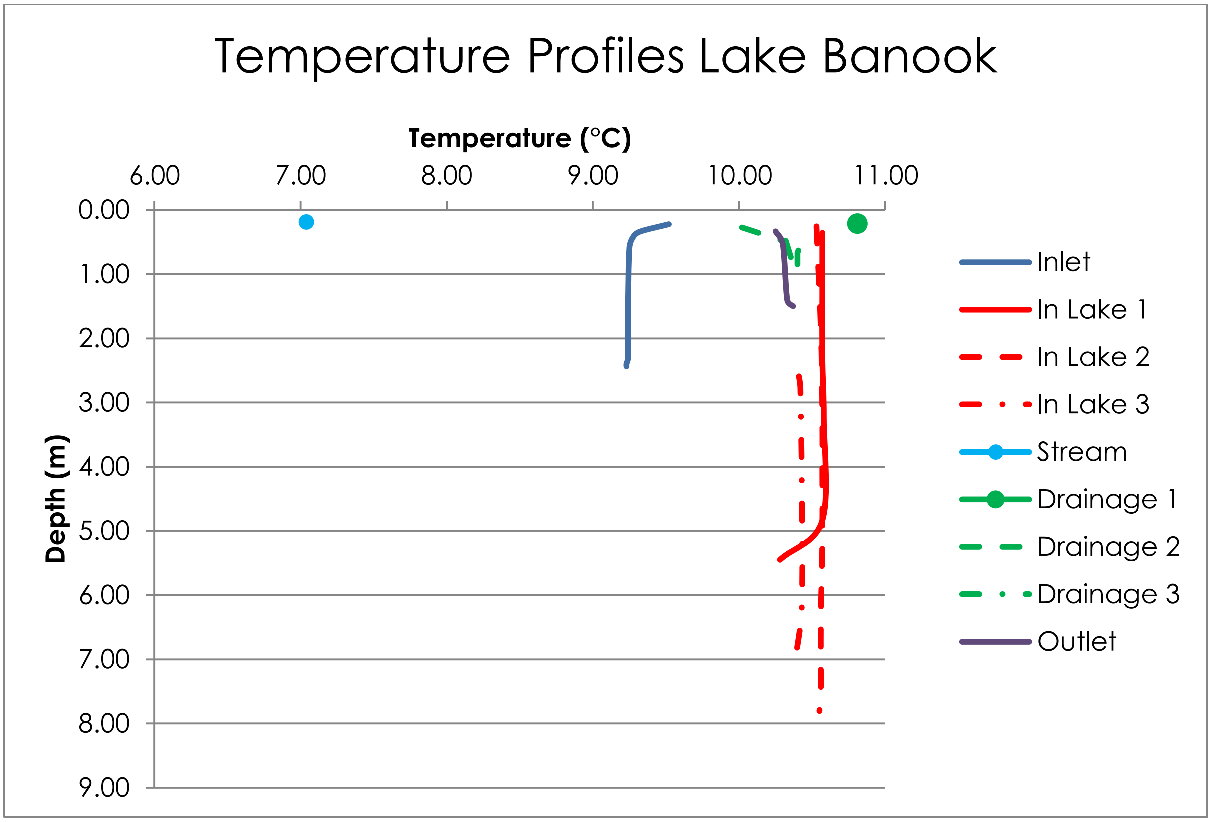


Figure 6 Temperature Profiles for Sampling Stations on Lake Banook.

The water column was well mixed on November 4, 2013. Temperature profiles were fairly uniform throughout the water column (Figure 6). Temperatures ranged from just over 7 °C to 10.8 °C. The coldest temperature was found in the Stream station, with the warmest temperature recorded at the Drainage 1 station. Overall, the In Lake stations had temperatures ranging from 10.2 to 10.58 °C. The Inlet station had slightly cooler temperatures ranging from 9.23 to 9.53 °C throughout the water column. The Drainage and Outlet sampling stations had temperatures in between the cooler Inlet Station and the warmer In Lake Stations, with the exception of Drainage Station 3. For full details on each of the temperature profiles refer to Appendix A.

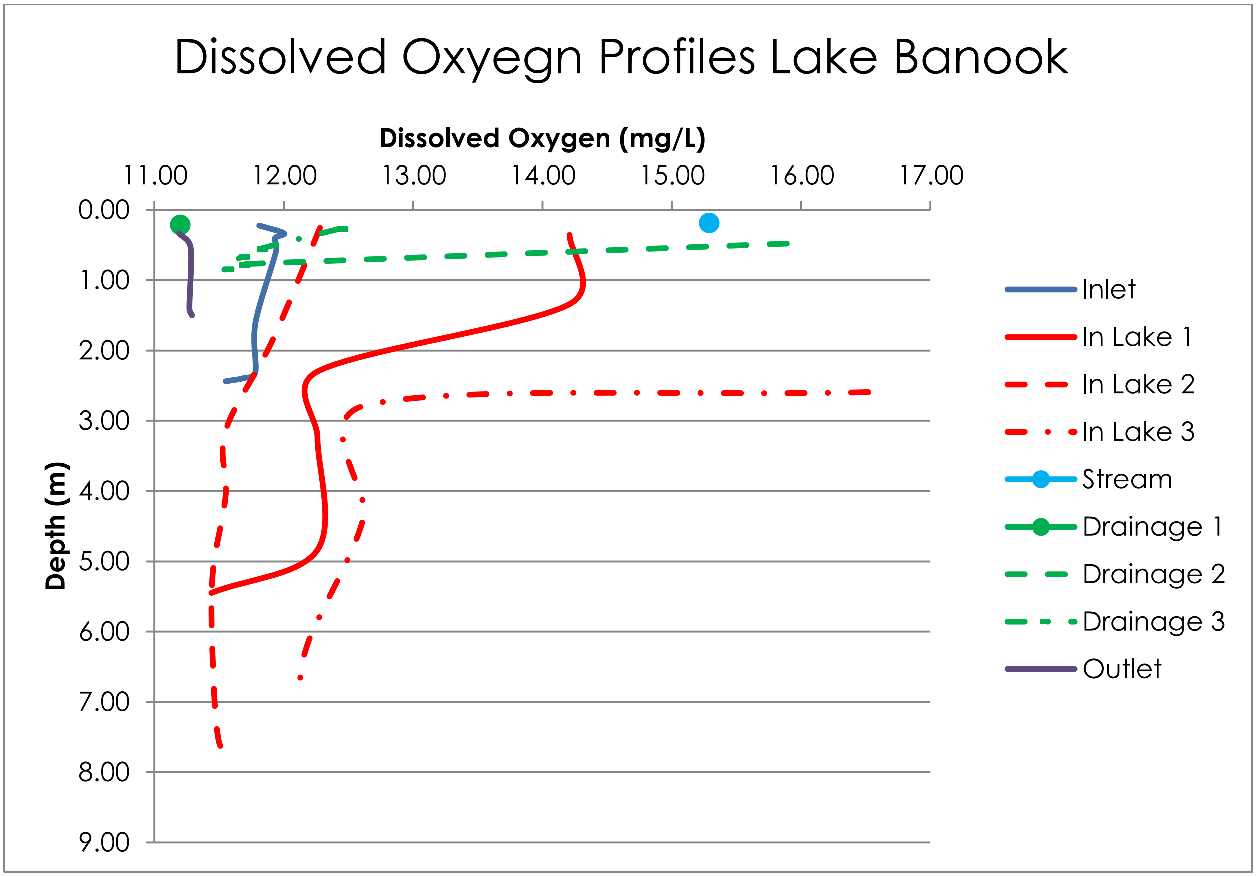


Figure 7 Dissolved Oxygen Profiles for Sampling Stations on Lake Banook.

The dissolved oxygen levels in Lake Banook and its various tributary and municipal inputs were high, ranging from just over 11 mg/L to 16.5 mg/L (Figure 7). Low temperatures and biotic activity late in the year may account for this. Dissolved oxygen levels were higher at the surface and declined with depth, which is fairly typical for oxygen levels in an aquatic environment. The lowest levels were observed in the outlet of the lake, with the highest levels being found at mid-depth at In Lake stations. For full details on each of the dissolved oxygen profiles refer to Appendix A.

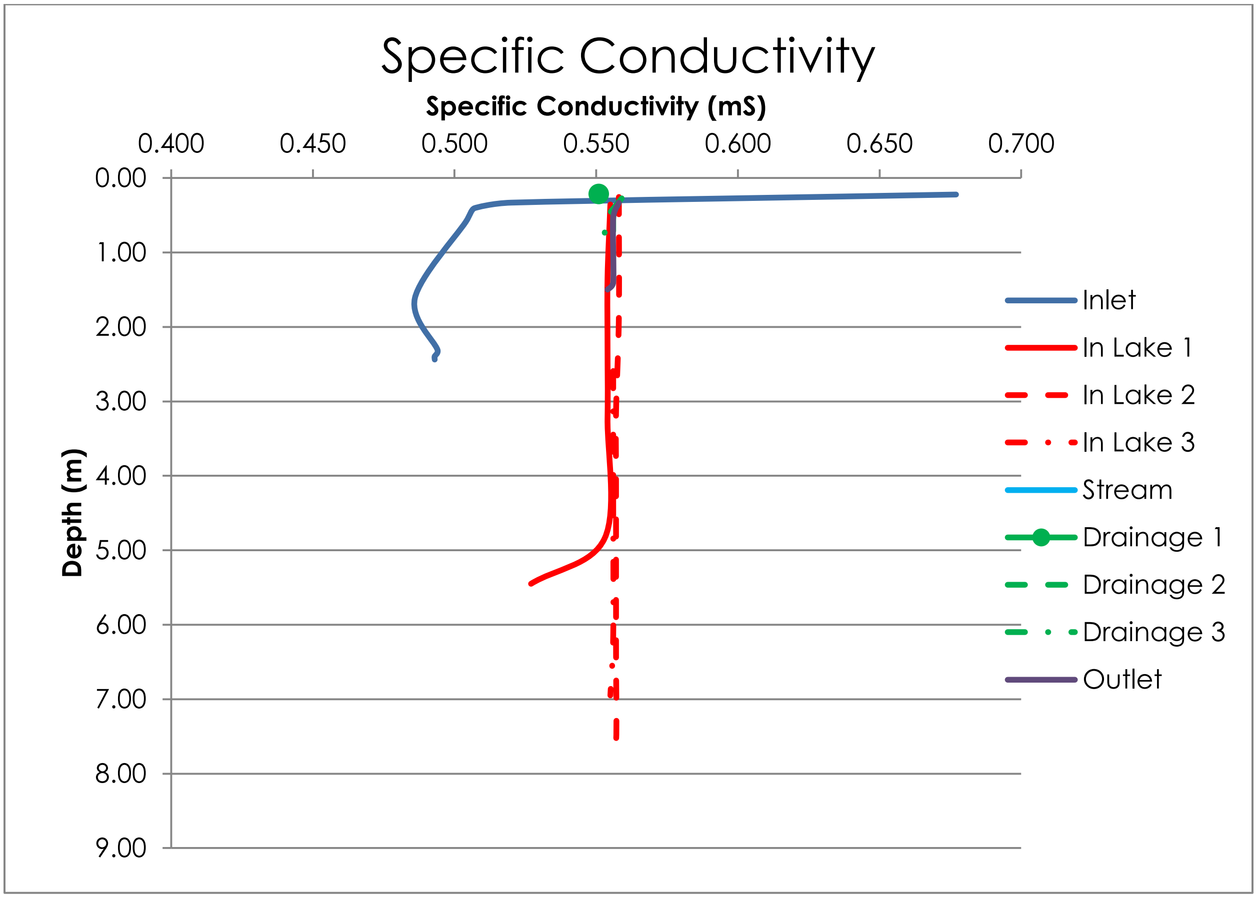


Figure 8 Specific Conductivity Profiles for Sampling Stations on Lake Banook.

Specific conductivity recorded in Lake Banook and its tributary and municipal inputs was relatively high (Figure 8). The levels observed are consistent with historical observations. Specific conductivity was recorded between 0.486 to 0.677 mS/cm. Samples were uniform with depth at approximately 0.550 mS/cm. The exception to this was in the Stream sample which was recorded to be 0.003 mS/cm. It is suspected that a mechanical error affected recording of specific conductivity in the Stream samples. The other exception was the Inlet station, which had a larger range of values throughout the depth profile. For full details on each of the specific conductivity profiles refer to Appendix A.

Profiles of salinity, TDS, and pH recorded in the lake are presented in Appendix A. Salinity concentrations in the lake were recorded to be approximately 0.27 ‰, with little variation. Levels of pH ranged from 5.85 to 9.98, with the lowest levels recorded at the Stream station and the highest levels recorded at the Inlet station. TDS levels ranged from 316 - 440 mg/L at the Inlet station. Smaller ranges of TDS, from 342 - 363 mg/L, were recorded at the In Lake, Drainage, and Outlet stations.

On November 13, 2013, water samples and in-situ water quality measurements were recorded at the Drainage and Stream sample stations in Lake Banook only (no in-lake measurements).

Temperatures ranged from 7.7 - 9.5 °C. Dissolved oxygen ranged from 50 % to 75 %. Specific conductivity levels ranged from 0.223 - 0.766 mS/cm with the highest level being recorded in the Stream sample and lower levels in the Drainage stations. Salinity found to range from 0.1 to 0.5 ‰, with the highest levels measured in the Stream. Observations of pH fell within the range of 7.38 to 8.47. TDS was observed at 520 mg/L in the Stream sample and at lower levels of 143 to 281 mg/L in the Drainage samples. It should be noted that a different YSI water quality meter was used on November 13, 2013. Both water quality meters were made by YSI using the same probes and calibrated in a replicated manner. As a result, it was not anticipated to skew results. Refer to Appendix A for full details on in-situ water quality from November 13, 2013.

4.0 Assessment of Potential Causes

A review of watershed development, historical and current water quality, and distribution and species of nuisance aquatic vegetation growth has suggested that one of the likely causes of the problem vegetation growth is the result of sediment enrichment as a result of non-point source urban sediment loading to the lake.

It has been documented that both Lake Banook and Mic Mac Lake follow a trend of increasing levels of sodium, chloride, and total phosphorus as compared to studies completed in 1980, 1991, 2000, and 2011 (Gordon *et al.* 1981, Keizer *et al.* 1993, Clement *et al.* 2007, and HRM 2014b). Although elevated total phosphorus levels are not shown by available monitoring data (Table 2.1), a general increase in TDS and chloride levels is apparent indicating that nutrient inputs do not comprise a large proportion of TDS.

As previously stated, the relatively high levels of dissolved constituents in the water column of Lake Banook suggest enrichment from urban non-point source inputs. However, the elevated dissolved concentrations are not accompanied by high levels of suspended parameters. This suggests that Lake Banook may be acting as a net sink for suspended particulate matter. The lack of suspended nutrients is consistent with the apparent absence of suspended algal matter in the lake and the presence of problematic species of rooted pondweeds.

During the Stantec field survey, two species of problematic aquatic vegetation were found to be prevalent in shallow and/or nearshore areas. Aquatic vegetation was not observed in waters which had a depth of greater than 4 – 5 meters. There is anecdotal evidence to support that increases in pondweed proliferation are related to the lowering of lake levels.

A sudden increase in the growth of aquatic vegetation was observed in 2009, and by 2010 the vegetation was reported to seriously hinder recreational activities in the lake. This sudden growth was following a significant lake drawdown in the winter and early spring season. Winter drawdown is often suggested as a means of vegetation control; freezing and drying of rooted vegetation can stress and kill overwintering plants (*e.g.,* Helfrich *et al.* 2009). However, winter drawdown can also disrupt the existing ecology if hearty species are able establish to out-compete certain species in the existing community in the stressed conditions (Wilcox and

Meeker 1991). Drawdown can also expose sediments to light, oxygen and wind disturbance, which can alter sediment biogeochemistry and the survivability of existing vegetation, creating new niches for colonization of hearty and adaptable species. The degree to which pondweed proliferation is exacerbated is dependent upon time of year and the duration of sustained lower lake levels (Thomann and Mueller 1987).

5.0 Evaluation of Solutions

The nuisance growth of rooted submersed aquatic vegetation has been attributed to a combination of sediment enrichment from non-point source urban sediment loading and disturbance ecology from water level manipulations. Control of aquatic vegetation in Lake Banook may include control of the causes (sediment loading) or control of the symptoms (aquatic vegetation bloom) or a combination of both.

5.1 LONG TERM SOLUTIONS

The problem of urban non-point source sediment loading to urban lakes is not unique to Lake Banook. Addressing the sources and transport of urban sediment to the lake is not likely to reduce aquatic vegetation growth because of the enduring effects of sediment loading. Continued or elevated sediment input may further enrich sediment and has the potential to affect phosphorus dynamics in the water column, which may in-turn lead to eutrophication.

Sediment input measured during wet weather events in November was not elevated. Inputs may be episodic or seasonal and not captured in the November sampling. Wet weather sampling of water quality entering the lake in the spring and summer may confirm whether there is a substantial source and from what area of the watershed it is originating.

Reduction of sediment loading to Lake Banook can be achieved through source control or through sedimentation/capture before release to the lake. General guidance for source control related to construction and earth moving activities is provided in the Erosion and Sediment Control Handbook for Construction Sites (Nova Scotia Environment 1988, due for revision and release in late 2014). Reduction of sources from developed areas can be improved through improved maintenance or enhancement of stormwater management infrastructure, vegetation of bare areas, and replacement of impermeable surfaces with materials that enhance infiltration where feasible.

If watershed sources of sediment are determined to be substantial, there may be opportunities for in-channel or discharge capture and settling before the sediment is released to the lake. These opportunities may include engineered or naturalized containment or plunge pools to encourage settling at the mouth of the inlet.

5.2 SHORT TERM SOLUTIONS

A phased evaluation approach was undertaken in order to determine the preferred solutions to the problem of excessive aquatic vegetation growth in Lake Banook. The first phase involved a high level summary of available technologies and methods based on their specific requirements for applicability, expectations for effectiveness in the short and long term, and associated risks. Chemical and physical/mechanical remedies were considered and biological remedies (*e.g.*, species introduction) were excluded from the evaluation at the request of HRM. The results are presented in Table 5.1.

Table 5.1 Summary of Potential Remedies

Category	Method/Technology	Description	Specific Requirements or Limitations	Expected Effectiveness in the Short Term	Expected Effectiveness in the Long Term	Risks
Chemical	**Aquatic herbicide: Endothall**	A contact, rapid acting herbicide that is applied in early spring (Helfrich *et al*, 2009). Can reduce shoot biomass and the production of turions (Poovey *et al*., 2002). More suited to whole lake or large block treatments in lakes with little wind and wave action (Johnson *et al*., 2012).	Water temperature range is an important consideration in the effectiveness of this herbicide on shoot biomass and turion formation (Poovey *et al*., 2002,Netherland *et al*., 2000). Treatment requires the use of a boat (Government of Nova Scotia).	Excellent (Helfrich *et al*., 2009). Large reduction in biomass in each year of treatment (Johnson *et al*., 2012).	Will need yearly treatments. Turion numbers should decrease with each year of treatment. Ongoing management necessary (Johnson *et al*., 2012).	Can be toxic to fish and other aquatic life. Important to note that dead plants remaining in the water will release nutrients into the lake-this can promote growth of weeds. Fish kills may also result due to reduced oxygen content caused by rotting vegetation. Lake should be treated in sections and/or combined with aeration to maintain sufficient oxygen levels for fish (NSE). Algae blooms are possible due to nutrients released when macrophytes are killed (NSE). Herbicide may also kill beneficial vegetation (Helfrich *et al*., 2009). Soil along the shoreline may be influenced by the lack of vegetation, erosion may result (NSE). May require more than five consecutive years of treatment to get rid of all turions (Johnson *et al*., 2012).
	Aquatic herbicide: Fluridone	Persistant and slow-acting herbicide that is applied in early spring. Residue can persist for 2-12 months. Expensive and will not kill algae (Helfrich *et al*., 2009).	No restrictions for fishing, swimming or human consumption. Cannot use water for crop irrigation for 30 days following application (Helfrich *et al*., 2009). Treatment requires the use of a boat (Government of Nova Scotia).	Excellent but slower acting than other two; expect to see results in 30-90 days (Helfrich *et al*., 2009). Large reduction in biomass in each year of treatment (Johnson *et al*., 2012).	Will need yearly treatments. Turion numbers should decrease with each year of treatment. Ongoing management necessary (Johnson *et al*., 2012)	
	Aquatic herbicide: Diquat	Wide-spectrum contact herbicide, applied in early spring, used to control submersed weeds. Rarely found in the water after 10 days (Helfrich *et al*., 2009). Can reduce shoot biomass as well as the production of turions (Poovey *et al*., 2002). Good for use in areas with wind and wave action as this herbicide will still reduce shoot biomass despite short exposure time (Johnson *et al*., 2012). Rapid acting and kills top growth only (NSE).	Following application, must wait fourteen days before water can be used for livestock, irrigation or drinking. One day waiting period required before swimming (Helfrich *et al*., 2009). Water temperature range is an important consideration in the effectiveness of this herbicide on shoot biomass and turion formation (Poovey *et al*., 2002; Netherland *et al*., 2000). Treatment requires the use of a boat that does NOT stir up the bottom (herbicide is ineffective following contact with soil) (NSE).	Good (Helfrich *et al*., 2009). As with other herbicides, can expect to see a large decrease in biomass in the first year of treatment.	Will need yearly treatments. Ongoing management necessary (Johnson *et al*., 2012)	
	Dye (shade)	Dyes reduce the light available to underwater plants, inhibiting photosynthesis (Roegge & Evans, 2003; NSE). Plants will still grow but as a result of diminished light intensity will have far fewer stems per turion and stems will be weak (Tobiessen *et al*., 1992).	This method is not effective when there is significant outflow (Roegge & Evans, 2003). Roots must be in water that is about 0.5-1.0 m deep; dye is not effective in depths less than 1 meter (NSE). This should be done at the onset of the growing season and the dye must persist for several weeks (Helfrich *et al*., 2009).	Productivity of most all plants in the lake will be diminished.	Several yearly treatments required to significantly impact density and distribution of plant.	Low productivity of plants will result in a change in the productivity of the system. Fish and other aquatic species may be affected.
	Alum binding (nutrient limitation)	Internal phosporus (P) loading to a eutrophic lake from sediment can continue after the external source has been removed. Dosing lake sediments with aluminum sulfate can bind P that exists in the water column and render it neutral in the sediment and unable to further contribute to excessive weed growth (Kennedy & Cooke, 1983; James, 2011).	Most effective on suspended algae. Control of nutrient inputs mandatory. May need to combine with aeration (NSE).	In the first year, can expect P to be precipitated out of water column and held in the sediment on the bottom of the pond-unavailable for uptake by plants.	Higher volumetric doses may result in effective long-term control (James, 2011). Ongoing treatments may be necessary.	
Mechanical	**Sand capping**	Black plastic sheeting is used to line the bottom of the lake and a layer of sand or gravel is used to cover the plastic. Nutrient exchange is reduced and rooted weeds are unable to establishment themselves (Helfrich *et al*., 2009; NSE).	Plastic must be perforated in order to permit gases to escape. Waterfowl nesting sites and fish spawning areas should not be covered (Helfrich *et al*., 2009). Use is restricted to smaller areas (Tobiessen *et al*., 1992)	Cap will prevent plant growth in the first year.	Very effective long term. Plant growth will be prevented so long as the cap remains.	Reduction of aquatic macrophytes will impact the ecosystem severely.

Table 5.1 Summary of Potential Remedies

Category	Method/Technology	Description	Specific Requirements or Limitations	Expected Effectiveness in the Short Term	Expected Effectiveness in the Long Term	Risks
	Mechanical Harvesting	Cutting, pulling or dredging is performed to remove plants from the problem area (Roegge & Evans, 2003). Mechanical harvesters or cutters can be used. Process must include collection of free-floating material.	Might only be temporary; elimination of the whole plant and entire root system is desirable (Roegge & Evans, 2003). Plant cuttings should be removed promptly from the lake in order to prevent propagation.	Most plant biomass can be removed in the year of harvest- results are seen immediately (Roegge & Evans, 2003).	Without multiple treatments, may not be effective over the long-term (Roegge & Evans, 2003). Unless roots are removed, success will remain short-term (NSE). Difficult to acheive long-term results.	Pondweed can propagate through cuttings; this method could intensify the problem (Roegge & Evans, 2003). Plants left in the water could contribute to further weed growth (Helfrich *et al.*, 2009).
	Water level manipulation	Manipulating the water level of the lake during the fall and winter months will expose the aquatic vegetation to harsh conditions (Helfrich *et al.*, 2009) Method 2: Drain lake to allow suspended solids and phosphorus to exit the system (Shantz *et al.*, 2004)	Water level would need to be altered during the fall/winter. Mud on the bottom of the pond should freeze up to 10 cm and weeds should be physically removed (Helfrich *et al.*, 2009)	Likely to see results in the year following the water level drawdown.	Unsure of long term success; recolonization may occur. Other management tools may be necessary. Repeat treatments may be required.	
	Sediment Dredging/Removal	The removal of the sediments on the bottom or along the shoreline of the lake. This method can also physically remove plants as well as nutrients required for plant growth. Dredging can be done following lake drainage or by using draglines (Helfrich *et al.*, 2009).	Severe disruption of the habitat and human activities occuring on/near the lake. Depth at which plants typically grow as well as water clarity are determining factors of whether dredging will work to reduce pondweed. Space for a settling lagoon may be necessary (NSE; Tobiessen *et al.*, 1992).	Physical removal of the plants will result in a decrease of biomass in the first year (Tobiessen *et al.*, 1992).Dredging may also disrupt/remove turions buried in the soil, which would minimize pondweed growth in the following year.	Long term success may be possible. Plants may grow the year after dredging but at a much smaller density and biomass (Tobiessen *et al.*, 1992).	Glacial boulders may be present in area from shore up to 5 m water depth (Huppertz *et al.*, 2008).
	Shading	A dark colored geotextile material can be attached to floats. This device can be positioned near dense areas for spot treatment. The float creates shade and decreases the amount of light reaching the plants (Helfrich *et al.*, 2009). Plants may still grow but as a result of diminished light intensity will have far fewer stems per turion and stems will be weak (Tobiessen *et al.*, 1992).	Must be in place for at least a month to be effective (Helfrich *et al.*, 2009), and floast must be well anchored (NSE). Timing would be key in order to limit the light available to plants during turion formation. Limited to smaller areas, and area being treated is unusable while floats are in place (NSE).	May reduce plant productivity and turion development in the first year.	More likely to see results in consecutive years and with continued treatments.	May not be effective in reducing pondweed populations. May influence other plant species.
Biological	**Species introduction**	**Not Considered in this Study**				

5.2.1 Evaluation of Potential Remedies

The second phase of evaluation involved a review of the potential remedies in the context of the understanding of the causes of excessive aquatic vegetation growth (Section 4.0) to identify the remedies that are expected to provide the best results given the conditions present. Based on the results of the watershed study (Section 2.0), field study (Section 3.0), and the evaluation of causes (Section 4.0) the following assumptions were made in this phase of the evaluation.

- the lake is mesotrophic (Stantec 2012) and the water column is not a significant source of excess nutrients to rooted aquatic vegetation growth;
- the sediment of the lake is enriched and a hospitable medium for rooted aquatic vegetation;
- the source of the enriched sediment is non-point source loading from the watershed which has settled out of the water column; and
- lake-drawdown events may have allowed aquatic macrophytes to establish and proliferate.

Table 5.2 presents the results of the second phase of remedy evaluation, based on the interpretation of the findings of research presented in Table 5.1.

Table 5.2 Evaluation Summary of Expected Effectiveness of Potential Remedies

Remedy Option	Evaluation Results	Expected effectiveness
Herbicide (*e.g.*, Endothall, Fluridone, Diquat)	Herbicide has potential to stunt early season growth and prevent the plants from reaching the top of the water column and access to sunlight. After several years of application, established roots may perish and vegetation may be inhibited from reestablishing due to insufficient light penetration.	Expected to be effective in the short term. Single application will not result in long term effectiveness
Dye (chemical shading)	Reducing vegetation access to sunlight by treating the lake with a dye may induce plant mortality. Decomposition of plants in-situ will further enrich sediments and exacerbate the problem.	Not expected to be effective in the long term. May be somewhat effective in the short term
Alum binding (nutrient limitation)	This is an effective means of removing phosphorus from the water column and preventing re-suspension. The rich sediments in which rooted vegetation are established may be capped, but existing rooted vegetation would likely persist.	Not expected to be effective in the short or long term
Sand capping	This is a means of preventing re-suspension of phosphorus sediments into the water column; however water column phosphorus concentrations are not a concern. The established rooted vegetation would likely persist through the sand cap.	Not expected to be effective in the short or long term
Mechanical Harvesting	Mechanical harvesting will provide an immediate reduction in aquatic biomass. Repeated harvesting to	Expected to be effective in the short

Table 5.2 Evaluation Summary of Expected Effectiveness of Potential Remedies

Remedy Option	Evaluation Results	Expected effectiveness
	prevent the plants from gaining access to sufficient sunlight in the upper portions of the water column may result in the death of the established roots, and vegetation may be inhibited from reestablishing due to insufficient light penetration if water levels are maintained.	and long term
Water level manipulation	Stressing vegetation may reduce vegetation growth in the short term, but it is expected that the rooted vegetation would migrate or adapt to the deeper water levels in the long term. Would result in flooding of existing shore-based infrastructure and recreation areas. This is also an applied means of expelling phosphorus from the system to reduce in-lake recycling of phosphorus. Low phosphorus levels in the water column indicate that lake discharge will not be a significant export of phosphorus from the sediment.	Not expected to be effective in the short or long term
Sediment dredging / removal	Removal of enriched sediment and established rooted vegetation would provide immediate and long-term reduction in rooted aquatic vegetation in problem areas.	Expected to be effective in the short and long term
Physical shading (*e.g.*, tarps)	Shading vegetation using physical barriers (weighted or floating tarps) may cause plant mortality. Decomposition of plants in-situ will further enrich sediments. This method is intended for small, confined areas of weed growth where remediated areas will not be quickly recolonized by adjacent weed growth. This method is labour intensive and could create additional safety hazards to boaters and swimmers in the lake.	May be effective in the short term in small patches. Not expected to be effective in the long term

Three remedies with the highest potential for effectiveness were selected for detailed evaluation, including herbicides, mechanical weed harvesting, and sediment dredging.

5.2.2 Detailed Evaluation of Preferred Remedies

The third phase of evaluation was a more detailed investigation into each of these options, particularly with respect to physical requirements for implementation, costs and approval requirements. The results of this detailed evaluation of the three preferred remedies (herbicide, mechanical weed harvesting, and dredging) are presented below.

5.2.2.1 Herbicides

Description

Aquatic herbicides can be effective at controlling vegetation at small concentrations, and harm to fish can be minimal when administered properly. Pondweed produces axillary turions (an overwintering bud) that detach from the plant, fall to the bottom of the waterbody, and enable the plant to reproduce the following spring (Poovey *et al*. 2002). Effective long term control of aquatic vegetation often depends on the ability to interrupt turion development and dispersal. Aquatic herbicides have been found to inhibit turion production, in addition to reducing biomass in pondweed (Johnson *et al.* 2012).

There are two types of aquatic herbicides; systemic and contact. Contact herbicides are lethal to any plant cell it comes in contact with. This type of herbicide works within the plant to kill internal plant tissues or roots (Avery 2003). Contact herbicides are quick-acting and can quickly reduce visible the biomass of aquatic macrophytes. They are non-selective and most effective on annual herbaceous plants (Avery 2003). Some examples include Diquat and Endothall.

Diquat is a contact herbicide that is fast acting and non-selective. This herbicide is still effective in areas that have wind and wave action as a long exposure time is not necessary. Diquat only effectively kills top growth (the vegetative portion of the plant) and does not typically destroy the roots (Washington State Department of Ecology 2013). As a result, plants can reproduce from root systems that remain following treatment. Diquat is applied as a liquid solution to the water column.

Endothall is a contact herbicide suited to whole lake or large block treatments in waterbodies with little wind and wave action, but can also be used for spot treatment as it is promoted as fast-acting (Washington State Department of Ecology 2013). Endothall is typically used for one-season treatment of weeds. Exposure period is critical when using this herbicide and success of the treatment is related to exposure period (Netherland *et al.* 2000). Exposure time required for adequate biomass injury >85% depends on the concentration of herbicide applied, and can range from 12-48 hours (Netherland *et al.* 1991).

Systemic herbicides take longer to have a notable impact on aquatic vegetation because they require uptake (absorption) by the plant in order to have an effect (Avery 2003). This type of herbicide is more effective in controlling perennial plants (both clasping- and slender-leaf pondweeds are perennials) and is generally more selective in which species it affects (Avery 2003). Fluridone is an example of a slow-acting, non-selective, systemic herbicide. Results are expected within 30-90 days and a specific concentration needs to be maintained (Helfrich *et al.* 2009). It is not effective in spot treatments that are less than 2 ha and may be better suited to whole-lake treatments (Washington State Department of Ecology, 2013).

<u>Specific requirements</u>

Time of year, temperature of the water, windspeed, and movement of water within the system are all important variables in the efficacy of an herbicide treatment. Interruption of turion production is especially important in long-term management of pondweed (Netherland *et al.* 2000). Treatments may need to be administered each year for several years in order to lower the abundance of pondweed within the lake.

Timing of application:

Plants are most susceptible to herbicidal treatment when they are young and actively growing (Lembi 2009). Therefore, it is recommended that aquatic herbicides be applied in early spring (Johnson *et al.* 2012). Less plant biomass will have accumulated at this time compared to later in the spring or in the summer, which will limit the amount of decaying plant matter in the lake following treatment. Application of herbicides during the late spring or summer imposes a serious risk to fish, due to extensive plant growth, warmer temperatures, and slow moving water (Lembi 2009).

The temperature of the water cannot be too cold, or the herbicide will be rendered ineffective; 18-20.5 degrees Celsius is the recommended range for application (Netherland *et al.* 2000). Diquat and Endothall have been found to be most effective at 25 degrees Celsius. However, both are found to be effective at 18 degrees Celsius as well, which means that application can occur before other vegetation in the lake has started to grow and will enable control of the weed's ability to form turions. Typically Nova Scotia urban lake surface temperatures begin to reach 18 degrees Celsius around June. Bottom temperatures typically lag behind surface temperatures and monitoring would be required to determine when the entire water column is above the desired temperature.

It is important to apply aquatic herbicides when wind is at a minimum. Depending on which herbicide is used for treatment, consideration of outflow and amount of suspended sediment are important variables in predicting and understanding the success of each treatment.

How it is applied:

Aquatic herbicides are available in granular and liquid form, both of which can be used to treat submersed weeds. Most are formulated as liquids, which can be sprayed over the surface of the lake from a spray tank mounted on a boat or a small backpack-style tank (Avery 2003). The herbicide is applied directly to the water's surface. Lake can be treated in sections (either 1/4, 1/3 or 1/2), or in whole lake treatments. Granular forms can be applied from the shore or a boat using a hand spreader or a hand scoop. There are important considerations when choosing equipment with which to apply the herbicide, such as using chemical resistant hoses and wearing proper protective equipment (Avery 2003).

Specific requirements for each of the herbicide types evaluated:

Endothall — Temperature of the water should be in the range of 18-25 degrees. Temperatures in the cooler end of this range are recommended in order to affect plants before turion production commences. Long contact times may be required for endothall herbicides to be effective. Use of Endothall does not require restrictions for swimming in the lake, but 3 day restrictions are required for fishing and 7 days for irrigation.

Diquat	Temperature of the water should be in the range of 18-25 degrees. Following application, fourteen days are required before the water can be used for livestock, irrigation or drinking. Fishing is restricted for one day after application, and a restriction of 2-3 days is recommended before the lake is used for irrigation or swimming (Helfrich *et al.* 2009). There must be very little suspended sediment in the water column, as herbicide is ineffective once in contact with soil (Government of Nova Scotia *no date*).
Fluridone	Temperature of the water should be in the range of 18-25 degrees. No restrictions are recommended for fishing, swimming or human consumption, however the water cannot be used for crop irrigation for 30 days following application (Helfrich *et al.* 2009).

It is recommended that use of the lake be restricted during application of any herbicide.

<u>Risks</u>

Extreme care must be taken during application of herbicides. Improper application may cause harm to humans, fish and other wildlife. Most aquatic herbicides are not directly toxic to fish when applied properly, but fish may be killed indirectly through suffocation when oxygen concentration is diminished by rotting vegetation (Government of Nova Scotia *no date*). The lake can be treated in sections and/or combined with aeration to maintain sufficient oxygen levels for fish (Government of Nova Scotia *no date*). Dead plants remaining in the water will also release nutrients into the water which can promote further weed growth and/or algae blooms.

Herbicide may also kill beneficial vegetation (Helfrich *et al.* 2009). Soil along the shoreline may be influenced by the lack of vegetation, and erosion may result (Government of Nova Scotia *no date*). Five consecutive years of treatment may be necessary to get rid of all turions and eliminate the species from the lake (Johnson *et al.* 2012).

<u>Approvals required</u>

The application of an aquatic herbicide falls under the direction of the Pesticide Regulations made under Section 84 of the Nova Scotia *Environmental Act*. These regulations qualify persons certified to sell, supply or distribute pesticides/herbicides as well as those persons certified to in the application of pesticides/herbicides. A person holding a Class V Aquatic Vegetation Certificate "authorizes the use of an herbicide by ground application for the control of aquatic weeds including the use of an herbicide in a lake, river, irrigation canal or ditch".

Herbicide application activities require a Class II approval under the Activities Designation Regulations, this approval application is to be completed in addition to the individual's herbicide applicator certificate and serves to provide notice to the Nova Scotia Environment that the herbicide application is to be conducted and that the environmental controls to avoid unwanted pesticide release have been undertaken. There are no exemptions from this permit.

As part of the application of herbicides in the aquatic environment, public notification may be required up to 30 days prior to the application via signage or notices in newsprint.

If an herbicide application program is selected as a treatment option for Lake Banook, it is recommended that DFO is consulted on the proposed herbicide program to evaluate the effects of the herbicide on the local fish community and whether a Fisheries Act authorization is required. The recent changes to the Fisheries Act and updated Fisheries Protection Policy Statement alter the focus from habitat protection to fisheries protection. Specifically the prohibitions relate to the death of fish species that are part of a commercial, recreational or Aborignial fishery and include species that support such a fishery. The changes to the Act did not eliminate habitat protection, though current prohibitions apply to projects that permanently alter or destroy fish habitat in such a scale that limits the ability of fish to use such habitats.

The changes to the Act encompass a broad number of species and habitats and are largely untested. On that basis, it is advised that DFO is consulted prior to implementing an herbicide program.

Costs

Table 5.3 presents a summary of estimated costs for herbicide treatment in Lake Banook each year. These estimates will vary depending on treatment rates and water depth. Other variables include shipping costs and whether liquid or granular form is desired. These estimations do not take into account the costs for equipment required in applying the herbicide. It is assumed that application can be completed by boat in one day by a team of two. Labour and boat rental are expected to range from $1000-$2500 per application.

Table 5.3 Estimated Costs of Herbicide Treatment, Lake Banook (Canadian Dollars)

Herbicide	Cost per ha	Cost for 1/3 of lake (approx. 16 ha)	Cost for 1/2 of lake (approx. 24 ha)	Whole Lake Treatment (47 ha)
Endothall	$1,730 - $ 2,470	$ 28,000 - $ 40,000	$ 42,000 - $ 60,000	$ 81,500 - $ 116,000
Fluridone	$990 - $1,850	$ 16,000 - $ 30,000	$ 24,000 - $ 45,000	$ 46,500 - $ 87,000
Diquat	$740 -$990	$ 12,000 - $ 16,000	$ 18,000 - $ 24,000	$ 35,000 - $ 46,500
Summary	**$740 - $2,470**	**$ 12,000 - $ 40,000**	**$ 18,000 - $ 60,000**	**$ 35,000 - $ 116,000**

Estimates are adapted from Washington State Department of Ecology 2013; and supplier websites

Annual costs are expected to range from $36,000 to $ 119,000 per year. Multiple years of application would be expected.

5.2.2.2 Mechanical Weed Harvesting

Mechanical harvesting involves the use of a vessel equipped with submersed reciprocating blades and a collection system to mow and collect aquatic biomass for disposal. When on-vessel storage of the biomass is at capacity, it is transported to a dump truck *via* a shoreline conveyor. Results are apparent immediately following cutting, but several treatments may be required per season.

Harvested material would be transported to the Miller Composting Facility in the Burnside Industrial Park, Dartmouth. In order to dispose of the harvested vegetation at this facility, the plant material would have to be approved as an acceptable material for the facility. There is no limitation on the amount of material that can be brought to the facility, assuming the harvested vegetation has been deemed an approved material.

As the vegetation is being harvested from a lake, water content may pose an issue for transportation and disposal. Further discussion with the plant manager is necessary to understand more specific limitations regarding the nature of the harvested material.

<u>Specific requirements</u>

Plants can be harvested at any time during the growing season, assuming open water conditions exist. Harvesting can happen as often as required. The water body is usable immediately following harvesting.

The harvester has reciprocating knives mounted on a harvesting head that cuts the vegetation and then transfers it to a conveyor system that moves the cut vegetation into onboard storage. When the storage area is full, the plant biomass must be transferred *via* a shore conveyor to a dump trunk on shore. The plant biomass can then be taken to an appropriate disposal site.

<u>Risks</u>

Long-term control with this method involves a significant financial investment. Harvesting can be labour intensive and slow, depending on the density of plant growth. Fragmentation of the plants is a risk as pondweed can reproduce from cuttings. Success depends on the prompt removal of cuttings from the lake (Helfrich *et al.* 2009). Any plant material left in the water will decompose, reducing oxygen levels in the water which can lead to fish mortality (Helfrich *et al.* 2009). Small fish and invertebrates may also be trapped within the plant material and will be affected by the harvesting.

Harvesting the material may be difficult near docks and shorelines and manual cutting and removal may be required to clear vegetation from these areas.

Harvesting in this method is non-selective and desirable vegetation will be removed with the undesirable vegetation.

Approvals required

The removal of aquatic vegetation using mechanical harvester would require approval from NSE. Under the Activities Designation Regulations made under Section 66 of the *Environment Act* "the use of equipment in the water course or three meters from the edge of the watercourse" requires a Water Approval from NSE. This Division I Category I Water Approval provides notice to NSE of when and where the vegetation removal is to be conducted and that environmental controls are in place to mitigate environmental damage or unwanted releases of sediment and hydrocarbons. NSE may forward the Water Approval Application on to the Department of Fisheries and Oceans (DFO) who will assess whether potential effects on fish, fish habitat or aquatic Species at Risk are possible. Should DFO determine that serious harm to fish or fish habitat is likely from harvesting activities; and these effects cannot be eliminated by avoidance or mitigation, a *Fisheries Act* authorization may be required. Under the *Fisheries Act* authorization an offset plan must be submitted DFO in which the proponent identifies the offset measures used to counterbalance the loss of fish and fish habitat. The offset measures are variable though can include habitat restoration of the affected area, habitat creation in a new area, fish stocking or in remote locations complementary measures such as data collection and scientific research. The offsetting plan was formerly conducted under a Harmful Alterations Damage or Destruction (HADD) authorization.

The Water Approval Application has a maximum waiting period of 60 days by which time NSE must return a formal Approval with conditions, a request for more information/clarification or in rare cases a rejection of the application. The time line for a *Fisheries Act* authorization is significantly longer, DFO has up to 60 days to determine if the submitted *Fisheries Act* authorization is complete. From the date of the determination DFO has an additional 90 days to issue an authorization or deny the application.

Costs

A weed harvester can be purchased, operated and maintained by HRM, or a company can be contracted to perform this service. Both options are evaluated here.

Purchase

A variety of models are available that range in price from $56 000-$230 000 CAD. Shipping would be an additional $2000-$3000 assuming a smaller model was purchased and no permits were required for the transportation process. Manufacturers and distributers are located in Ontario and New York State, with a range of diesel-powered machines and offer rust-proof, stainless steel models (Lawrence Hirstwood, Aquamarine in Ontario, Personal Communication, Jan. 29/14).

In addition to the mechanical harvester, other equipment is required. Shore conveyors and trailers designed to work together with the harvester make transport of the biomass from the harvester to the disposal site efficient and controlled. A shore conveyor will allow the transfer of plant biomass from the harvester to a dump truck, stationed on land. The biomass can then transported to an approved facility, in accordance with the HRM regarding proper disposal of solid waste (HRM by-law S-600). A custom trailer is required to transport the harvester upon removal from the lake.

The following is a summary of the expected ranges of capital costs for a mechanical harvester and associated equipment:

Estimated cost of a mechanical harvester:	$56 000 - $230 000
Estimated cost of a shore conveyor:	$33 000 - $40 000
Estimated cost of a trailer:	$5 000 - $15 000
Estimated cost of delivery:	$2 000 - $10 000

Total capital for purchase is expected to range from $ 96,000 to $ 295,000, depending on the size of machine purchased.

Operation costs include the labour, transport and disposal associated with weed harvesting. For estimation purposes it is assumed that

- harvesting would be required for 9 ha of the lake (based on Figures 3 and 4);
- wet biomass in harvested areas is 7.5 ton/ha (adapted from McComas and Stuckert 2008);
- harvesting would be required three times per year;
- harvesting is completed at a rate of 5 hr/ha (adapted from McComas and Stuckert 2008); and
- biomass would be disposed at the Miller Composting Facility at $75/ton (HRM 2014).

Estimates of operation costs are summarized in Table 5.4 based on 100 to 150 hours of harvesting per year.

Table 5.4 Estimated Annual Operation Costs

Item:	**Assumptions:**	**Estimated cost:**
Harvester operator	$20/hour; 100 - 150 hours per year	$2000 - $3000
Maintenance/parts	Minor repairs/maintenance	$2000 - $5000
Fuel for harvester	50 liters/8 hours = 625 - 938 liters @ $1.50/l	$940 - $1400
Helper	$20/hour; 100 hours	$2000
Dump truck driver	$20/hour; 100 hours	$2000
Disposal	$75 per ton disposal costs, 135 ton/yr	$10,000
	Approximate Annual Operation Cost Total	**$19,000-$24,000**

Contracted Harvesting Services

It is possible to contract a company for harvesting services without capital purchase (Wayne Powers, ECO Technologies in New Brunswick, Personal communication, Feb. 12/14). An annual cost of $182,000 (plus tax) for harvesting is estimated based on:

- Mobilization to Dartmouth (fixed rate) of $16,500, required twice annually;
    - Includes Mob/demob and launching of excavator and small barge (to "ferry" harvested material to shore);
- Harvesting operation daily rate $13,700, required ten days annually;
- Transport to disposal facility annual estimate (Table 5.4) is $2,000; and
- Annual disposal fees at facility (Table 5.4) is $10,000.

5.2.2.3 Sediment Dredging

Dredging involves the removal of vegetation and sediment from the lake bottom or along the shoreline of the lake. Several methods are available for this work. Draglines that pull heavy objects behind a boat remove nutrient-rich sediment lining the bottom of the lake. This method can remove existing plants as well as the nutrient-rich sediment in which they grow, however the disturbance is difficult to contain and may result in high levels of suspended solids. Hydraulic dredging involves suction of sediments into a containment line which is diverted out of the lake system. This method has more precision and sediment is contained. For controlling aquatic vegetation, hydraulic dredging may be completed with equipment that has a cutter-head suction bucket-pump to remove and collect vegetation at the same time as the sediment (Wayne Powers, ECO Technologies in New Brunswick, Personal communication, Feb. 12/14). Choice of method depends on site characteristics.

Dredged materials require dewatering before disposal. This is typically done in drainage ponds or by using permeable geotextile bags. Containment lagoons or drainage ponds are a contained area to control the sediment release while water evaporates and drains from the materials. This may be a temporary or permanent disposal option. Saturated dredged materials can also be directed into permeable geotextile bags that allow water to seep out but sediment is retained. This reduces the water content before the sediment is spread or transported.

Disposal options may include spreading as a land amendment or disposal at a licensed facility.

<u>Specific requirements</u>

The specific details of the approach to dredging would require careful consideration. Removal of the material without suspension of sediment into the water column will require some level of containment (*e.g.,* silt curtains or temporary lake drawdown and damning of work areas). Transportation of materials will require dewatering, which can be achieved through on-site temporary stockpiling or geotextile bags. Stockpiles will require erosion prevention and sediment control to prevent the release of sediments to adjacent waterbodies, stormwater management systems or properties. The length of time the soils will require stockpiling will depend on the soil hydraulic conductivity (permeability to water) and specific yield (fraction of pore water that will be released when water is allowed to drain by the forces of gravity).

Once dewatered, sediment must be disposed of appropriately, either as a land amendment or at a disposal facility that will accept the composition and volume of materials dredged. If there is potential for elevated concentrations of sediment contaminants (*e.g.,* metals or petroleum hydrocarbons), the Nova Scotia Guidelines for Disposal of Contaminated Solids in Landfills (Government of Nova Scotia 1992) provides guidance for testing and acceptable limits for transport and disposal in landfills. Several facilities in HRM have approvals for the acceptance and treatment of contaminated materials.

<u>Risks</u>

Sediment dredging will result in disruption of the benthic habitat in the lake. The dredging work will likely interrupt human activities that would otherwise be taking place on or near the lake. Dredging will drastically change the aquatic environment, and aquatic species present (DFO 2010). This may not be a permanent solution as sediment accumulation may continue *via* lake inflows.

<u>Approvals required</u>

The removal of sediment using dredges would require approval from NSE. Under the Activities Designation Regulations made under Section 66 of the *Environment Act* "the dredging or any other modification of a surface watercourse" requires a Water Approval from NSE. This Division I Category II Water Approval provides notice to NSE of when and where the dredging is to be conducted and that environmental controls are in place to mitigate environmental damage or unwanted releases of sediment and hydrocarbons. NSE will forward the Water Approval Application on to the Department of Fisheries and Oceans (DFO) who will assess whether potential effects on fish, fish habitat or aquatic Species at Risk are possible. Should DFO determine that serious harm to fish or fish habitat is likely from dredging activities; and these effects cannot be eliminated by avoidance or mitigation, a *Fisheries Act* authorization may be required. Under the *Fisheries Act* authorization an offset plan must be submitted DFO in which the proponent identifies the offset measures used to counterbalance the loss of fish and fish habitat. The offset measures are variable though can include habitat restoration of the affected area, habitat creation in a new area, fish stocking or in remote locations complementary measures such as data collection and scientific research. The offsetting plan was formerly conducted under a Harmful Alterations Damage or Destruction (HADD) authorization.

The Water Approval Application has a maximum waiting period of 60 days by which time NSE must return a formal Approval with conditions, a request for more information/clarification or in rare cases a rejection of the application. The time line for a *Fisheries Act* authorization is significantly longer, DFO has up to 60 days to determine if the submitted *Fisheries Act* authorization is complete. From the date of the determination DFO has an additional 90 days to issue an authorization or deny the application.

Should dewatering of Lake Banook be needed to facilitate dredging additional approvals would be required. A Water Approval from NSE would be required for the alteration of flow. This Division I Category II Water Approval provides notice to NSE of the method of dewatering and that environmental controls are in place to avoid erosion and sedimentation. As with the Water Approval application for the dredging activities NSE will forward the Water Approval Application on to the Department of Fisheries and Oceans (DFO) who will assess whether potential effects on fish, fish habitat or aquatic Species at Risk are possible. It is not anticipated that DFO will require a *Fisheries Act* Authorization for the dewatering activities.

The water level in Lake Banook was previously lowered between October 2008 and April 2009, this was accomplished using two sand bag cofferdams and multiple water pumps at the outlet. Should a similar approach be undertaken to facilitate dredging it is recommended a *Navigation Protection Act* authorization be obtained. This authorization is not required for Lake Banook though would provide notice to various water users of the temporary hazard to navigation and ensure the Common Law right to navigate is maintained.

Disposal of dredged materials would be required. There are many facilities within HRM that accept dredged materials depending on their contaminant levels. The dredged materials would require testing to confirm concentrations of metals, petroleum hydrocarbons and other contaminants to determine whether they meet the approved limits of the facility. The dredged material may require temporary stockpiling for dewatering and testing prior to transport to a disposal facility, as per the Nova Scotia Guidelines for Disposal of Contaminated Soils in Landfills (Government of Nova Scotia 1992).

<u>Costs</u>

The volume of wet sediment requiring removal and dewatering is estimated to be 9,000 m^3 based on an average 0.1 m thickness over approximately nine hectares of highest vegetation abundance (Figures 3 and 4).

The costs of dredging the material are dependent on the approach taken. Substantial design and site characterization would be required to determine the appropriate method of dredging. Factors such as the benthic topography, water depth and the thickness of sediment to be removed would determine whether a bucket or suction would be effective. Dewatering would be required prior to transport the materials for disposal, as there is not sufficient space available on-site for spreading the volume of sediment that would require disposal. Dewatering the sediment will also require engineering design considering the volume of sediments requiring dewatering and the lack of available space adjacent to Lake Banook.

If we assume dredging is to an average depth of 0.1 m, and the sediment is silty sand with a high organic component (specific gravity of 2.5, porosity 0.3), and dewatering was successful at reducing water content to 10%, we can also estimate the mass of sediment for disposal as follows:

$$m = \rho_b V$$

$$m = [(0.7)\left(2500\frac{kg}{m^2}\right) + (0.1)\left(1000\frac{kg}{m^2}\right)](0.1m)(90{,}000m^2)$$

$$m = 16{,}650{,}000\ kg$$

$$m = 16{,}650\ tonne$$

Tipping fees at local facilities range from $30 to $45 per ton depending on the quality and volume of material requiring disposal. Disposal costs at a local facility are estimated to be $499,500. Assuming that tandem trucks with a hauling capacity of 22 ton would be used for transport to the disposal facility, and the round trip to the facility was $40, hauling costs are estimated to be approximately $16,500.

The costs of erosion and sediment control, sedimentation reduction in the water column, dewatering of sediment, and design and monitoring of these features could range from $25-$200,000 depending on the level of effort taken to reduce sediment release into the environment. Retaining a consultant to manage approvals for this work may necessary as well. The estimated magnitude of costs associated with sediment dredging and disposal are provided in Table 5.5.

Table 5.5 Magnitude of Costs Estimated for Dredging Affected Areas of Lake Banook

Item	Assumptions	Magnitude of Cost Estimate
Engineering Design	Method selection, sediment and erosion control design, dewatering design, *etc.*	$20,000 - $50,000*
Approvals	Consultants retained for this work	$10,000 - $20,000*
Dredging	9,000 m^3 of sediments for removal	$100,000 to 1,000,000*
Dewatering	9,000 m^3 of sediments of saturated sediments	**Not likely feasible**
Transport	16,650 ton to be transported in 22 ton tandem trucks at $40 for a round trip	$16,500
Disposal	16,650 ton disposed at $30 per ton	$499,000

*based on professional experience

The estimated total cost of dredging is expected to range from $645 000 to $ 1 000 000.

6.0 Conclusions and Recommendations

6.1 SUMMARY AND CONCLUSIONS

The objectives of this study were to assess the causes of, and recommend possible solutions to, excessive growth of submersed aquatic vegetation in Lake Banook. A review of recent historical watershed landuse and water quality data, as well as current water quality and vegetation distribution in Lake Banook indicates that the sudden growth of vegetation in the lake was likely the result of following sequence:

- non-point source urban sediment input;
- sediments enrichment; and
- lake level draw-down in 2009 caused disturbance which allowed the colonization of rooted aquatic vegetation.

Options for remediation were presented, and the preferred options were evaluated in more detail, including herbicides, weed harvesting and sediment dredging (Section 5.2.2). In summary, it is expected that all three options would be effective at controlling vegetation in Lake Banook. Herbicides are the most affordable approach ($36,000 to $ 119,000 per year for multiple years). Approvals would be required, and the risks are minimal if the herbicide is chosen carefully and applied effectively. Applying herbicides would affect recreational use of the lake for a period of time (days to weeks) following application. Public perception and acceptance of this approach may be a barrier.

Dredging the enriched sediment is expected to be effective, however there are substantial costs associated with this method in both engineering design, approvals, labour, transport and disposal fees. The estimated total cost of dredging is expected to range from $645,000 to $ 1,000,000. This option will be highly disruptive to the lake ecosystem and may have unpredictable results. Recreational use of the lake will be limited throughout the work. Dewatering excavated sediments may be the biggest barrier to this work, as there isn't sufficient space available on site for dewatering or disposing of the volume of sediments that would require removal.

Harvesting and disposing of aquatic biomass through the use of a vessel-mounted submerged harvester is associated with the lowest risk, approval requirements and disruption to recreational activities on the lake. Costs for this option can be either as capital purchase ($ 96,000 to $ 295,000) and operation ($19,000 to $24,000 annually) or an annual cost of $182,000 to contract supply and operation of a harvester to a third-party, including disposal costs.

6.2 RECOMMENDATIONS

The field portions of this study were conducted in November, which is not ideal for capturing growing season conditions (May 1 to September 30 in Nova Scotia). The following three recommendations are made to further characterize the water quality and source zones for non-point source loading of contaminants to Lake Banook:

- Wet and dry weather sampling of water quality entering the lake in the spring and summer could confirm whether there is a substantial source and from what area of the watershed it is originating;
- More detailed sediment sampling and characterization in areas with and without rooted problematic vegetation can confirm enrichment; and
- Quantitative biomass monitoring before any weed control methods are undertaken and then each year prior to implementation of control methods to confirm whether there is a year to year decrease in biomass to confirm the effectiveness of the chosen method of vegetation control.

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APPENDIX A

Water Quality Profiles

Table 1: In-situ Water Quality Profile for the Inlet Station in Lake Banook, November 4, 2013

Inlet – November 4, 2013							
Depth	Temperature (°C)	DO (%)	DO (mg/L)	Spc. Cond. (mS)	Salinity	TDS (mg/L)	pH
0.22	9.52	103.7	11.81	0.677	0	440	9.98
0.33	9.33	104.8	12.00	0.520	0	338	9.88
0.41	9.28	104.1	11.93	0.507	0	330	9.82
0.59	9.25	104.1	11.94	0.504	0	328	9.75
1.61	9.24	102.6	11.78	0.486	0	316	9.67
2.31	9.24	102.6	11.78	0.494	0	321	9.58
2.39	9.23	101.9	11.69	0.493	0	320	9.39
2.44	9.23	100.6	11.55	0.493	0	320	9.30

Table 2: In-situ Water Quality Profile for the In Lake Stations in Lake Banook, November 4 2013

In Lake 1 – November 4, 2013							
Depth	Temperature (°C)	DO (%)	DO (mg/L)	Spc. Cond. (mS)	Salinity	TDS (mg/L)	pH
0.36	10.57	127.7	14.21	0.555	0.27	360	8.08
1.34	10.57	127.7	14.21	0.554	0.27	360	8.03
2.30	10.57	110.2	12.26	0.554	0.27	360	8.02
3.23	10.58	110.2	12.26	0.554	0.27	360	8.01
4.84	10.57	110.2	12.26	0.553	0.27	360	8.00
5.45	10.28	102.2	11.44	0.527	0.26	342	7.99
In Lake 2 – November 4, 2013							
Depth	Temperature (°C)	DO (%)	DO (mg/L)	Spc. Cond. (mS)	Salinity	TDS (mg/L)	pH
0.25	10.53	110.4	12.28	0.558	0.27	363	8.03
1.86	10.56	107.1	11.91	0.558	0.27	363	7.98
3.14	10.57	103.8	11.55	0.557	0.27	362	7.97
4.06	10.57	103.8	11.55	0.557	0.27	362	7.93
5.18	10.57	103.0	11.45	0.557	0.27	362	7.92
6.38	10.56	103.0	11.45	0.557	0.27	362	7.90
7.58	10.56	103.4	11.50	0.557	0.27	362	7.89
7.81	10.55	104.6	11.64	0.555	0.27	361	7.86
In Lake 3 – November 4, 2013							
Depth	Temperature (°C)	DO (%)	DO (mg/L)	Spc. Cond. (mS)	Salinity	TDS (mg/L)	pH
2.59	10.41	148.0	16.52	0.556	0.27	362	8.03
2.78	10.42	113.2	12.63	0.556	0.27	361	7.98
4.35	10.43	113.2	12.62	0.556	0.27	362	7.94

Table 2: **In-situ Water Quality Profile for the In Lake Stations in Lake Banook, November 4 2013**

6.14	10.43	109.3	12.19	0.556	0.27	361	7.93
6.95	10.39	108.4	12.11	0.555	0.27	361	7.89

Table 3: **In-situ Water Quality for the Stream Station in Lake Banook, November 4 2013**

Stream – November 4, 2013							
Depth	Temperature (°C)	DO (%)	DO (mg/L)	Spc. Cond. (mS)	Salinity	TDS (mg/L)	pH
0.19	7.04	126.1	15.29	0.003	0.00	2	5.85

Table 4: **In-situ Water Quality Profile for the Drainage Stations in Lake Banook, November 4 2013**

Drainage 1 – November 4, 2013							
Depth	Temperature (°C)	DO (%)	DO (mg/L)	Spc. Cond. (mS)	Salinity	TDS (mg/L)	pH
0.21	10.81	101.3	11.20	0.551	0.27	358	7.88
Drainage 2 – November 4, 2013							
Depth	Temperature (°C)	DO (%)	DO (mg/L)	Spc. Cond. (mS)	Salinity	TDS (mg/L)	pH
0.48	10.32	142.0	15.89	0.556	0.27	362	7.84
0.77	10.36	104.2	11.65	0.556	0.27	362	7.81
Drainage 3 – November 4, 2013							
Depth	Temperature (°C)	DO (%)	DO (mg/L)	Spc. Cond. (mS)	Salinity	TDS (mg/L)	pH
0.27	10.02	110.3	12.42	0.559	0.27	363	7.90
0.56	10.40	105.7	11.80	0.553	0.27	359	7.73
0.67	10.40	104.5	11.66	0.553	0.27	360	7.73
0.79	10.40	104.5	11.66	0.553	0.27	359	7.71
0.85	10.40	103.4	11.54	0.553	0.27	359	7.71

Table 5: **In-situ Water Quality Profile for the Outlet Station in Lake Banook, November 4 2013**

Outlet – November 4, 2013							
Depth	Temperature (°C)	DO (%)	DO (mg/L)	Spc. Cond. (mS)	Salinity	TDS (mg/L)	pH
0.33	10.25	99.9	11.19	0.558	0.27	363	7.85
0.54	10.30	100.8	11.28	0.556	0.27	361	7.82
1.40	10.33	100.8	11.27	0.556	0.27	361	7.81
1.50	10.37	101.0	11.29	0.554	0.27	360	7.76

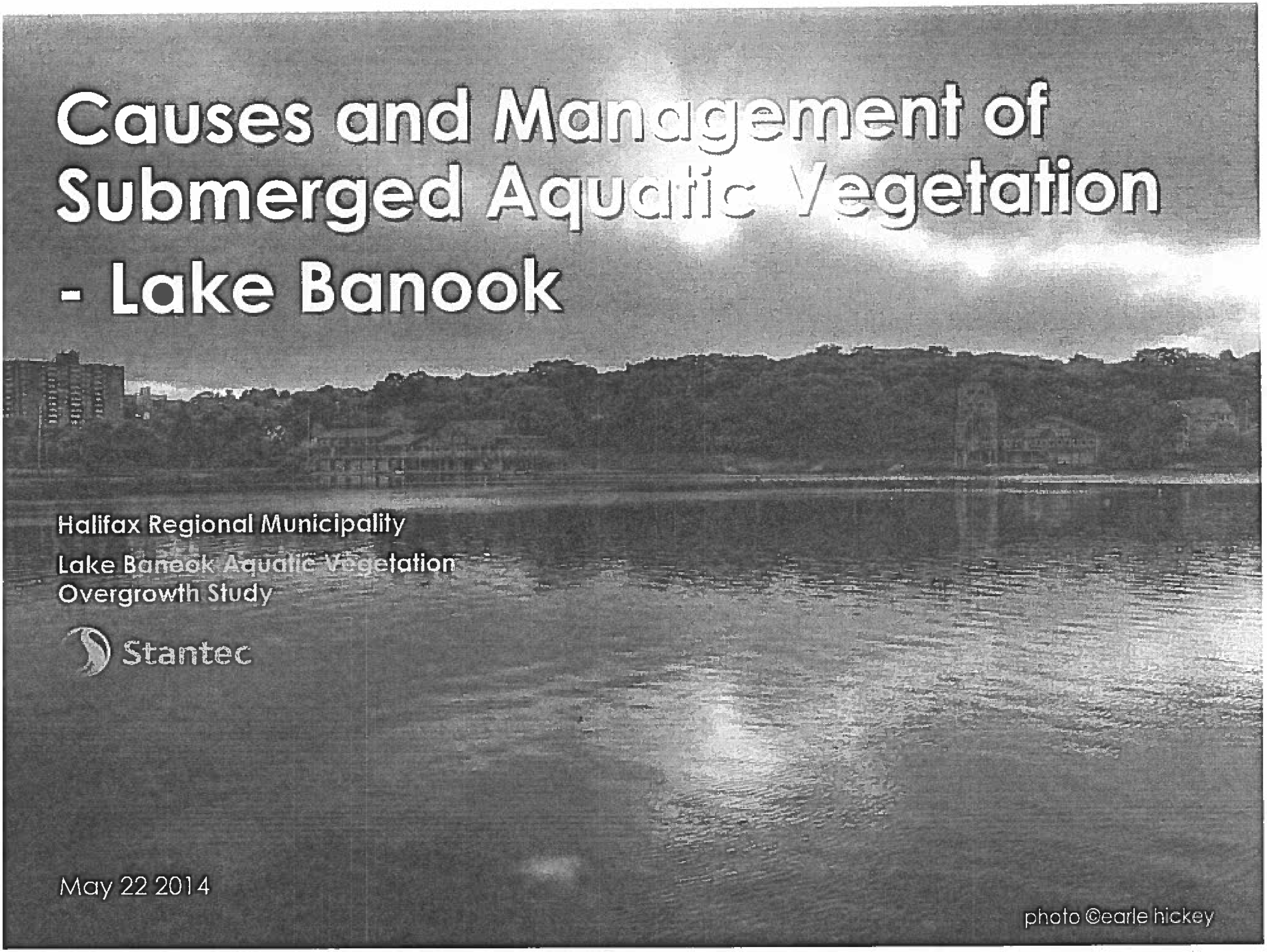
Table 6: In-situ Water Quality Profile for the Stream Station in Lake Banook November 13 2013

Stream - November 13, 2013						
Temperature (°C)	DO (%)	DO (mg/L)	Spc. Cond. (mS)	Salinity	TDS (mg/L)	pH
9.00	75.0	8.60	0.766	0.50	520	7.38

Table 7: In-situ Water Quality Profile for the Drainage Stations in Lake Banook November 13 2013

Drainage 1- November 13, 2013						
Temperature (°C)	DO (%)	DO (mg/L)	Spc. Cond. (mS)	Salinity	TDS (mg/L)	pH
9.50	50.0	5.60	0.223	0.10	143	7.55
Drainage 2- November 13, 2013						
Temperature (°C)	DO (%)	DO (mg/L)	Spc. Cond. (mS)	Salinity	TDS (mg/L)	pH
7.70	67.0	8.00	0.425	0.30	N/A	N/A
Drainage 3- November 13, 2013						
Temperature (°C)	DO (%)	DO (mg/L)	Spc. Cond. (mS)	Salinity	TDS (mg/L)	pH
7.70	67.0	8.00	0.425	0.30	281	8.47

Attachment 2



Agenda

1 Scope and key Findings of Our Study

2 Discussion of likely Causes

3 Options for Management

4 Consideration of Options

5 Questions

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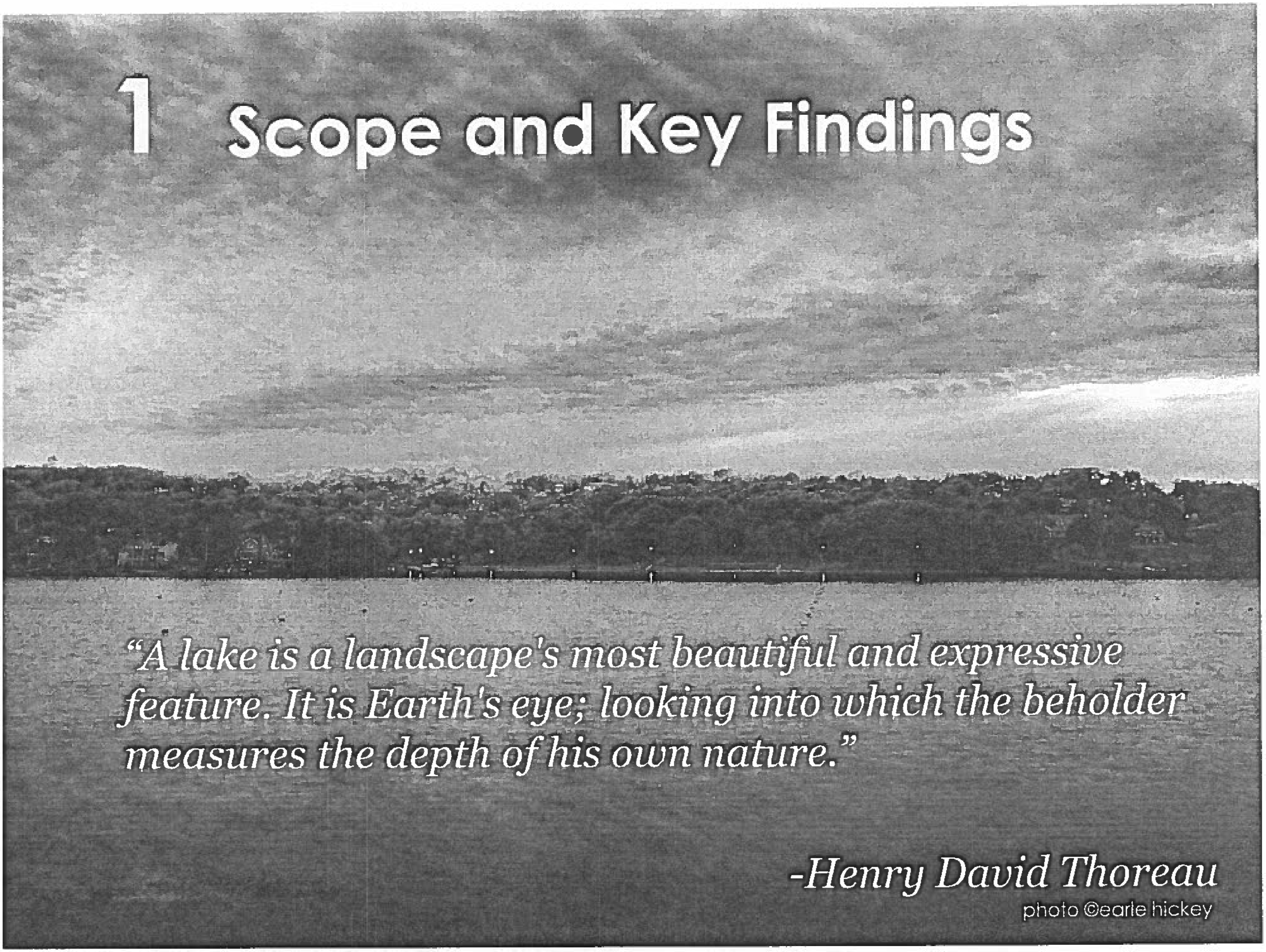
1 Scope and Key Findings



Scope

- Stantec was contracted in November 2013 to assess the causes of the weed growth and identify opportunities for reduction of the growth for implementation in the short term (2014) and long term (beyond)
- Study focused in Lake Banook to manage the scale of the investigation, but results are reflective of Lake MicMac and the entire watershed.

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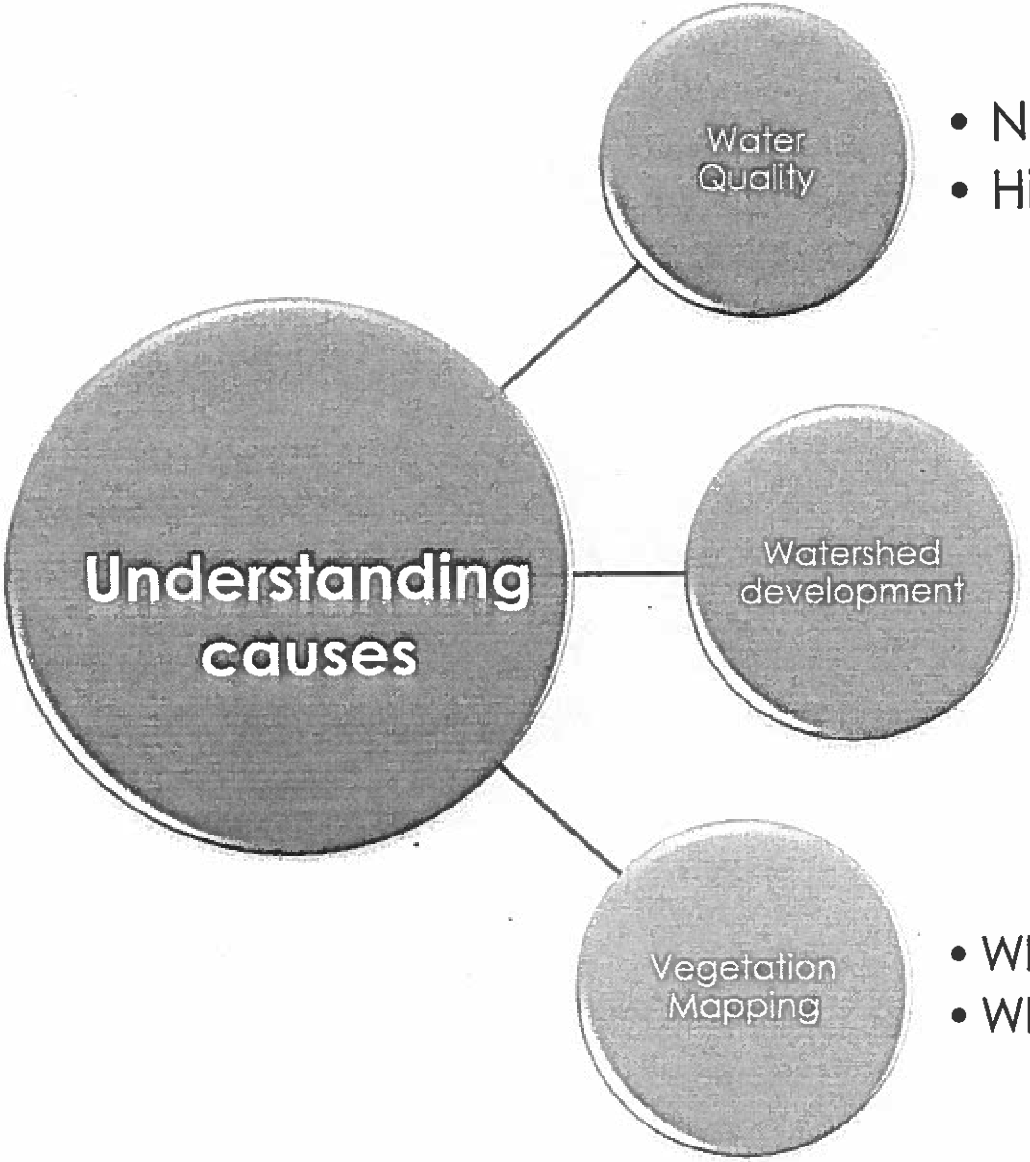

- November 2013
- Historic

- Types
- Maturity
- Recent changes

- Where is the density
- What species

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Water Quality
November 2013

In situ
- temperature
- oxygen
- specific conductivity

Laboratory
- nitrogen
- phosphorus
- total suspended solids

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Water Quality – November 2013

- In Lake
  - Low nutrients
  - No total suspended solids detected
  - High specific conductance
- Lake inputs before rain
  - Higher nutrients than lake (specifically stream)
  - High TSS from Drain 1
- Lake inputs immediately after rain
  - Slightly higher nutrients than before rain
  - TSS similar to before rain

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Historic Water Quality

Duration
- Dating back to 1980

Frequency
- Annually since 2006
- Spring and fall

Where
- Lake center

What
- In situ parameters
- Lab parameters

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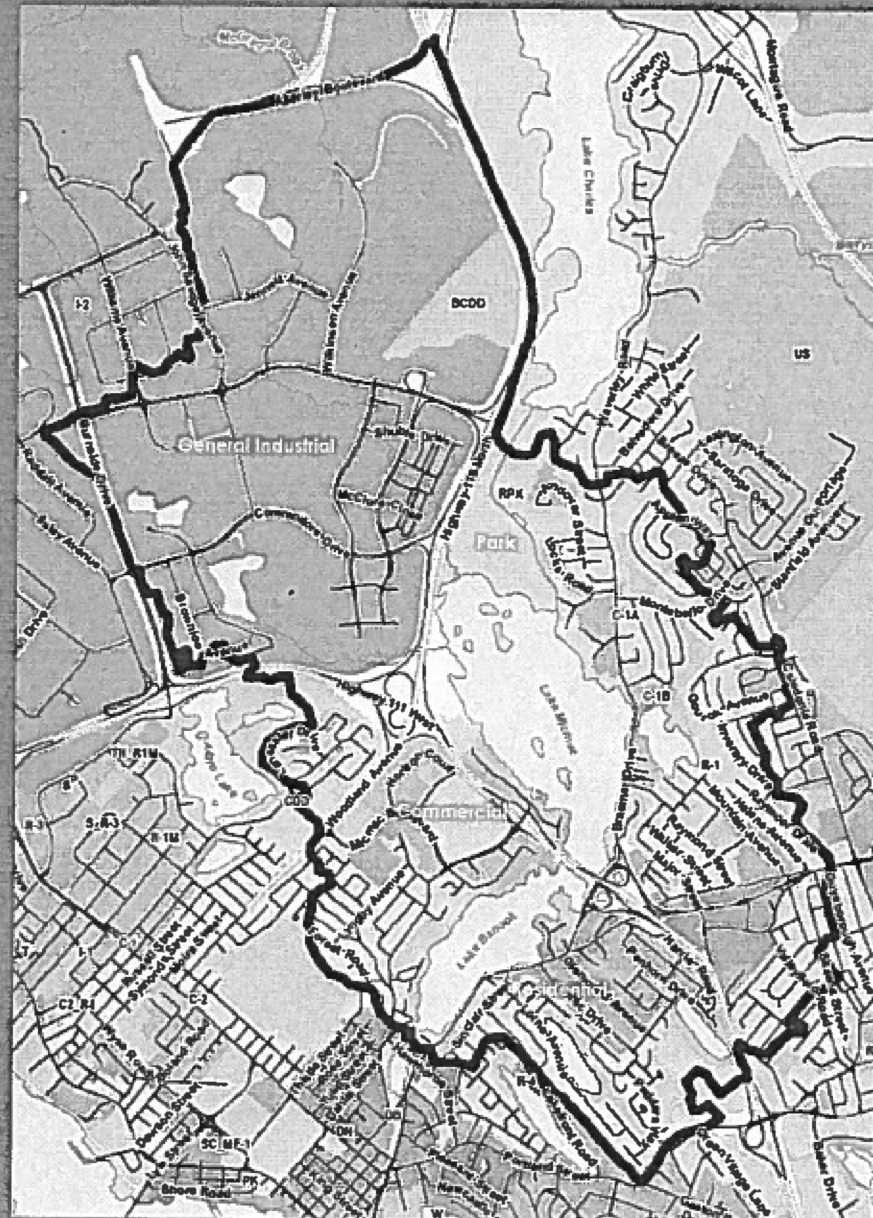
Historic Water Quality

Key Findings

- High total dissolved solids
- High chloride
- Low levels of nutrients in the water column
- Very low total suspended solids

Watershed Development

General Industrial	• *Developing*
Residential	• *Various densities* • *Mature*
Commercial	• *Mature*
Park	• *Various*



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Watershed Development

General Industrial	• *Developing*
Residential	• *Various densities* • *Mature*
Commercial	• *Mature*
Park	• Various

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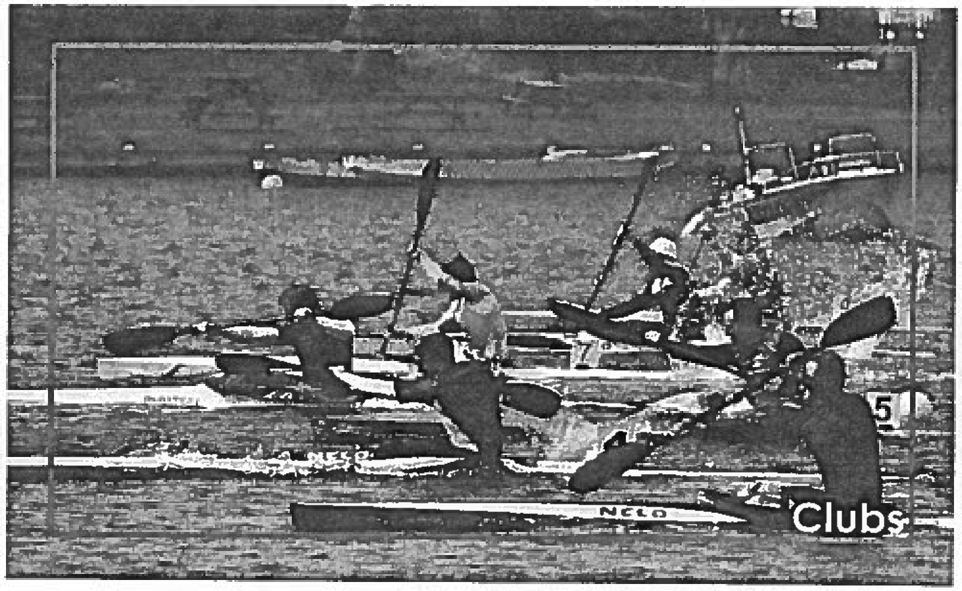

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photos ©earle hickey

Vegetation Mapping

Transects run across Lake Banook in a small vessel and at intervals, submersed video was recorded to identify species and estimate abundance. A map of abundance for the two dominant species was produced

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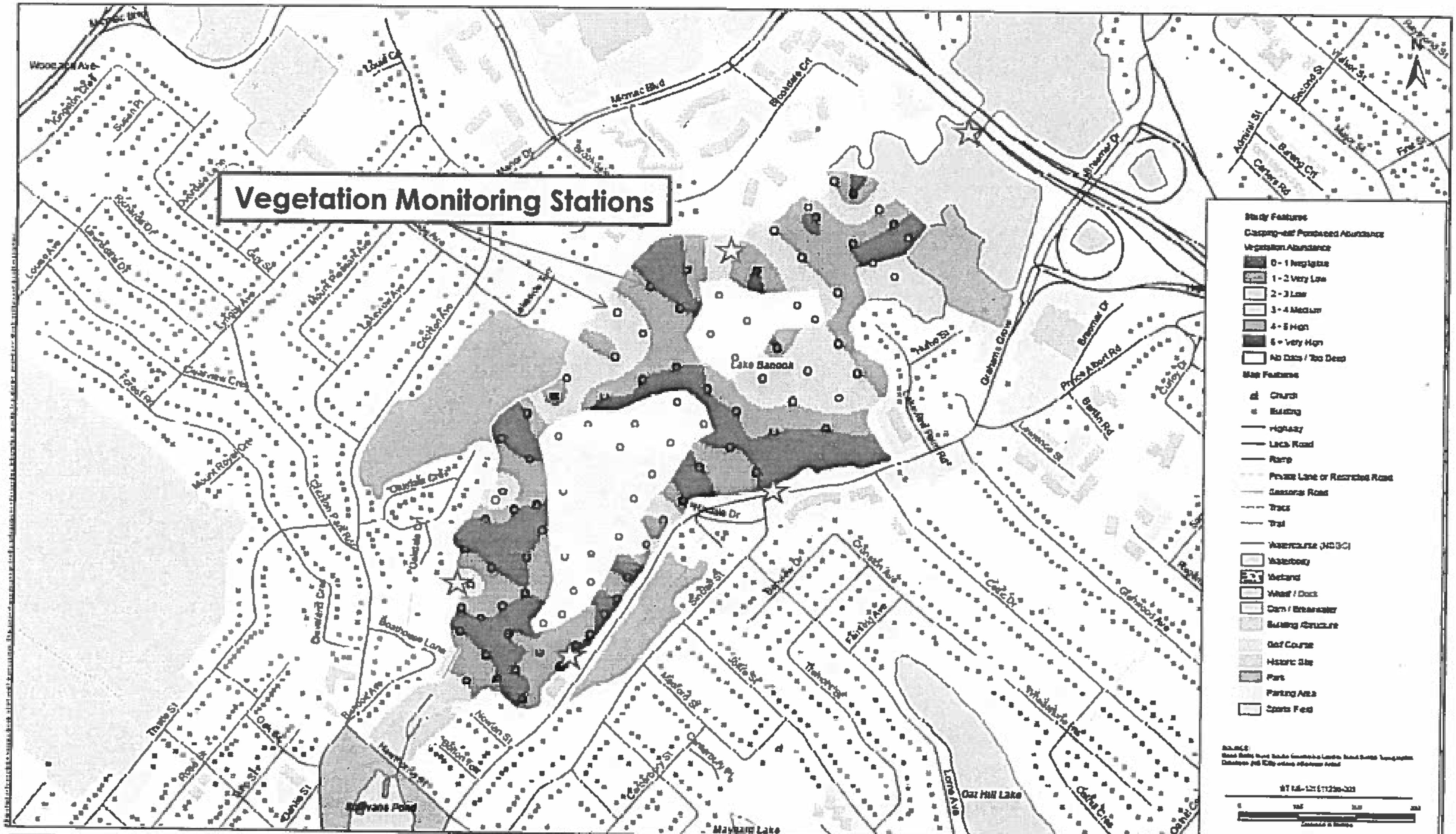

Banook Lake Weed Study

Lake Banook Vegetation Coverage Results - Clasping-leaf Pondweed

4

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	Banook Lake Weed Study	3
	Lake Banook Vegetation Coverage Results - Slender-leaf Pondweed	Feb 20, 2014
Halifax Regional Municipality		Stantec

2 Discussion of Likely Causes

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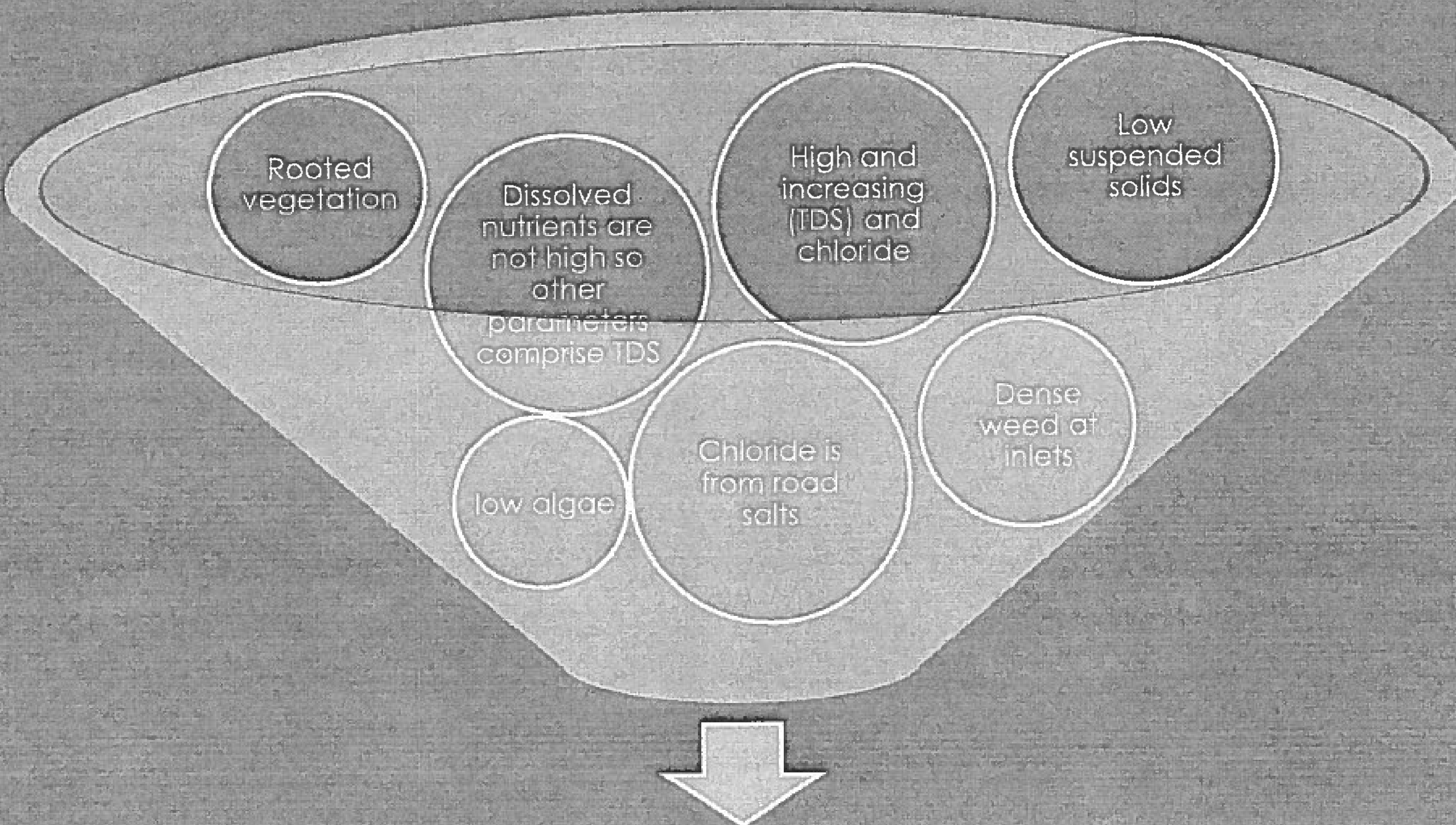
Lets put it together…



Suggests that there are urban non-point source contaminants getting to the lake but they are settling out, enriching sediments

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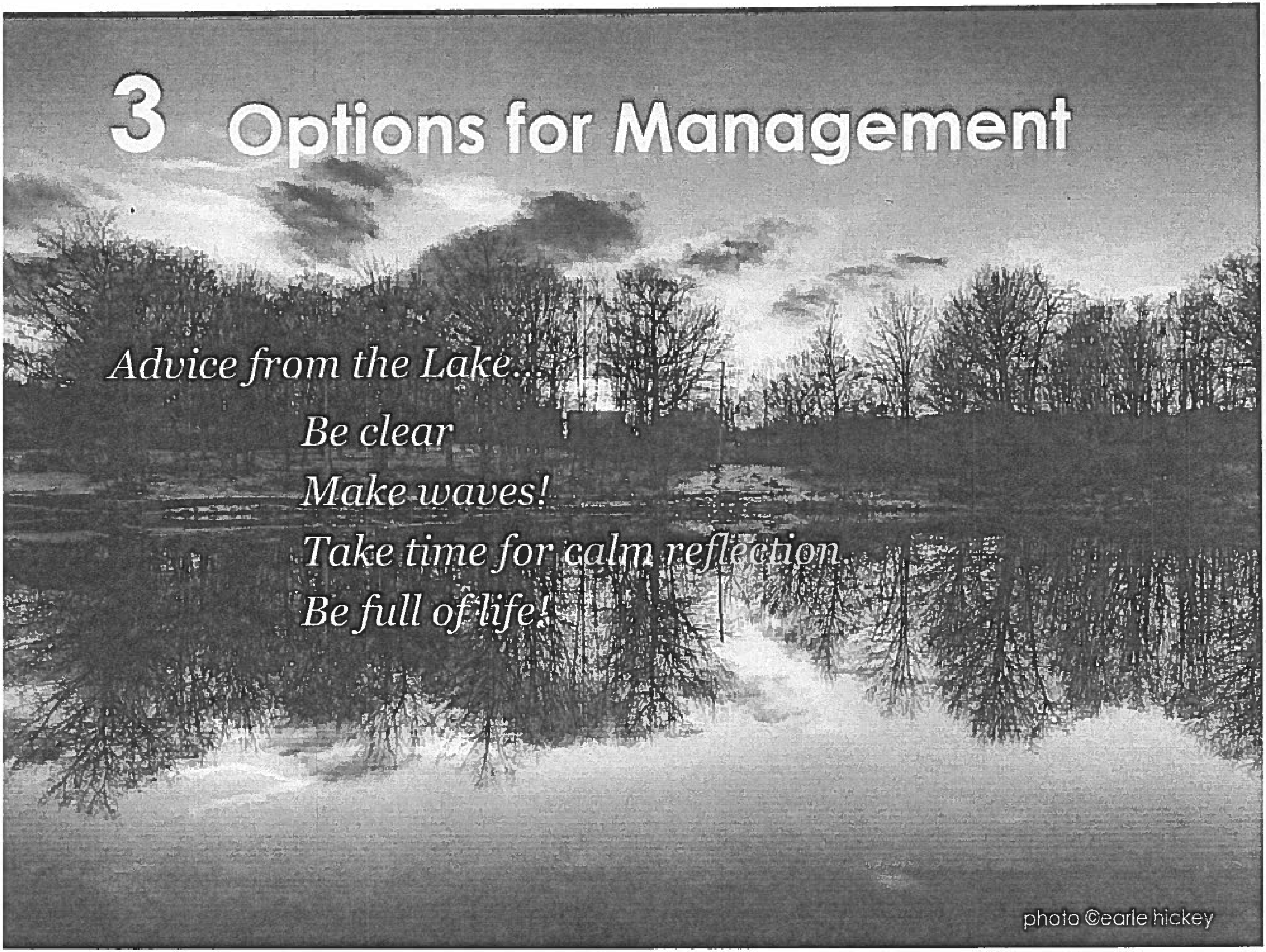
Lets put it together...

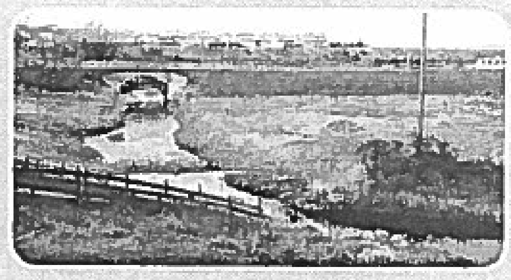
...sudden bloom in 2009 following winter/spring lake drawdown

- Disturbance ecology – hearty plants given the chance to out-compete existing plants
- Light/oxygen/wind exposure to sediments alters biogeochemistry
- New niches for colonization by hearty and adaptable vegetation


3 Options for Management
Advice from the Lake...
Be clear
Make waves!
Take time for calm reflection
Be full of life!
photo ©earle hickey

Long Term

Addressing the causes:
Reduction of sediment loading to the lake



Source control
- Erosion Prevention

Conveyance control
- Infrastructure maintenance
- Green infrastructure solutions

Capture before delivery to the lake
- Engineered or natural containment
- Green infrastructure solutions

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Short Term Solutions

1. Identify and describe available options
2. Evaluate option applicability based on understanding of causes and conditions
3. Evaluate feasible options in terms of expected effectiveness, risk and cost.

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Category	Method/ Technology	Description	Specific Requirements or Limitations	Expected Effectiveness in the Short Term	Expected Effectiveness in the Long Term	Risks
Chemical	Aquatic herbicide: Endothall	A contact, rapid acting herbicide that is applied in early spring (Helfrich et al, 2009). Can reduce shoot biomass and the production of turions (Poovey et al, 2002). More suited to whole lake or large block treatments in lakes with little wind and wave action (Johnson et al, 2012).	Water temperature range is an important consideration in the effectiveness of this herbicide on shoot biomass and turion formation (Poovey et al, 2002,Netherland et al, 2000). Treatment requires the use of a boat (Government of Nova Scotia).	Excellent (Helfrich et al, 2009). Large reduction in biomass in each year of treatment (Johnson et al, 2012).	Will need yearly treatments. Turion numbers should decrease with each year of treatment. Ongoing management necessary (Johnson et al, 2012).	Can be toxic to fish and other aquatic life. Important to note that dead plants remaining in the water will release nutrients into the lake-this can promote growth of weeds. Fish kills may also result due to reduced oxygen content caused by rotting vegetation. Lake should be treated in sections and/or combined with aeration to maintain sufficient oxygen levels for fish (NSE). Algae blooms are possible due to nutrients released when macrophytes are killed (NSE). Herbicide may also kill beneficial vegetation (Helfrich et al, 2009). Soil along the shoreline may be influenced by the lack of vegetation, erosion may result (NSE). May require more than five consecutive years of treatment to get rid of all turions (Johnson et al, 2012).
	Aquatic herbicide: Fluridone	Persistant and slow-acting herbicide that is applied in early spring. Residue can persist for 2-12 months. Expensive and will not kill algae (Helfrich et al, 2009).	No restrictions for fishing, swimming or human consumption. Cannot use water for crop irrigation for 30 days following application (Helfrich et al, 2009). Treatment requires the use of a boat (Government of Nova Scotia).	Excellent but slower acting than other two; expect to see results in 30-90 days (Helfrich et al, 2009). Large reduction in biomass in each year of treatment (Johnson et al, 2012).	Will need yearly treatments. Turion numbers should decrease with each year of treatment. Ongoing management necessary (Johnson et al, 2012)	
	Aquatic herbicide: Diquat	Wide-spectrum contact herbicide, applied in early spring, used to control submersed weeds. Rarely found in the water after 10 days (Helfrich et al, 2009). Can reduce shoot biomass as well as the production of turions (Poovey et al, 2002). Good for use in areas with wind and wave action as this herbicide will still reduce shoot biomass despite short exposure time (Johnson et al, 2012). Rapid acting and kills top growth only (NSE).	Following application, must wait fourteen days before water can be used for livestock, irrigation or drinking. One day waiting period required before swimming (Helfrich et al, 2009). Water temperature range is an important consideration in the effectiveness of this herbicide on shoot biomass and turion formation (Poovey et al, 2002; Netherland et al, 2000). Treatment requires the use of a boat that does NOT stir up the bottom (herbicide is ineffective following contact with soil) (NSE).	Good (Helfrich et al, 2009). As with other herbicides, can expect to see a large decrease in biomass in the first year of treatment.	Will need yearly treatments. Ongoing management necessary (Johnson et al, 2012)	
	Dye (shade)	Dyes reduce the light available to underwater plants, inhibiting photosynthesis (Roegge & Evans, 2003; NSE). Plants will still grow but as a result of diminished light intensity will have far fewer stems per turion and stems will be weak (Tobiessen et al, 1992).	This method is not effective when there is significant outflow (Roegge & Evans, 2003). Roots must be in water that is about 0.5-1.0 m deep; dye is not effective in depths less than 1 metre (NSE). This should be done at the onset of the growing season and the dye must persist for several weeks (Helfrich et al, 2009).	Productivity of most all plants in the lake will be diminished.	Several yearly treatments required to significantly impact density and distribution of plant.	Low productivity of plants will result in a change in the productivity of the system. Fish and other aquatic species may be affected.
	Alum binding (nutrient limitation)	Internal phosporus (P) loading to a eutrophic lake from sediment can continue after the external source has been removed. Dosing lake sediments with aluminum sulfate can bind P that exists in the water column and render it neutral in the sediment and unable to further contribute to excessive weed growth (Kennedy & Cooke, 1983; James, 2011).	Most effective on suspended algae. Control of nutrient inputs mandatory. May need to combine with aeration (NSE).	In the first year, can expect P to be precipitated out of water column and held in the sediment on the bottom of the pond-unavailable for uptake by plants.	Higher volumetric doses may result in effective long-term control (James, 2011). Ongoing treatments may be necessary.	

Category	Method/Technology	Description	Specific Requirements or Limitations	Expected Effectiveness in the Short Term	Expected Effectiveness in the Long Term	Risks
Mechanical	Sand capping	Black plastic sheeting is used to line the bottom of the lake and a layer of sand or gravel is used to cover the plastic. Nutrient exchange is reduced and rooted weeds are unable to establishment themselves (Helfrich et al, 2009; NSE).	Plastic must be perforated in order to permit gases to escape. Waterfowl nesting sites and fish spawning areas should not be covered (Helfrich et al, 2009). Use is restricted to smaller areas (Tobiessen et al, 1992)	Cap will prevent plant growth in the first year.	Very effective long term. Plant growth will be prevented so long as the cap remains.	Reduction of aquatic macrophytes will impact the ecosystem severely.
	Mechanical Harvesting	Cutting, pulling or dredging is performed to remove plants from the problem area (Roegge & Evans, 2003). Mechanical harvesters or cutters can be used. Process must include collection of free-floating material.	Might only be temporary; elimination of the whole plant and entire root system is desirable (Roegge & Evans, 2003). Plant cuttings should be removed promptly from the lake in order to prevent propagation.	Most plant biomass can be removed in the year of harvest-results are seen immediately (Roegge & Evans, 2003).	Without multiple treatments, may not be effective over the long-term (Roegge & Evans, 2003). Unless roots are removed, success will remain short-term (NSE). Difficult to acheive long-term results.	Pondweed can propagate through cuttings; this method could intensify the problem (Roegge & Evans, 2003). Plants left in the water could contribute to further weed growth (Helfrich et al, 2009).
	Water level manipulation	Manipulating the water level of the lake during the fall and winter months will expose the aquatic vegetation to harsh conditions (Helfrich et al, 2009) Method 2: Drain lake to allow suspended solids and phosphorus to exit the system (Shantz et al, 2004)	Water level would need to be altered during the fall/winter. Mud on the bottom of the pond should freeze up to 10 cm and weeds should be physically removed (Helfrich et al, 2009)	Likely to see results in the year following the water level drawdown.	Unsure of long term success; recolonization may occur. Other management tools may be necessary. Repeat treatments may be required.	
	Sediment Dredging/Removal	The removal of the sediments on the bottom or along the shoreline of the lake. This method can also physically remove plants as well as nutrients required for plant growth. Dredging can be done following lake drainage or by using draglines (Helfrich et al, 2009).	Severe disruption of the habitat and human activities occuring on/near the lake. Depth at which plants typically grow as well as water clarity are determining factors of whether dredging will work to reduce pondweed. Space for a settling lagoon may be necessary (NSE; Tobiessen et al, 1992).	Physical removal of the plants will result in a decrease of biomass in the first year (Tobiessen et al, 1992).Dredging may also disrupt/remove turions buried in the soil, which would minimize pondweed growth in the following year.	Long term success may be possible. Plants may grow the year after dredging but at a much smaller density and biomass (Tobiessen et al, 1992).	Glacial boulders may be present in area from shore up to 5 m water depth (Huppertz et al, 2008).
	Shading	A dark colored geotextile material can be attached to floats. This device can be positioned near dense areas for spot treatment. The float creates shade and decreases the amount of light reaching the plants (Helfrich et al, 2009). Plants may still grow but as a result of diminished light intensity will have far fewer stems per turion and stems will be weak (Tobiessen et al, 1992).	Must be in place for at least a month to be effective (Helfrich et al, 2009), and floast must be well anchored (NSE). Timing would be key in order to limit the light available to plants during turion formation. Limited to smaller areas, and area being treated is unusable while floats are in place (NSE).	May reduce plant productivity and turion development in the first year.	More likely to see results in consecutive years and with continued treatments.	May not be effective in reducing pondweed populations. May influence other plant species.

Remedy Option	Evaluation Results	Expected effectiveness
Herbicide (e.g., Endothall, Fluridone, Diquat)	Herbicide has potential to stunt early season growth and prevent the plants from reaching the top of the water column and access to sunlight. After several years of application, established roots may perish and vegetation may be inhibited from reestablishing due to insufficient light penetration.	Expected to be effective in the short term. Single application will not result in long term effectiveness
Dye (chemical shading)	Reducing vegetation access to sunlight by treating the lake with a dye may induce plant mortality. Decomposition of plants in-situ will further enrich sediments and exacerbate the problem.	Not expected to be effective in the long term. May be somewhat effective in the short term
Alum binding (nutrient limitation)	This is an effective means of removing phosphorus from the water column and preventing re-suspension. The rich sediments in which rooted vegetation are established may be capped, but existing rooted vegetation would likely persist.	Not expected to be effective in the short or long term
Sand capping	This is a means of preventing re-suspension of phosphorus sediments into the water column; however water column phosphorus concentrations are not a concern. The established rooted vegetation would likely persist through the sand cap.	Not expected to be effective in the short or long term
Mechanical Harvesting	Mechanical harvesting will provide an immediate reduction in aquatic biomass. Repeated harvesting to prevent the plants from gaining access to sufficient sunlight in the upper portions of the water column may result in the death of the established roots, and vegetation may be inhibited from reestablishing due to insufficient light penetration if water levels are maintained.	Expected to be effective in the short and long term
Water level manipulation	Stressing vegetation may reduce vegetation growth in the short term, but it is expected that the rooted vegetation would migrate or adapt to the deeper water levels in the long term. Would result in flooding of existing shore-based infrastructure and recreation areas. This is also an applied means of expelling phosphorus from the system to reduce in-lake recycling of phosphorus. Low phosphorus levels in the water column indicate that lake discharge will not be a significant export of phosphorus from the sediment.	Not expected to be effective in the short or long term
Sediment dredging / removal	Removal of enriched sediment and established rooted vegetation would provide immediate and long-term reduction in rooted aquatic vegetation in problem areas.	Expected to be effective in the short and long term
Physical shading (e.g., tarps)	Shading vegetation using physical barriers (weighted or floating tarps) may cause plant mortality. Decomposition of plants in-situ will further enrich sediments. This method is intended for small, confined areas of weed growth where remediated areas will not be quickly recolonized by adjacent weed growth. This method is labour intensive and could create additional safety hazards to boaters and swimmers in the lake.	May be effective in the short term in small patches. Not expected to be effective in the long term

Remedy Option	Evaluation Results	Expected effectiveness
Herbicide (e.g., Endothall, Fluridone, Diquat)	Herbicide has potential to stunt early season growth and prevent the plants from reaching the top of the water column and access to sunlight. After several years of application, established roots may perish and vegetation may be inhibited from reestablishing due to insufficient light penetration.	Expected to be effective in the short term. Single application will not result in long term effectiveness
Mechanical Harvesting	Mechanical harvesting will provide an immediate reduction in aquatic biomass. Repeated harvesting to prevent the plants from gaining access to sufficient sunlight in the upper portions of the water column may result in the death of the established roots, and vegetation may be inhibited from reestablishing due to insufficient light penetration if water levels are maintained.	Expected to be effective in the short and long term
Sediment dredging / removal	Removal of enriched sediment and established rooted vegetation would provide immediate and long-term reduction in rooted aquatic vegetation in problem areas.	Expected to be effective in the short and long term

4 Consideration of Options

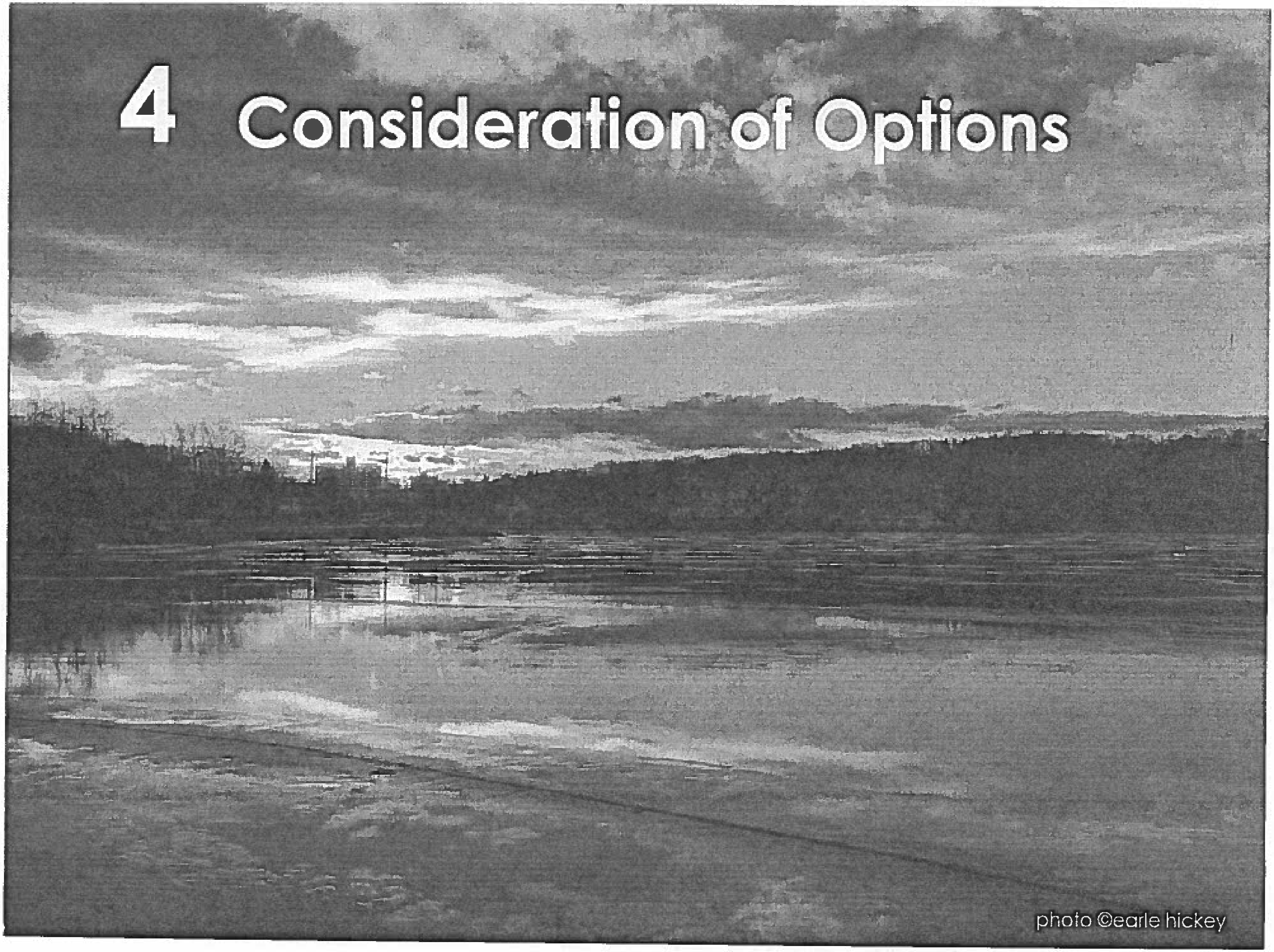


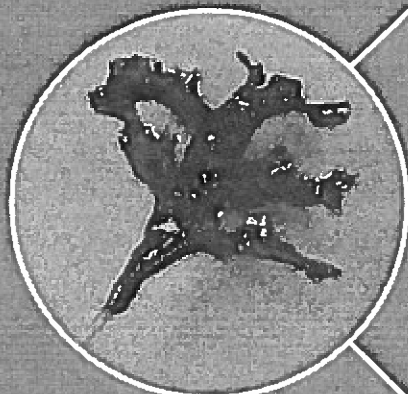
photo ©earle hickey

Detailed Evaluation

1. Herbicides
2. Mechanical Harvesting
3. Sediment Dredging

- General Description
- Specific Requirements
- Risks
- Approvals Required
- Costs

Herbicides



Goal is to affect plant before turion are produced to prevent reproduction

Many options available

- Contact herbicides act immediately and kill plant tissue on contact
- Systemic require uptake and take several weeks to act

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Herbicides

Further evaluation of specific options required to balance risk, timing, expected effectiveness in Lake Banook

- Early spring, before turion growth but after water has reached 18°C
- Low wind/mixing conditions
- Low suspended solids
- Granular or liquid form

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Herbicides

Considerations

- Not directly toxic to fish, but BOD* of decomp. may suffocate them
- May kill beneficial vegetation, including shore-stabilizing plants
- Releases nutrients during decay, which further enriches sediment
- May take 5 years of application to achieve balance

*biological oxygen demand

Herbicides

Recommendations for restrictions on activities following herbicide treatments using common types

Herbicide	Swimming	Fishing	Irrigation	Drinking
	Days of Restriction			
Endothall	0	3	7	-
Diquat	3	1	3	14
Fluridone	0	0	30	0

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Herbicides

- Class II approval under Activities Designation Regulations of the Nova Scotia *Environment Act*
- Class V Aquatic Vegetation Certificate
- Department of Fisheries and Oceans consultation
- Advance public notification

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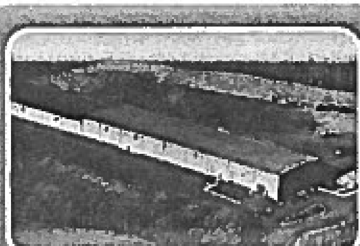
Mechanical Harvesting

Vessel based mowing and collection

Transfer to truck



Disposal at appropriate facility

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Mechanical Harvesting

Considerations

- Can be completed any time and multiple times a year
- May not be required after several years
- Vegetation should be removed to remove BOD demand, propagules and nutrients from the system
- Incidental kill of fish and invertebrates
- Difficult near docks and in shallow water
- Desirable vegetation removed as well

Mechanical Harvesting

- Water Approval from NS Environment
- Consultation with Department of Fisheries and Oceans; authorization may be required
- Approval from disposal facility

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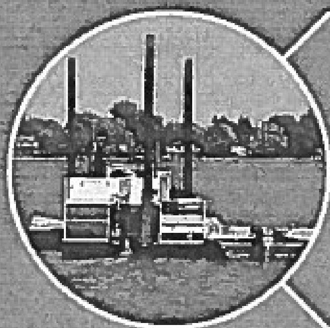
Sediment Dredging



Physical removal of enriched sediment and problem biomass

Dewatering of sediment

Disposal

Sediment Dredging

Considerations

- Benthic habitat destruction
- Removal without suspension
- Large area required for containment for dewatering
- No on-site disposal options, so transport required for disposal
- Interruption of activities
- Sediment may continue to accumulate

Sediment Dredging

- Water Approval from NS Environment
  - Dewatering
  - Alteration of water body
- Department of Fisheries and Oceans will review for harmful alteration of fish, fish habitat or aquatic Species at Risk
- *Navigation Protection Act* authorization
- Approval from disposal facility
- Testing for land disposal/dewatering
- Transport requirements

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Costs

Herbicides $36,000 to $119,000 per year*

* Multiple years required

Herbicide	Cost per ha	Cost for 1/3 of Lake Banook (approx. 16 ha)	Cost for 1/2 of Lake Banook (approx. 24 ha)	Whole Treatment of Lake Banook (47 ha)
Endothall	$1,730 - $ 2,470	$ 28,000 - $ 40,000	$ 42,000 - $ 60,000	$ 81,500 - $ 116,000
Fluridone	$990 - $1,850	$ 16,000 - $ 30,000	$ 24,000 - $ 45,000	$ 46,500 - $ 87,000
Diquat	$740 -$990	$ 12,000 - $ 16,000	$ 18,000 - $ 24,000	$ 35,000 - $ 46,500
Summary	$740 - $2,470	$ 12,000 - $ 40,000	$ 18,000 - $ 60,000	$ 35,000 - $ 116,000

*Lake Banook only

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Costs

Mechanical Harvester

Contracted for $182,000 per year*

Purchase from $ 96,000 to $ 295,000

Operate $19,000-$24,000 per year

Item:	Assumptions:	Estimated cost:
Harvester operator	$20/hour; 100 - 150 hours per year	$2000 - $3000
Maintenance/parts	Minor repairs/maintenance	$2000 - $5000
Fuel for harvester	50 liters/8 hours = 625 - 938 liters @ $1.50/l	$940 - $1400
Helper	$20/hour; 100 hours	$2000
Dump truck driver	$20/hour; 100 hours	$2000
Disposal	$75 per ton disposal costs, 135 ton/yr	$10,000
	Approximate Annual Operation Cost Total	$19,000-$24,000

*Lake Banook only

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Costs

Dredging $645,000 to $1,000,000*
(not including dewatering)

Item	Assumptions	Magnitude of Cost Estimate
Engineering Design	Method selection, sediment and erosion control design, dewatering design, etc.	$20,000 - $50,000*
Approvals	Consultants retained for this work	$10,000 - $20,000*
Dredging	9,000 m³ of sediments for removal	$100,000 to 1,000,000*
Dewatering	9,000 m³ of sediments of saturated sediments	Not likely feasible
Transport	16,650 ton to be transported in 22 ton tandem trucks at $40 for a round trip	$16,500
Disposal	16,650 ton disposed at $30 per ton	$499,000

*Lake Banook only

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Summary

Sudden growth of vegetation in the lake was likely the result of following sequence:

non-point source urban sediment input; → sediments enrichment; and → lake level draw-down caused disturbance ecology

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Summary

Long Term Solutions

- Source Control
- Infrastructure maintenance
- Green Infrastructure

Short Term Solutions

- Herbicides
- Mechanical harvesting
- Sediment dredging

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5 Reflection

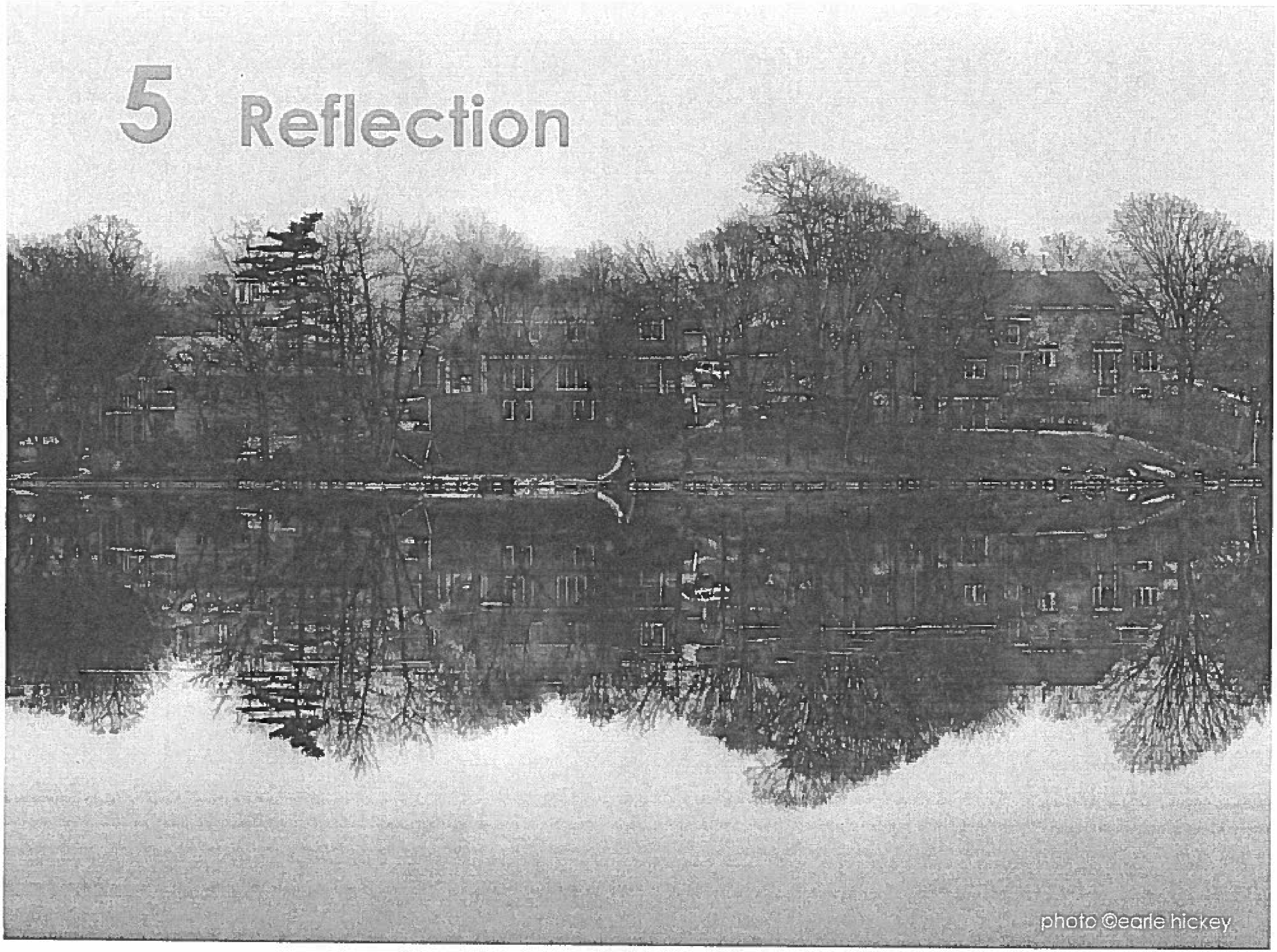

photo ©earle hickey

Detailed Cost Estimates for Short Term Weed Management Options

The Stantec report exclusively addressed Lake Banook, and consequently costing estimates assumed that each short term weed management option would occur exclusively in that lake, and not in Lake MicMac. This report assumes that each short-term option will be applied to both Lake Banook and Lake MicMac, and provides revised assumptions for each option.

The following table summarizes the cost estimate assumptions applied in this report compared against the Stantec Report.

Option	Assumptions – This report	Assumptions – Stantec report
Herbicide Application	Herbicides will be applied to the surface area of Lake Banook and Lake MicMac in the following ratios: 1/2, 1/3 and 1/1 (whole lake). Since Lake Banook is about 1/3rd the size of Lake MicMac, the cost estimates are about 4x greater than in the Stantec report.	Herbicides will be applied to the surface area of Lake Banook only, in the following ratios: 1/2, 1/3 and 1/1 (whole lake).
Mechanical Harvesting	9 hectares would be harvested in each of Lake Banook and Lake MicMac. The Lake MicMac harvesting area estimate simply assumes that the same area would apply, in the absence of weed maps for this lake.	9 hectares would be harvested in Lake Banook – based on weed maps generated in study.
Sediment Dredging	9 hectares would be dredged in each of Lake Banook and Lake MicMac. The Lake MicMac dredged area estimate simply assumes that the same area would apply, in the absence of weed maps for this lake.	9 hectares would be dredged in Lake Banook – based on weed maps generated in study.

Herbicide Application Summary

Herbicide application may be obtained as a contracted service from any qualified company that meets provincial and federal regulatory requirements, holds appropriate certificates and/or permits, and applies an approved product in compliance with the label directions. Cost estimates presented below do not incorporate the costs for labour and equipment (boat rental) required for herbicide application. Stantec estimates that these are $1,000 - $2,500 per application. Other factors that may affect the total cost of herbicide application include: shipping costs, treatment rate (dose strength), water depth, and herbicide form (liquid or granular). The estimate assumes that each application may be completed within one day by a two-person crew operating a boat.

Cost Estimate Summary, Herbicide Application to Lake Banook & MicMac

Cost per ha	Third of Lake Area (62ha)	Half Lake Area (93ha)	Whole Lake Treatment (187 ha)
$740-$990	$46,000 - $61,000	$69,000 - $92,000	$138,000 - $185,000

Mechanical Harvesting Summary

Two options are available for consideration: purchase/operate and contract services. These are broken down into separate capital, operating, and contracting costs based on a suite of assumptions, as presented below.

Purchase/Operate
Mechanical harvesters are available in a range of sizes to suit site conditions. In addition to the mechanical harvester, additional equipment is required. Shore conveyers and trailers that are designed to work with each other and the harvester are used to control the movement of harvested material from the harvester to a dump truck located on shore, which then transports the material to an approved disposal site.

Cost Estimates, Harvester Purchase/Operate (Capital)

Item	Cost Estimate (Range)
Mechanical Harvester	$56,000 - $230,000
Shore Conveyer	$33,000 - $40,000
Trailer	$5,000 - $15,000
Delivery	$2,000 - $10,000
Approximate One-Time Cost Total	**$96,000 - $295,000**

Operating costs consist of labour, transport and disposal of the harvested weeds. For estimation purposes in this report, it is assumed that:

- Harvesting is required for 18ha in total, 9ha in Lake Banook & 9ha in Lake Micmac.
- The amount of wet weed matter (biomass) in harvested areas is 7.5 ton per hectare
- Harvesting is required and will be completed three times per year
- Harvesting is completed at a rate of 5 hours per hectare
- Harvested weeds will be disposed of at the Miller Composting Facility at $75/ton

Operating cost estimates shown below are based on 200-300 hours of harvesting per year.

Cost Estimates, Harvester Purchase/Operate (Operating)

Item	Assumptions	Estimated Costs
Harvester operator	$20/hour; 200-300 hours/year	$4,000 - $6,000
Maintenance/parts	Minor repairs/maintenance	$2,000 - $5,000
Fuel for harvester	50 litres /8 hours= 1250-1875L @ $1.50/L	$1900 - $2800
Operator’s assistant	$20/hour, 200 hours	$4,000
Dump truck driver	$20/hour, 200 hours	$4,000
Disposal	$75/ton, 135 ton/year	$10,000
	Approximate Annual Operation Cost Total	**$26,000 -$32,000**

Contracted Harvesting Services

Services may be contracted without the need to purchase equipment. The estimated costs are provided below, based on the assumption of two harvesting events per year.

Cost Estimates, Harvester Contracted Service

Item	Assumptions	Estimated Costs
Mobilization to Dartmouth	Fixed rate, required twice annually. Includes mobilization, demobilization, launching excavator & barge to move material to shore	$33,000
Harvesting operation (labour)	Daily rate $13,700 @ 10 days/year	$137,000
Transport		$2,000
Disposal		$10,000
	Approximate Annual Contracted Service Cost Total	**$182,000**

Sediment Dredging & Removal Summary

The costs of dredging and removal consist of engineering design, approvals, dredging, dewatering, transport and disposal. For estimation purposes in this report, it is assumed that:

- Contaminant levels within dredged sediments meet approval conditions for facilities located within Halifax
- The volume of wet sediment requiring removal and dewatering is estimated at 18,000 sq. m

Item	Assumptions/Description	Estimated Costs (Order of Magnitude)
Engineering Design	Method selection, sediment and erosion control	$20,000 - $50,000*
Approvals	Consultants retained for this work	$10,000 - $20,000*
Dredging	18,000 m^3 of sediments for removal	$100,000 to $1,000,000*
Dewatering	18,0000 m^3 of saturated sediments	**Not likely feasible**
Transport	33,300 ton to be transported in 22 ton tandem trucks at $40 for round trip	$33,300
Disposal	33,300 ton disposed of at $30/ton	$1,000,000
	Approximate One-Time Cost Total	**$1,163,000 - $2,083,000**

* Based on Stantec professional experience

Attachment 4

Lake Management
Services – Canada

22 September 2014

Mr. Richard MacLellan
Manager, Energy and Environment
Halifax Regional Municipality

Re: HRM Waterway's Aquatic Vegetation Follow-up

Dear Mr. MacLellan:

As a follow-up to several discussions related to this topic throughout this year, I would like to discuss some specifics related to product applications in HRM's jurisdiction. The only product approved specifically by the PCP Act as an aquatic herbicide for the treatment of pondweeds is Reward (Diquat) (PCP Registration # 26271). This product can be effective and safe by administering the product pursuant to the legal limits and conditions set forth by the herbicide's label. There are several environmental factors that may hinder or assist in the efficacy of the herbicide's use, but the safety aspects to environment, residents and applicators are not affected by these environmental factors. Safety of treatment is controllable due to the low residual effects of the product, the relatively small concentrations of the product, and the applicator's ability to halt treatment until conditions are safe and favorable for maximum efficacy. Due to potential growth from fragmentation, capital purchases for mechanical harvesting equipment and the subsequent maintenance of the equipment, dedicated labor for harvesting equipment's operation and maintenance, disposal of harvested biomass, harvesting equipment limitations, and ongoing harvesting practices, aquatic herbicide treatments offer several potential benefits versus mechanical harvesting. With a proper long term plan for aquatic herbicide use, previous treatments, worldwide, have shown success and overall reductions in biomass growth and potential reduction in additional reproduction.

Related to the MicMac/Banook/Sullivan's Pond complex, the application of the Reward product will be done sub surface (eliminating spray drift via wind). The product is a contact herbicide in which the product is absorbed by the targets aquatic vegetation and the product starts working immediately. The efficacy of the treatment is based upon contact time with the aquatic vegetation. In a matter of hours, the active ingredient breaks down and is diluted by adjacent waters, rendering it neutralized. Juvenile vegetation is impacted at a higher level and mature populations of vegetation may take multiple applications to reach an acceptable level of control. Multiple applications within the prescribed retreatment timeframes compounds the effects to untreated and previously treated biomass in each treated area. Underwater currents, temperature, contact time, sunlight, and density of the biomass will all play a part in the efficacy of the initial treatment. Subsequent treatments will utilize variables from the initial treatment to improve subsequent applications.

Lake Management Services has and will continue to assist HRM in any aquatic vegetation related questions. We have made several on-site visits, attended the town hall meeting, evaluated the Stantec report and have commented favorably on their findings, and we have easily successfully completed all the required testing needed by the Environment Act & Pesticides Regulations to gain a Pesticide Certification of Qualifications issued by Nova Scotia Environment. We understand the public's apprehension to the use of aquatic herbicides, and rightfully so, in addition to the specialized testing and certification, the use of aquatic herbicides is a technical task that involves several disciplines. This type of treatment is done by specialized personnel working for specialized companies which the public does not typically interact with on a day to day basis. That is why we believe education is a major part of any treatment we coordinate or assist on. If the government is comfortable in licensing these products for use, we should feel comfortable telling you how they work before we apply.

We propose a pilot project for the treatment of Sullivan's Pond. It would serve as a small manageable test location with the same species of aquatic vegetation with reduced potential human interaction. We can follow the protocol we would use on the potential treatment of the entire lake complex. This would include an up to date evaluation, bathymetric survey, cost estimate, treatment plan, execution and post treatment evaluations and recommendations. The protocol can easily be monitored by Lake Management Services and/or Stantec. Based upon their previous work, we would be very comfortable with Stantec, acting as a third party consultant, to verify monitoring and water quality parameters throughout the pilot project. Stantec could potentially host the results of the testing online via the HRM website, if the HRM was open to that suggestion.

We would like to thank the entire Halifax Regional Municipality for their attention to this matter and their consideration of evaluating alternative methods to reduce aquatic vegetation. We understand the unique situation this is for Halifax, because we are often chosen to evaluate, opine, coordinate and treat cases similar to this on a daily basis during the growing season. We are always available to discuss any aspect of lake management, our products and services at your convenience.

Sincerely yours,

Original Signed

Jeff Garner, Vice President
Lake Management Services – Canada
Nova Scotia Environment Certificate# A5695

Original Signed

Kevin J. Matocha, Principal
Lake Management Services – Canada

Cc: Mayor Savage, Councillor McCluskey, Deputy Mayor Fisher, Municipal Clerk