GRAFTON LAKE WATERSHED STUDY
2002-2003

Prepared for:

Cove Bay Water System
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Executive Summary

This report present the results of the Grafton Lake Watershed Study 2002 - 2003. The purpose of the study was to contribute to the development of a Master Plan for the CBWS, following the recommendations of the Cove Bay Water System (CBWS) Long Term Plan (1997). The specific objectives were to:

1. Complete a watershed assessment to identify existing land uses in the watershed that pose a risk to water quality;
2. Design and implement a water quality monitoring program to determine the "baseline" conditions in the major watercourses draining into Grafton Lake; and
3. Develop and begin to implement a watershed-level public education and communication program to address land use issues related to the protection of water quality and quantity.

It was also intended that the approach developed in the present study may be adapted for use in other community water supply watersheds on Bowen Island, as these come under municipal administration in the future.

The approach used in the study, and its principal findings, conclusions and recommendations are summarized below in relation to each of the three objectives.

Land use assessment

The land use assessment was completed by evaluating the vulnerability of the Grafton Lake watershed by examining its constituent sub-watersheds and catchments, and the land uses in each were identified. In addition, a helicopter over-flight and a limited number of ground inspections were also carried out. The results of the vulnerability assessment were used to design the water quality sampling program.

The vulnerability analysis identified six types of land uses which were considered to have a high potential to degrade drinking water quality: onsite sewage disposal (failing septic systems), incineration of waste, dumping of construction waste, and commercial logging, keeping of horses, raising of poultry and other small livestock. Fire emergencies, which can occur in most land uses, were also found to pose a high risk to water quality. Specific sub-watersheds in which each of these lands uses are present are identified in the report.

Water quality monitoring

The water quality monitoring program in 2002 consisted of sampling stream water at four sites or stations within the Grafton Lake watershed. Three of these stations were located, respectively, in the headwaters, middle and lower reach of Bowen Brook, the largest of the sub-watersheds. The fourth station was located at the lower end of the Harding Brook sub-watershed, which has been most altered by human activity. Samples were collected on two occasions: June 26th (early summer) during a period of prolonged dry weather, and November 7th (mid-fall) during flushing flows from a rain storm following a period of dry weather. Analyses of duplicate samples were conducted at a commercial laboratory to measure the concentrations of a broad range of water quality parameters, including physical properties, anions, nutrients, total metals, hydrocarbons and coliform bacteria. An additional sample was collected in Harding Brook to measure PCB, PAH and pesticides. The laboratory results were compared with existing Canadian and British Columbia drinking water quality guidelines.

Water Quality Results

In general, water quality was found to be highest at the headwaters and to decrease progressively downstream, reflecting the increasing inputs of materials from both, human and natural sources. Water quality at the station on lower Harding Brook was found to be consistently lower than at the stations on Bowen Brook. Of the 156 parameters measured, only colour, pH, iron, manganese, and fecal coliform exceeded the Canadian and/or British Columbia maximum acceptable concentrations for raw drinking water.

The finding of greatest concern is the high levels of fecal coliform contamination at all stations. However, because fecal coliform also are released by wildlife (birds and mammals) and domestic animals, further monitoring is necessary at additional sites to ascertain the degree to which the fecal contamination is due to anthropogenic sources such as failing septic fields, which would pose the greatest risks to human health.

The herbicide Bromacil was the only pesticide detected in Harding Brook. However, its concentration was well below the USEPA's drinking water guideline for this substance.

The 2002 monitoring program has established a preliminary water quality baseline for the Grafton Lake watershed. Completion of an database that gives a reliable measure of natural variability will require a minimum of two additional years of monitoring. The water quality data obtained during subsequent years can be added to the database developed in 2002, and used in support of land use planning, education and watershed management decisions.

Education and Communication Program

The education and communication portion of this study included completing background research into programs and strategies used for public outreach/education and communication for source water protection. The effort included literature review, dialogue with community organizations and key individuals about Bowen Island water issues, a gap analysis of current public education programming in the island, development of a conceptual framework for public education, and the design of an education and communication plan for CBWS for 2003 –2007.

The research confirmed that any drinking water source water protection plan should include public involvement through an education and communication plan. Such a plan helps to maintain public trust in the system, helps prevent and mitigate negative impacts in the watershed, and ideally saves fiscal resources through prevention of the need for treatment to remove contaminants entering the water system.

Recommendations

Land Use (Watershed Management)

1. The Bowen Island Municipality should embark on a program to develop bylaws to regulate land uses for the protection of drinking water sources.
2. Source water protection bylaw(s) should include provisions for:
   a. public education;
   b. monitoring (inspection) of land uses in the watershed areas;
   c. enforcement in the event of non-compliance; and
   d. allocation of adequate financial and human resources to achieve the preceding provisions.
3. Land uses that should be explicitly addressed in a source water protection bylaw should include, though not be limited to:
   a. on-site sewage treatment and disposal systems (particularly septic systems);
   b. use of fertilizers and pesticides near watercourses;
   c. keeping of horses, poultry and other livestock;
   d. land clearing and drainage;
   e. quarrying and soil extraction;
   f. logging;
   g. fuel storage;
   h. crop farming; and
   i. waste incineration and dumping (these activities should be prohibited).
4. Accurate mapping of all streams and topography in the Grafton Lake watershed should be completed without delay (in conjunction with an island-wide mapping effort by the municipality). Ideally, the resolution of topographic mapping should be increased to a minimum contour interval of 2 m, although 5 m is adequate.

Water Quality Monitoring

1. Continue the water quality monitoring program in the Grafton Lake watershed for a minimum of another two years.
2. Expand the program to cover more sub-watersheds; in particular, additional information should be obtained from the following sub-watersheds or catchments if funds are available: 3, 4, 1-2, 1-8, 1-10 and 1-11, 1-13 and 1-16, as well as the outlet of Grafton Lake (see Figures 3 and 4). At the very least, the program in 2003-2004 should include the same stations as in 2002 plus Grafton Lake.
3. Increase the frequency of sampling to monthly or, at the very least, to four times per year. If sampling is increased to four times per year, the recommended timing of sample collection is:

   a. early summer (as in 2002);
   b. late summer or early fall during lowest flow conditions;
   c. fall during flushing conditions after a prolonged period of dry weather (as during 2002); and
   d. winter during the thaw immediately after a period of freezing weather.
4. Revise the sampling program to also measure the dissolved fraction of metals, for at least one year.
5. Revise the microbiological sampling program to include source-specific indicator organisms, to pinpoint failing septic systems and/or distinguish between natural (e.g., wildlife) and human or livestock sources of contamination.
6. Measure PAHs, PCBs and pesticides in all stations where sampling is to take place, particularly in the early summer, late summer low flow, and fall flushing conditions.
7. Complete an ecological assessment of the Grafton Lake reservoir every three years, as previously recommended in the Long Range Plan (1997). The first follow-up assessment should be scheduled for the spring - summer of 2003.
8. Allocate the necessary resources to include an assessment of water quality with reference to protection of aquatic life. This does not require any additional sampling; however, it does entail establishing the appropriate detection limits in the laboratory.
9. Review the water monitoring results as they become available, to detect potential problem sites and prioritize supplementary sampling, management, and education or enforcement efforts. After the third year of monitoring, review the findings and re-evaluate the list of parameters with a view toward reducing the number of analyses or stations and increasing cost-efficiency if warranted.
10. Incorporate source water quality protection as a key element in the public education program.

Water Quantity (Hydrology) Monitoring

1. Develop a hydrological monitoring program for the Grafton Lake watershed. At the very least, this program should include measurement of stream flows at or near each of the water quality stations, and on each sampling occasion.
2. The Bowen Island Municipality should consider the installation of a series of permanent, automated hydrometric stations at key locations within the watershed. As a minimum, one station should be installed near the mouth of Bowen Brook and another at the outlet of Grafton Lake.
3. The Bowen Island Municipality should consider the installation of a municipal weather station (recording rain gauge and air temperature thermometer) at a secure location within the Grafton Valley.

Public Education and Communication

1. The Bowen Island Municipality and the CBWS should adopt a policy affirming public education and communication as an integral and on-going part of the Watershed Management Plan.
2. The CBWS should implement an education and communication plan as described in this report, using a phased approach over the next four years, as is consistent with source water protection programs in other jurisdictions across North America.
3. The focus of the first phase of the program should be on raising the profile of source water protection at the “awareness” and “information” end of the outreach and education continuum. At the same time, care should be taken to maintain efforts in the area of education and technical assistance to island residents who are ready to be active stewards during the first phase of the program. Ideally, programming should be on-going right across the continuum. However, this would require more fiscal resources as well as staff and CBWS Board time than is reasonable for a small jurisdiction like Bowen Island. Therefore, the phased approach is recommended.
4. To increase cost-efficiency, funding should be shared by other water districts on the island. Many components of the program can be delivered to target audiences through public media (the Undercurrent) which reaches all island residents. However, costs of activities which specifically target CBWS users should be borne by the CBWS district.
5. Future plans should include addressing water conservation issues. A specific work plan to address this aspect of the program should be completed after the evaluation and recommendations at the completion of phase one (2003-2004).

Recommended Work Plan and Budget for 2003 – 2004

The recommended work plan for Fiscal Year 2003 – 2004 includes the following components:

- Water quality and hydrology monitoring
- Grafton Lake ecological assessment 2003
- Public education and communication
- Bylaw development

The table on the following page provides a summary description of each, and an estimate of the associated costs. Bylaw development costs have not been estimated, since it was assumed that this component would be implemented directly by the Bowen Island Municipality’s planning staff.

Recommended Work Plan and Budget
for the Grafton Lake Watershed Management Program in Fiscal Year 2003-2004

Component	Description	Estimated Cost
1. Water Quality and Hydrology Monitoring	Collect triplicate water samples 4 times per year at the same four stations as in 2002, plus at the outlet of Grafton Lake. Measure the same parameters as in 2002, plus dissolved metals, PAH, PCB and pesticides at all stations. Measure stream flows at all water quality sampling stations on each sampling date.	Professional fees: 13,400 Lab. costs and other disbursements: 21,250 Subtotal: $ 34,650
2. Grafton Lake Ecological Assessment 2003	Inspect the lake during: the peak water level in the spring, the waterfowl nesting season, and maximum draw-down in the late summer early fall. Use the information to update the environmental assessment of proposed raising of the dam spillway level and recommend procedures to mitigate impacts of reservoir level management.	Professional fees: 6,400 Disbursements: 100 Subtotal: $ 6,500
3. Public education & communication	Launch the education program: publish logo; assess community knowledge; finalize program design; focus on key land uses; begin outreach through Undercurrent articles, workshops, etc.; evaluate Year 1 results.	Professional fees: 11,400 Disbursements: 800 Subtotal: $ 12,200
4. Bylaw development	Review available documentation on bylaws and other legal instruments pertaining to drinking water quality protection through regulation of land use, incentives, and enforcement. Develop draft bylaws for review by local government and the public.	(Not costed; it is assumed that this component would be carried out by municipal planning staff)
		Professional fees: $ 31,200 (58%) Disbursements: $ 22,150 (42%) Total estimated cost: $ 53,350

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Acknowledgements

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The report was written by Alan Whitehead and D.G. Blair-Whitehead.

1.0 INTRODUCTION

1.1 Background

The Grafton Lake watershed is the largest surface source of drinking water on Bowen Island. Occupying only 16 percent (~696 hectares) of the island's surface area, this catchment basin supplies water for approximately 40 percent of the island's 3,400 residents. The watershed's location is shown in Figure 1.

Approximately one third of the residents who's water is supplied from the Grafton Lake watershed live within its topographic boundaries, while the other two thirds live outside of the basin, on the east side of the island. The former group obtain their water from a variety of wells, springs and surface water intakes within the watershed and upstream of the lake, while the latter are supplied directly from an intake in Grafton Lake.

The Cove Bay Water System (CBWS), administered by a volunteer Board under the Bowen Island Municipality, is the utility that supplies the residents who live outside of the watershed. The sole water source for the CBWS is Grafton Lake, which has a dam at the outlet and is used as a reservoir. There are several other water supply utilities on Bowen Island, which under the terms of municipal incorporation, will also become the responsibility of the Municipality over time.

The CBWS was formerly administered by the Greater Vancouver Regional District (GVRD), before Bowen Island incorporated as a municipality in 1999. The GVRD in 1997 commissioned a study to update the Long Range Plan for the CBWS, which was released in March 1998 (Dayton & Knight Ltd and A.J.Whitehead & Associates, 1998). The new Long Range Plan addressed a number of issues including water demand projections to 2010, water supply and storage needs, watershed land uses and source water quality, the distribution system, water use efficiency, the ecological status of the Grafton Lake reservoir, and related recommendations.

The Long Range Plan (LRP 1997)) recommended that, among other actions to be included in an overall management plan, the CBWS should:

1. Develop and implement a watershed-level educational program to address land use issues related to the protection of water quality and quantity;

2. Design and implement a water quality monitoring program on the major watercourses draining into Grafton Lake;

3. Design and implement a water quantity (hydrological) monitoring program to encompass the major watercourses draining into Grafton Lake and the lake outlet;

4. Undertake an ecological assessment of Grafton Lake every three years, beginning in 2001; and

5. Develop a drought management plan tied to the lake level.

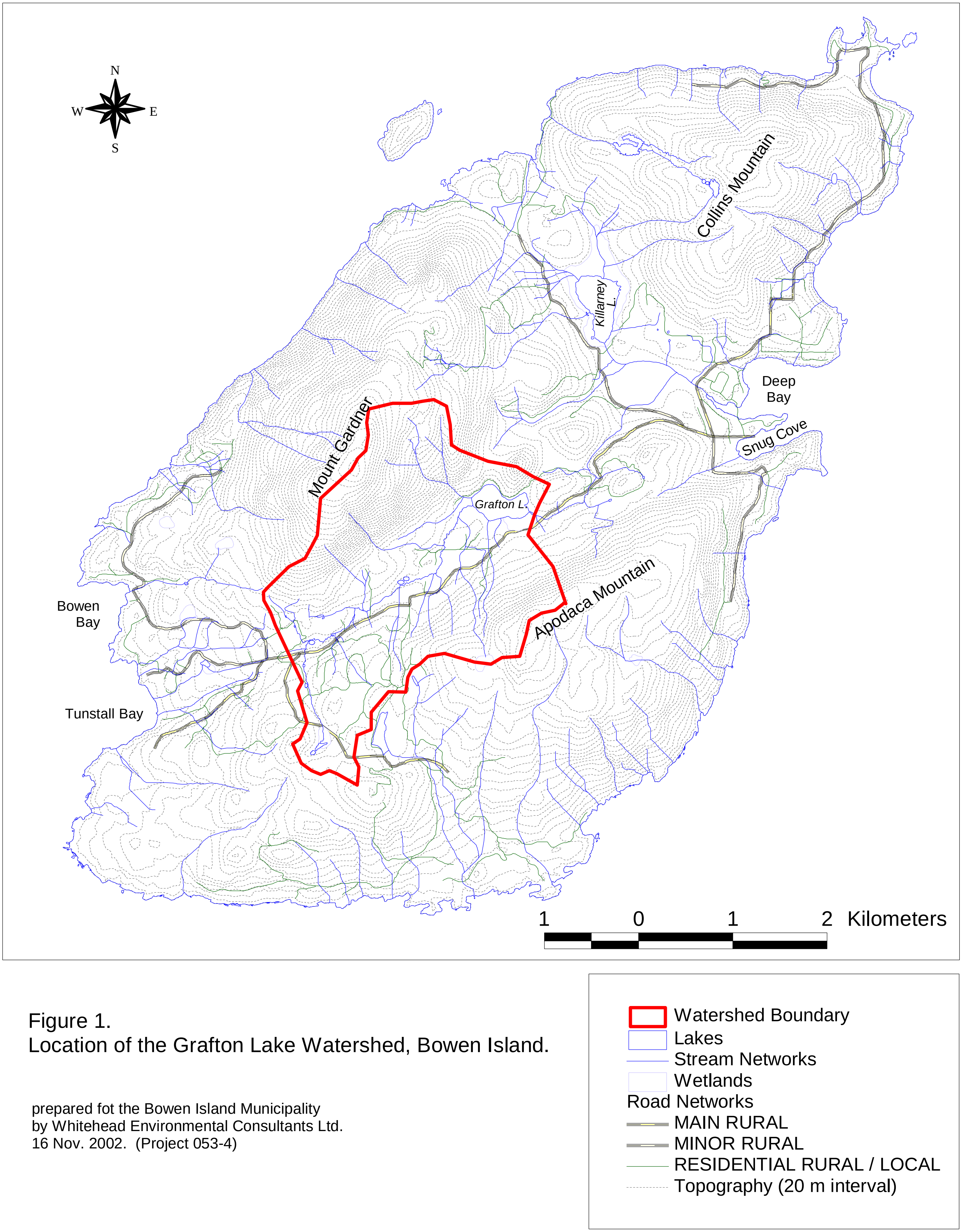


Figure 1.
Location of the Grafton Lake Watershed, Bowen Island.

prepared fot the Bowen Island Municipality
by Whitehead Environmental Consultants Ltd.
16 Nov. 2002. (Project 053-4)

Base map courtesy of the Bowen Island Forest & Water Management Society GIS

The Bowen Island Municipality, in October 2001 issued a request for Expressions of Interest to begin the implementation of the first two of these recommendations, and in January 2002 retained Whitehead Environmental Consultants Ltd. (WEC). This report presents the results on the work completed over the past year.

1.2 Source Water Protection

What is source water protection?

Source water protection is aimed at the prevention of drinking water contamination. It can save future costs in water treatment and the need to find alternative drinking water supplies. “Source water protection has a simple objective: to prevent the pollution of the lakes, rivers, streams, springs, and groundwater that serve as sources of drinking water. It is part of the growing effort to protect drinking water sources before they become contaminated.” (US EPA, undated). Most source water protection programs address both surface water and groundwater issues.

Benefits of Source Water Protection

If community drinking water sources are not protected, contamination can cause significant expense and endanger the health of a community. Cleaning up a drinking water contamination incident is complicated, costly and sometimes an impossible process. A source water protection program can protect both groundwater and surface water supplies of drinking water. “Since source water protection is a new approach, there is little data on its long term financial benefits.” (US EPA, undated) . Benefits can be measured in terms of what the costs might be, if this protection was not provided. Some of the areas for which costs can be estimated are:

- increased treatment
- remediation
- consulting services
- staff time.

There may also be significant costs to satisfy public and media interest and concern if source water contamination does occur. Experience in other localities shows that the most dramatic costs can involve locating a new water supply and the legal costs of litigating those responsible for contamination of an existing well or reservoir. Even if only a part of a town’s water supply is lost, diminishing the reserves from other sources and installing new lines all have their costs.

Communities with effective source water protection programs may enjoy savings in the following forms:

- less disinfection costs;
- less filtration costs;
- support of continued economic growth;
- maintenance of real estate values; and
- avoidance of potential loss of tax revenue and jobs in areas with known water safety problems.

1.3 Selected Approach

The selected approach to this study was based on Source Water Protection. A Source Water Protection program can consist of the following elements:

- Assessment of potential contaminant problems in the drinking water source;
- Development of source water protection plans; and
- Implementation and follow-up.

These elements can be broken into the following steps:

1. delineate source water protection areas (SWPA);
2. identify sources of contamination within SWPA that may impact public water systems;
3. determine vulnerability of SWPA to the contaminants or contaminant sources;
4. involve the public (Education and Communication)
5. implement plan to manage any current or potential contamination;
6. establish on-going management plan (adapted from, US EPA, undated).

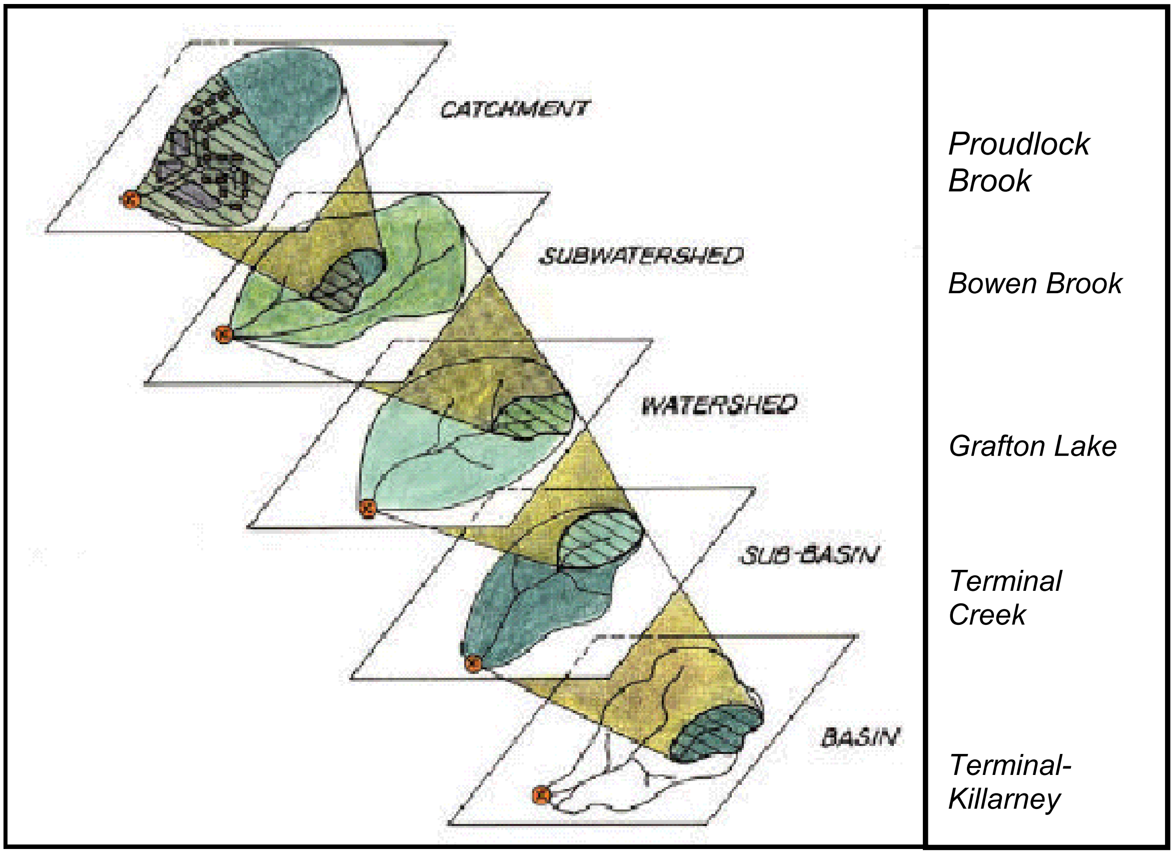
Watershed Vulnerability Assessment

The watershed assessment approach used in this study was based on the classification of the stream networks and their catchment areas according to the hierarchy shown in Figure 2. This approach allows the various water sources to the Grafton Lake watershed to be identified and linked to specific geographic areas and their land uses. In this manner, the vulnerability of each tributary stream to water quality degradation can be examined systematically, and effort can be allocated to the sub-watersheds presenting the higher levels of risk. This, in turn, increases efficiency and facilitates further diagnostic planning and on-going management.

An important short-term goal of the watershed assessment is to aid in the initial selection of stream locations where water samples should be collected for determination of water quality. These locations may also be suitable for measurement of water quantity (i.e., stream flows).

The medium term goal is to refine the monitoring program on the basis of prior sampling results, and to define clear management objectives that are based on actual knowledge of existing conditions. The long term goal is to adopt and implement a watershed management plan to sustain the quality and quantity of the water resource for all users.

Fig. 2. Watershed classification hierarchy applied to the Grafton Lake Watershed.



Adapted from: Center for Watershed Protection (2002)

1.4 Objectives

The purpose of the present study was to contribute to the development of a Master Plan for the CBWS. The specific objectives were to:

1. Complete a watershed assessment to identify existing land uses in the watershed that pose a risk to water quality;
2. Design and implement a water quality monitoring program on the major watercourses draining into Grafton Lake; and
3. Develop and begin to implement a watershed-level education and communication program to address land use issues related to the protection of water quality and quantity.

It is intended that the approach developed in the present study may also be adapted to other community water supply systems and watersheds on Bowen Island, as these come under municipal administration in the future.

2.0 METHODS

2.1 Watershed Assessment

The watershed assessment consisted of the following activities:

1. The watershed and sub-watershed boundaries were delineated and mapped according to standard methods using available topographic and stream mapping and information obtained from a variety of sources, including:
   - the provincial government's Sensitive Habitat Inventory and Mapping (SHIM) program on Bowen Brook;
   - the Bowen Island Geolibrary (Journeay and Dunster 2002);
   - the geographic information system (GIS) developed and maintained by the Bowen Island Forest & Water Management Society's (BIFWMS); and
   - a limited number of field inspections.

2. Land uses of concern were identified though a variety of methods including:
   - local knowledge and personal interviews;
   - review of the LRP (1997) report;
   - a helicopter over-flight on April 2nd 2002; and
   - a limited number of ground inspections.

The land use information obtained was then combined with the watershed delineations to identify the sub-watersheds where existing land uses were considered to pose a risk to water quality.

2.2 Water Quality Monitoring

2.2.1 Water sampling stations

A total of 21 locations were identified where water sampling was considered desirable for diagnosing the state of water quality in the Grafton Lake watershed and its sub-watersheds. The sub-watersheds and catchment boundaries are shown in Figure 3 on page 14 of this document. The sampling station locations are shown in Figure 4 (page 21). The main reasons for selecting these particular sites were that they are located:

- on the streams that drain the main sub-watersheds tributary to Grafton lake;
- downstream of known land uses that may pose a risk to water quality; and
- on publicly accessible lands (with one or two exceptions where the landowner's permission would need to be obtained).

The number of stations, frequency of sampling and parameters to be analyzed during 2002 were established on the basis of the available funds for laboratory analyses. Unfortunately, sampling of water directly from Grafton Lake was precluded by the available budget. Four sites were selected for sampling during 2002, as described in Table 1 and shown in Figure 4.

Table 1. Description of the water quality sampling stations in the Grafton Lake Watershed

Station No.	Stream (sub-watersheds)	Location	Rationale
1	Bowen Brook (1)	At the mouth, immediately upstream of Grafton Lake; on private property	Drains the hobby farms north of Harding Rd., which include horticultural, equestrian, goats and poultry operations.
2	Unnamed creek (1-16)	At the mouth, immediately upstream of Grafton Lake; on private property	Drains undeveloped lands; would be a good "control" or reference station
3	Grafton Lake	At the outlet, immediately upstream of the dam; on CBWS dam	Lake water; represents the raw source water used by the CBWS; Note: an alternative sampling site for raw lake water is at the CBWS chlorination station.
4 *	Bowen Brook (1-1, 1-2, 1-3, 1-4, 1-14)	Approx., 50 m downstream of Harding Road; elevation 110 m (approx.)	***Lower valley****; approx. 600 m upstream of the discharge to Grafton Lake; and is downstream of Spooner Brook that drains an area of mixed residential, equestrian and heavy machinery use.
5	Spooner Brook (1-15)	At Harding Road culvert, immediately upstream of confluence with Bowen Brook	Drains an area of hobby farms including an equestrian facility and a heavy machinery maintenance yard.
6	Bowen Brook (1-1 through 1-13)	At Harding Road, upstream of confluence with Spooner Brook	Drains the lower mid-valley area, in an area of hobby farms.
7 *	Harding Brook at McDonald Farm (4-1, 4-2)	Approx. 100 m downstream of Harding Road; elevation 115 m	***Highly altered sub-watershed**** with extensive clearing and development, including the lumberyard, residential, horticultural and small and large livestock uses.
8	Clink Brook (4-3, incl. tribs)	At Harding Road culvert	Drains an area where commercial logging has taken place in the recent years; no residential development
9	Unnamed creek (4-2)	At Harding Road culvert, upstream of confluence with Harding Brook	Small catchment, drains an area of hobby farms with potential livestock and solid waste piles
10	Harding Brook (4-1)	At Grafton Road, below lumber yard	Receives drainage from the lumber yard and up-slope cleared area
11	Mac-Wha Creek (1-2)	At Grafton Road culvert	Drains a cleared slope that was source of much turbidity in the past; azalea "plantation"
12	Proudlock Brook (1-3)	At Grafton Road culvert	Drains hobby farms with poultry, former nursery and tilled cropland
13	Bowen Brook (1-1, 1-4 to 1-13)	At private driveway culvert	Approximate centre of watershed, drains east half of dense residential along Adams Rd.
14 *	Bowen Brook (1-1, 1-5 to 1-13)	Approx. 30 m upstream of Buchanan Road culvert; elevation 155 m	***Mid-valley**** near the centre of the watershed, is below an area of relatively higher density residential use and downstream of the discharge from Billington Brook that drains an industrial site (quarry, dump and incineration).
15	Billington Brook (1-13)	On private property, immediately upstream of discharge into Bowen Bk	drains an industrial site (quarry, dump and incineration)
16	Bowen Brook (1-1)	On private property, immediately upstream of discharge from Billington Bk	Drains numerous hobby farms and dense residential development along Adams Rd.; mid-watershed location.
17	Lister Creek (1-4)	At Adams Road culvert	drains the Willies way subdivision, with horses and poultry
18	Peggy's Creek (1-10, 1-11)	At end of Westside Road allowance	Drains an area of hobby farms including the island's largest equestrian operation
19	Upper Bowen Brook (1-8, 1-9)	At Adams Road culvert, upstream of confluence with Murray Creek	Drains the hobby farms along Sunset Drive, which include livestock and orchards.
20 *	Upper Bowen Brook (1-8, 1-9)	upstream of Sunset Drive culvert; elevation 230 m [(1)]	***Headwaters**** catchment area with no existing development other than pond construction upstream of the natural wetland.
21	Phantom creek (1-7)	At Adams Rd. culvert	Drains a large headwaters wetland in D.L.1546

* - stations sampled during 2002 (see Figure 4).

2.2.2 Sampling frequency

The sampling frequency was dictated by the available monetary resources. Samples were collected twice during 2002, once on June 24th and once on November 7th. This timing was selected to provide an initial characterization of the range of water quality conditions than might be expected to occur in the watershed. The sample collected in June represented the "end of the wet season" during dry weather and conditions of decreasing flow after the land has been thoroughly flushed or rinsed by the preceding seasons' precipitation and runoff. The sample in November represented the "end of the dry season" during conditions of increasing precipitation and stream flow when the land was being first flushed after a period of prolonged dry weather.

2.2.3 Parameters analyzed

The analytical tests or parameters were selected to provide information on the overall status of water quality, including physical characteristics such as colour and turbidity; chemical constituents such as fertilizers, metals and other compounds; and microbial content such as coliform bacteria. The parameters analyzed are listed in Table 2.

An opportunity to conduct limited additional testing for complex synthetic organic compounds and pesticides was made possible by a funding donation from the Bowen Island Forest & Water Management Society (BIFWMS). Accordingly, one water sample from Station 7 (Harding Brook below Harding Road) was collected, on November 7th 2002 and analyzed for the parameters listed in Table 3.

The water sampling procedure consisted of collecting duplicate samples at each station on each date. The samples were collected using specialized glass or plastic containers provided by the laboratory, then preserved where necessary according to the laboratory's instructions; refrigerated in a cooler with icepacks; and sent within 24 hours by courier to an accredited commercial laboratory. The laboratory used during 2002 was ALS Laboratories Inc. in Vancouver. Water temperature and pH were measured directly in the field using a manual thermometer and a hand-held electronic pH meter (Hanna Instruments, model pHep1).

Bacteriological sampling for total and fecal coliform was carried out separately by the Bowen Island Municipality. Total and fecal coliform counts were measured by the CBWS at the same stations as the other water quality parameters, on August 26th and November 17th, 2002. In addition, samples were collected in Grafton Lake at the outlet and, on November 17th only, at two additional locations in the Harding Brook watershed upstream of Station 7. The locations of the additional stations are shown in Figure 5.

Table 2. Water quality parameters analyzed in the Grafton Lake Watershed study during 2002.

Physical Tests	*Nutrients*
Colour (CU)	Ammonia Nitrogen
Conductivity (uS/cm)	Total Kjeldahl Nitrogen
Total Dissolved Solids	Nitrate Nitrogen
Hardness as $CaCO_3$	Nitrite Nitrogen
pH	Organic Nitrogen
Total Suspended Solids	Total Nitrogen
Turbidity (NTU)	Dissolved ortho-Phosphate P
	Total-Phosphorus
Dissolved Anions	
Alkalinity-Total $CaCO_3$	*Total Metals*
Chloride Cl	Aluminum T-Al
Fluoride F	Antimony T-Sb
Sulphate SO_4	Arsenic T-As
	Barium T-Ba
Bacteriological Tests	Boron T-B
Coliform Bacteria - Fecal	Cadmium T-Cd
Coliform Bacteria - Total	Calcium T-Ca
	Chromium T-Cr
Non-Halogenated Volatile Organics	Copper T-Cu
Benzene	Iron T-Fe
Ethylbenzene	Lead T-Pb
Styrene	Magnesium T-Mg
Toluene	Manganese T-Mn
meta- & para-Xylene	Mercury T-Hg
ortho-Xylene	Potassium T-K
Total Xylenes	Selenium T-Se
Volatile Hydrocarbons (VH6-10)	Sodium T-Na
Volatile Petroleum Hydrocarbons	Uranium T-U
	Zinc T-Zn

Table 3. Additional water quality parameters analyzed in Harding Brook at Station 7, November 7th 2002.

Polycyclic Aromatic Hydrocarbons	Endrin	Dacthal
Acenaphthene	Heptachlor	Desethyl Atrazine
Acenaphthylene	Heptachlor Epoxide	Desmetryn
Acridine	Lindane (gamma - BHC)	Diclofop-methyl
Anthracene	Methoxychlor	Eptam
Benz(a)anthracene	Mirex	Ethalfluralin
Benzo(a)pyrene	cis-Nonachlor	Hexazinone
Benzo(b)fluoranthene	trans-Nonachlor	Metolachlor
Benzo(g,h,i)perylene	Oxychlordane	Metribuzin
Benzo(k)fluoranthene		Profluralin
Chrysene	**Organophosphate Pesticides**	Prometryn
Dibenz(a,h)anthracene	Azinphos methyl	Pronamide
Fluoranthene	Carbophenothion	Propanil
Fluorene	Chlorpyrifos	Propazine
Indeno(1,2,3-c,d)pyrene	Coumaphos	Simazine
Naphthalene	Diazinon	Terbacil
Phenanthrene	Dichlorvos/Naled	Terbuthylazine
Pyrene	Dimethoate	Terbutryn
Quinoline	Disulfoton	Triallate
	Ethion	Trifluralin
Polychlorinated Biphenyls	Fenitrothion	
Total Polychlorinated Biphenyls	Fensulfothion	**Acid Extractable Herbicides**
	Fenthion	2,4,5-T
Organochlorine Pesticides	Fonofos	2,4-D
Aldrin	Malathion	Dicamba
alpha-BHC	Mevinphos (Total)	2,4-DB
beta-BHC	Parathion	Dichloroprop
delta-BHC	Parathion-methyl	Dinoseb
cis-Chlordane (alpha)	Phorate	MCPA
trans-Chlordane (gamma)	Phosalone	Mecoprop (MCPP)
2,4'-DDD	Phosmet	Picloram
4,4'-DDD	Terbufos	Silvex (2,4,5-TP)
2,4'-DDE		
4,4'-DDE	**Herbicides**	**Pyrethroids**
2,4'-DDT	Alachlor	Cypermethrin-1
4,4'-DDT	Atrazine	Cypermethrin-2
Dieldrin	Benfluralin	Cypermethrin-3
Endosulfan I	Bromacil	Cypermethrin-4
Endosulfan II	Butylate	Deltamethrin
Endosulfan Sulfate	Cyanazine	cis-Permethrin
(cont'd.)	(cont'd.)	trans-Permethrin

2.2.4 Water Quality Database

Development of the water quality database involved:

- Gathering any previously available data on water quality in the watershed, from the CBWS and other sources, in addition to the new data generated by this study during the 2002 sampling campaign; and
- Compiling and tabulating the data in a computerized spreadsheet, using Microsoft Excel® software.

2.3 Education & Communication Program

The objectives of this portion of the study were to:

- Begin to develop an educational program identifying existing and long-term land use issues and their impact on water quality as well as methods to avoid, prevent and mitigate impacts and restore damaged areas.

- Open dialogue with community groups for their potential involvement in the program (e.g. B.I. Forest & Water Management Society, Nature Club, Fish & Wildlife Club, Horse Owners & Riders Association, etc.).

The approach used to meet these objectives included standard environmental education and communications methodology, as described below.

2.3.1 Background Research

- Research into other programs and strategies implemented elsewhere that have similar objectives of the CBWS study;
- Literature reviewed included: journals, teacher and education guides, and websites. The U.S. Environmental Protection Agency, Ontario's Stewardship Centre, York Regional Water for Tomorrow, Greater Vancouver Regional District (GVRD) and Capital Regional District CRD) websites were especially helpful;
- Information specifically about Bowen Island water issues was gathered from various sources. The water poster working group (Geological Survey of Canada Bowen Island Water Poster) was chosen as a key group as it gathered representatives from a variety of groups such as water districts, BIFWMS, Nature Club, BIHORA and others in regular meetings. Other sources included; Sustainable Communities Water meeting, Cove Bay Water System Public meetings, and CBWS Board meetings;
- Information specific to Grafton Lake watershed water quality including sites or activities requiring mitigation was based on this study's water quality program;
- Further information about these sources may be found in the references section of this document.

2.3.2 Gap Analysis

A gap analysis was conducted reviewing any projects related to water and watershed stewardship education programs underway on Bowen Island. Gaps in programming were identified. This gap analysis was undertaken in conjunction with the Bowen Island Forest & Water Management Society's FsRBC Watershed Education Project.

2.3.3 Conceptual Framework Development

Based on background research and the gap analysis a conceptual framework was developed, which identified "key concepts" or messages, the understanding of which is essential to the CBWS education program.

2.3.4 Education and Communication Program Design

Based on the findings of the literature review and gap analysis, an education and communication program was designed which includes public involvement, communication, and education components aimed at meeting the long term outcome of Source Water Protection. The program design includes overall goals and objectives focused on source water protection of the Grafton Lake Watershed using a phased approach over the next four years.

3.0 RESULTS AND DISCUSSION

3.1 Source Water Quality Assessment

3.1.1 Sub-Watersheds and Land Uses

The network of mapped streams that flow into Grafton Lake, and the corresponding sub-watershed boundaries are shown in Figure 3. By convention, the sub-watersheds and catchments are numbered in a clockwise direction from the mouth (Center for Watershed Protection 2002). Where available, stream names as listed in the BIFWMS GIS are also provided (Table 4).

A total of four sub-watersheds were identified (Figure 3). The largest is Bowen Brook, which contains at least 16 catchments (or sub-sub-watersheds). A number of streams, particularly in sub-watershed 3 and catchments 1-4, 1-5, 1-6, 1-7, 1-9, 1-10, 1-12, 1-13, and 1-16 are not yet accurately mapped. In addition, the available topographic mapping, which provides 20 m contour intervals, does not provide a sufficient level of resolution to enable accurate delineation of the boundaries of the smaller catchments.

Table 4 provides a description of the main land uses in each sub-watershed and identifies land uses that were considered to pose a concern for water quality. The land uses and the water quality concerns associated with each, are discussed below in decreasing order of abundance. Representative photographs are provided in Appendix B.

Undeveloped Forest (Photo 1): is present in all of the sub-watersheds and, since it is largely undisturbed, poses the no significant water quality concerns. This also includes areas such as nature reserves and lands protected by conservation covenants. Secondary land uses that are associated with undeveloped forest are largely limited to passive recreation, such as hiking, mountain biking and horse riding (the latter where well established trails or old logging roads are available). The risks to water quality from these are considered minor, since the secondary activities are extensive rather than intensive. (See Horses, below.)

Residential (Photo 2): is present in all but three of the sub-watersheds. Potential sources of water quality impairment from this land use include: improperly maintained septic systems; garden fertilizers and pesticides (insecticides, nematicides, herbicides and fungicides), erosion from driveways and other unvegetated areas (particularly during clearing and construction of new driveways and residences), and leaks or spills of fuel and lubricants from furnace oil tanks, home-based maintenance of vehicles and other machinery. Residences are by far the most intensive land use in the watershed; although the impacts from any one residence may be small, the cumulative impact from numerous houses can be significant. (See Fire Emergency, below.) The level of water quality concern is considered moderate to high; however, this is one land use in which the level of risk can be most readily reduced through prevention at the household level.

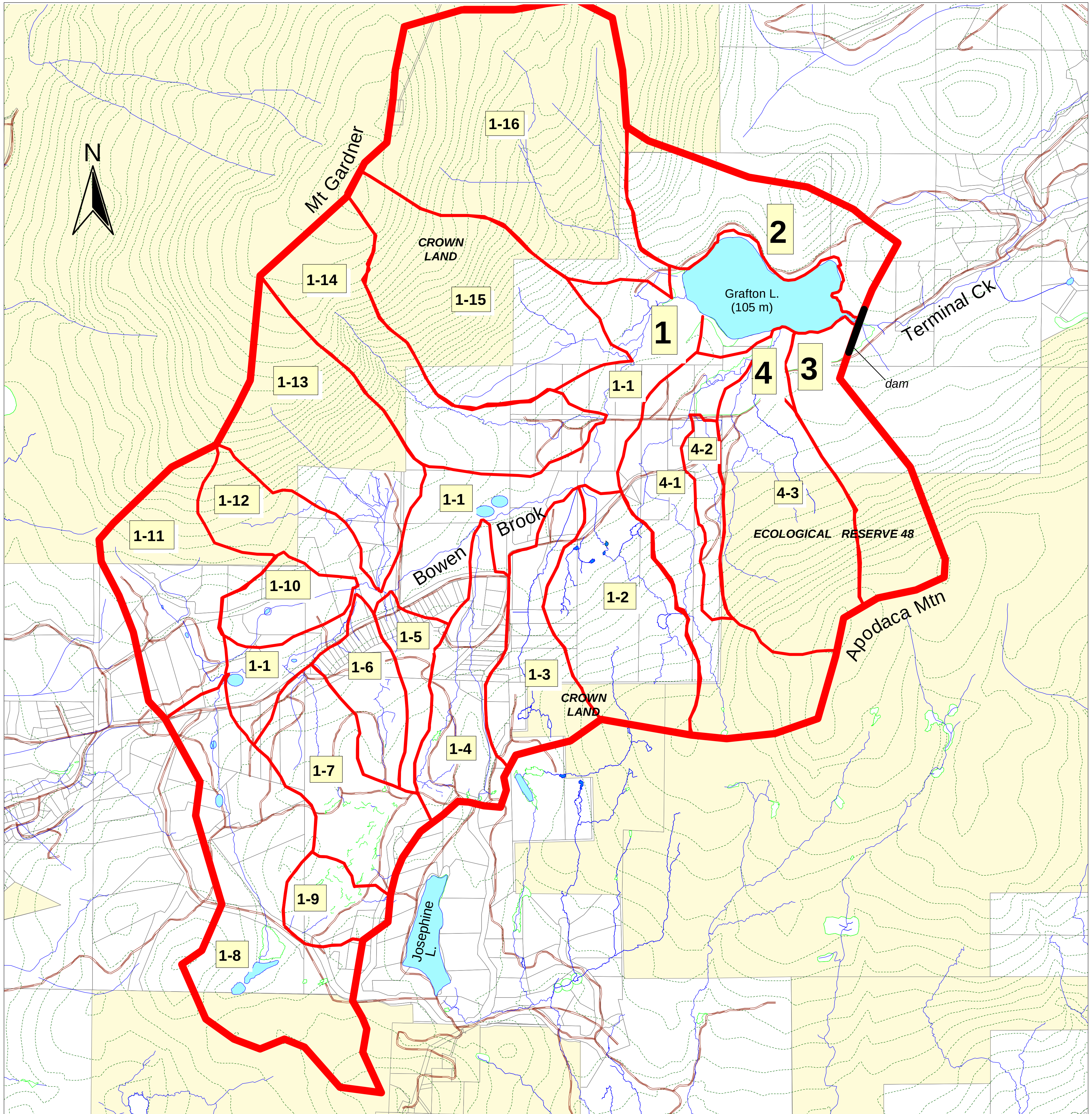


Figure 3.
Grafton Lake Watershed and Sub-watersheds, Bowen Island

- Grafton Lk Watershed Boundary
- Creeks (updated to March 27 2003)
- Lake or Large Pond
- Wetlands (updated to March 27 2003)
- Roads
- Elevation (20 m contours)
- Small pond
- Crown Land or Municipal Park
- Property boundary
- Sub-watershed boundary
- 1 Sub-watershed number
- 1-4 Catchment number

500 0 500 1000 Meters

Prepared for the Bowen Island Municipality. November 12, 2002.
Whitehead Environmental Consultants Ltd. (Project 053-4)
Rev. 4, 28-Mar-03

Note: Sub-watershed and catchment boundaries are based on creek locations shown in earlier mapping. While some creek locations have been updated, corresponding catchment boundaries will need to be updated.

Base map courtesy of the Bowen Island Forest & Water Management Society GIS.

Table 4. Land Uses in the Sub-watersheds and Catchments of the Grafton Lake Watershed, Bowen Island.

No.	Name	Area			Land Uses													
Sub-watershed *Catchment*	**Grafton Lake watershed**	(ha)	(%) of whole	(%) of sub-ws	Forest & Outdoor Recreation	Residential	Public Roads	Crops	Horses	Poultry & Other Livestock	Machinery Maintenance	Rock and Topsoil Quarrying	Waste Incineration	Waste dumping	Horticultural Supply/ Nursery	Lumber & Hardware Store	Logging	Number of land uses
1	**Bowen Brook**	547.4	79%															
1-1	[direct drainage]	75.0	11%	14%	**x**	**x**	**x**	**?**	**x**	**x**							**x**	**≤7**
1-2	Mac-Wha Ck	36.0	5%	7%	**x**	**x**	**x**			**x**		**x**	**x**	**x**				**7**
1-3	Proudlock Br	22.5	3%	4%	**x**	**x**	**x**	**x**	**x**						**x**			**6**
1-4	Lister Creek	23.1	3%	4%	**x**	**x**	**x**	**x**	**x**	**x**								**6**
1-5	?	8.5	1%	2%	**x**	**x**	**x**		**x**	**?**								**≤5**
1-6	?	13.2	2%	2%	**x**	**x**	**x**			**x**								**4**
1-7	Phantom Ck	26.6	4%	5%	**x**	**x**	**x**	**?**										**≤4**
1-8	upper Bowen Bk	56.2	8%	10%	**x**	**x**	**x**	**x**	**x**	**x**								**6**
1-9	?	10.2	1%	2%	**x**	**x**	**x**											**3**
1-10	?	11.6	2%	2%	**x**	**x**	**x**			**?**								**≤4**
1-11	Murray Ck	33.1	5%	6%	**x**	**x**	**x**	**x**	**x**									**5**
1-12	?	17.6	3%	3%	**x**													**1**
1-13	Billington Ck	40.9	6%	7%	**x**	**x**	**x**					**x**		**x**				**5**
1-14	Spooner Bk	41.4	6%	8%	**x**	**x**	**x**	**x**	**x**	**x**	**x**							**7**
1-15	Robb Ck + ?	51.0	7%	9%	**x**	**x**			**?**	**?**								**≤4**
1-16	?	80.3	12%	15%	**x**	**x**			**?**	**?**								**≤4**
2	**[direct drainage]**	27.9	4%		**x**												**x**	**2**
3	**?**	27.8	4%		**x**		**x**										**x**	**3**
4	**Harding Brook**	93.0	13%															
4-1	Harding/Cliff Bk	42.5	6%	46%	**x**	**x**	**x**	**x**	**x**	**x**	**x**		**?**	**?**		**x**		**≤10**
4-2	?	7.2	1%	8%	**x**		**x**										**x**	**3**
4-3	Clink Ck	43.3	6%	46%	**x**		**x**										**x**	**3**
Totals	**19**	696.1	100%		**19**	**16**	**14**	**9**	**8**	**9**	**3**	**3**	**2**	**2**	**1**	**1**	**1**	
Level of concern regarding water quality: N = none, L = Low, M = Moderate, H = High					*N - L*	*M-H*	*M*	*M*	*H*	*H*	*M*	*M*	*H*	*H*	*L*	*M-H*	*H*	

Note: question marks (?) indicate either unnamed stream, or possible (unconfirmed) land use in the indicated sub-watershed or catchment; "≤" in land use totals at right indicates this uncertainty.

Public roads (Photos 1, 3): are present in all but five of the sub-watersheds. Bowen Island's main east-west artery, Grafton and Adams Road, crosses through ten of the sub-watersheds, and the main route to the south side, Sunset Drive, follows the upper watershed to the headwaters. Surface drainage from these roadways is conveyed through a system of ditches to Bowen Brook, either directly or indirectly via its tributaries. The potential contaminants from the roadways include salt used for ice control in winter, hydrocarbons from lubricant and fuel drips on the road surface, and spills of fuel or other materials due to vehicle accidents (see Fire Emergency, below). The level of water quality concern is considered moderate.

Horses and equestrian facilities (Photo 3): are known to be present in six of the sub-watersheds, and are probably present in at least another two. The size of the facilities varies from family to commercial scale stables. The water quality concerns associated with this use include contamination by manures, leachates from paddock and pen bedding, erosion from areas denuded of vegetation by trampling, erosion due to direct access of animals into the watercourses, and possibly veterinary chemicals. The level of water quality concern is considered high; however, the level of risk can be readily reduced through appropriate mitigation. As with poultry and small livestock, the most effective control is to prevent animal access to water courses and streamside areas; and to cover any piles of manure and bedding removed from stables, which may be stored out of doors.

Poultry and small livestock (Photos 4, 10): are known to be raised in seven of the sub-watersheds, and are probably present in another two. Most of these are family scale operations for home consumption; however, commercial operations also exist, notably in sub-watersheds 1-1, 1-8 and 4. The main potential sources of water contamination are the manures, erosion from areas denuded of vegetation by chickens, and possibly antibiotics and other veterinary chemicals. (The dog kennel was inspected during the course of this study and was found to pose no risk of surface water contamination.) The level of water quality concern is considered high at present, particularly with free-range poultry; however, the degree of risk can be readily reduced through appropriate mitigation, the most effective of which is to prevent access to water courses and streamside areas.

Crop farming (Photos 2, 4): is known to take place at a small (hobby farm) to commercial scale in six sub-watersheds and may be present in another two. Much of the eastern valley floor lies within the agricultural land reserve (ALR), although only a small portion of the ALR is presently used for agriculture. The main water quality concerns associated with this land use are erosion from tilled, unvegetated fields, and potential release of fertilizers and pesticides into surface and groundwaters. The level of water quality concern is considered moderate; however, the level of risk can be readily reduced through appropriate mitigation, including best practices such as contour ploughing, planting of winter cover crops, use of organic farming methods and integrated pest management, among others.

<u>Machinery maintenance</u>: is known to take place in at least three sub-watersheds, and ranges from small-engine and automotive repair to heavy equipment and transport trucks. Sources of potential contamination include spills of stored fuels (diesel and gasoline), lubricants, and metals in used motor oils (See Fire Emergency, below). The level of water quality concern is considered moderate; however, the level of risk can be readily reduced through appropriate mitigation. Key preventive measures include the use of secondary containment for fuel tanks, use of impermeable liners and/or absorbent pads to collect fuel and lubricant drips during maintenance, and storing of used oils or fuels for off-site disposal at an approved facility.

<u>Quarrying and gravel crushing</u> (Photos 5, 9): commercial quarrying and topsoil extraction operations exist or have existed in up to four sub-watersheds; small quarrying also takes place incidentally during residential construction projects. Sources of potential surface or groundwater contamination include release of sediments in surface runoff, leaks or spills of stored fuels, lubricants, and metals. The level of water quality concern is considered moderate; however, the level of risk can be readily reduced through appropriate mitigation. The main preventive measures include appropriate drainage management including the use of sediment traps, and use of absorbents to prevent soil contamination by lubricant drips from heavy duty machinery.

<u>Waste incineration and dumping</u> (Photos 5, 6): is known to have taken place at two locations, and possibly another. The risks to water quality due to incineration of construction debris and other non-natural materials are associated with the release of contaminants such as metals and other potentially toxic substances, either directly from the ash through runoff or indirectly through precipitation (e.g., toxic rain). The risks due to waste dumping relate mainly to leaching of metals, acids and other potentially toxic substances from the dumped materials by rainfall and subsequent release into surface or groundwaters. The level of water quality concern is considered very high; these activities should not take place in a water supply watershed.

<u>Commercial Nursery and Horticultural Supplies</u> (Photos 4, 7): one facility exists at present, which stores and sells a broad range of horticultural products and chemicals, and another has existed in the past. Perceived potential water quality concerns are associated with any release of fertilizers or pesticides due to on-going operations or spills. The level of water quality concern is considered low because the supplies are stored under cover and operational use of potential contaminants is limited.

<u>Lumberyard and Hardware Supplies</u> (Photo 7): one facility exists at present, which stores and sells a wide variety of building products. This is also the largest human-made impervious surface in the watershed. The main concerns regarding water quality are the potential release of anti-sap stain chemicals and wood preservatives due to leaching from the stored lumber by rainfall. The level of water quality concern is considered moderate to high (see Fire Emergency, below). The level of risk associated with any materials that are stored outdoors can be readily reduced through appropriate mitigation, such as use of tarps or permanent covers, and adequate stormwater management, including collection during emergencies and treatment if necessary.

Commercial Logging (Photo 8): takes place intermittently on one private property. Water quality impacts associated with this location have been identified in the past, and include erosion in the skidder trails and haul road, and resulting turbidity in surface waters draining from the site into the lake and Terminal Creek. The level of water quality concern is considered high; however, the degree of risk can be reduced through appropriate mitigation, such as on-going maintenance of stormwater systems including the use of sediment traps, and avoidance of logging in streamside areas or very steep slopes.

Fire Emergency: (not listed in Table 3-1) was identified as an additional risk that is associated with most of the land uses described above. With the exception of forest fires, most fire emergencies are generally short-lived. In the case of fires involving human-made materials, there is a high potential for the combustion to release a variety of contaminants, such as complex organic molecules, caustics, acids and metals, which can then be leached and transported from the site by the large volume of water that is typically used in fire fighting. Forest fires can also result in the release of contaminants used in fire suppression chemicals, and in subsequent erosion from the burned areas. The level of water quality concern is rated as high. The degree of risk can be reduced, however, through appropriate prevention, contingency planning and, possibly, site specific mitigation.

3.1.2 Water Quantity (Hydrology)

Water quantity was not measured during this study. However, it is recognized that watershed hydrology is intimately connected with water quality for a number of reasons. Possibly the most important reason is that the potential for release of certain types of contaminants to surface water is directly related to the amount of untreated runoff from the developed or otherwise disturbed portions of the landscape. This relationship is addressed in the Recommendations provided in Section 4.

Knowledge of the hydrological conditions at the time of water quality sampling is important to enable effective interpretation of the laboratory results. Information on precipitation during the week preceding sampling was obtained from the coordinator of the Bowen Island Forest & Water Management Society's volunteer rain gauge network, Anne Franc de Ferriere Chollat. Rainfall is measured daily at Westside Road (catchment 1-11). On the five days preceding water sampling on June 26th and August 27th (coliform only) there was no measurable precipitation. The sampling on November 7th was completed during first flush conditions resulting from a heavy rainstorm (26.4 mm on the November 6th) following several weeks with no precipitation.

3.1.3 Water Quality

Canadian Federal and B.C. Provincial Water Quality Guidelines

It is important, before proceeding, to provide some background on the Canadian federal and British Columbia provincial guidelines for water quality. In Canada, provincial and territorial governments are responsible for the provision of safe drinking water and the implementation of drinking water guidelines. However, there is considerable collaboration between the federal and provincial/territorial governments in this regard.

Canada

The *Canadian Water Quality Guidelines* are published by the Canadian Council of Ministers of the Environment (CCME 1993) from all the provinces and territories. The federal guidelines are not a legal requirement. The guidelines "consist of a set of recommended "safe limits" for various polluting substances in raw (untreated) drinking water, recreational water, water used for agricultural and industrial purposes, and water supporting aquatic life. They are designed to protect and enhance the quality of water in Canada. The guidelines apply only to inland surface waters and groundwaters and not to estuarine and marine waters.

"The guidelines for drinking water quality recommend[ed] maximum acceptable levels for various physical, chemical, radiological, and microbiological substances. Drinking water that contains these substances in concentrations greater than the limits is either potentially capable of producing negative health effects or aesthetically objectionable." (Government of Canada, undated)

Health Canada also publishes *Guidelines for Canadian Drinking Water Quality*, prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial- Territorial Committee on Environmental and Occupational Health. The latest (6th) edition of these guidelines was published in 1996. The CCME and Health Canada guidelines provide maximum acceptable concentrations (MAC), interim maximum acceptable concentrations (IMAC) and aesthetic objectives (AO) for specific parameters.

British Columbia

The former Ministry of Environment, Lands and Parks published the *Approved Water Quality Guidelines (Criteria) Report -1998*, which provides guidelines for the protection of six major water uses: Drinking Water, Aquatic Life (freshwater and marine), Wildlife, Recreation and Aesthetics, Agriculture (Irrigation and Livestock Watering), and Industrial (e.g., Food Processing Industry) (Government of B.C. 1998). The guidelines apply province-wide and are safe levels of substances for the protection of a given water use. The report also provides water quality objectives, which are "a refinement of the province-wide guidelines that are adapted to protect the most sensitive water use at a specific location, taking local circumstances into account." The B.C. criteria for drinking water cover fewer parameters than are addressed by Health Canada.

British Columbia is also in the process of enacting Drinking Water Protection legislation and regulations. However, these legal instruments are not presently in effect.

Water Quality Results

The complete results of the 2002 water quality monitoring program are included in Appendix A. The locations of the sampling stations are shown in Figures 4 and 5. In general, the concentrations of most parameters increased from the upper to the lower watershed, as might be expected due to the increasing intensity of land use.

The following sections describe the results obtained for the more important parameters at each sampling station. For the reader's convenience, each parameter is reported on a separate page. The values obtained are compared with the reported ranges in the Pacific region of Canada and existing guidelines for drinking water, though not for protection of aquatic life.

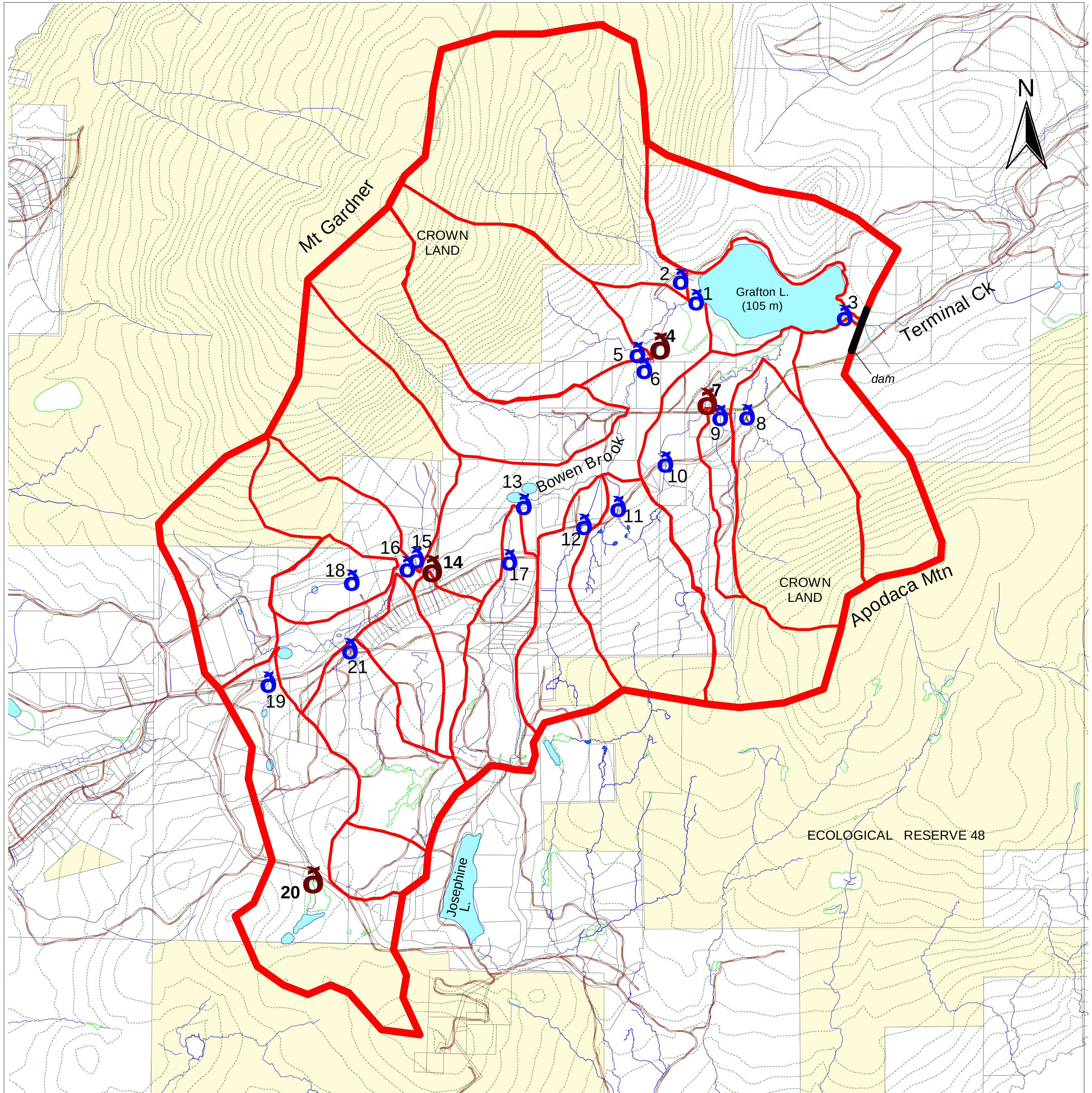


Figure 4.
Recommended Water Quality Sampling Stations, Grafton Lake Watershed, Bowen Island

Grafton Lk Watershed Boundary
Roads
Lake or Large Pond
Stream
Wetland
Elevation (20 m contours)
Small pond
Crown Land or Municipal Park
Property boundary
Sub-watershed boundary
3 Sampling station and number
14 Station sampled in 2002

500 0 500 1000 Meters

Prepared for the Bowen Island Municipality. November 12, 2002.
Whitehead Environmental Consultants Ltd. (Project 053-4)

Base map courtesy of the Bowen Island Forest & Water Management Society GIS.

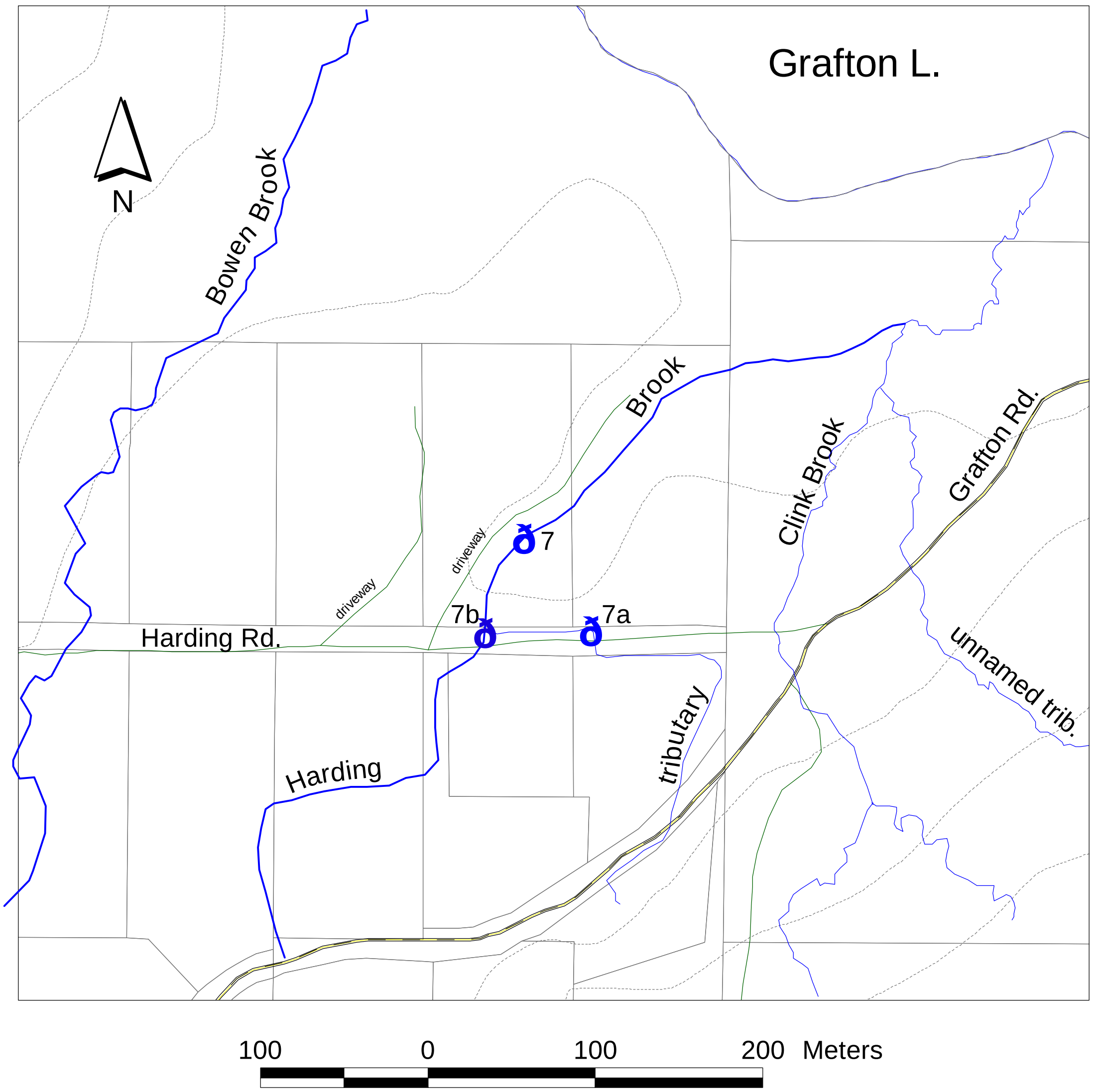


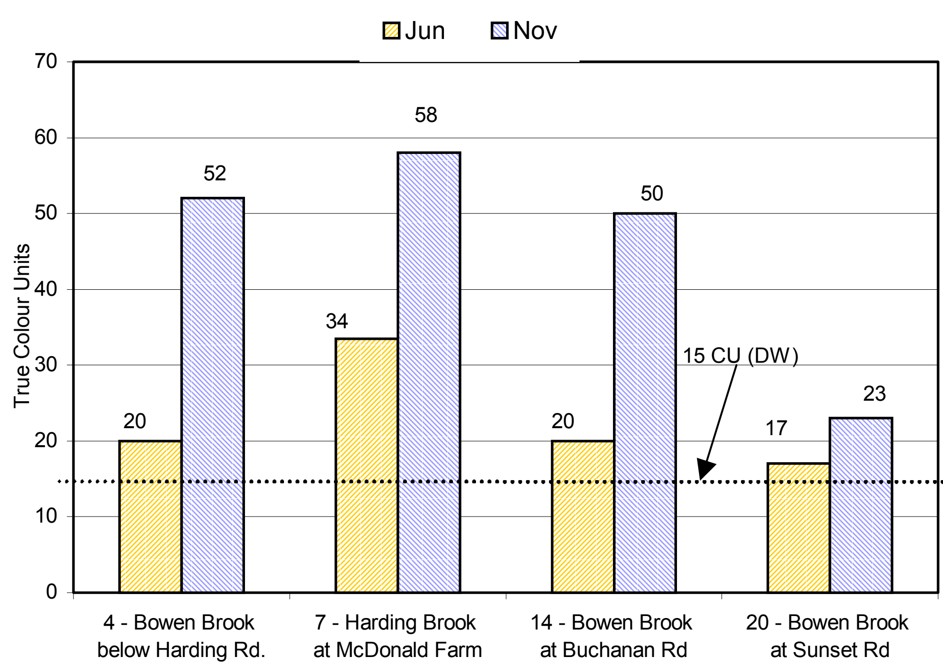
Figure 5.
Coliform sampling stations on Harding Brook and its unnamed tributary, Bowen Island.
November 17, 2002.

Colour

Colour is measured largely for aesthetic reasons. Colour can result from the presence of natural metallic ions, humus, peat materials, plankton, aquatic plants and other sources. "True" colour includes only dissolved substances, whereas "apparent" colour also includes material in suspension. The range of colour occurring in natural freshwaters in Pacific region of Canada is between <5 and 50 units (CCME 1993). The provincial and federal drinking guidelines stipulate that the colour of raw drinking water should be less than 15 true colour units (TCU) (CCME 1993; Government of B.C. 1998).

The results are shown in Figure 6. The values at all stations exceeded the guideline value of 15 CU. Colour values from the lower watershed in November were at or slightly higher than the upper limit of the range reported for Pacific Canada. Colour tended to increase from the headwaters toward the lake, and was higher in the fall than in the early summer, reflecting the proportionally greater inputs from runoff through organic matter.

Fig. 6. Colour in streams of the Grafton Lake Watershed
26 June and 7 November, 2002

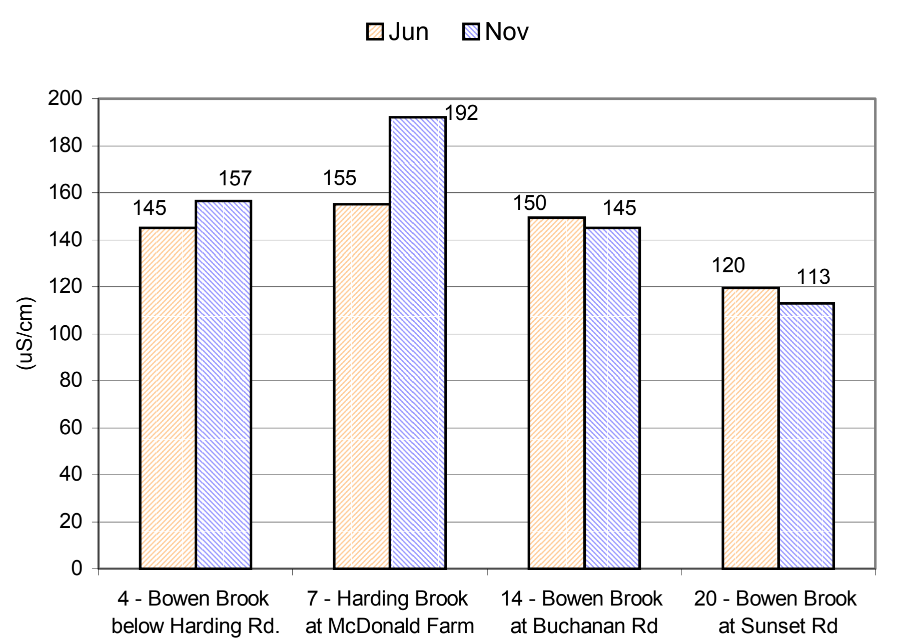


Conductivity

Conductivity is a measure of the total concentration of ionizable substances, such as inorganic acids, bases and salts dissolved in the water. The lower the conductivity, the lower is the concentration of dissolved solids, and the "purer" is the water. There are no federal and provincial criteria for conductivity. The range of conductivity in Pacific Canadian freshwaters is 4.8 - 84,600 µS/cm (CCME 1993). Coastal streams in BC are reported to have specific conductivity values of in the order of 100 µS/cm (Govt. of B.C. 1998).

The conductivity results from the Grafton Lake watershed in 2002 are shown in Figure 7. All samples were well below the federal guideline. The difference in conductivity between August and November was slight. The mid- and upper watershed stations (Stns. 14 and 20) reported higher values in early summer than during the fall, whereas the lower watershed (Stn. 4) and Harding Brook (Stn.7) showed higher conductivity during high flow conditions in the fall. The higher conductivity in the lower watershed stations in the fall suggests flushing of ionizable substances occurred to a greater degree in Harding Brook and, to a lesser degree, in lower Bowen Brook than in the middle and upper watershed. The lower conductivities at the upper stations in the fall would appear to reflect the effects of dilution by rainwater, which has a relatively low conductivity.

Fig. 7. Conductivity in the Grafton Lake Watershed, 26 June and November 7, 2002

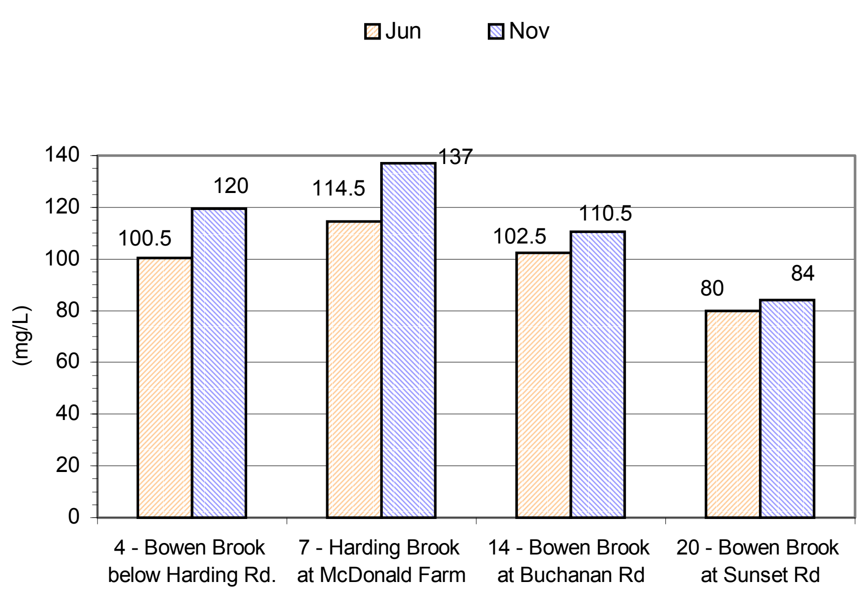


Total Dissolved Solids

Total dissolved solids (TDS) is a measure of the dissolved inorganic salts, organic matter, and other dissolved substances in the water. It is a "catch-all" parameter that encompasses a wide range of positively- and negatively-charged ions, and is closely related to salinity (CCME 1993). Waters with a TDS content of >1000 mg/L is considered slightly saline or brackish. The federal criteria for TDS is 500 mg/L.

All samples from the Grafton Lake watershed showed a TDS content under 140 mg/L, well within the "freshwater" range (Figure 8). TDS increased during the fall rains relative to the early summer, reflecting the flushing and dissolution of materials from the landscape by runoff. The difference between summer and fall values was lowest at the upper watershed, and increased in a downstream direction; this trend reflects the additive effect of inputs from the successive downstream tributaries and their catchment areas. The greatest difference between summer and fall (+22.5 mg/L) was recorded in Harding Brook, which drains one of the more intensively developed sub-watersheds. Conversely, the lowest increase (+4 mg/L) was measured in the headwaters of Bowen Brook (Stn.20), one of the least developed catchments.

Fig. 8. Total Dissolved Solids in the Grafton Lake Watershed, 26 June and November 7, 2002



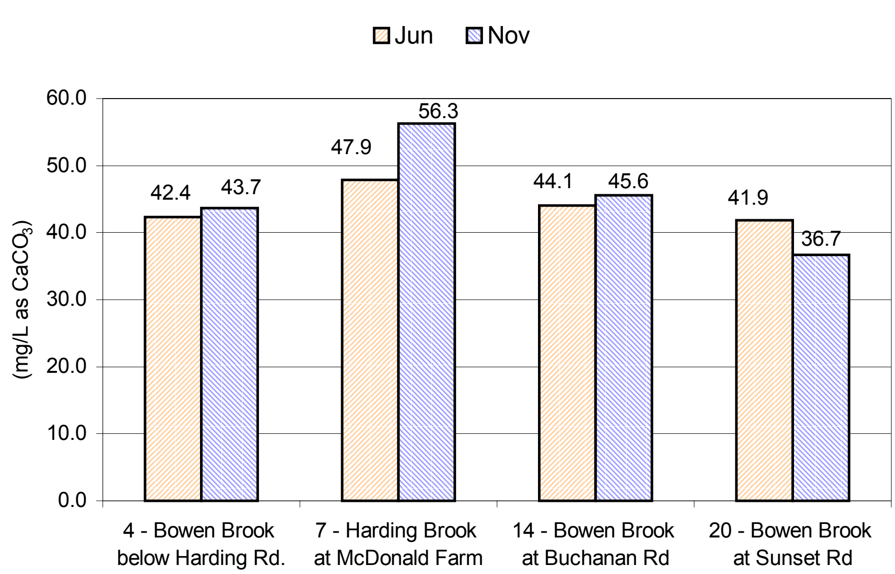
Hardness

Hardness is a measure of the concentrations of calcium and magnesium which influence the capacity of water to precipitate soap, and are the main constituents of mineral deposits that can form in water pipes. By convention, hardness is expressed as the concentration of calcium carbonate ($CaCO_3$). Table 5 shows the classification of water hardness. The range of natural freshwater hardness in Pacific Canada is 12.6 - 236 mg/L (CCME 1993); the optimal range for drinking water is 80 - 100 mg/L; the BC drinking water maximum criteria for hardness is 500 mg/L as $CaCO_3$ (Govt. of B.C. 1998). Figure 9 shows the results obtained in the Grafton lake watershed.

Table 5. Degrees of water hardness (CCME 1993)

Hardness (mg/L as $CaCO_3$)	**Degree of Hardness**
0 - 30	Very soft
31 - 60	Soft
61 - 120	Moderately soft (hard)
121 - 180	Hard
180 and over	Very hard

Fig. 9. Water Hardness in the Grafton Lake Watershed, 26 June and November 7, 2002



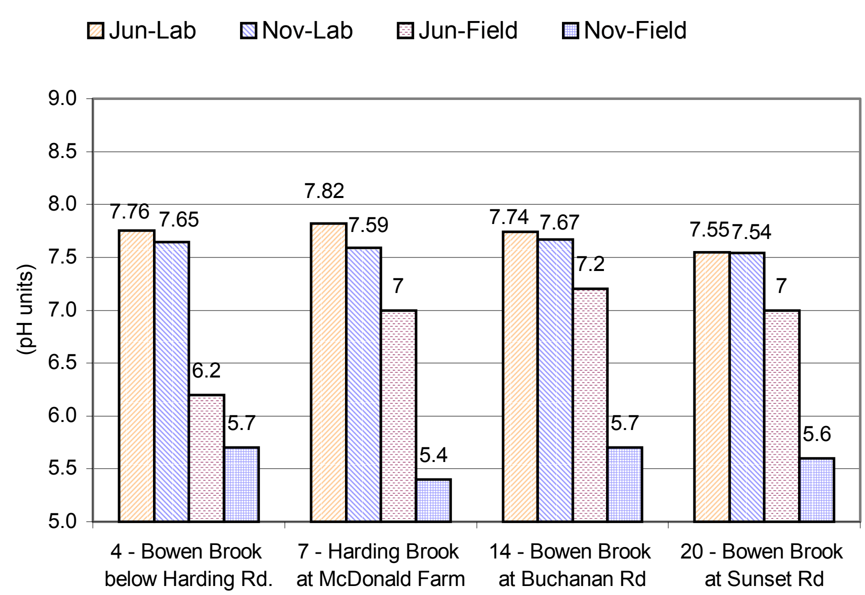
The results show that the water at all stations on both sampling dates can be classified as "soft" and was well below the BC drinking water criteria. Hardness at the upper watershed (Stn.20) was higher in June than in November, whereas at all other sites the values increased slightly in the fall, and most so at Harding Brook (Stn.7). The results suggest an increase in the release of calcium and magnesium into the watershed with the onset of the fall rains, particularly in sub-watersheds where development predominated. Geological influences may be present as well, although these were not evaluated.

pH

pH is a measure of the concentration of hydrogen ions (H^+) in water and soil. Water with a pH value of 7 is considered neutral, whereas values above 7 are defined as alkaline or basic and values below 7 are defines as acidic. A change of one pH unit represents a 10 times increase or decrease in H^+. Acidic waters are responsible for leaching certain metals out of the rocks and soils in the watershed, and are also the cause of pipe corrosion and release of metals into the drinking water. The recommended range for drinking water pH is 6.5 - 8.5, and for protection of aquatic life is 6.5 - 9. Naturally occurring pH in BC coastal streams, however, is often below this range, due to acidification by rainfall, which is naturally acidic (pH 5.6).

Measurements of pH were taken in the field and the laboratory (Figure 10). The pH values recorded in the field were consistently lower, and are considered more reliable than those measured in the laboratory, because of the chemical and physical changes that can take place within the sample bottles in transit. The interpretation below is based on the field results.

Fig. 10. Water pH in the Grafton Lake Watershed, 26 June and November 7, 2002



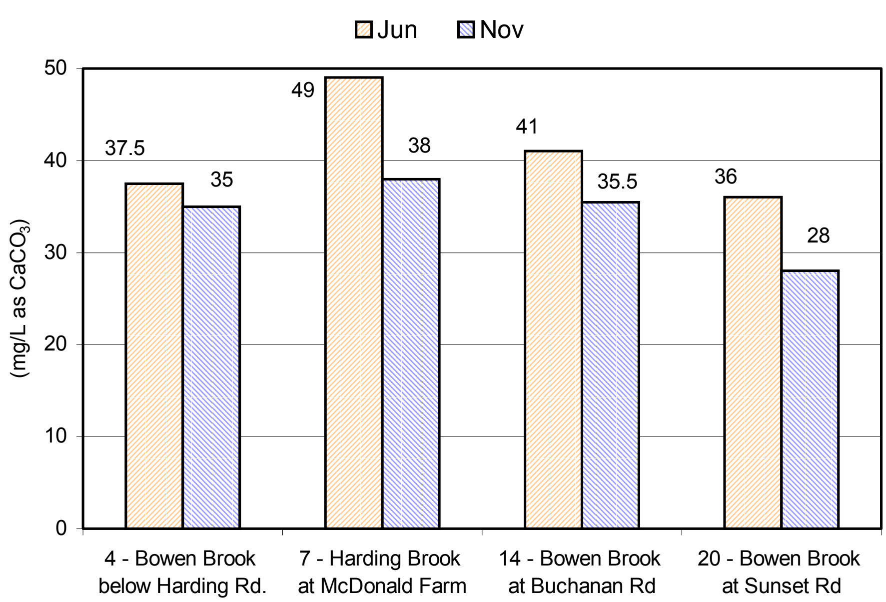
All the pH readings were within the upper limits of the recommended guideline; however, the field readings in November were all below the lower guideline limit of pH 6.5. In June, the pH at all sites except lower Bowen Brook (Stn.4) was neutral. The reason for the lower value at Station 4 may be related to sub-watershed specific influences downstream of Station 14. The pH at all sites decreased between June and November, reflecting the acidification by rainfall. Station 7 reported the lowest pH of 5.4, which is below that of rainfall; the reason for this low value is unclear, but may reflect watershed-specific natural or anthropogenic conditions.

Alkalinity

Alkalinity is a measure of the capacity of water to neutralize acid. For this reason, alkalinity is also known as the buffer capacity. The acid-neutralizing solutes in water are typically carbonate, bicarbonate and hydroxide; however, by convention the measurement is expressed as calcium carbonate ($CaCO_3$). Alkalinity in Pacific Canadian natural freshwaters is reported to range between 0.5 and 163 mg/L (CCME 1993). There are no federal or provincial criteria for alkalinity. The results are shown in Figure 11.

Alkalinity in Bowen Brook ranged from 36 to 41 mg/L in June and from 28 to 35.5 mg/L in November. These values are well within the range reported for the region. The trend among stations on both sampling dates was similar, with values being lowest in the upper watershed (Stn.20) and higher though similar in the mid and lower watershed (Stations 14 and 4). Alkalinity in Harding Brook was consistently higher than in Bowen Brook, reflecting different mineralogical or anthropogenic influences. All stations showed a decrease in alkalinity in the fall relative to the early summer, which indicates a decrease in the buffer capacity available due to increasing acid inputs from rainfall. The pH results (Figure 10) correlate well with this result.

Fig. 11. Total alkalinity in streams of the Grafton Lake Watershed, 26 June and November 7, 2002

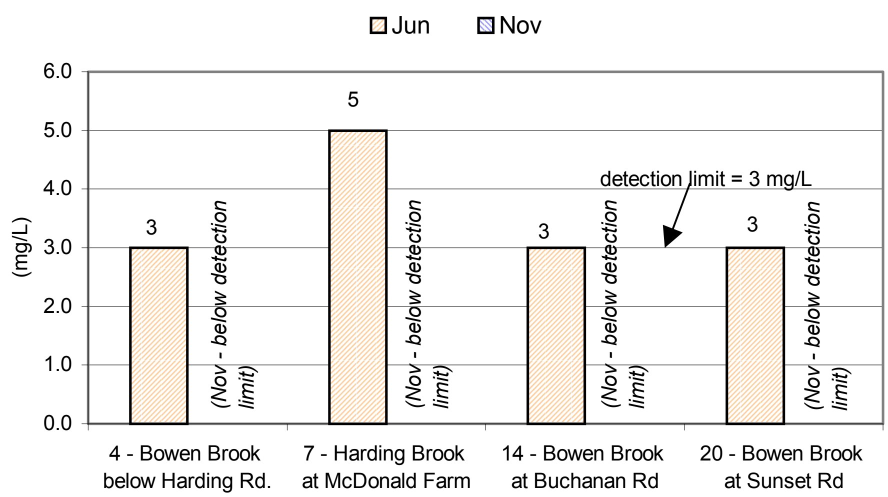


Total suspended Solids

Total suspended solids (TSS) is a measure of the amount of material that can be filtered out of a water sample. TSS is the material that settles out of the water plus matter which can remain in colloidal suspension. (The portion that passes through the filter - i.e., the non-filterable fraction - is made up of dissolved materials and particles that are smaller than the filter pores.) There is no federal or provincial drinking water criterion for TSS; however, it is an aesthetic parameter which is closely related to turbidity and apparent colour. The TSS results from 2002 are shown in Figure 12.

TSS content in June was similar at all stations on Bowen Brook and very low (at the laboratory's limit of detection), but higher in Harding Brook (Fig. 12). The latter result almost certainly reflects the influence of active land uses in the sub-watershed of Harding Brook, possibly including grazing animals. In November, TSS values at all stations were below the detection limit; this result probably reflects dilution or laboratory error. The relatively high detection limits and consequently poor resolution capacity of the data suggest that TSS may not be very useful in waters that are relatively free of suspended solids, in comparison with turbidity, for example.

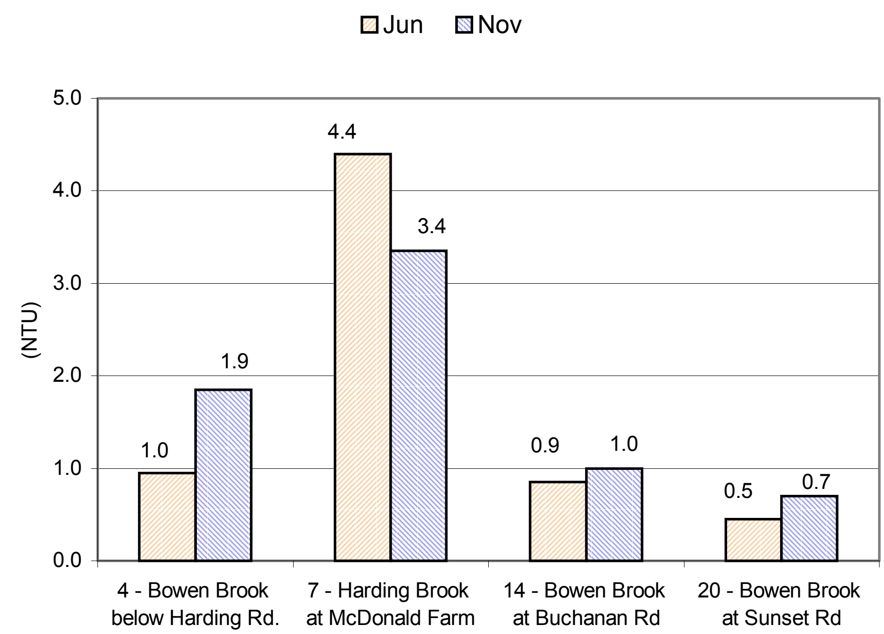
Fig. 12. Total Suspended Solids in streams of the Grafton Lake Watershed, 26 June and November 7, 2002



Turbidity

Turbidity is a measure of the clarity of the water. Turbidity is caused by the presence of matter suspended in the water, such as soil, sediment, fine particles of organic matter, and microscopic organisms including plankton. The federal criteria for raw drinking water is 5 NTU , and the provincial criteria for induced turbidity (i.e. the increase on turbidity due to some activity) are 1 NTU and 5 NTU above background, depending on the initial clarity of the water. The turbidity results from the Grafton Lake watershed in 2002 are shown in Figure 13.

Fig. 13. Turbidity in streams of the Grafton Lake Watershed, 26 June and November 7, 2002



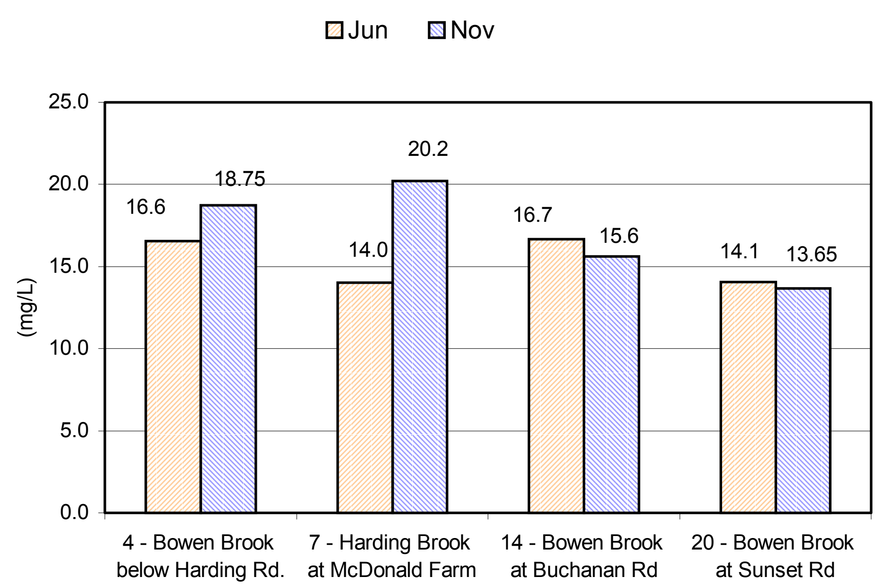
All turbidity values were below the federal drinking water criterion of 5 NTU. In June, turbidity was less than 1 NTU at all stations on Bowen Brook, with values increasing from the upper to lower watershed. Values in Bowen Brook increased between June and November, and the difference between summer and fall was highest in the lower watershed (Stn.4). The higher turbidity in the fall indicates an increase in the content of light-scattering particles, such as organic matter and suspended minerals (however, the quantities were minute relative to the volume of water, as suggested by the TSS results). In Harding Brook (Stn.7), turbidity was much higher on both dates than at any of the other stations, and showed a decrease between June and November; the decrease at this station is suggestive of dilution by the fall rains.

Chloride

Chloride (Cl^-) is one of the predominant inorganic anions in fresh water. It is also introduced to streams by runoff containing road salt and, depending on the location, through salt spay from the ocean. If sodium is abundant, excess chloride can give a salty taste to drinking water. The federal criterion for chloride is 250 mg/L; there is no provincial guideline. The range of chloride concentrations in natural freshwaters in the Pacific region of Canada is <0.1 - 27 mg/L (CCME 1993).

The 2002 sampling results for Cl^- are shown in Figure 14. None of the samples exceeded the existing chloride criteria, and all were within the reported natural range. In June, values in Bowen Brook changed little between the upper and mid watershed, and decreased in the lower watershed, while chloride in Harding Brook was similar to the level in the upper watershed. Chloride increased in November at lower Bowen Brook (Stn.4) and markedly in Harding Brook (Stn.7), and decreased slightly at the mid- and upper watershed (stations 14 and 20). The increases in the lower watershed in November suggest the erosion and dissolution or leaching of chloride from the landscape, from mineralogical or anthropogenic sources. The slight decreases in Cl^- in the mid and upper Bowen Brook watershed appears to correlate with dilution by rainfall, reflecting the lesser degree of development in the corresponding sub-watersheds.

Fig. 14. Chloride in streams of the Grafton Lake Watershed, 26 June and November 7, 2002

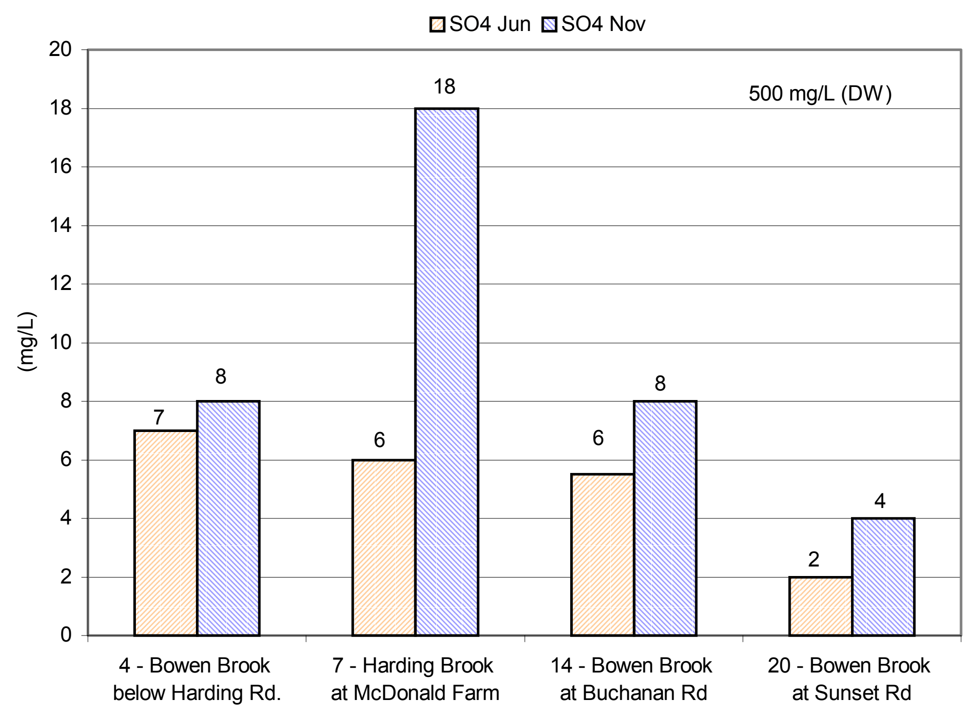


Sulphate

Sulphate is an oxidized form of sulphur which is widely distributed in nature. Natural sources include the weathering of sedimentary rock and oxidation of organic matter. Anthropogenic sources include a wide range of products, including fertilizers, wood preservatives and waste dumps containing gypsum (e.g. drywall). When combined with sodium or magnesium in excessive concentrations, $SO4^{=}$ has a purgative effect and is, therefore, not desirable in drinking water. The reported range of sulphate in natural freshwaters in Pacific Canada is <1 - 820 mg/L (CCME 1993). The federal and B.C. criteria for $SO4^{=}$ is 500 mg/L.

The $SO4^{=}$ concentrations measured in 2002 are shown in Figure 15. Sulphate content was well below the criteria level at all stations, and was within the reported natural range for the region. Sulphate in June increased from the upper to lower watershed, possibly reflecting the additive inputs from each of the tributaries. Concentrations in November were higher, reflecting the transport of $SO4^{=}$ into the surface waters by runoff; the highest concentration was measured in Harding Brook (Stn.7), which reported 18 mg/L in November, over twice the concentration at the other stations. The source of the additional sulphate in Harding Brook is unclear, although it may be associated with the existing land uses, including waste deposits and soil disturbance in the mid watershed, above Grafton Road, or natural mineralogical influences.

Fig. 15. Sulphate-sulphur content in streams of the Grafton Lake Watershed, 26 June and 7 November, 2002



Nutrients

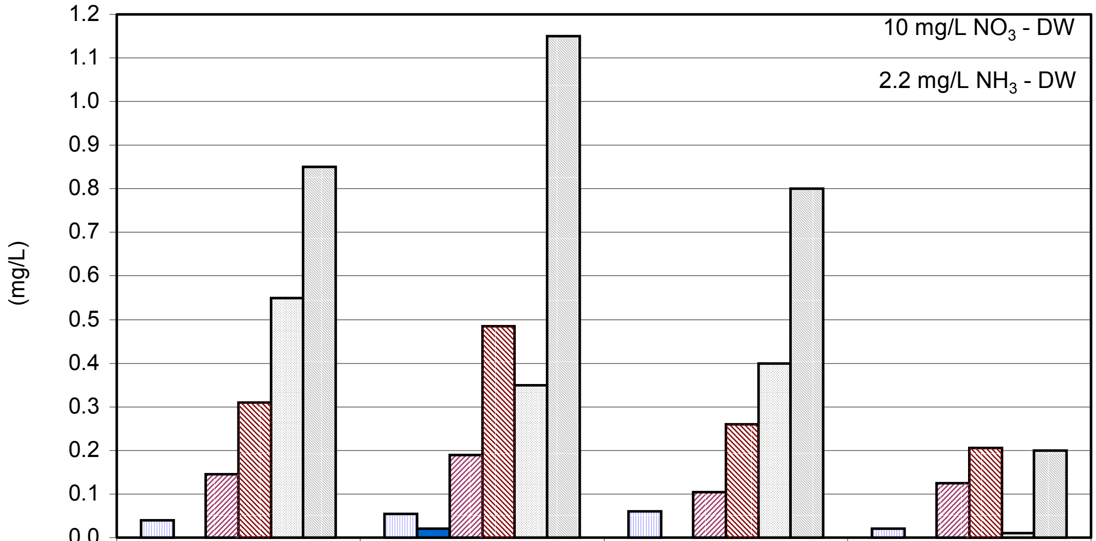
The main nutrients of concern for water quality are nitrogen and phosphorus because they act as fertilizers. When present in excess, nitrogen and phosphorus can contribute to euthrophication of streams and reservoirs, with consequent increases in pre-treatment requirements to produce drinking water of acceptable quality, as well as adverse effects on aquatic life such as fish, due to depressed levels of dissolved oxygen.

Nitrogen in water occurs in many forms, which include organic nitrogen, ammonia, nitrite and nitrate. Organic nitrogen (protein, uric acid, urea and other compounds) is the form that occurs in living and dead tissues of plants and animals and in feces and urine. As organic nitrogen breaks down it is converted from organic to the mineralized forms through a processes that initially produces ammonium (NH_4^+) and ammonia (NH_3), which are in turn oxidized to form nitrite (NO_2) and nitrate (NO_3). NO_2 is relatively unstable and tends to be quickly oxidized to NO_3 under aerobic conditions. All of these forms of N act as fertilizers; however, the solubility of the mineral forms is much higher than the organic forms. The ranges of nitrogen content reported in natural freshwaters in Pacific region of Canada are as follows: 0.002 - 6.6 mg/L NO_3-N; 0.014 - 20 mg/L Organic-N + NH_3-N (Total Kjeldahl N); and 0.05 - 0.10 mg/L Organic-N (CCME 1993).

Ammonia at high concentrations produces odour that is objectionable to humans, and at very low concentrations is toxic to aquatic life. Nitrite and nitrate can be toxic at excessive concentrations. The federal and BC drinking water criteria are 1 mg/L for nitrite, 10 mg/L for nitrate and 2.2 mg/L for ammonia; there are no criteria for organic nitrogen.

The results for ammonia-N, organic-N, and nitrate-N are shown below in Figure 16. Nitrite-N content was very low and was not graphed. None of the values of any nitrogen species exceeded the guidelines.

**Fig. 16. Nitrogen content in streams of the Grafton Lake Watershed
26 June and 7 November, 2002**



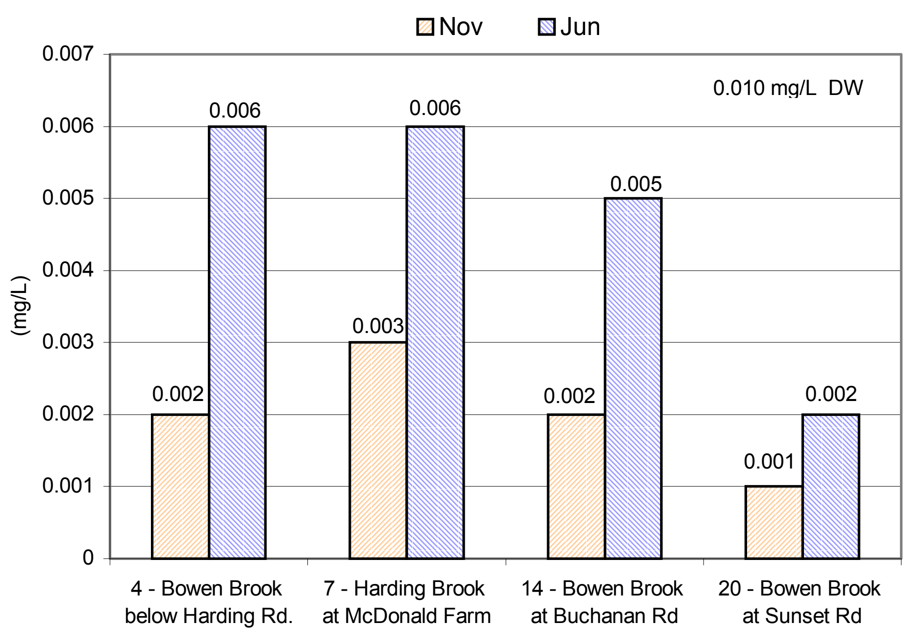
	4 - Bowen Brook below Harding Rd.	7 - Harding Brook at McDonald Farm	14 - Bowen Brook at Buchanan Rd	20 - Bowen Brook at Sunset Rd
NH3-N Jun	0.04	0.06	0.06	0.02
NH3-N Nov	0	0.02	0	0
Org-N Jun	0.15	0.19	0.11	0.13
Org-N Nov	0.31	0.49	0.26	0.21
NO3-N Jun	0.55	0.35	0.4	0.01
NO3-N Nov	0.85	1.15	0.8	0.2

All nitrogen species in Bowen Brook tended to increase in a downstream direction. The highest concentrations were usually recorded in Harding Brook, following the pattern observed with most other parameters. In most cases, nitrate was dominant, followed by organic-N and ammonia. Concentrations of nitrate and organic-N were higher in the fall than in the spring; however, the reverse was observed in the case of ammonia. The higher nitrate and organic-N in the fall suggest mobilization of these N species by increasing runoff; the lower ammonia content in the fall likely reflects the prior conversion to nitrate during the summer months and dilution by fall rains.

Phosphorus also occurs in organic and mineral forms, and is typically present at much lower concentrations than nitrogen. The most soluble species is the oxidized mineral form, ortho-phosphate (o-PO_4), which is readily absorbed by microalgae and plants that contribute to euthrophication of water bodies; it is not normally toxic. The natural range of total phosphorus reported in Pacific Canadian freshwaters is 0.0013 - 1.75 mg/L (CCME 1993). There is no federal drinking water guideline for phosphate; the BC criterion of 0.01 mg/L is limited to lakes.

The results are shown in Figure 17. None of the readings exceeded the drinking water guideline for lakes. Phosphate content in the streams ranged between 0.001 and 0.006 mg/L, with the highest concentrations recorded at Harding Brook (Stn.7, lower watershed) in June. Values measured in the fall were typically twice as high as in the early summer, reflecting the flushing of P from the watershed by the rains, after a summer of biodegradation of organic matter.

Fig. 17. Dissolved orthophosphate-P content in streams of the Grafton Lake Watershed, 26 June and Nov ember 7, 2002



Metals

The content of metals in drinking water supplies is a concern for public health and aesthetic reasons. Metals occur in dissolved and suspended particulate form, and as ions adsorbed to non-metallic particles such as suspended sediment and organic matter. Some metals, such as mercury, cadmium, arsenic and lead are toxic at very low concentrations. Other metals, such as iron and manganese, are highly coloured and can stain household fixtures, utensils and laundry. The solubility of some metals is dependent on the water pH; many of the toxic metals are readily leached from the surrounding rock or water distribution pipes by acidic waters. The results and drinking water criteria for selected metals are shown in Table 6.

The only metals that exceeded the water quality guidelines were iron (Fe) and manganese (Mn), the criteria for which are based on aesthetics rather than health. Iron was consistently highest in Harding Brook (Station 7) followed by lower Bowen Brook (Stn.4) with higher values recorded in June than in November; the criterion of 0.3 mg/L was exceeded at these two stations, though not at stations 7 and 4. The higher Fe values in June probably reflect a higher proportion of groundwater inputs compared to November, when rainwater runoff predominated.

Manganese exceeded the criterion only at Harding Brook (Station 7) in June and November, and at upper Bowen Brook (Stn.20) in June. Values at these two stations were higher in June than in November; this pattern was also observed at Station 14, though not at Station 4. As with Fe, the higher Mn concentrations in June probably also reflect groundwater inputs.

Total aluminum at Station 4 in June exceeded the B.C. criterion of 0.2 mg/L dissolved Al. The significance of this result cannot be ascertained, since the sampling program did not include measurement of the dissolved fraction.

Hydrocarbons and Non-halogenated volatile organics

Hydrocarbons and non-halogenated volatile organics are a group of substances that are associated with petroleum-based products. Their presence in drinking waters indicates contamination by materials such as gasoline, Diesel and other fuel oils, as well as motor oils, lubricants, hydraulic fluids and solvents. The following nine compounds were tested for: Benzene, Ethylbenzene, Styrene, Toluene, meta- & para-Xylene, ortho-Xylene, Total Xylenes, Volatile Hydrocarbons (VH6-10), and VPH (volatile petroleum hydrocarbons). None of these compounds were found at detectable concentrations at any of the sampling stations in the watershed (Appendix A).

Table 6. Concentrations of selected metals measured in the Grafton Lake watershed on June 27th and November 7th, 2002, and their drinking water quality guidelines.

All values are in mg/L.

Metal[a]	**Station 20** Upper Bowen Bk below Sunset Dr.		**Station 14** Bowen Brook above Buchanan Rd.		**Station 7** Harding Bk at McDonald Farm		**Station 4** Bowen Brook below Harding Rd.		**Drinking Water Guidelines**		**Notes**
	Jun	Nov	Jun	Nov	Jun	Nov	Jun	Nov	Canada	B.C.	
Aluminum (Al)	0.03	0.03	0.04	0.07	0.09	0.16	0.29	0.14	-	0.2	(b)
Arsenic (As)	0.001	<0.001	0.0015	<0.001	0.005	0.003	0.002	0.001	0.025	0.025	(c)
Barium (Ba)	0.02	<0.02	0.02<	0.02	0.02	0.02	0.02	<0.02	1	5	
Boron (B)	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	5	5	
Cadmium (Cd)	0.0002	<0.0002	0.0002	<0.0002	0.0002	<0.0002	0.0002	<0.0002	0.005	0.005	
Chromium (Cr)	0.002	<0.002	0.002	<0.002	0.002	<0.002	0.002	<0.002	0.05	0.05	
Copper (Cu)	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	10	5	
Iron (Fe)	0.27	0.15	0.29	0.29	1.12	0.78	0.57	0.49	0.3	0.3	(d)
Lead (Pb)	0.001	<0.001	0.001	<0.001	0.001	<0.001	0.001	<0.001	0.01	0.01	
Magnesium (Mg)	2.2	1.8	3.2	2.7	4.2	4.2	3.4	3.2	-	100	(e)
Manganese (Mn)	0.202	0.035	0.035	0.027	0.289	0.199	0.035	0.038	0.05	0.05	(f)
Mercury (Hg)	0.0002	<0.0002	0.0002	<0.0002	0.0002	<0.0002	0.0002	<0.0002	0.001	0.001	
Potassium (K)	0.4	1.5	1.3	1.6	1.8	3.3	1.5	2.2	-	-	not regulated
Selenium (Se)	0.001	<0.001	0.001	<0.001	0.001	<0.001	0.001	<0.001	0.01	0.01	
Uranium (U)	0.0001	<0.0001	0.0001	<0.0001	0.0001	<0.0001	0.0001	<0.0001	0.02	0.1	
Zinc (Zn)	0.05	<0.05	0.05	<0.05	0.05	<0.05	0.05	<0.05	5	5	(g)

a - The concentrations refer to total metals.
b - BC guideline refers to dissolved Al.
c - formerly 0.05 mg/L, changed in 1994
d - aesthetics (staining, taste)
e - aesthetics (taste)
f - aesthetics (staining)
g – aesthetics (taste)

Polycyclic Aromatic Hydrocarbons (PAH)

PAHs are "compounds composed of two or more benzene rings fused together. They are ubiquitous in the environment. The environmentally significant PAHs contain two to seven benzene rings. PAHs are used as intermediaries in pharmaceutical, photographic, and chemical industries. Some are used in the production of fungicides, insecticides, and surfactants. They are reported in µg/L in water or µg/L in sediments or tissues… Anthropogenic sources include fossil fuels, agricultural burning, industrial processes, pest treatment, urban runoff… The lower molecular weight PAHs (two or three benzene rings) are acutely toxic to aquatic life. PAHs with four to seven rings are not as acutely toxic, but several are known to be carcinogenic." (Government of B.C. 1998). PAHs originate from incomplete combustion of wood, garbage, oil, tar and other organic substances, and were also manufactured for use in pesticides and plastics. (Agency for Toxic Substances and Disease Registry [ATSDR] 1995)

Criteria for PAH in drinking water are limited to Benzo[a]pyrene (maximum 0.01 µg/L); maximum criteria for protection of aquatic life are Anthracene (0.1 µg/L), Acridine (0.05 µg/L), Fluoranthene (0.2 µg/L), Pyrene (0.02 µg/L) and Benzo[a]anthracene (0.1 µg/L) (Government of B.C. 1998)

A total of 18 PAHs were measured at Station 7 only on November 7th 2002. None exceeded the B.C. criteria listed above. The detection limits used by the laboratory ranged from 0.01 to 0.05 µg/L. The full results are provided in Appendix A.

Polychlorinated Biphenyls (PCB)

PCBs are a "group of industrial chemicals that were used as plasticizers and thermal insulators in transformers and electrical wires. They are now banned for use in Canada. PCBs are highly resistant to biological, chemical and thermal degradation. They are inert chemicals that are relatively insoluble in water and tend to accumulate in sediments… They bioaccumulate and tend to be in highest concentrations in fatty tissues. PCBs interfere with reproductive capabilities (this has been amply demonstrated with animals that are high on a food chain such as predatory birds)… The main anthropogenic sources are municipal and industrial effluent discharges." (Government of British Columbia 2001). They were also formerly used as a component of insecticides and other products; there are no known natural PCBs (ATSDR 2000).

No drinking water criteria have been developed for PCBs in B.C.; however, criteria are in use for protection of aquatic life (0.0001 µg/L) and irrigation (0.5 µg/L) (Government of B.C. 2001)

The concentration of total PCBs at Station 7 was less than 0.001 mg/L (1 µg/L), which was the detection limit used by the laboratory. This detection limit is higher than the recommended minimum concentration published online by the BC Water Quality Criteria for irrigation and aquatic life (Govt. of B.C. 2001).

Pesticides

Pesticides include a broad range of natural and synthetic compounds, such as insecticides, nematicides, fungicides, and herbicides that are used in agriculture, horticulture and residential gardens, and in keeping of livestock and pets. These are divided into a number of groups or families of chemical compounds, such as organophosphate and organochlorine pesticides, acid-extractable herbicides and pyrethroids, each of which is comprised of many individual chemicals.

The sample collected in Harding Brook at Station 7 on November 7th, 2003, contained only one detectable pesticide, which was the herbicide Bromacil at a concentration of 0.6 micrograms per liter (µg/L). The laboratory detection limit was 0.5 µg/L. Bromacil is not specifically mentioned in either the federal or B.C. water quality guidelines. The full results are provided in Appendix A.

According to the Extension Toxicology Network at Cornell University (EXTONET), Bromacil is a broad spectrum herbicide used for non-selective weed and brush control on non-cropland, as well as for selective weed control on a limited number of crops. This compound is used as an active ingredient in the following trade names: Borea, Bromax 4G, Bromax 4L, Borocil, Rout, Cynogan, Uragan, Isocil, Hyvar X, Hyvar XL, Urox B, Urox HX, Krovar, and possibly others. (EXTONET 1993)

The United States Environmental Protection Agency (EPA) has established a Lifetime Health Advisory (LHA) level of 90 µg/L for bromacil in drinking water. Consumption of bromacil at high levels well above the LHA concentration over a long period of time has been shown to cause damage to the testes, liver and thyroid of laboratory animals. There is little information available on the breakdown rate of bromacil in water; however, it has been suggested that, in clean river water which is low in sediment, the half-life of this herbicide is two months. (EXTONET 1993).

The median tolerance limit, or the concentration of bromacil that will kill 50% of the exposed fish after 48 hours of exposure (LC50), varies from 40 ppm to 164 parts per million (ppm), depending on the type of fish tested. The 48-hour LC50 for bromacil in rainbow trout is 56-75 ppm . (EXTONET 1993)

It is evident that bromacil measured at Station 7 was not a concern for human health or fish, since the concentration was 150 times less than the EPA limit for drinking water and many thousands of times less than the LC50 for trout.

Coliform bacteria

The results for fecal coliform are shown in Figure 18. The samples collected on August 27 corresponded to a period of very low stream flows in late summer, whereas those from November 17th were collected during the beginning of the fall rains. All sites exceeded the B.C. maximum acceptable concentration of fecal coliform in raw drinking water, of less than one cell per 100 ml (<1 cell/100 mL).

The trend in August, during low flows, was similar to that observed in the other parameters: concentrations increased with distance downstream, except in the lake, which had the lowest fecal coliform content. The results from the stream sites are consistent with the notion of increasing inputs of mammalian and avian fecal matter from the headwaters to the lower watershed, from natural and anthropogenic sources, reflecting increasing effects of development. The lower value in the lake during summer reflects the physical settling and natural die-off of the coliform bacteria in the quiescent water body, which has a long residence time.

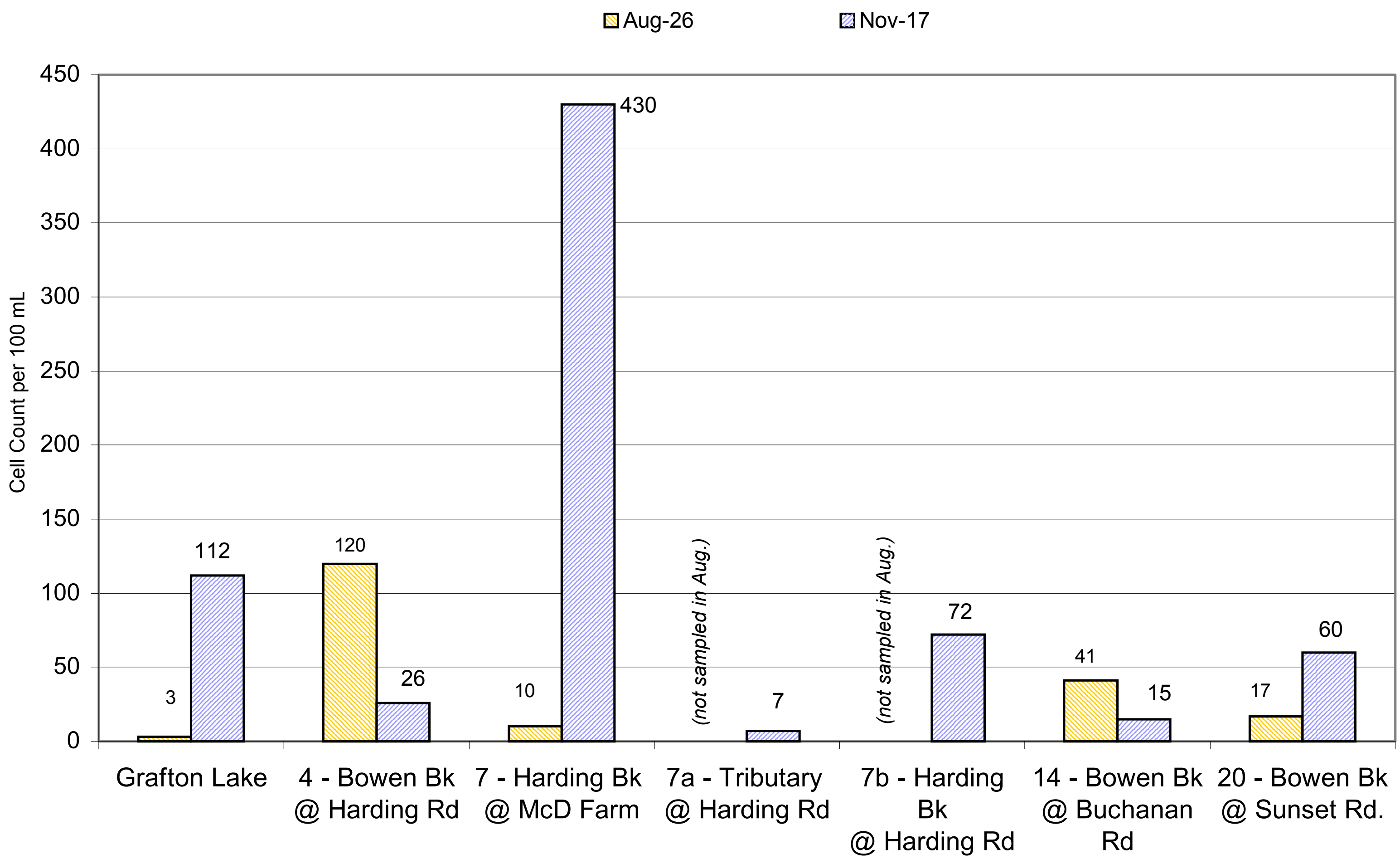
The results from November 2002, during the fall rains, varied considerably among stations and showed no discernible trend along the length of the watershed. Also, within each station, fecal coliform values in the fall were either higher or lower than in the spring. It is likely that this additional variability during the fall rains can be attributed to site specific natural and anthropogenic factors within the individual catchments of each sub-watershed, as well as dilution by uncontaminated runoff. For example, the relatively high fecal coliform count of 60 cells/100 mL at Station 20, which is located at the outlet of a natural wetland, can only be attributed to natural causes, such as the presence of waterfowl and other birds and mammals in the wetland and upstream ponds and the flushing effect of the recent heavy rains.

The fecal coliform count of 120 cells/100 mL at the outlet of Grafton Lake in November was much higher than the 3 cells/100 mL measured in August (Figure 17). Moreover, the former value was over four times as high as the 26 cells/100 mL recorded on the same date in lower Bowen Brook at Station 4. These results suggests that the lake may have been receiving significant additional inputs of fecal coliform from sub-watersheds other than Bowen Brook upstream of Station 4. Based on available knowledge of land uses, the potential additional sources of fecal coliform could include horses and other livestock within the Bowen Brook sub-watershed downstream of Harding Road, and in sub-watershed 6 (Harding Brook).

The coliform sampling on November 17th provided an opportunity to conduct more detailed measurements within sub-watershed 4 (Figure 3). An additional two samples were collected at Stations 7a (an unnamed tributary) and 7b (Harding Brook at Harding Road); these stations are located upstream of Station 7 (Harding Brook at McDonald Farm) (Figure 5).

Fig. 18. Fecal Coliform content in streams of the Grafton Lake Watershed, August and November 2002

Maximum Acceptable Concentration in raw drinking water: less than 1cell/100 mL



The laboratory results (Figure 18) showed that Station 7 reported the highest fecal coliform content (430 cells/100 mL) measured at any of the stations. Over 80% of the fecal coliform bacteria at Station 7 originated immediately downstream of Harding Road, whereas the unnamed tributary and the catchment of Harding Brook above Harding Road each contributed a minor fraction (1.6% and 17%, respectively). The high fecal coliform count at Station 7 very likely resulted from the presence of a flock of domestic turkeys that had free range of the field through which the brook passes immediately upstream of the sampling station (Photo 13).

It is important to note that the presence, in surface waters, of fecal coliform bacteria from poultry, horses or other livestock does not necessarily mean that the water will cause disease in humans. However, since fecal coliforms are usually associated with feces and are relatively easy to test for in the laboratory, they are used as indicators of the possible presence of organisms that can cause disease in humans. Nevertheless, since this indicator is included in the health regulations, there is a legal requirement to meet coliform criteria.

The need for source-specific microbiological indicators

The use of fecal coliform as an indicator of fecal contamination has its limitations because it cannot distinguish between human sewage and other sources of fecal bacteria. This limitation is acute in watersheds that contain significant populations of warm-blooded wildlife (mammals and birds) and livestock in addition to humans. The risk to public health is associated mainly with the human (and, to a lesser extent, pets and livestock) sources of microbial contamination, rather than natural wildlife. The Grafton Lake watershed, indeed many watersheds on Bowen Island, are a case in point, because they support large populations of deer and other mammals, as well as numerous birds including waterfowl.

The need for indicators other than coliform bacteria to distinguish among the natural and human-related sources of microbiological contamination has been identified for some time (Mara and Oragui 1985). With advancing knowledge of microbiology and related laboratory methods, alternative indicators have been proposed and are beginning to be used for this purpose (Long et al. 2000). Table 7 presents a list of alternative microbes and the specific contamination sources indicated by them.

Table 7. Microbial indicators of specific sources of water contamination.

Organism	Contamination source
Bifidobacteria (bacterium)	Human feces and sewage only (e.g. septic systems); not present in the feces of other animals; indicates recent or nearby sources, since the bacteria are short-lived in the environment.
Rhodococcus coprophilus (bacterium)	Grazing animals though not humans or other non-grazing wildlife; long-lived in nature, therefore indicates distant or recent contamination.
Serotypes of F+RNA coliphages (virus)	Human feces and sewage only.
Escherichia coli O157:H7 (toxic strain of E.coli, a bacterium)	Human sewage and livestock manures.

(Long et al. 2000; CDC 2003)

Laboratory methods to detect these source-specific indicators in water samples have been developed and published (Long 2002) and are being used for watershed management purposes in the Unites States (Dr. Sharon Long, personal communication). The use of this approach in the Grafton Lake watershed and elsewhere on Bowen Island is desirable in order to pinpoint sources of contamination by leaking septic systems, for example.

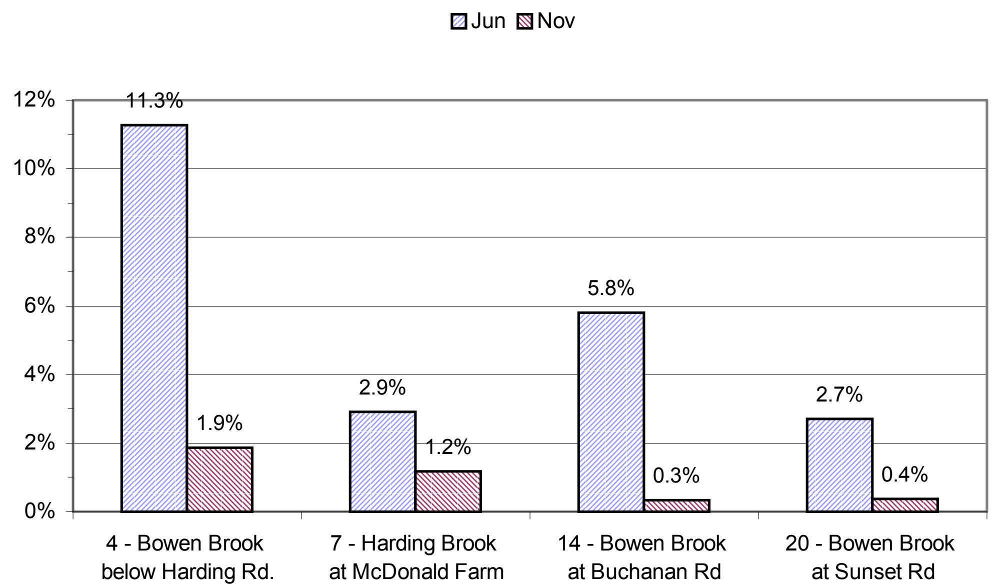
Variability between duplicate samples

Duplicate samples were collected at all stations for analysis of most parameters except coliform, PAH, PCB and pesticides. The purpose of duplication was to gain a minimum measure of understanding of the variability in the results obtained from each site on any occasion. Normally, a minimum of three replicates is necessary in order to determine the statistical variability between any one result and the average of all the results obtained at that station on one date (i.e., the standard deviation about the mean). However, due to budgetary constraints, only two replicates could be collected at each station in 2002.

The purpose of measuring the variability was to ascertain whether duplicates were sufficient, or whether the number of replicates should be increased, or whether a single sample would suffice. The approach taken in this case was to calculate the difference between the two duplicates as a percentage of the average. The variability data for each duplicate sample set are provided in Appendix A.

Figure 19 shows the average of the variability of all the results obtained at each station in June and November, 2002.

Fig. 19. Average variation in water quality results for standard parameters, in duplicate samples collected in the Grafton lake Watershed, June 26 and November 7, 2002.



Note: variability is expressed as the difference between the duplicate results for each paramater, as a percentage of the average of the results from the the two samples, averaged across all parameters.

The variability between duplicate samples ranged overall between 0.4% and 11.3% on average across all parameters. The difference between duplicates was much higher in June than in November, possibly reflecting the greater homogenization of the stream waters under conditions of higher flow in November. The average difference between duplicates in Bowen Brook increased from the headwaters to the lower watershed, possibly reflecting the greater diversity of inputs from tributaries. Interestingly, the variability in Harding Brook (Stn.7) was relatively low, possibly reflecting the smaller area of the sub-watershed and less diversity of inputs.

The 11 (out of 36) individual parameters that exhibited the highest degree of variability in June ($\geq$5%), and their corresponding values for November, are listed in Table 8. Fluoride, turbidity, organic-N and ammonia-N all showed a variability ranging of 20% - 30% in June. Maximum variability in November did not exceed 5%, when the highest variability was observed in nitrate-N and organic-N.

A good understanding of the natural variability is necessary in order to ascertain whether a change in water quality is due to random factors or to outside causes. These results from 2002 are inconclusive in terms of providing an indication of whether or not replication should be increased to triplicates or decreased to a single sample. Additional data are needed over a longer period of time in order to determine, with an adequate level of statistical confidence, what is the natural range of variability of each water quality parameter.

Table 8. Variability between duplicate sample results for selected water quality parameters measured in the Grafton Lake watershed, June and November, 2002.[a]

Parameter	June 26, 2002	November 7, 2002
Fluoride	30%	0%
Turbidity	29%	2%
Ammonia-N	21%	0%
Organic-N	20%	5%
Ortho-Phosphate-P	18%	0%
Arsenic	17%	0%
Aluminum	14%	2%
Nitrate-N	12%	5%
Iron	9%	1%
Manganese	7%	1%
Sulphate-S	5%	0%

[a] Variability shown is the difference between duplicate values, expressed as a percentage of the mean of the two duplicates, averaged across all stations.

3.2 Education and Communication Program

3.2.1 Background Research

The results of the study in the area of CBWS education component focuses on a number of key issues and best practices that emerged for watershed stewardship education and communication by local and regional governments.

The use of local and/or regional governments is a well documented vehicle for delivery of water and watershed education/ communication programs. In their comprehensive five year watershed management plan, the GVRD's plan focuses their communications and education implementation plan to reflect the high degree of public interest and includes "public involvement, community relations, and education components to develop and maintain confidence and trust that the GVRD is managing the watershed resources in an environmentally responsible and cost efficient manner." (GVRD, undated) On Vancouver Island, the Capital Regional District's (CRD) mandate includes the use of education as a means of supporting water conservation efforts to foster behaviour changes that support efficient water use (CRD, undated). Currently they are implementing a five year program to education school aged children about CRD's water supply, water quality, and water conservation (CRD Water Dept. pers. comm..) Internationally, US Agency for International Development used education and communication programs to help achieve sustainable management of the Panama Canal watershed using local governments within the watershed (Cardwell 2002). As mentioned in the introduction, the US Environmental Protection Agency has initiated a Source Water Protection program which includes local governments implementing public involvement and source water public education programs as part of the overall management of local watersheds (US EPA, undated).

The background research also indicated the importance of public involvement in any overall Source Water Protection Management Plan. Numerous case studies supplied by the US EPA from communities around the United States include public involvement, public outreach, and education as essential parts of any source water protection or watershed management plan.

<u>Case Studies</u>

The case study about New York City's water supply watersheds has interesting parallels to Bowen's Grafton Lake watershed (although, of course, on a different scale). In this case study, the water supply watersheds are removed from the majority of users of the water. They have a variety of land uses within the source water watersheds with agriculture is one of the major land uses in the source water protection areas. They state: "the challenge regarding agriculture is to reconcile the public health and environmental resource protection interests of a large and distant city with the farming community's desire to maintain an agricultural way of life in the watershed region." (US EPA, undated). Key elements of the NY City plan include: public involvement, developing a protection plan, management measures, contingency planning, and measuring program effectiveness. In terms of public involvement, programs include "a large community involvement component. Some initiatives, such as the Watershed Agricultural Program, are designed to target specific communities or stakeholders. In this case, the goal is to reduce pollution from farms within the watershed through thoughtful management of agricultural practices." (US EPA, undated).

In the Skaneateles Lake watershed (New York) public involvement is through direct participation in protection efforts (non point source reduction) and as the targets of educational initiatives. Initiatives in public involvement included "Talks and Treks" programs throughout the Skaneateles Lake area for public education as well as the Cornell Cooperative Extension (CCE) public outreach tools to residents of the Skaneateles Lake Watershed as part of the national Home*A*Syst program, which is a pollution prevention and risk assessment program . In addition, "Water Quality Educators" are available to help residents assess pollution risks and provide information on how to lower the risks of contaminating water supplies. (US EPA, undated).

In Stanley, Virginia, public involvement is part of their ground water protection program in a watershed serving approximately 2,000 residents. The watershed management plan recognizes that public acceptance and support for resource protection bylaws are essential, therefore public education is a primary focus of their wellhead protection program. "Early in the program, town officials recognized the need to educate local citizens about drinking water protection, and developed a brochure for distribution to all water customers." Information includes: the source of Stanley's drinking water, maps with the location of the town's wells, and lists possible contamination sources and s a list of simple things that citizens can do to protect their drinking water. (US EPA, undated).

In Oregon through the Oregon Watershed Enhancement Board, the focus is on public involvement using watershed councils. In that state, initiatives for 2001-2003 includes work with watershed councils to determine ways to more strategically support groups to improve citizen understanding of local watersheds. As well, citizen understanding of watershed health will be advanced through outreach and education opportunities for the general public and youth. Program initiatives include: curriculum development in watershed education, teacher workshops (K-12), workshops for landowners, and public outreach designed to designed to help residents and volunteers be good stewards of their watersheds, with important background information, exercises, actions, and resources for gaining assistance (OWEB, undated).

In the York region in Ontario, the focus of public involvement activities is on water conservation efforts. Their "Water for Tomorrow" program includes activities such as a retrofit program, industrial water audits, leakage reduction programs and public education. Public education is reported to be an important component of the overall Water for Tomorrow program. Public education is intended to educate and change water use attitudes of residents. Education activities include newsletters, a website, workshops, demonstration gardens (water efficient), home visits, school programs, newspaper advertising, water bill bulletins and watershed tours. To date, the York Region estimates that through the Water for Tomorrow program it has saved over 12 million litres of water/day and approximately 25-35% of the costs of new infrastructure by reducing demands on water supply (York Region 2002).

3.2.2 Grafton Lake Watershed Issues

Closer to home, issues of concern in the Grafton Lake Watershed were identified through attendance of public meetings, Cove Bay Water public meetings, Water Poster working group meetings, literature research, and the results of water sampling program in the Grafton Lake watershed. Issues identified include:

- Drinking water safety
- Watershed water quality sampling results
- Negative effects of poor water quality
- Agricultural practices – effects on water quality
- Non-point source pollution
- Land-use and effect on water quality
- Surface run-off, leachates, pesticides/ herbicides
- Importance of water for all living things
- Household use of water
- Stewardship of our water & watershed resources
- Septic systems
- Water conservation
- Water distribution system
- Logging
- Waste incineration

Several key issues were highlighted as priorities for an education and communication plan by a number of sources. These issues are:

- Agricultural practices – effects on water quality
- Failing Septic fields
- Drinking water safety
- Non-point source pollution
- Logging

3.2.3 Best Practices – Education and Communication

Research in current best practices for education about source water protection were undertaken. Summaries of these practices in program design, program delivery, and program evaluation follow.

<u>Program design</u>

A number of research journals and case studies were reviewed to indicate best practices in environmental education and communication applicable to this study. Fein et. al. (2002) compiled a comprehensive evaluation of programs for conservation education which highlighted best practices in the field. This study identified a set of best practices whereby educational programs should:

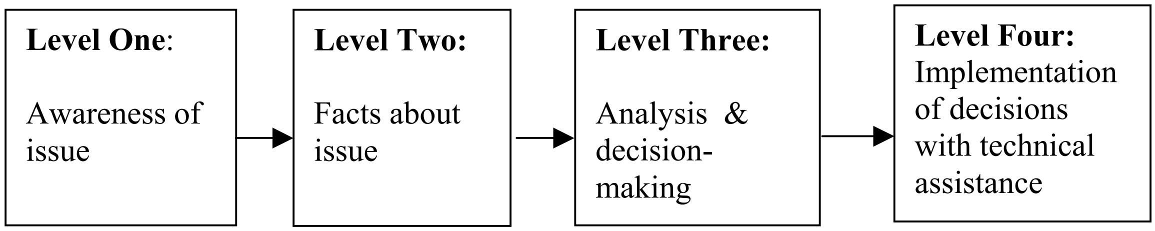
- Focus on outcomes and impacts
- Promote sustainability of resources
- Be integrated with other stewardship/ conservation strategies
- Develop knowledge, understanding, values, and skills
- Embrace a wide range of audiences
- Make use of "multipliers" – individuals and groups who can effectively help spread the concepts
- Build partnerships with a wide range of community organizations and local government
- Focus on key decision-makers
- Empower people to live more sustainably
- Be innovative, flexible, and creative
- Be supportive by active leadership and appropriate resources
- Involve participatory planning with stakeholders
- Employ effective management of programs
- Include on-going monitoring and evaluation of programs.

Program Delivery

Effective source water protection outreach and education consists of a well-designed programs aimed at a variety of audiences: adults, children, and youth. It encompasses both formal and non-formal settings (schools, community programs, special events, and public awareness through media and other means of communication). It acknowledges that people have different learning styles and different needs and resources available to them. Key concepts and messages are clearly defined and are linked to measurable objectives in the program design. (Grantham et al., 2000; Hammond, 1997; Gibbons, 1988; CWP, 2003).

Community Outreach and Education

More specifically, community outreach and education takes place on a continuum: from outreach through to technical assistance for implementation of a desired change. For example: community outreach is designed to make an audience aware of an issue. Next on the continuum is providing information to the community. Education allows the community to interpret information, analyze an issue, draw conclusions and to make decisions. Finally, technical assistance enables a community member to implement those decisions. (Grantham et al., 2000).



Studies have indicated there is not a good fit between the outreach and education methods used by project coordinators and those preferred by community participants. (US EPA 2000). Often, stewardship project's outreach and education efforts are aimed at too complex a level and thus the intended audience does not "get the message." It has been shown that training workshops and brochures are the most favoured education and outreach methods by project managers to the exclusion of other methods. However, community residents prefer a mix of public media (newspapers, radio, TV, Internet) and education/ training (US EPA 2000, McKenzie-Mohr 1999).

Formal Education (School-based)

When looking at the formal education (public schools) sector, a different pattern emerges in the effectiveness of water, watershed, and stewardship education. In this case, there is a wealth of environmental education materials available to teachers and community stewardship groups. However, there are many gaps and missed opportunities in programs for students on water and watershed stewardship. In general, key gaps in water and watershed stewardship education include:

- Students may study the ecology and science of watersheds but there is a lack of programs that put these studies in the context of their own community;
- Students may learn about environmental action skills but seldom get a chance to practice them;
- Existing programs often lack hands-on stewardship activities in their own communities;
- Students are seldom exposed to people engaged in watershed stewardship careers, community service projects, or hobbies. (Husby & Finlayson, 2002)

Research was also done in the areas of public involvement in watershed issues. Results indicated the role by local/ regional governments to support public involvement in watershed issues may include participating in public meetings, open houses, focus groups, watershed councils, public watershed tours, workshops, and other communications activities (GVRD, undated; US EPA, undated).

<u>Program Evaluation</u>

Quality programs are an outcome when an pro-active approach is taken to monitoring and evaluation of outreach and education programs and their delivery. Program implementation should be approached with the "action-research" perspective whereby on-going evaluation results in program modifications based on evaluation (Fein et al. 2002). Evaluation tools should be used prior to program implementation (audience pre-survey) as well as post survey (US EPA, undated). As well, program outcomes should be specific and measurable to be evaluated at program completion (Blair Whitehead 2002). Evaluation tools such as criteria of merit checklists, survey forms, and evaluation templates are all useful for the active practice of quality outreach and education programs (Dark, et al., 2002, Fien et al., 2002, US EPA No date). Samples of these tools may be found in Appendix C.

3.2.4 Gap Analysis

A gap analysis of source water protection and/or watershed stewardship outreach and education programs currently underway on Bowen Island as part of another study (Blair Whitehead 2003). This study presents a number of indicators for the Grafton Lake study. Information was collected on outreach and education efforts by individuals and community organizations from 1992 to 2002. Projects done in the past include: signage (groundwater protection zones, fish sensitive areas), workshops (Howe Sound Watershed, BILLS), brochures (*Sensitive Habitat Mapping of Bowen Brook, Forests of Bowen*), maps and posters (BIFWMS watershed maps, GSC Water Poster –draft), organization displays (Earth Day & Bowfest), newsletters (CBWS Newsletter) and the Bowen Geolibrary project. Prior to 1992, a series of "Nature Matters" articles in the Undercurrent newspaper included some information about Bowen's water supply and watersheds. All these efforts indicate an interest by the a number of key individuals and organizations to help understand and then educate the general public about their water and island watersheds and should be commended. However, upon analysis, many of Bowen projects are targeted at an audience that have mastered the concepts and are ready for implementation (Level Three and Level Four) and few to no projects aimed at audiences who are at Level One and Two in their awareness and understanding of watershed issues. There have been no efforts to date specifically on source water protection awareness and education. Projects by community organizations and local teachers have been dependent on the individual teachers rather than tied to a community effort to educate about our water and watersheds. Several projects have occurred at both Bowen Island Community School and Island Pacific School over the last decade (Watershed Mapping BISC 1995, Stream mapping, IPS 2000) but were of short duration. There has not been a consistent program on local water and watershed issues with schools on Bowen to date.

3.2.5 Conceptual Framework

A conceptual framework was developed to help guide the program developed below. A conceptual framework is tool used by educational program developers to help ensure that the resultant program is consistent with its messages, uses appropriate language, contains learning outcomes, and is based on current science. The resultant conceptual framework is described in the following Table 9.

Table 9. Conceptual framework for a public education and communication program for source water protection in the Grafton Lake Watershed.

Key Concepts	Outcomes
Safe and abundant water is essential for all life.	To understand the importance of water to all living things and that when water is scarce or of poor quality, humans and other living things may suffer.
Watersheds connect many parts of our community.	To understand that a watershed is land that drains rain and snow into a stream, lake, wetland, or ocean and that humans play a significant role impacting our watersheds through our activities.
Water resources are managed for both quality and quantity.	To understand the water cycle on Bowen Island and the way our drinking water resources are managed.
Water conservation benefits our whole community.	To understand why water conservation is important and to identify actions that will help conserve our water resources.

3.2.6 Logo design and other media examples

As part of the background research for this study, many examples of newsletters, brochures, posters, fact sheets and other media were collected from various jurisdictions locally to downloaded images and materials from right across North America. Many of these examples will be useful tools during the implementation of the CBWS education and communication plan. One tool, the logo, is now “camera ready,” as shown in Figure 20.

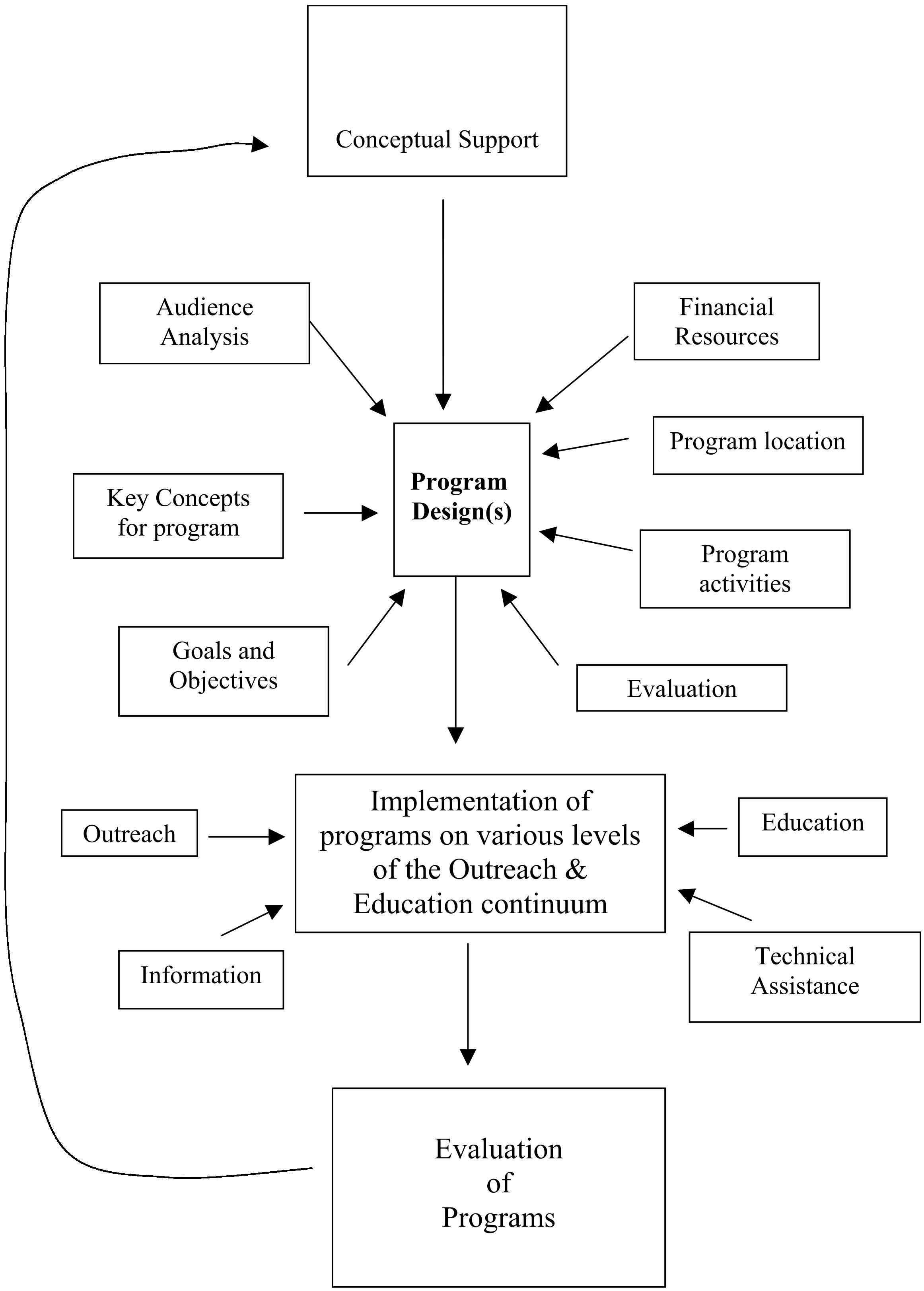
This image is based on the US EPA’s *Drinking Water Source Awareness Media Guidelines* (US EPA, undated). Included with the guide are sample materials (in tagged image format [tif.] files) that can be downloaded over the Internet. The files are in the public domain and are intended to be adapted for local uses. After discussions with the Bowen Island Water Poster group, it was decided that the logo should be included on the poster. Dr. Bob Turner was instrumental in making available the staff and resources of Natural Resources Canada to adapt the image file to make the logo more relevant to Bowen Island, for which the authors are very grateful.

Fig. 20. Bowen Island Source Water Protection Logo

3.2.7 Discussion

Based on the above results, the CBWS Grafton Lake Outreach & Education program should begin by focusing on the gaps identified above. Namely, awareness and information about source water protection (level one and two) moving onto more advanced levels in future years. Concepts and outcomes listed above will be consistent in all programs (levels one to four) to re-enforce the concepts. The program design incorporates the task framework illustrated in Figure 21.

Fig. 21. Overview of tasks involved in the development and implementation of a public education and communication program for source water protection.



The suggested approach would be to use a phased approach to outreach and education efforts over the next two to three years. Phase one (2003-04) would focus on source water protection concepts while Phase two (2004-05) and beyond would add water conservation concepts. The audience for phase one would be Grafton Lake watershed residents, CBWS users, teachers, and the general public. The program design focuses on the key concepts:

- ***Safe and abundant water is essential for all life.***
- ***Watersheds connect many parts of our community.***

The goal of the program is to build understanding of source water protection and water conservation as well as increase activities by Bowen Island residents to prevent and mitigate impacts, and to improve our local watersheds. Specifically, the objectives of the program are to:

1. Increase awareness of the benefits of source water protection and conservation using a variety of education and communication tools;
2. Implement a two phase outreach and education program with stakeholders in the Grafton Lake Watershed, Cove Bay Water users, and the general public.

The program will be implemented in the Grafton Lake Watershed and Cove Bay Improvement District. Options also include some island-wide programs as well. Over time, the program activities will include:

1. Assess community knowledge (Audience knowledge pre-survey);
2. Participate in community committees (Water poster, Cove Bay Board, etc.);
3. Design of concept logo and themes;
4. Media activities (articles, logo);
5. Development of material:
   (newsletters, Q&A fact sheets, tips, poster, brochures);
6. Provide products with logo (rain gauges, pencils, 'fridge magnets, etc.)
7. Participate in community events:
   (Bowfest and other e.g. "Watershed Weeks" or "Watershed Days");
8. Grafton Lake Watershed Tours;
9. Initiate promotion and development of School program(s);
10. Development of incentives, awards, and recognition programs with BIM:
    (e.g. "Watershed Pledge" recognition)
11. Development and promotion of Home-site visit program and "watershed hotline";
12. Public involvement and consultation activities.

The evaluation part of the program should be "action – research" oriented and be comprised of a post- program community assessment (audience survey), an analysis of goals & objectives met/ unmet, and recommendations for future work using recognized evaluative tools as mentioned previously.

An overview of suggested outreach and education activities is provided in Appendix D.

3.2.8 Proposed Work Plan

The proposed Education and Communication work plan for 2003-2004 would include the following tasks:

Task #1 Assess community knowledge
This task would consist of identifying questionnaire participants, designing an audience pre-program and post program questionnaire, completing a phone survey of the target audiences, and summarizing the data found. This data would be used the fine tune the program design to better meet the needs of our Bowen audiences.

Task #2 Revise Program Design
This task consists of identifying the specific issues, misunderstandings, need for awareness and information by island residents regarding our key concepts (safe and abundant water is essential for all life and watersheds connect many parts of our community). Then specific goals, outcomes, activities and evaluation strategies would be outlined to address these needs.

Task #3 Deliver Program Activities
This task would consist of finalizing the program logo, write articles, tips, and contribute to CBWS newsletters; select and order logo products; organize and participate in community events, Watershed Tours/ Watershed Day; development and promotion of Home-site visit program and "watershed hotline" as needed; develop and coordinate awards and recognition program, and initiate teacher contact at Bowen Island Community School and Island Pacific school. Use will be made, wherever possible, of pre-existing materials such as GVRD brochures & materials, teachers guides, posters, pamphlets etc. to avoid "re-inventing the wheel" and to help minimize material development costs. All education and communication material will specifically address the issues previously identified with the objective to prevent and mitigate impacts and improve our local watersheds.

Task #4 Evaluation
This task would consist of completing a post-program survey, summarizing the findings, evaluating the program's effectiveness and developing recommendations for future programs.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Land Use

Thirteen categories of land uses were identified in the Grafton lake watershed (Table 4). The following six were considered to pose a high potential to degrade drinking water quality: onsite sewage disposal (failing septic fields), incineration of waste, dumping of construction waste, keeping of horses, raising of poultry and other small livestock, and commercial logging. Fire emergencies, which can occur in most land uses, were also found to pose a high risk to water quality.

Land uses associated with a moderate level of risk to water quality included: public roads, crop farming, machinery maintenance, and quarrying; the lumber yard was rated as low to moderate. Nurseries and horticultural supply stores were rated as low. Undeveloped natural forest (and related passive recreation) is the only land use that poses no significant risks to water quality.

The risks to water quality associated with most land uses can be readily minimized through the use of preventive measures and, as in the case of fire, contingency planning. However, waste incineration and solid waste dumping pose unacceptable risks, which are difficult to mitigate; these land uses are, therefore, considered inappropriate in a water supply watershed.

The available mapping of streams has improved considerably since 1997. However, many streams are still either not mapped, or mapped inaccurately. In addition, the available topographic mapping is inadequate. Accurate mapping of streams and topography is necessary to enable effective watershed assessment and subsequent planning and management.

Recommendations:

1. The Bowen Island Municipality should embark on a program to develop bylaws to regulate land uses for the protection of source water quality.
2. Source water protection bylaw should include provisions for:
   a. public education;
   b. monitoring (inspection) of land uses in the watershed areas;
   c. enforcement in the event of non-compliance; and
   d. allocation of adequate financial and human resources to achieve the preceding provisions.
3. Land uses that should be explicitly addressed in a source water protection bylaw should include, though not be limited to:
   a. on-site sewage treatment and disposal systems (particularly septic systems);
   b. use of fertilizers and pesticides near watercourses;
   c. keeping of horses, poultry and other livestock;

d. land clearing and drainage;
e. quarrying and soil extraction;
f. logging;
g. fuel storage;
h. crop farming;
i. storage of construction materials; and
j. waste incineration and dumping (these activities should be prohibited).

4. Accurate mapping of all streams and topography in the Grafton Lake watershed should be completed without delay (in conjunction with an island-wide mapping effort by the municipality). Ideally, the resolution of topographic mapping should be increased to a minimum contour interval of 2 m, although 5 m is adequate.

4.2 Water Quality

The monitoring program undertaken during 2002 has provided an initial characterization of stream water quality in the Grafton Lake watershed. The data that are now available cover the upper, middle and lower watershed of Bowen Brook, which is the largest sub-watershed in the system, as well as Harding Brook, which is the most highly altered by human activity. No data were collected on Grafton Lake itself. A total of 156 parameters were measured, encompassing broad range of physical, chemical and microbiological parameters. The following five exceeded the Canadian and/or British Columbia maximum acceptable concentrations for raw drinking water: colour, pH, iron, manganese, and fecal coliform.

The criteria for colour, iron and manganese are based on aesthetic considerations, whereas the criteria for pH and fecal coliform are based on health. The finding of greatest concern is the high levels of fecal coliform contamination. However, because fecal coliform also are released by wildlife (birds and mammals), further monitoring using a different set of indicators is necessary at additional sites to ascertain the degree to which the fecal contamination is due to anthropogenic sources.

Hydrocarbons and solvents were not present at detectable concentrations in any of the samples collected from the four stations. Similarly, PAHs and PCBs, as well as organochlorine, organophosphate and other pesticides, which were only measured in November at Harding Brook (Station 7, sub-watershed 6), were not detected, with one exception. The herbicide Bromacil was detected, although at a concentration that was well below the USEPA's drinking water guideline for this herbicide.

Geographically, water quality tended in most cases to decrease from the headwaters to the lower watershed, in direct proportion to human land use. Water quality in Harding Brook (sub-watershed 6) was consistently inferior to that in Bowen Brook, further reflecting the human-made sources of degradation. No significant decrease in water quality was found in Bowen Brook downstream of the discharge from Billington Brook (catchment 1-13, in which incineration and waste dumping are known to take place).

Seasonally, the samples collected in June, during conditions of dry weather and decreasing flow in the early summer, tended in most cases to have better quality than those collected in November, when conditions of heavy rain and increasing flow exacerbated the inputs of substances causing colour, as well as total dissolved solids, sulphate, nitrate and organic nitrogen, and phosphorus. However, most of the metals tended to decrease in November, due to dilution, with the exception of aluminum.

The watershed sampling program to date has increased the available data. However, the number of sampling sites was limited and there is still no information on water quality during summer low flow conditions nor during cold weather in winter. Therefore, additional monitoring is needed at a greater number of stations and at different times of year in order to gain a better understanding of the influences that land uses in each sub-watershed or catchment may have on water quality.

Recommendations:

1. Continue the water quality monitoring program in the Grafton Lake watershed for a minimum of another two years.
2. Expand the program to cover more sub-watersheds; in particular, additional information should be obtained from the following sub-watersheds or catchments if funds are available: 3, 4, 1-2, 1-8, 1-10 and 1-11, 1-13 and 1-16, as well as the outlet of Grafton Lake (see Figures 3 and 4). At the very least, the program in 2003-2004 should include the same stations as in 2002 plus Grafton Lake.
3. Increase the frequency of sampling to monthly or, at the very least, to four times per year. If sampling is increased to four times per year, the recommended timing of sample collection is:
   - early summer (as in 2002);
   - late summer or early fall during lowest flow conditions;
   - fall during flushing conditions after a prolonged period of dry weather (as during 2002); and
   - winter during the thaw immediately after a period of freezing weather.
4. Revise the sampling program to also measure the dissolved fraction of metals, for at least one year
5. Revise the microbiological sampling program to include source-specific indicator organisms, to pinpoint failing septic systems and/or distinguish between natural (e.g., wildlife) and human or livestock sources of contamination.
6. Measure PAHs, PCBs and pesticides in all stations where sampling is to take place, particularly in the early summer, late summer low flow, and fall flushing conditions.
7. Complete an ecological assessment of the Grafton Lake reservoir every three years, as previously recommended in the Long Range Plan (1997). The first follow-up assessment should be scheduled for the spring - summer of 2003.
8. Allocate the necessary resources to include an assessment of water quality with reference to protection of aquatic life. This does not require any

additional sampling; however, it does entail establishing the appropriate detection limits in the laboratory.

9. Review the water monitoring results as they become available, to detect potential problem sites and prioritize supplementary sampling, management and education or enforcement efforts. After the third year of monitoring, review the findings and re-evaluate the list of parameters with a view toward reducing the number of analyses or stations and increasing cost-efficiency if warranted.
10. Incorporate source water quality protection as a key element in the public education program.

4.3 Hydrology

Hydrological information is not available for the Grafton Lake watershed. Since water quality, water quantity and watershed health are intimately interrelated, there is a need to complement the water quality data with the corresponding hydrological measurements.

Recommendations:

1. Develop a hydrological monitoring program for the Grafton Lake watershed. At the very least, this program should include measurement of stream flows at or near each of the water quality stations, and on each sampling occasion.
2. The Bowen Island Municipality should consider the installation of a series of permanent, automated hydrometric stations at key locations within the watershed. As a minimum, one station should be installed near the mouth of Bowen Brook and another at the outlet of Grafton Lake.
3. The Bowen Island Municipality should consider the installation of a municipal weather station (recording rain gauge and air temperature thermometer) at a secure location within the Grafton Valley.

4.4 Public Education and Communication

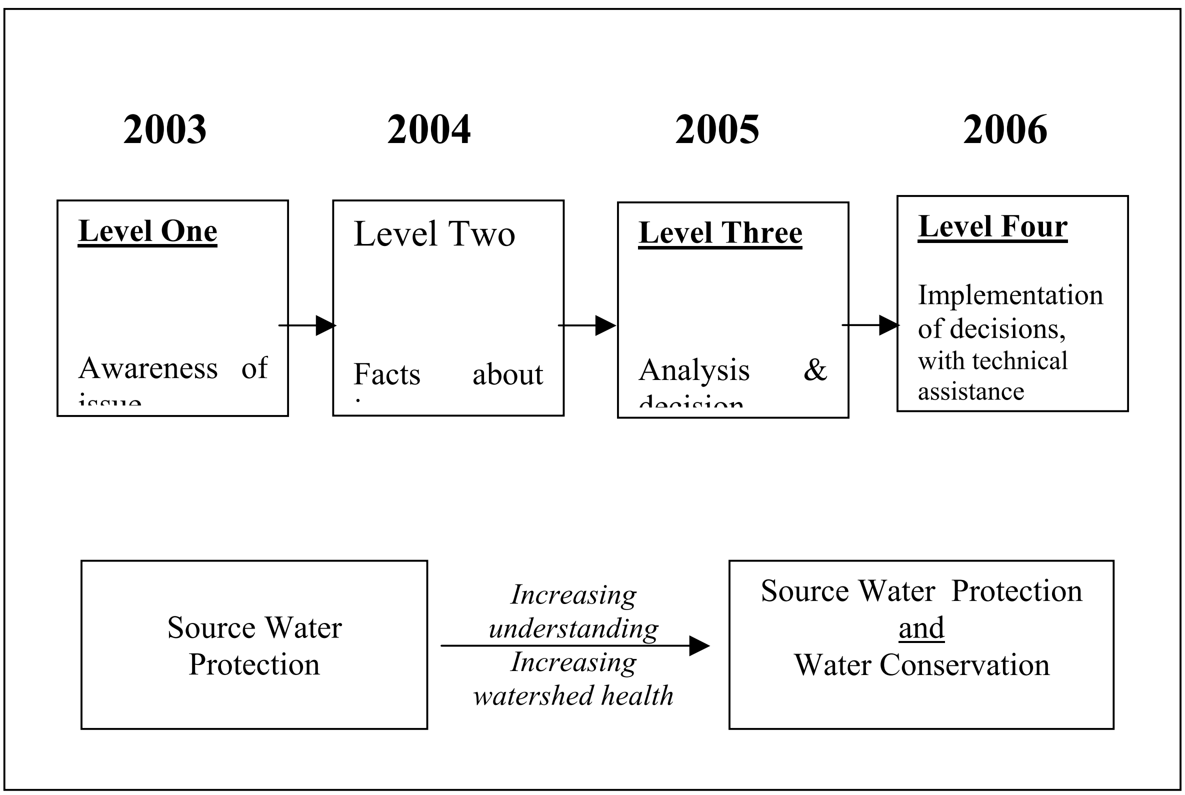
There is a wealth of information on how to communicate and educate the public about source water protection. Experience elsewhere in North America has shown that drinking water source water protection plans should involve the public using an education and communication plan. This approach helps maintain public trust in the system, prevent and mitigate any negative impacts in the watershed, and ideally save fiscal resources through prevention of contaminants entering the water system.

Recommendations:

1. The Bowen Island Municipality and the CBWS should adopt a policy affirming public education and communication as an integral and on-going part of the Grafton Lake Watershed Management Plan.
2. The CBWS should implement an education and communication plan as described in this report, using a phased approach over the next four years, as is consistent with source water protection programs in other jurisdictions across North America.

3. The focus of the first phase of the program should be on raising the profile of source water protection at the "awareness" and "information" end of the outreach and education continuum. At the same time, care should be taken to maintain efforts in the area of education and technical assistance to island residents who are ready to be active stewards during the first phase of the program. Ideally, programming should be on-going right across the continuum. However, this would require more fiscal resources as well as staff and CBWS Board time than is reasonable for a small jurisdiction like Bowen Island. Therefore, the phased approach is recommended (see figure below).
4. To increase cost-efficiency, funding should be shared by other water districts on the island for some parts of the program as many components will reach target audiences through public media (the Undercurrent) which reaches all island residents. However, with the activities which specifically target CBWS users, the costs should be borne by the CBWS district.
5. Future plans should include addressing water conservation issues. A specific work plan to address this aspect of the program should be completed after the evaluation and recommendations at the completion of phase one (2003-2004).

Fig. 22. Overview of Recommended Education & Communication Programming 2003 – 2006



4.5 Proposed Work Plan and Budget for Fiscal Year 2003 – 2004

Table 10
Recommended Work Plan and Budget
for the Grafton Lake Watershed Management Program in Fiscal Year 2003-2004

Component	Description	Estimated Cost
1. Water Quality and Hydrology Monitoring	Collect triplicate water samples 4 times per year at the same four stations as in 2002, plus at the outlet of Grafton Lake. Measure the same parameters as in 2002, plus dissolved metals, PAH, PCB and pesticides at all stations. Measure stream flows at all water quality sampling stations on each sampling date.	Professional fees: 13,400 Lab. costs and other disbursements: 21,250 Subtotal: $ 34,650
2. Grafton Lake Ecological Assessment 2003	Inspect the lake during: the peak water level in the spring, the waterfowl nesting season, and maximum draw-down in the late summer early fall. Use the information to update the environmental assessment of proposed raising of the dam spillway level and recommend procedures to mitigate impacts of reservoir level management.	Professional fees: 6,400 Disbursements: 100 Subtotal: $ 6,500
3. Public education & communication	Launch the education program: publish logo; assess community knowledge; finalize program design; focus on key land uses; begin outreach through Undercurrent articles, workshops, etc.; evaluate Year 1 results.	Professional fees: 11,400 Disbursements: 800 Subtotal: $ 12,200
4. Bylaw development	Review available documentation on bylaws and other legal instruments pertaining to drinking water quality protection through regulation of land use, incentives, and enforcement. Develop draft bylaws for review by local government and the public.	(Not costed; it is assumed that this component would be carried out by municipal planning staff)
		Professional fees: $ 31,200 (58%) Disbursements: $ 22,150 (42%) Total estimated cost: $ 53,350

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Environmental Education and Communication
Environmental Education Research

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Watershed Outreach Conference, USEPA San Diego, March 2000
Water Environment Federation Watershed 2000 Conference, July 8, 2000

Teacher Guides

Project Wild
Project WET
Water, Watershed & Stewardship: A teachers guide
Protected Areas: Preserving Our Future
Water Conservation: Environmental Action
Kids 'n Creeks Teachers Guide

Websites

US EPA: http://www.epa.gov/safewater/protect.html
York Ontario's Water For Tomorrow program www.waterfortomorrow.com
Ontario's Stewardship Centre: www.stewardshipcentre.on.ca
GVRD: http://www.gvrd.bc.ca/services/water/sheds/default.html;
Center for Watershed Protection: www.cwp.org

APPENDIX A (continued) Page 2 of 3

Sample Location:	4 = Bowen Brook. below Harding Rd		7 = Harding Brook at McDonald Farm		14 = Bowen Brook at Buchanan Rd.		20 = Bowen Brook at Sunset Rd.		Guidelines - CCME	
Date Sampled	*1-Jul-2002*	*7-Nov-2002*	*1-Jul-2002*	*7-Nov-2002*	*1-Jul-2002*	*7-Nov-2002*	*1-Jul-2002*	7-Nov-2002		
Number of field replicat	(n=2)	(n=2)	(n=2)	(n=2)	(n=2)	(n=2)	(n=2)	(n=2)		
Non-Halogenated Volatiles										
Benzene	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	-	0.3
Ethylbenzene	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	-	0.07
Styrene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-
Toluene	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	-	0.3
meta- & para-Xylene	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	-	-
ortho-Xylene	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	-	-
Total Xylenes	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-
Volatile Hydrocarbons (	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
VPH	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-

Bacteriological Tests

Fecal Coliform (FC counts/100 ml) - membrane filtration MAC = <1 (DW)

	STATION						
	Lake	**4**	**7**	**14**	**20**	**7a**	**7b**
29-Jul-02	4	84	370	76	116		
06-Aug-02			65				
12-Aug-02	3	120	10	41	17		
19-Aug-02		55	1	12	5		
26-Aug-02		53	26	33	4		
17-Nov-02	112	26	430	15	60	7	72

Total Coliform (TC counts/100 ml) - membrane filtration MAC = <10 (DW)

	STATION				
	Lake	**4**	**7**	**14**	**20**
29-Jul-02	11 - 37	230		300	480
06-Aug-02			330		
12-Aug-02	21	430	310	350	720

APPENDIX A (*completed*)

SAMPLE LOCATION **7 - Harding Brook at Harding Road**

Date sampled *2002-11-07*

Polycyclic Aromatic Hydrocarbons (PAH)	
Acenaphthene	<0.00005
Acenaphthylene	<0.00005
Acridine	<0.00005
Anthracene	<0.00005
Benz(a)anthracene	<0.00005
Benzo(a)pyrene	<0.00001
Benzo(b)fluoranthene	<0.00005
Benzo(g,h,i)perylene	<0.00005
Benzo(k)fluoranthene	<0.00005
Chrysene	<0.00005
Dibenz(a,h)anthracene	<0.00005
Fluoranthene	<0.00005
Fluorene	<0.00005
Indeno(1,2,3-c,d)pyrene	<0.00005
Naphthalene	<0.00005
Phenanthrene	<0.00005
Pyrene	<0.00005
Quinoline	<0.00005

Polychlorinated Biphenyls (PCB)	
Total Polychlorinated Biphenyls	<0.001

Organochlorine Pesticides	
Aldrin	<0.00005
alpha-BHC	<0.00005
beta-BHC	<0.0001
delta-BHC	<0.00005
cis-Chlordane (alpha)	<0.00005
trans-Chlordane (gamma)	<0.00005
2,4'-DDD	<0.0001
4,4'-DDD	<0.00005
2,4'-DDE	<0.0001
4,4'-DDE	<0.00005
2,4'-DDT	<0.0001
4,4'-DDT	<0.0001
Dieldrin	<0.00005
Endosulfan I	<0.00005
Endosulfan II	<0.00005
Endosulfan Sulfate	<0.00005
Endrin	<0.0002
Heptachlor	<0.0001
Heptachlor Epoxide	<0.00005
Lindane (gamma - BHC)	<0.00005
Methoxychlor	<0.0002
Mirex	<0.00005
cis-Nonachlor	<0.00005
trans-Nonachlor	<0.00005
Oxychlordane	<0.00005

Organophosphate Pesticides	
Azinphos methyl	<0.0005
Carbophenothion	<0.0005
Chlorpyrifos	<0.0005
Coumaphos	<0.0005
Diazinon	<0.0005
Dichlorvos/Naled	<0.0005
Dimethoate	<0.0005
Disulfoton	<0.0005
Ethion	<0.0005
Fenitrothion	<0.0005
Fensulfothion	<0.0005
Fenthion	<0.0005
Fonofos	<0.0005
Malathion	<0.0005
Mevinphos (Total)	<0.0005
Parathion	<0.0005
Parathion-methyl	<0.0005
Phorate	<0.0005
Phosalone	<0.0005
Phosmet	<0.0005
Terbufos	<0.0005

Herbicides	
Alachlor	<0.0002
Atrazine	<0.0002
Benfluralin	<0.0002
Bromacil	0.0006
Butylate	<0.0002
Cyanazine	<0.0002
Dacthal	<0.0002
Desethyl Atrazine	<0.01
Desmetryn	<0.0002
Diclofop-methyl	<0.0002
Eptam	<0.0002
Ethalfluralin	<0.0002
Hexazinone	<0.0002
Metolachlor	<0.0002
Metribuzin	<0.0002
Profluralin	<0.0002
Prometryn	<0.0002
Pronamide	<0.0002
Propanil	<0.01
Propazine	<0.0002
Simazine	<0.01
Terbacil	<0.01
Terbuthylazine	<0.0002
Terbutryn	<0.0002
Triallate	<0.0002

Acid Extractable Herbicides	
2,4,5-T	<0.0005
2,4-D	<0.0005
Dicamba	<0.0005
2,4-DB	<0.0005
Dichloroprop	<0.0005
Dinoseb	<0.0005
MCPA	<0.0005
Mecoprop (MCPP)	<0.0005
Picloram	<0.0005
Silvex (2,4,5-TP)	<0.0005

Pyrethroids	
Cypermethrin-1	<0.001
Cypermethrin-2	<0.0002
Cypermethrin-3	<0.0002
Cypermethrin-4	<0.0002
Deltamethrin	<0.0002
cis-Permethrin	<0.0002
trans-Permethrin	<0.0002

Footnotes: Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

APPENDIX B:

PHOTOGRAPHS

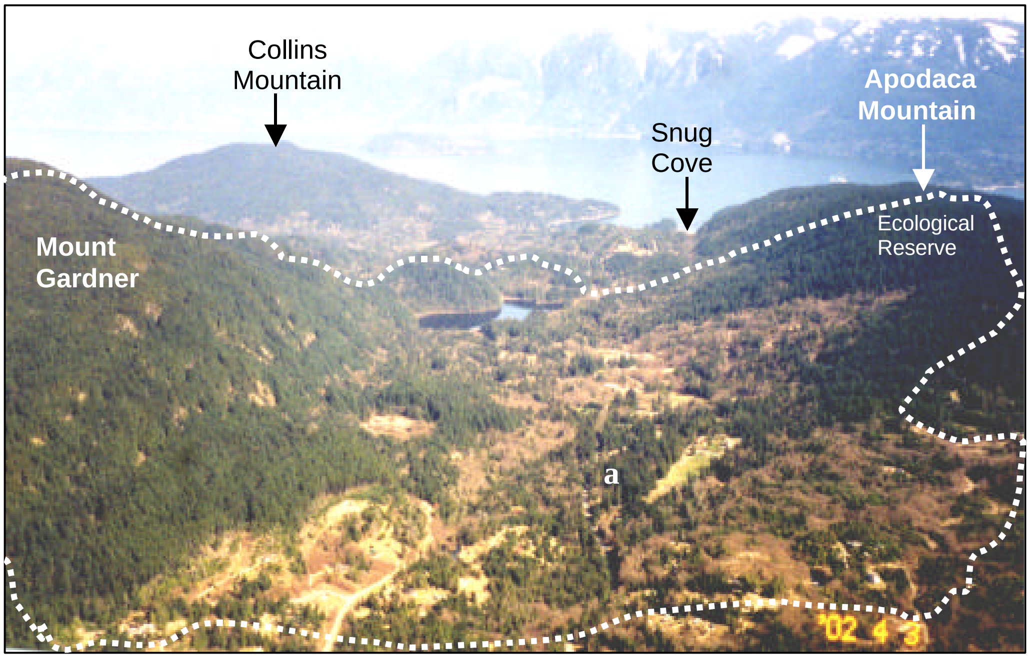


Photo 1. Aerial view of the watershed looking east toward Grafton Lake. Dotted line shows approx. watershed boundary. Extensive areas of undeveloped forest can be seen on the mountain slopes and summits. Dense residential development along Adams Road (a) is obscured by trees. 3-Apr-02

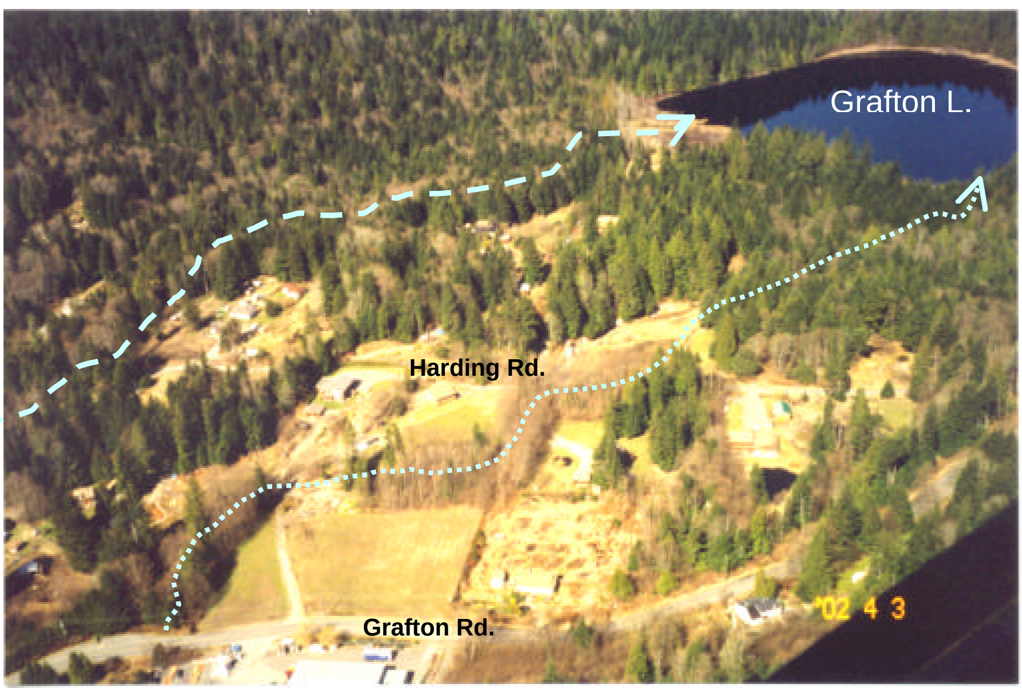


Photo 2. Residential lots in the Harding Road neighbourhood of the Grafton Lake Watershed, viewed to the northeast. These properties are also in the Agricultural Land Reserve. Grafton Road, in the foreground, is the main public road across the island. Dashed line is approx. location of Bowen Brook (catchment 1-1); dotted line is Harding Brook (catchment 4-1). 3-Apr-02

Photo 3. Equestrian facilities in the vicinity of catchment 1-14 (Spooner Brook (a)) and 1-1 (Bowen Brook (b)). Harding road is visible on right (c). 3-Apr-02

Photo 4. Cropland (a), hobby farms with livestock (b), former plant nursery (c), kennels (d) in the vicinity of catchments 1-3 (Proudlock Brook (e)), 1-4 (Lister Creek (f)) and 1-1 (Bowen Brook (g)), viewed to south. 3-Apr-02

Photo 5. Rock quarry and scrap metal dump in the headwaters of catchment 1-13, Billington Creek (arrow), viewed to south. Incineration at this site has also been reported. 3-Apr-02

Photo 6. Solid waste dump in the headwaters of catchment 1-2, viewed to north. Incineration on this property has also been reported. 3-Apr-02

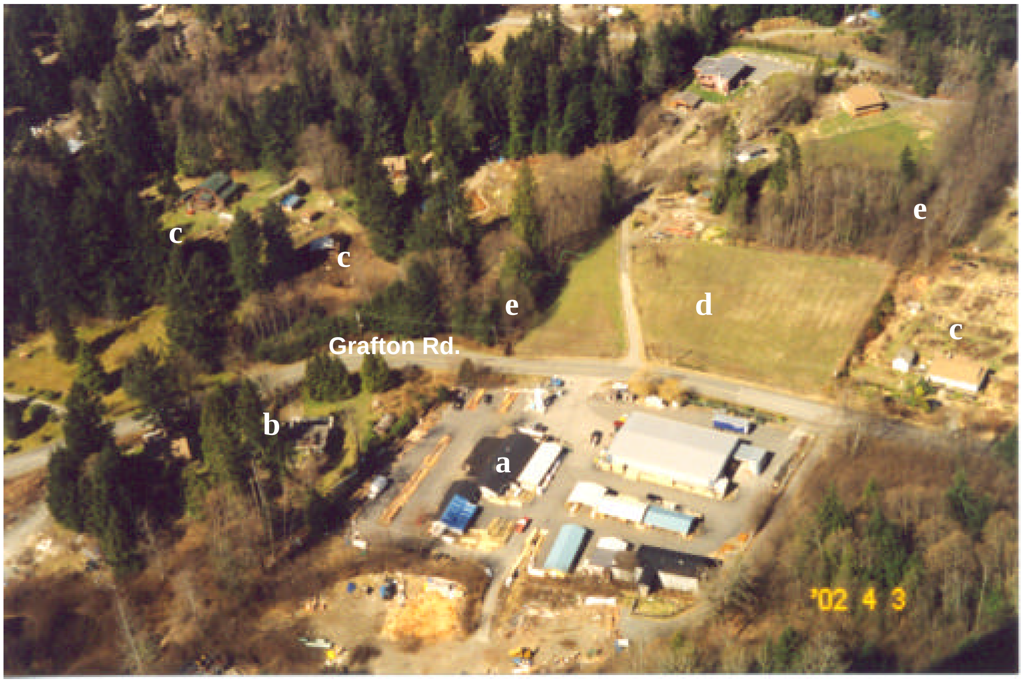


Photo 7. Lumberyard and hardware store (a), residential (b), hobby farm (c) and agriculture (d) in subwatershed 4 (Harding Brook (e)). 3-Apr-02

Photo 8. Site of commercial logging within subwatershed 4 on lower slopes of Apodaca Mountain south of Grafton Lake. 3-Apr-02

Photo 9. Site of former soil quarry (a) and sediment ponds (b) to west of lumberyard (c) in catchment 1-2 (Mac-Wha Creek). Grafton Rd is visible in lower left corner. 3-Apr-02

Photo 10. Flock of free-range turkeys beside Harding Brook (subwatershed 4-1) at a farm on the north side of Harding Road. 2-Nov-02.

APPENDIX C

PROGRAM EVALUATION TOOLS

Education Program Planning & Evaluation Form

1. Program Information

Name of program: ___________________________

Program Location: ___________________________

Type of Program: ____________________________

Duration of Program: _________________________

Program to be delivered by: ______________________

2. Program Planning
All education and outreach programs should have a guide to their development and delivery. By answering the following questions, you can ensure a better program both for the presenters as well as your audience.

Audience Analysis:

Who is your target audience? Provide details.

What is their knowledge of the topic you will be presenting? How will you ascertain this? (pre-check test? Or other discussions with teacher/ contact?). Provide details.

What is your audience capable of? (Physical limitations? Cognitive skills? Emotional development?) Provide details.

Describe how you plan to address your audience's needs through program design and educational strategies.

Site Analysis:

Where will you deliver the program?

What are the challenges or opportunities at this site?

Program Description:

Describe the goals of the program.

List the program objectives (identification of Learning Outcomes - what will your audience learn or be able to do after completing your program?);

Describe your **educational program design**. Include:

- Identification of key concepts or messages you wish to convey to your audience;
- How you will select and organize program content;
- Include a variety of strategies that:
    - ► provoke appropriate experiences of inquiry and activity;
    - ► include time to de-brief or reflect on experience
    - ► include applying and integrating new knowledge and skills.
- If you will be using an existing program such as Salmonids in the Classroom or Project WET, please list these resources and how you intend to use them.

3. Program Evaluation

How will you assess learning of your participants?

Who will evaluate your program?

When will the program be evaluated?

Education Program Delivery Evaluation Template:

Name of program: ______________________

Date: ________________________________

Program Location: ______________________

Program delivered by: ___________________

Your Name: __________________________

School/
Organization:_________________________

Address/Email: __________________________

____

1. Did the program presenter ascertain background information about the participants' knowledge and/ or skills prior to or during the program?

2. Did the program address participants' background, learning styles, and skill levels? How?

3. Was the program site appropriate for the program? Why or why not?

4. Were the program's goals and learning outcomes clearly presented? Explain.

5. Did the presenter make use of effective presentation techniques such as visual aids, a variety of activity types, and encouragement of group interaction?

6. Did the program include some form of evaluation or assessment of participant learning? Based on this assessment, participant learned:

7. The best features of this program were:

8. Ways in which this program could be improved include:

9. Overall, this program was:
Excellent ______ Good _______ Satisfactory _______ Poor ___

EETAP Communications Checklist follows on next two pages.

EETAP Communications Checklist

EVIDENCE OF WELL PLANNED COMMUNICATIONS

Audience Identification

- ☐ Audience is identified through words or pictures.
- ☐ Audience identification is apparent to the target audience.
- ☐ Persons portrayed in the communication are reflective of the demographics of target audience (age, gender, profession, etc.).
- ☐ Persons portrayed in the communication are reflective of the cognitive and affective characteristics of the target audience (previous knowledge, attitudes, interests, motivations, etc.).

Comments

☐ 4 Excellent ☐ 3 Very Good ☐ 2 Fair ☐ 1 Poor

Message Identification

- ☐ Message is clearly identified through words and/or pictures.
- ☐ The instrumental utility and/or entertainment value of message to the target audience is clearly identified.
- ☐ Message is defined in ways that are similar to cognitions and beliefs held by the target audience.
- ☐ Desired conclusions and/or intended actions are stated explicitly rather than requiring receivers to draw their own conclusions.

Comments

☐ 4 Excellent ☐ 3 Very Good ☐ 2 Fair ☐ 1 Poor

Message Processability

- ☐ Message uses simple, well-known facts. When facts are more complex, message uses repetition with slight variability.
- ☐ Message is related to concepts and facts previously known to the target audience.
- ☐ Message diminishes perceived risks of holding the attitude, beliefs, or interest.
- ☐ Message relates to existing attitudes, beliefs, and interests of the target audience.

Comments

☐ 4 Excellent ☐ 3 Very Good ☐ 2 Fair ☐ 1 Poor

Effective Use of Sources in the Message

- ☐ An expert source is used for content that will be highly technical for the receiver; a trustworthy source is used for content that might be risky for the receiver to adopt an attitude/interest/belief; like/known message sources are used (people similar to the target audience).
- ☐ A like person (model) is used in the message to demonstrate the intended outcome (e.g., if the intended outcome is to raise awareness of how EE can be used to teach geometry, a math teacher is featured talking about how EE can be used to teach geometry).
- ☐ Message includes rewards for the model exhibiting the desired behavior (e.g., a geometry student talking about how the unit on EE in geometry motivated him to do his best in geometry class or social acceptability of the desired behavior by showing strength in numbers).
- ☐ Rewards demonstrated (e.g., a student being more motivated, a student scoring higher on an achievement test) are consistent with intrinsic and/or extrinsic values of target audience.

Comments

☐ 4 Excellent ☐ 3 Very Good ☐ 2 Fair ☐ 1 Poor

Accessibility of Ideas

- ☐ Most important points are stated first, second most important points next, and so on.

Comments

Figure 1 Sample portion of checklist for evaluating the quality and potential effectiveness of communication tools for promoting environmental education programs.

☐ Importance of ideas is based on needs and perceptions of the target audience. ☐ Information is chunked into manageable pieces. ☐ Reiteration is used to accentuate important points and/or to clarify complex information.	
☐ 4 Excellent ☐ 3 Very Good ☐ 2 Fair ☐ 1 Poor	
Content Readability	
☐ Present tense is used. ☐ Active voice is used. ☐ Rhythm of sentences is controlled by varying the length and the beginnings of sentences. ☐ Transitions are provided using words like "however," "therefore," and "also" and by beginning sentences where the former sentence ended.	Comments
☐ 4 Excellent ☐ 3 Very Good ☐ 2 Fair ☐ 1 Poor	
Graphical/Textual Readability	
☐ Cues (font style, size, etc.) are given to signal important points. ☐ Common font sizes and styles are used. ☐ Left justification is used. ☐ Numbered/bulleted lists, icons, and other organizational tools are used to organize information for readability.	Comments
☐ 4 Excellent ☐ 3 Very Good ☐ 2 Fair ☐ 1 Poor	
Consistency	
☐ Terms mean the same thing throughout. ☐ Tables, lists, diagrams, bullets, etc., are consistent in style and use throughout. ☐ Headings and subheadings are consistent in style and use throughout. ☐ Voice is consistent throughout.	Comments
☐ 4 Excellent ☐ 3 Very Good ☐ 2 Fair ☐ 1 Poor	
Clarity	
☐ Large words are used sparingly, if at all. ☐ Qualifying phrases and clauses are eliminated. ☐ No unnecessary information is included (only information that is relevant to the defined purpose is included). ☐ Key points are summarized.	Comments
☐ 4 Excellent ☐ 3 Very Good ☐ 2 Fair ☐ 1 Poor	

Scoring for Evidence of Well Planned Communications

Add the following:

Number of Excellent ratings (0–9) _____x 4 = _____

Number of Very Good ratings (0–9) _____x 3 = _____

Number of Fair ratings (0–9) _____x 2 = _____

Number of Poor ratings (0–9) _____x 1 = _____

Total Score: = _____ divided by 36 = _____ x 100 = _____

Score > 85 Excellent

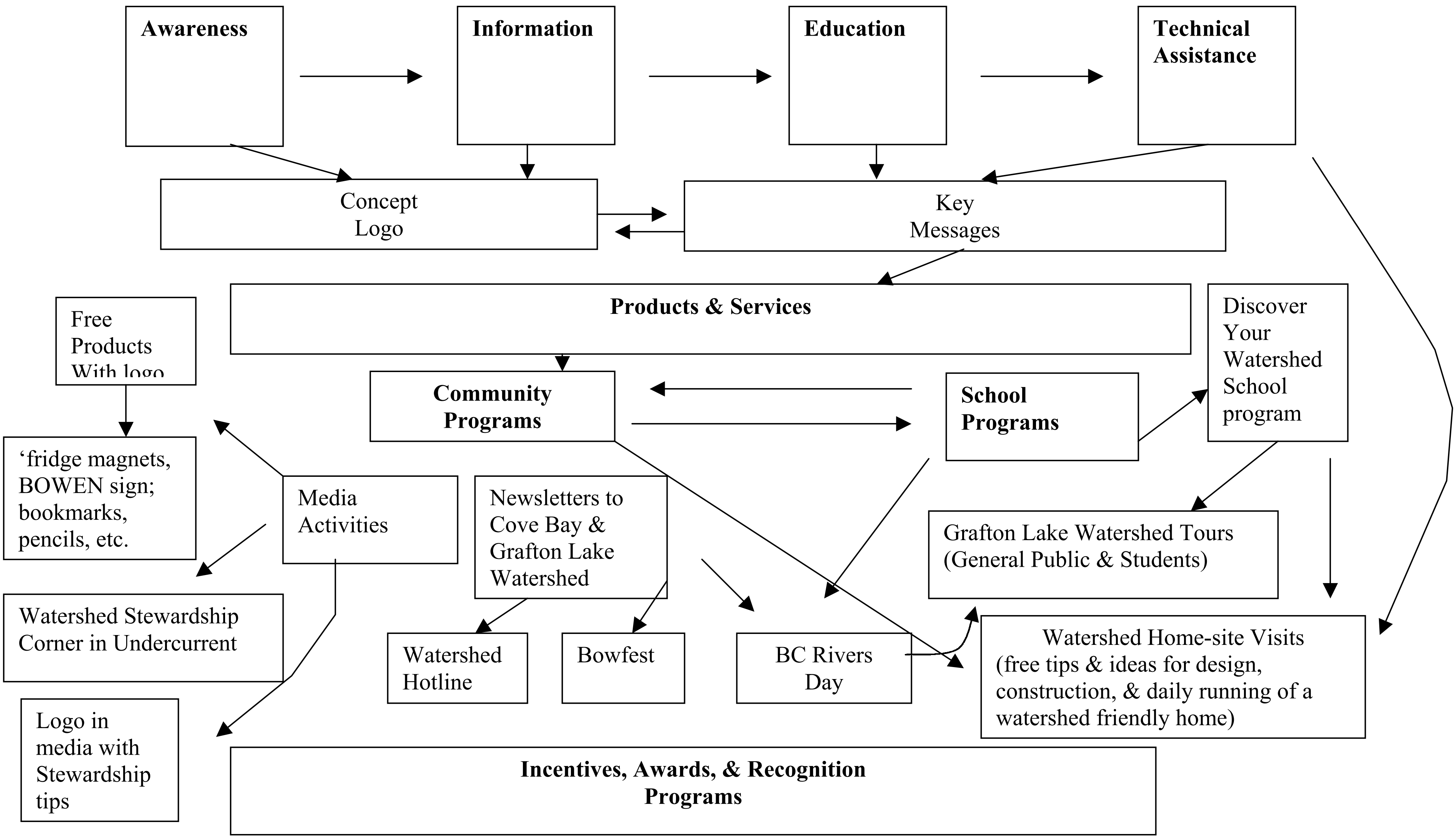
Score 70–85 Very Good

Score 50–70 Fair

Score < 50 Poor

APPENDIX D

Overview of Outreach & Education Activities for Source Water Protection
Bowen Island, BC


Awareness
Information
Education
Technical Assistance
Concept Logo
Key Messages
Products & Services
Free Products With logo
Community Programs
School Programs
Discover Your Watershed School program
'fridge magnets, BOWEN sign; bookmarks, pencils, etc.
Media Activities
Newsletters to Cove Bay & Grafton Lake Watershed
Grafton Lake Watershed Tours (General Public & Students)
Watershed Stewardship Corner in Undercurrent
Watershed Hotline
Bowfest
BC Rivers Day
Watershed Home-site Visits (free tips & ideas for design, construction, & daily running of a watershed friendly home)
Logo in media with Stewardship tips
Incentives, Awards, & Recognition Programs