Public Copy

Pugwash Water Supply Investigation

Final Report

120806.01 ● Final Report ● July 24, 2012

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Prepared for:
Municipality of Cumberland

Prepared by:
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24 July 2012

Rennie Bugley, CAO
The Municipality of Cumberland
1395 Blair Lake Road
RR # 6 Amherst NS B4H 3Y4

Dear Mr. Bugley:

RE: Municipality of Cumberland - Pugwash Water Supply Investigation

Attached please find the *Pugwash Water Supply Investigation, Final Report - Public Copy.*

The "Confidential" *Pugwash Water Supply Investigation - Final Report* that was previously sent to you includes references to water quality at specific civic addresses, and therefore has to be kept confidential.

In this "Public Copy" Report, the civic addresses have been replaced with "well codes" that prevent the reader from identifying the well locations, and mapping has been revised to summarize water quality.

Yours very truly,

CBCL Limited

Willard D'Eon

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Attachments

Issue or Revision:	Reviewed By:			Issued By:		
	Name:	**Signature:**	**Date:**	**Name:**	**Signature:**	**Date:**
Final Report Public Copy	C. Walker		07/24/2012	W. D'Eon		07/24/2012
Final Report	C. Walker	C.W.	07/13/2012	W. D'Eon	W.D.	07/13/2012
Draft Report	C. Walker	C.W.	04/19/2012	W. D'Eon	W.D.	04/19/2012

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Signed and Sealed:

REGISTERED PROFESSIONAL ENGINEER
W. J. D'EON
23 July/2012

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EXECUTIVE SUMMARY

The "Confidential" *Pugwash Water Supply Investigation - Final Report* includes references to water quality at specific civic addresses, and therefore has to be kept confidential. In this "Public Copy" Report, the civic addresses have been replaced with "well codes" that prevent the reader from identifying the well locations, and mapping has been revised to summarize water quality.

A groundwater sampling program was completed for wells in central Pugwash and surrounding area. Work was completed to determine whether a central water supply and distribution system could be developed within the boundaries of the Village of Pugwash. A central supply system would replace individual supplies, many of which are compromised by elevated concentrations of chloride, hardness, and health related parameters. Raw well water samples were collected from 25 locations in Pugwash, West Pugwash, Pugwash Point, and locations to the southeast along Highway #6. Data from an additional 28 wells that were sampled in 2004 were included in the analysis.

The quality of water drawn from wells in the Pugwash Areas varied according to the source aquifer and quality of well construction. Many wells installed in evaporite rock of the Windsor Group showed elevated concentrations of chloride, sodium, iron, and manganese. Chloride concentrations exceeded the Guideline for Canadian Drinking Water Quality (GCDWQ) of 250 mg/L at 14 of 23 locations underlain by Windsor Group bedrock, compared to only 1 of 30 wells underlain by Cumberland Group sandstone. Concentrations of arsenic, lead and uranium exceeded the GCDWQ at selected locations, generally in areas underlain by Windsor Group rocks. The quality of water drawn from Cumberland Group aquifers was generally good.

Bromide/Chloride ratios were assessed in seven wells in an effort to determine the source of elevated chloride. The ratios in three wells indicate that the source of chloride is attributable to sea water or mineral formation water, while the ratios in the remaining four wells indicate that these wells may be affected by road salting, and that reduction of salting in these areas and upgrades to the wells should improve water quality with time.

The results indicate that Windsor Group bedrock is generally responsible for the poor quality of water that is observed at some domestic wells in the Pugwash area. Improvements to these wells would not in most cases improve the quality of pumped water. As water of good quality can be drawn from Cumberland Group or Pictou Group aquifers, a central supply installed in one of these aquifers would

improve the quality of water supplied to many homeowners in the Pugwash area. Other alternatives include individual treatment systems and bottled water / refillable cisterns.

A potential target aquifer for a Pugwash central water supply was identified, by the client, located to the south of the Village. The target aquifer is located in Pictou Group Sedimentary rock, where reported yields suggest that the aquifer has the potential to provide the required withdrawal rates. Development of a well field would require the installation of test wells, aquifer testing (pumping tests and water quality sampling), and additional hydrogeological investigation to ensure that the water supply will be secure for time frames exceeding 20 years.

CHAPTER 1 INTRODUCTION

1.1 Background

Domestic water in the Pugwash area is supplied by individual private water wells. The quality of water obtained in the Pugwash area varies; elevated chloride concentrations have been identified as a primary concern, and concentrations of sodium, sulphate, iron and manganese can exceed operational and taste objectives. Potential sources of undesirable groundwater constituents include sea water intrusion, dissolved minerals arising from the composition of Windsor Group bedrock, poor well construction, and infiltration of road salt.

Aquifer tests and water quality sampling were completed in 1982 in an effort to assess the potential to develop a central water supply and distribution system (H.J. Porter and Associates Ltd, 1982). The study concluded that water of adequate quality was available, but that the pumping rates needed to sustain the system over long time frames had the potential to induce salt water intrusion from coastal areas and/or Windsor Group bedrock. An earlier study described salt water intrusion in the Pugwash Area as a “serious problem” (H.J. Porter and Associates Ltd, 1979).

In 2005, CBCL completed groundwater supply and remedial options evaluations of four communities in the Municipality of Cumberland, one of which was Pugwash. The objective of the study was to provide an updated evaluation of groundwater quality and quantity and identify health and aesthetic issues associated with existing individual groundwater supplies. Remedial options were developed based on the results of the study.

The quality of water drawn from wells exhibiting “good” construction (i.e. wells that appeared to satisfy the NSE Water Well Regulations) was better than the baseline levels typical of other wells observed during the study. The results suggested that it may be possible to locate and develop the aquifer(s) that supply the wells exhibiting high quality water. On this basis an additional investigation of Pugwash area aquifers was completed in 2012. Objectives were developed by the Municipality and are summarized below.

1.2 Goals and Objectives

The primary goal of this investigation was to augment current understanding of the aquifer(s) underlying the Pugwash area, and to determine if a central water supply and distribution system could be developed. To this end the following objectives were completed:

- Conduct water quality testing for general chemistry and metals on a group of five wells that were sampled in Pugwash in 2004. The purpose of this item was to determine temporal water quality tends of wells considered to be of good construction;
- Conduct water quality testing for general chemistry and metals on 10 additional private wells of good construction at representative locations throughout the community. These locations were determined using the NSE water well database and in consultation with the Project Steering Committee. The purpose of this item was to obtain additional water quality data from wells of good construction. Older drilled wells are often buried, inadequately sealed, or placed in buried crocks, all of which can compromise water quality;
- Conduct water quality testing for general chemistry, metals and bromide on wells in the following targeted locations:
  - Four wells on Water Street between Durham Street and King Street;
  - One well in Pugwash Point; and
  - Two wells in West Pugwash.

  The purpose of this item was to better delineate the zone of elevated chloride in the middle area of Water Street where there was a gap in the existing database, and to resample wells in Pugwash Point and West Pugwash where elevated chloride concentrations had been detected. Bromide was sampled in an effort to distinguish between seawater and road salting as potential sources of saline water;
- Conduct water quality testing for general chemistry and metals on four "paired" wells. Paired wells included a sample from a "good" construction well and a nearby "'poor" construction well, and were compared to assess the potential influence of well construction on water quality; and
- Compare results for all tests with the Guidelines for Canadian Drinking Water Quality (GCDWQ) and identify any health related issues that become evident.

The information obtained in this investigation was used to update an evaluation and costs of remedial activities for Pugwash as outlined in the 2005 Study by CBCL. The proposed servicing strategy was updated, assuming that the groundwater source would need to be located within 5 kilometres from the distribution system in an aquifer where water quality meets the GCDWQ.

1.3 Physical Setting

The study area is situated adjacent to a coastal estuary comprising the outlet of the Pugwash River and Pugwash Basin (Figure 1.1). The estuary discharges to the Northumberland Strait. The study area includes Pugwash (at the outlet of the estuary), Pugwash Point, which forms a peninsula on the east side of the Basin, West Pugwash, to the west of the outlet and along the shoreline of the Pugwash Basin, and homes located on the northeast coastline of the Pugwash Basin.

The peninsula forms a topographic high in the study area, reaching elevations of 38 m geodetic. Surface water drainage is expected to radiate away from the peninsula, discharging directly to the

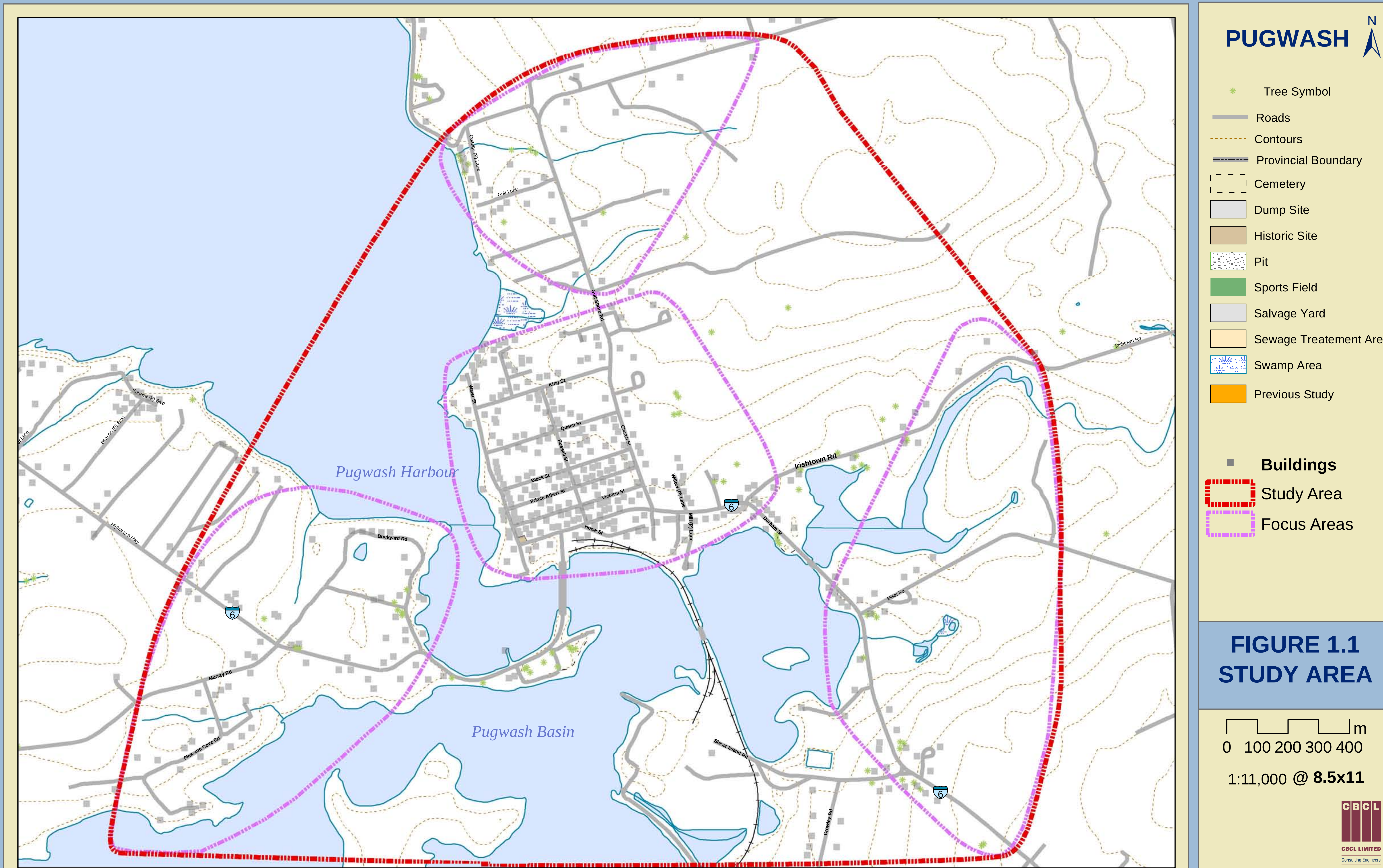


FIGURE 1.1
STUDY AREA

estuary and Pugwash Basin. The centre of the peninsula is expected to constitute a groundwater recharge area; previous investigators suggested that this area provides recharge to the underlying bedrock aquifer, establishing an intermediate flow system between the peninsula and coastal discharge area (H.J. Porter and Associates Ltd., 1982).

There is a major bedrock contact in the study area extending approximately west to east through the study area (Figure 1.1). Locations to the south of the outlet, including parts of Pugwash, are underlain by evaporite rock of the Windsor Group. The Windsor Group typically provides moderate to high yields but the water commonly exhibits elevated concentrations of dissolved minerals. Concentrations of chloride, sodium, sulphate, iron, manganese and other metals can exceed the GCDWQ.

Bedrock to the north of this contact is mapped as Cumberland Group sedimentary rock of the Malagash Formation; NSE water well records from this area indicate that the bedrock aquifer underlying the northern part of the study area is predominantly sandstone. Detailed logging of three test wells (H.J. Porter and Associates Ltd, 1982) showed interbedded units of shale and sandstone. A 10-metre thick sandstone unit was logged at depths of 56 to 61 metres in two of the three wells. Existing mapping and core logs from the 1982 study indicated that the sandstone aquifer is part of an anticline, dipping at 30^{o} to the north-northwest and striking to the east-northeast at Az 70^{o}.

The till thickness in the Pugwash area is generally 6 to 12 m, indicating that the underlying bedrock unit is confined. The presence of interbedded shale units would contribute additional confining effects on underlying sequences of sandstone. A conceptual model was developed as part of the aquifer test completed to the northeast of Pugwash (H.J. Porter and Associates Ltd, 1982). The 1982 study suggested that there is an intermediate flow system originating in the centre of the Pugwash Point Peninsula, discharging radially to coastal areas. This aquifer would be bounded to the south by the Windsor Group. The 1982 study conceptualizes the sandstone aquifer as a freshwater lens overlying and bounded on all sides by salt water interfaces (sea water to the west, north and east, and mineral water from the Windsor Group to the south). Fresh water extraction rates would be limited by:

- The basin yield, estimated in 1982 at 411 m^3/day (62 igpm) (H.J. Porter and Associates Ltd, 1982); and
- The position of the salt water interface(s). Declines in hydraulic head caused by long-term pumping could draw this interface in-land from its current position.

These factors were expected to supersede the apparent sustainable pumping rate of wells drilled in the aquifer. A 24-hour pumping test of a 6-inch well in the sandstone aquifer produced a drawdown of 7 m at a pumping rate of 100 igpm. The theoretical (Jacob Method) 20-year drawdown at this pumping rate was estimated at 23 metres.

1.4 Guidelines and Regulations

Groundwater quality data are compared to the Guidelines for Canadian Drinking Water Quality (GCDWQ) maintained by Health Canada. The Nova Scotia Well Construction Regulations (made under Sections 66 and 110 of the *Environment Act*, S.N.S. 1994-95, c. 1, O.I.C. 2007-483 (September 7, 2007), N.S. e.g., 382/2007) were used as the basis to assess the quality of well construction in the Pugwash area.

CHAPTER 2 METHODOLOGY

2.1 Selection of Sampling Locations

Field inspections and information from the NSE Well Logs Database were used to identify wells of "Good Construction". Others were flagged to be of potentially inadequate construction due to buried well heads, poor sanitary seals, or inadequate casings above or below the ground surface. Poor water quality in previous sampling events was also considered to indicate a well with potentially inadequate construction. Wells were selected from these subsets to provide an adequate distribution throughout the Pugwash area, and to satisfy the objectives listed in Section 1.2. The proposed sample locations (private water wells) were reviewed and finalized by the Project Steering Committee.

2.2 Sampling Methodology

CBCL field staff visited selected domestic well locations to collect a raw water sample. The field survey was conducted March 5th and 6th, 2012.

Generally, a raw water sample was collected from the kitchen tap and analysed for inorganic chemical parameters (including trace metals and bromide).

The sampling protocol was as follows:

- The aerator (if present) was removed;
- Samples were collected from the selected cold water tap;
- The water was run for at least five minutes to ensure that groundwater, rather than water in the piping, was being sampled;
- Samples were filled to the indicated water line and immediately stored in an insulated cooler filled with ice; and
- Samples were delivered to AGAT Laboratories in Dartmouth, Nova Scotia within the required hold-times for the specified analyses.

If a water treatment system was present and could not be bypassed, the raw water sample was collected from a sampling tap prior to treatment or from the pressure tank.

The analytical results were mailed to each of the residents participating in the survey.

2.3 Analysis of Water Quality

Chemical data were mapped to provide an indication of the spatial variability of indicator parameters with respect to bedrock geologic units, proximity to coastlines, and proximity to major roadways. Maps are provided for chloride, iron, manganese, arsenic, lead, uranium, bromide/chloride ratio, and GCDWQ parameters exceeded. Data from the 2004 sampling program were included in the mapping exercise.

Water quality data from four registered water supplies in Pugwash, and from a new well at the Nova Scotia Transportation and Infrastructure Renewal (NSTIR) Maintenance Depot, were reviewed and compared to the private well sampling data. Data from the 1982 aquifer testing program (H.J. Porter and Associates Ltd., 1982) and from a review of salt water intrusion in coastal areas of Nova Scotia were also reviewed (Briggins and Cross, 1995).

CHAPTER 3 RESULTS

3.1 Distribution of Chemical Parameters in the Pugwash Area

Selected indicator parameters were plotted to provide an indication of the effects of proximity to features such as coastlines, major roadways, and underlying bedrock units. Data from 2004 and 2012 were included in the analysis. In locations where data was available for both 2004 and 2012, the most recent data was used.

3.1.1 Chloride

Chloride concentrations are shown on Figure 3.1. Wells overlying the Cumberland Group sandstone generally showed concentrations below 100 mg/L. The chloride concentration at well PP1 Road was 1340 mg/L. The source of elevated chloride concentrations is discussed in Section 3.1.2. Chloride concentrations at locations to the south and east of the Windsor Group contact were between 159 and 191 mg/L.

Wells underlain by Windsor Group evaporite rock generally exhibited higher chloride concentrations, ranging to 3189 mg/L. The chloride concentration exceeded the GCDWQ of 250 mg/L at 14 of 23 locations underlain by Windsor Group bedrock, compared to only 1 of 30 wells underlain by Cumberland Group sandstone.

3.1.2 Bromide/Chloride

Bromide concentrations were measured in an effort to distinguish wells affected by road salting from those affected by salt water interfaces. Road salt typically exhibits low bromide concentrations whereas sea water or mineral aquifer water exhibit higher concentrations. As such the bromide to chloride ratio [Br:Cl x 10 000] of water affected by road salt is typically below 10 whereas sea water and mineral formation water are generally associated with [Br:Cl x 10 000] ratios of 10 to 100 (Briggins and Cross, 1995).

In other studies, use of the [Br:Cl x 10 000] ratio focused on groundwater considered to be adversely affected by salt water inputs; the chloride concentrations in these studies exceeded 250 mg/L. Only seven of 25 locations sampled in 2012 showed chloride concentrations exceeding 250 mg/L, and bromide was detected at only two locations. An analysis of [Br:Cl x 10 000] ratios for this sampling program is limited to seven wells shown to be adversely affected by chloride. At all other locations low concentrations of bromide could be attributed to the higher quality of the water drawn from those locations.

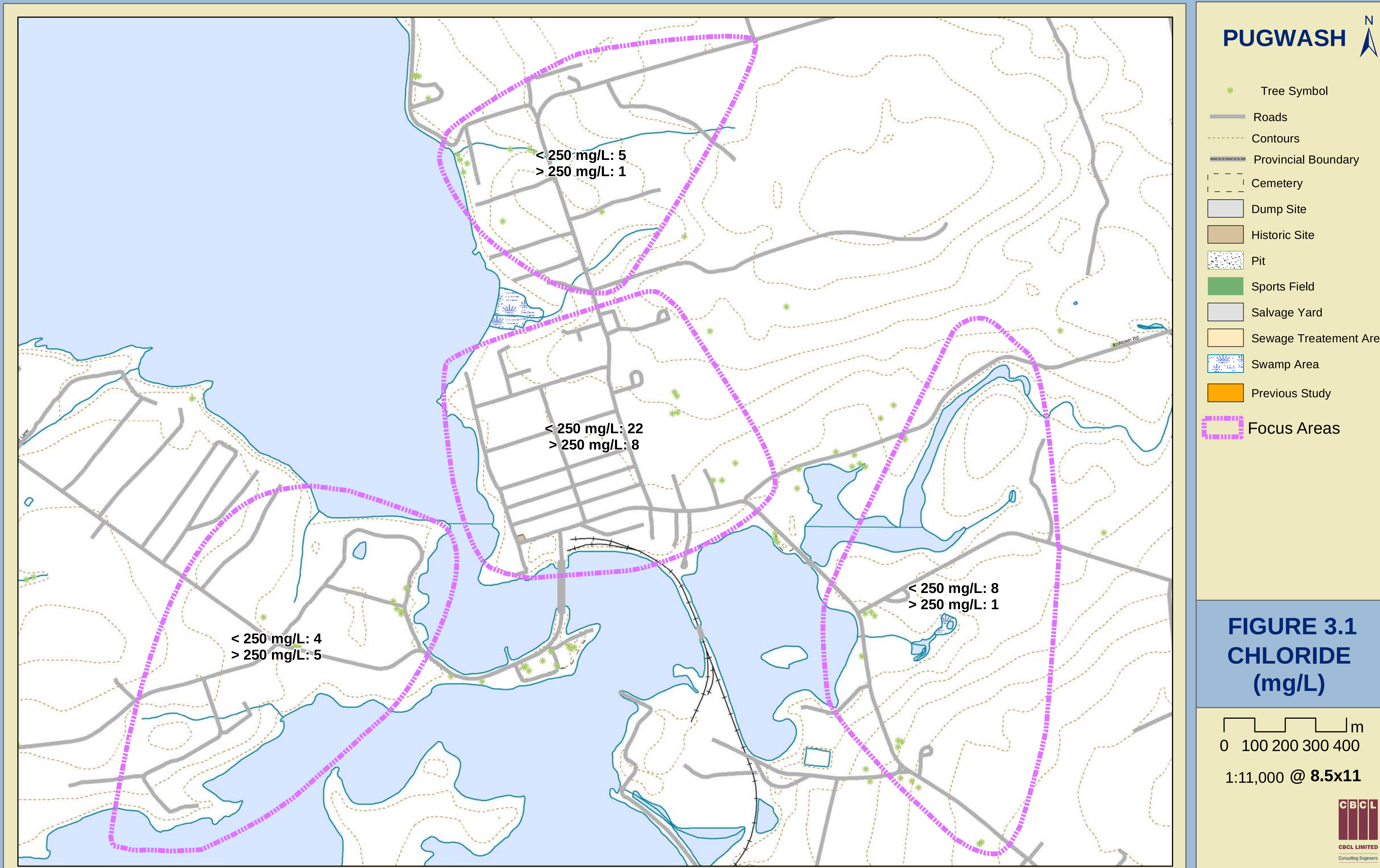


FIGURE 3.1 CHLORIDE (mg/L)

Table 3.1 shows [Br:Cl x 10 000] ratios for seven wells in the study area. At locations where bromide was not detected the concentration was set to half of the reported detection limit for that sample. [Br:Cl x 10 000] ratios exceeded 10 at three locations, indicating that the source of chloride is attributable to sea water or mineral formation water.

[Br:Cl x 10 000] ratios were below 10 at the remaining four locations (PP1, R4, B9, and C2). Three of these wells were identified in 2004 as exhibiting potential construction problems above or below the ground surface. [Br:Cl x 10 000] ratios suggest that these wells may be affected by road salting, and that reduction of salting in these areas and upgrades to the wells should improve water quality with time.

3.1.3 Iron

The distribution of iron concentrations in the Pugwash areas is shown on Figure 3.2. Iron concentrations were generally below 300 μg/L in areas underlain by Cumberland Group sandstone. Both low and higher concentrations were observed at locations underlain by Windsor Group bedrock, ranging from 17 to 10,468 μg/L. This is consistent with Windsor Group groundwater, caused by the variable mineral composition of Windsor Group bedrock.

3.1.4 Manganese

The distribution of manganese concentrations in the Pugwash areas is shown on Figure 3.3. Manganese concentrations were generally below 50 μg/L in areas underlain by Cumberland Group sandstone. Both low and higher concentrations were observed at locations underlain by Windsor Group bedrock, ranging from 9 to 1953 μg/L. This is consistent with Windsor Group groundwater, caused by the variable mineral composition of Windsor Group bedrock.

3.2 Wells Sampled in 2004 and 2012

Data for five wells sampled in 2004 and 2012 are shown in Table 3.2. Samples from R1, R2, R3, and R4 showed consistent chemical composition between 2004 and 2012. Chloride concentrations increased from 430 mg/L to 508 mg/L at R1 and from 260 mg/L to 301 mg/L at R4. These increases represent minor changes, and the concentrations of other parameters remained relatively consistent. The data provide no clear indication of increasing chloride concentrations at the sampled wells, but additional sampling years would be required to confirm this.

Concentrations of chloride, sodium and manganese showed significant decreases between 2004 and 2012 at W1. The data show that the sample collected in 2004 was affected by a source of these ions. Potential sources include minerals (e.g., sediment) introduced at the time of sampling or a pulse of contaminated water from the aquifer. The well at W1 is close to both a coastal area to the west and the contact with the Windsor Group to the south. Dry conditions in 2004 or unusually high pumping rates at or near the well could have drawn down the hydraulic head in the well. This decrease could cause a sea water or mineral water interface to advance toward the well, or water may have been drawn from a deeper interval of the Cumberland Group.

Table 3.1. Ratio of Bromide to Chloride Concentration for Wells Exhibiting Chloride Concentrations Greater Than 250 mg/L

				Sample Location						
Parameter	**Unit**	**G / S**	**RDL**	**R1**	**R4**	**B9**	**W1**	**W2**	**PP1**	**C2**
Bedrock Group				Windsor	Windsor	Windsor	Windsor	Windsor	Pictou	Windsor
Depth										
Bromide*	mg/L		0.3	0.69	0.15	0.15	3	4.4	0.15	0.15
Chloride	mg/L	[250]	1	508	301	672	1960	1190	1340	507
[Br]/[Cl] x 10 000	mg/L	1.5	0.1	14	5.0	2.2	15	37	1.1	3.0

*Concentration set to half of reported detection limit for each sample

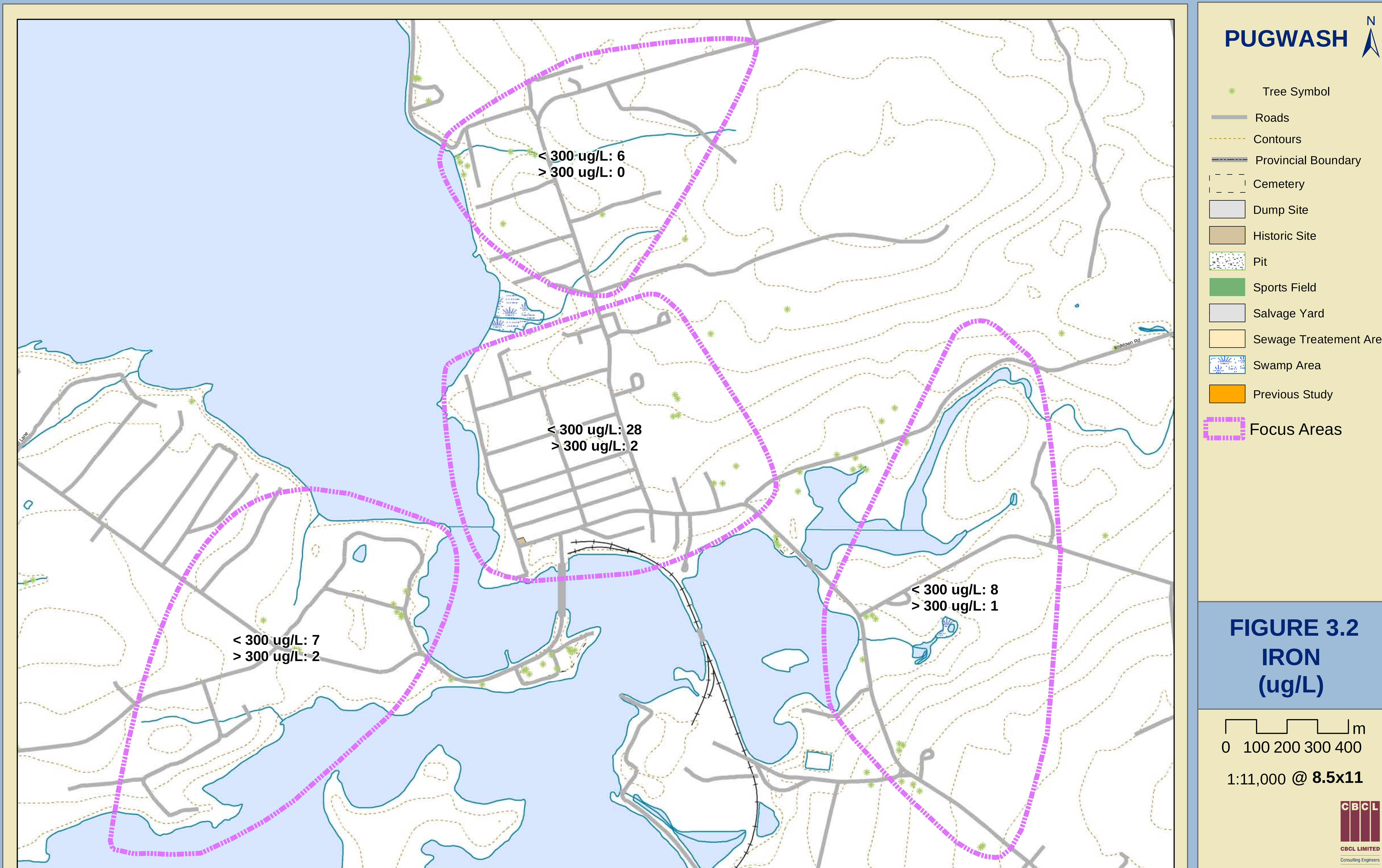


FIGURE 3.2
IRON
(ug/L)

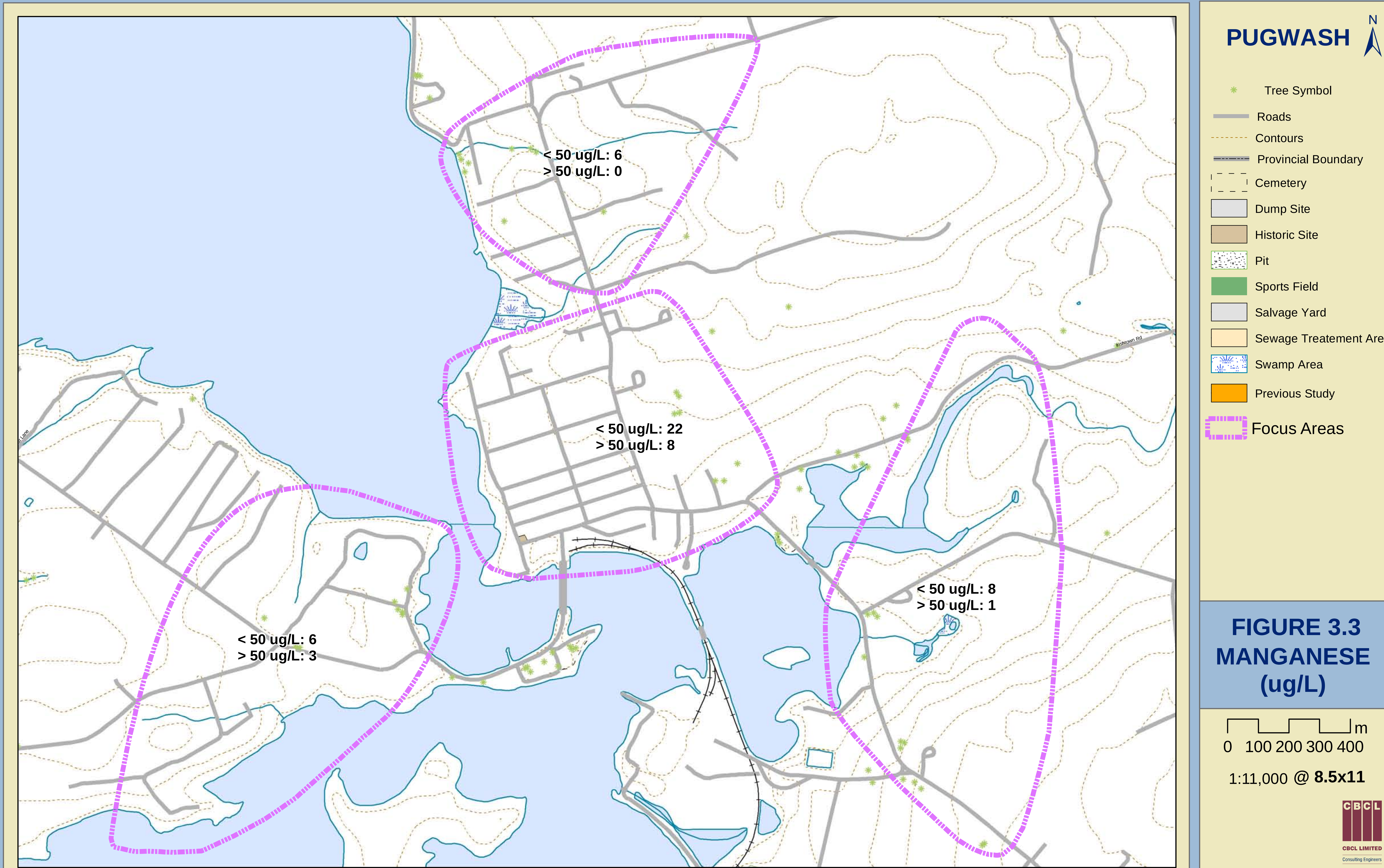


FIGURE 3.3 MANGANESE (ug/L)

0 100 200 300 400 m

1:11,000 @ **8.5x11**

Table 3.2. Inorganic Chemistry Data for Wells Sampled in 2004 and 2012

				Sample Location									
				R1		R2		R3		R4		W1	
Parameter	**Unit**	**G / S**	**RDL**	2004	2012	2004	2012	2004	2012	2004	2012	2004	2012
pH		[6.5-8.5]			8.0	7.9	8.2	7.7	8.0	8.6	8.5		8.0
Reactive Silica as SiO2	mg/L		0.5		12.5	15.0	15.7	10.0	10.6	8.6	9.5		11.5
Bromide	mg/L		0.3		0.69		<0.3		<0.3		<0.3		<6.0
Chloride	mg/L	[250]	1	***430***	***508***	10	13	12	18	***260***	***301***	***3402***	***1960***
Fluoride	mg/L	1.5	0.1		0.1		0.2		<0.1		0.3		<2.0
Sulphate	mg/L	[500]	2		40	9	10	7	6	62	59		175
Alkalinity	mg/L		5		101	140	130	130	117	300	246		186
True Color	TCU	[15]	5		<5	< 5	7	< 5	<5	< 5	5		<5
Turbidity	NTU	[0.1-1]	0.1		***2.0***	0.5	0.4	0.2	0.1	0.2	***1.2***		***1.4***
Electrical Conductivity	umho/cm		1		1750	285	285	289	279	1580	1460		6060
Nitrate + Nitrite as N	mg/L		0.05		0.53	0.20	0.17	0.84	0.88	< 0.05	<0.05		<0.05
Nitrate as N	mg/L	[10]	0.05		0.53	0.20	0.17	0.84	0.88	< 0.05	<0.05		<1.00
Nitrite as N	mg/L	[1.0]	0.05		<0.05	< 0.01	<0.05	< 0.01	<0.05	< 0.01	<0.05		<1.00
Ammonia as N	mg/L		0.05		<0.05	< 0.05	<0.05	< 0.05	<0.05	< 0.05	<0.05		<0.05
Total Organic Carbon	mg/L		0.5		<0.5	< 0.5	<0.5	< 0.5	<0.5	< 0.5	<0.5		<0.5
Ortho-Phosphate as P	mg/L		0.01		<0.01	< 0.01	<0.01	< 0.01	0.01	0.02	0.02		<0.01
Total Sodium	mg/L	[200]	0.1	152	162	16.5	9.4	8.8	5.4	***316***	***330***	***1581***	***973***
Total Potassium	mg/L		0.1		9.3	6.6	4.2	1.9	1.1	5.6	5.1		14.5
Total Calcium	mg/L		0.1		117	28.2	36.2	37.3	39.2	5.5	5.3		207
Total Magnesium	mg/L		0.1		26.8	8.1	4.5	7.3	4.1	0.7	0.7		87.2
Total Phosphorous	mg/L		0.1		<0.1	< 0.1	<0.1	< 0.1	<0.1	< 0.1	<0.1		<0.1
Bicarb. Alkalinity (as CaCO3)	mg/L		5		101	139	130	129	117	289	234		186
Carb. Alkalinity (as CaCO3)	mg/L		10		<10	1	<10	< 1	<10	11.0	12		<10
Hydroxide	mg/L		5		<5		<5		<5		<5		<5
Calculated TDS	mg/L	[500]	1		***926***	178	156	166	148	***839***	***849***		***3530***
Hardness	mg/L	180*			***403***	104	109	123	115	16.6	16.1		***876***
Langelier Index (@20C)	NA				0.39	-0.36	0.27	-0.47	0.06	-0.10	-0.06		0.84
Langelier Index (@ 4C)	NA				0.07	0.04	-0.05	-0.07	-0.26	0.30	-0.38		0.52
Saturation pH (@ 20C)	NA				7.61	8.26	7.93	8.17	7.94	8.70	8.56		7.16
Saturation pH (@ 4C)	NA				7.93	7.86	8.25	7.77	8.26	8.30	8.88		7.48
Anion Sum	me/L				17.2	3.3	3.19	3.14	3.04	14.6	14.6		62.7
Cation sum	me/L				15.3	3.0	2.70	2.90	2.56	14.2	14.8		60.2
% Difference/ Ion Balance (NS)	%				5.8	5.1	8.4	4.1	8.5	1.4	0.6		2
Total Aluminum	ug/L	[100]	10		<10	10	<10	< 10	<10	< 10	<10		<10
Total Antimony	ug/L	6	2		<2	< 2	<2	< 2	<2	< 2	<2		<2

Table 3.2. Inorganic Chemistry Data for Wells Sampled in 2004 and 2012

				Sample Location									
				R1		R2		R3		R4		W1	
Parameter	**Unit**	**G / S**	**RDL**	2004	2012	2004	2012	2004	2012	2004	2012	2004	2012
Total Arsenic	ug/L	10	2		***10***	***14***	***16***	**3**	3	8	4		6
Total Barium	ug/L	1000	5		207	110	206	160	316	140	128		67
Total Beryllium	ug/L		2		<2	< 2	<2	< 2	<2	< 2	<2		<2
Total Bismuth	ug/L		2		<2	< 2	<2	< 2	<2	< 2	<2		<2
Total Boron	ug/L	5000	5		25	11	7	10	9	230	231		161
Total Cadmium	ug/L	5	0.3		<0.3	< 0.3	<0.3	< 0.3	<0.3	< 0.3	<0.3		1.6
Total Chromium	ug/L	50	2		<2	< 2	<2	< 2	<2	< 2	<2		<2
Total Cobalt	ug/L		1		<1	< 1	<1	< 1	<1	< 1	<1		<1
Total Copper	ug/L	[1000]	2		5	19	8	15	20	10	16		36
Total Iron	ug/L	[300]	50	0	72	< 50	<50	< 50	<50	80	87	128	115
Total Lead	ug/L	10	0.5		<0.5	< 0.5	3.7	0.7	<0.5	0.5	2.6		2.4
Total Manganese	ug/L	[50]	2	15	9	< 2	<2	2	<2	38	37	***2486***	***645***
Total Molybdenum	ug/L		2		<2	2	2	< 2	<2	13	10		<2
Total Nickel	ug/L		2		<2	2	<2	< 2	<2	< 2	<2		6
Total Selenium	ug/L	10	2		3	< 2	<2	< 2	<2	< 2	<2		***15***
Total Silver	ug/L		0.5		<0.5	< 0.5	<0.5	< 0.5	<0.5	< 0.5	<0.5		<0.5
Total Strontium	ug/L		5		4610	870	960	170	153	97	116		2300
Total Thallium	ug/L		0.1		<0.1	< 0.1	<0.1	< 0.1	<0.1	< 0.1	<0.1		<0.1
Total Tin	ug/L		2		<2	< 2	<2	< 2	<2	< 2	<2		<2
Total Titanium	ug/L		2		<2	< 2	<2	< 2	<2	2	<2		4
Total Uranium	ug/L	20	0.1		6.6	***20.0***	***21.3***	3.1	1.8	6.8	0.9		9.4
Total Vanadium	ug/L		2		<2	4	3	< 2	<2	< 2	<2		<2
Total Zinc	ug/L	[5000]	5		12	9	<5	14	32	9	16		19

Bold/Highlight: Parameter exceeds GCDWQ

*** Per NSE Guidelines**

3.3 Wells of Good Construction

Data for ten wells of good construction are shown in Table 3.3. The composition of these samples is intended to show the quality of water in the aquifer independent of sources of contamination that could be introduced at the well head (e.g., road salt). Elevated concentrations of undesirable species would thus be more likely to reflect the quality of water in the formation and/or sea water intrusion effects.

The chloride concentration exceeded the GCDWQ at only one location (B9). The turbidity, iron concentration, and lead concentrations were elevated at B3, suggesting that the sample may have been affected by sediment in the bottom of the well. The sample from B2 showed elevated concentrations of lead and manganese (and TDS), which appears to be connected to highly mineralized water in the south part of Pugwash. High mineral concentrations are attributed to the Windsor Group bedrock. Sodium and TDS were elevated at B10 but the chloride concentration was just 168 mg/L. The source of dissolved solids at this location is unknown, but does not appear to result in significantly reduced water quality.

3.4 Wells in Selected Target Areas

3.4.1 Water Street Area

Four wells in the Water Street Area were sampled to provide additional groundwater chemistry in central Pugwash. The contact between the Cumberland Group and Windsor Group bedrock traverses this area, and Water Street is situated to the immediate east of the coastline. Table 3.4 shows the results of sampling.

The wells at W1 and W2 showed elevated concentrations of chloride and other parameters, and the GCDWQ for selenium was exceeded at both locations. W1 is underlain by Windsor Group bedrock and W2 is situated on the bedrock contact. Mapping and sampling results indicate that the well at W2 intersects Windsor Group bedrock. The wells at W3 and W4, although situated adjacent to the coastline, do not indicate elevated chloride concentrations.

3.4.2 Pugwash Point

Pugwash Point is located outside of Pugwash centre and is adjacent to the coast. Samples in previous years suggested that the aquifer in this area could be affected by road salt or sea water intrusion. The sample from PP1 showed elevated sodium and chloride concentrations, but other parameters remained at background concentrations (Table 3.4). The chemical composition of the sampling and the bromide/chloride ratio at this location indicates that road salting could be a factor.

3.4.3 West Pugwash

Two wells directly across the inlet from Pugwash were selected to represent the water chemistry in West Pugwash. Groundwater from WP1 and WP2 showed elevated concentrations of sodium, arsenic and uranium, but chloride concentrations were moderate (Table 3.4). Chloride concentrations were not high enough to validate an analysis of bromide/chloride ratios at this location. Geology mapping indicates that both wells overly Windsor Group bedrock, and the chemical composition suggests mineral contributions from the Windsor Group most likely explain the elevated concentrations of dissolved solids.

Table 3.3. Inorganic Chemistry Data (2012) for Wells Exhibiting Good Construction*

				Sample Location									
Parameter	**Unit**	**G / S**	**RDL**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
pH		[6.5-8.5]		8.2	8.1	8.2	8.1	8.2	7.9	7.5	8.7	8.2	8.5
Reactive Silica as SiO2	mg/L		0.5	15.0	14.0	10.4	13.0	14.6	12.9	10.7	9.4	9.7	9.0
Bromide	mg/L		0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Chloride	mg/L	[250]	1	15	99	48	19	17	19	17	64	***672***	158
Fluoride	mg/L	1.5	0.1	0.1	0.1	0.2	0.1	<0.1	0.1	0.1	0.6	<0.5	1.2
Sulphate	mg/L	[500]	2	11	24	16	9	7	7	6	49	***659***	36
Alkalinity	mg/L		5	141	336	146	127	144	137	61	268	189	313
True Color	TCU	[15]	5	<5	9	5	<5	11	***15***	<5	<5	<5	<5
Turbidity	NTU	[0.1-1]	0.1	0.5	***1.9***	***57.2***	***1.8***	***2.8***	0.4	0.2	***1.6***	***1.3***	0.5
Electrical Conductivity	umho/cm		1	328	921	453	312	336	321	182	784	3440	1090
Nitrate + Nitrite as N	mg/L		0.05	0.19	0.10	0.15	0.16	0.91	0.48	0.58	<0.05	<0.05	<0.05
Nitrate as N	mg/L	[10]	0.05	0.19	0.10	0.15	0.16	0.91	0.48	0.58	<0.05	<0.50	<0.05
Nitrite as N	mg/L	[1.0]	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.50	<0.05
Ammonia as N	mg/L		0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Organic Carbon	mg/L		0.5	<0.5	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ortho-Phosphate as P	mg/L		0.01	0.01	<0.01	<0.01	<0.01	0.02	0.02	0.03	0.05	<0.01	0.01
Total Sodium	mg/L	[200]	0.1	19.2	72.7	46.7	20.9	13.1	9.6	8.1	198	***725***	***263***
Total Potassium	mg/L		0.1	4.3	5.8	2.8	7.8	4.1	1.3	0.6	2.6	9.6	5.0
Total Calcium	mg/L		0.1	40.8	102	36.0	27.5	42.4	43.1	19.6	1.2	95.4	7.9
Total Magnesium	mg/L		0.1	6.6	27.4	8.6	6.7	8.3	7.9	5.1	0.1	7.5	2.0
Total Phosphorous	mg/L		0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bicarb. Alkalinity (as CaCO3)	mg/L		5	141	336	146	127	144	321	61	247	189	301
Carb. Alkalinity (as CaCO3)	mg/L		10	<10	<10	<10	<10	<10	137	<10	22	<10	12
Hydroxide	mg/L		5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Calculated TDS	mg/L	[500]	1	182	***534***	251	168	182	172	96	476	***2280***	***660***
Hardness	mg/L	180**		129	***368***	125	96.3	140	140	69.9	3.4	***269***	28.0
Langelier Index (@20C)	NA			0.35	0.97	0.29	0.03	0.37	0.06	-1.01	-0.45	0.73	0.22
Langelier Index (@ 4C)	NA			0.03	0.65	-0.03	-0.29	0.05	-0.26	-1.33	-0.77	0.41	-0.10
Saturation pH (@ 20C)	NA			7.85	7.13	7.91	8.07	7.83	7.84	8.51	9.15	7.47	8.28
Saturation pH (@ 4C)	NA			8.17	7.45	8.23	8.39	8.15	8.16	8.83	9.47	7.79	8.60
Anion Sum	me/L			3.49	10.0	4.62	3.27	3.57	3.46	1.87	8.19	36.5	11.5
Cation sum	me/L			3.53	10.7	4.76	3.04	3.48	3.25	1.77	8.75	37.2	12.1
% Difference/ Ion Balance (NS)	%			0.6	3.3	1.6	3.7	1.3	3.0	2.7	3.4	1.1	2.8
Total Aluminum	ug/L	[100]	10	<10	<10	<10	<10	16	<10	<10	52	10	<10
Total Antimony	ug/L	6	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Arsenic	ug/L	10	2	6	<2	9	***12***	5	<2	<2	8	2	3

Table 3.3. Inorganic Chemistry Data (2012) for Wells Exhibiting Good Construction*

				Sample Location									
Parameter	**Unit**	**G / S**	**RDL**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
Total Barium	ug/L	1000	5	120	186	156	127	258	167	159	16	13	55
Total Beryllium	ug/L		2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Bismuth	ug/L		2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Boron	ug/L	5000	5	17	186	28	67	15	25	59	141	127	101
Total Cadmium	ug/L	5	0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Total Chromium	ug/L	50	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Cobalt	ug/L		1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Copper	ug/L	[1000]	2	31	287	47	25	15	23	36	23	560	<2
Total Iron	ug/L	[300]	50	<50	222	***4330***	107	98	<50	<50	67	***931***	58
Total Lead	ug/L	10	0.5	0.8	***62.3***	***14.1***	4.0	3.4	<0.5	0.7	1.9	***19.8***	0.6
Total Manganese	ug/L	[50]	2	<2	***598***	14	6	<2	<2	<2	10	***573***	17
Total Molybdenum	ug/L		2	<2	3	3	3	<2	<2	<2	22	9	23
Total Nickel	ug/L		2	<2	18	<2	<2	<2	<2	<2	<2	6	<2
Total Selenium	ug/L	10	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Silver	ug/L		0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Strontium	ug/L		5	764	1240	537	1750	427	106	34	19	3100	300
Total Thallium	ug/L		0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Tin	ug/L		2	<2	<2	<2	<2	<2	<2	<2	<2	8	<2
Total Titanium	ug/L		2	<2	<2	<2	<2	<2	<2	<2	<2	9	<2
Total Uranium	ug/L	20	0.1	18.7	11.4	3.6	2.9	10.6	2.1	0.2	6.3	2.7	8.7
Total Vanadium	ug/L		2	3	<2	<2	3	3	<2	<2	<2	<2	<2
Total Zinc	ug/L	[5000]	5	12	162	24	32	16	5	<5	37	219	6

*Good construction = proper well siting, drilling techniques, casing above and below ground, drive shoe and well cap as required by the Nova Scotia Water Well Regulations. Wells were selected based on records in the NSE Water Well Drilling Database and field inspections.

Bold/Highlight: Parameter exceeds GCDWQ

**** Per NSE Guidelines**

Table 3.4. Inorganic Chemistry Data (2012) for Wells in Selected Target Areas

		Target Areat		Sample Location						
Parameter	**Unit**	**G / S**	**RDL**	**W1**	**W2**	**W3**	**W4**	**PP1**	**WP1**	**WP2**
pH		[6.5-8.5]		8.0	8.1	8.2	8.1	7.9	8.4	8.4
Reactive Silica as SiO2	mg/L		0.5	11.5	8.6	13.8	11.1	13.3	8.2	10.2
Bromide	mg/L		0.3	<6.0	4.4	<0.3	<0.3	<0.6	<0.3	<0.3
Chloride	mg/L	[250]	1	***1960***	***1190***	31	64	***1340***	148	132
Fluoride	mg/L	1.5	0.1	<2.0	<1.0	0.2	0.1	<0.2	0.6	0.6
Sulphate	mg/L	[500]	2	175	152	36	12	18	87	74
Alkalinity	mg/L		5	186	165	153	138	180	224	248
True Color	TCU	[15]	5	<5	6	<5	<5	<5	<5	<5
Turbidity	NTU	[0.1-1]	0.1	***1.4***	***1.0***	0.6	***2.0***	***43.8***	0.6	0.6
Electrical Conductivity	umho/cm		1	6060	4020	446	475	3960	1020	989
Nitrate + Nitrite as N	mg/L		0.05	<0.05	<0.05	0.23	0.75	0.45	0.44	0.05
Nitrate as N	mg/L	[10]	0.05	<1.00	<0.50	0.23	0.75	0.45	0.44	0.05
Nitrite as N	mg/L	[1.0]	0.05	<1.00	<0.50	<0.05	<0.05	<0.10	<0.05	<0.05
Ammonia as N	mg/L		0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Organic Carbon	mg/L		0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ortho-Phosphate as P	mg/L		0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.03
Total Sodium	mg/L	[200]	0.1	***973***	***755***	51.0	39.6	***376***	***241***	***236***
Total Potassium	mg/L		0.1	14.5	14.3	5.6	3.2	21.5	3.9	3.7
Total Calcium	mg/L		0.1	207	96.8	38.0	37.7	249	7.9	5.3
Total Magnesium	mg/L		0.1	87.2	36.4	5.4	16.5	83.0	1.3	0.6
Total Phosphorous	mg/L		0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bicarb. Alkalinity (as CaCO3)	mg/L		5	186	165	153	138	180	218	240
Carb. Alkalinity (as CaCO3)	mg/L		10	<10	<10	<10	<10	<10	<10	<10
Hydroxide	mg/L		5	<5	<5	<5	<5	<5	<5	<5
Calculated TDS	mg/L	[500]	1	***3530***	***2340***	260	259	***2200***	***625***	***601***
Hardness	mg/L	180*		***876***	***392***	117	162	***964***	25.1	15.7
Langelier Index (@20C)	NA			0.84	0.58	0.34	0.19	0.83	-0.02	-0.15
Langelier Index (@ 4C)	NA			0.52	0.26	0.02	-0.13	0.51	-0.34	-0.47
Saturation pH (@ 20C)	NA			7.16	7.52	7.86	7.91	7.07	8.42	8.55
Saturation pH (@ 4C)	NA			7.48	7.84	8.18	8.23	7.39	8.74	8.87
Anion Sum	me/L			62.7	40.0	4.70	4.87	41.8	10.5	10.2
Cation sum	me/L			60.2	41.0	4.71	5.05	36.2	11.1	10.7
% Difference/ Ion Balance (NS)	%			2.0	1.2	0.1	1.8	7.2	2.7	2.1
Total Aluminum	ug/L	[100]	10	<10	<10	<10	<10	16	<10	12
Total Antimony	ug/L	6	2	<2	<2	<2	<2	<2	<2	<2
Total Arsenic	ug/L	10	2	6	6	6	6	<2	***20***	***34***

Table 3.4. Inorganic Chemistry Data (2012) for Wells in Selected Target Areas

			Target Areat	Sample Location						
Parameter	**Unit**	**G / S**	**RDL**	**W1**	**W2**	**W3**	**W4**	**PP1**	**WP1**	**WP2**
Total Barium	ug/L	1000	5	67	68	52	179	***3670***	21	17
Total Beryllium	ug/L		2	<2	<2	<2	<2	<2	<2	<2
Total Bismuth	ug/L		2	<2	<2	<2	<2	<2	<2	<2
Total Boron	ug/L	5000	5	161	83	45	30	21	104	125
Total Cadmium	ug/L	5	0.3	1.6	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Total Chromium	ug/L	50	2	<2	<2	<2	<2	<2	<2	<2
Total Cobalt	ug/L		1	<1	<1	<1	<1	<1	<1	<1
Total Copper	ug/L	[1000]	2	36	10	8	7	4	3	6
Total Iron	ug/L	[300]	50	115	147	85	152	269	<50	78
Total Lead	ug/L	10	0.5	2.4	2.1	1.0	1.5	0.7	<0.5	<0.5
Total Manganese	ug/L	[50]	2	***645***	***103***	9	<2	43	13	19
Total Molybdenum	ug/L		2	<2	13	3	3	<2	21	36
Total Nickel	ug/L		2	6	3	<2	<2	<2	<2	<2
Total Selenium	ug/L	10	2	***15***	***20***	<2	<2	2	<2	<2
Total Silver	ug/L		0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Strontium	ug/L		5	2300	3020	882	474	3220	271	146
Total Thallium	ug/L		0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Tin	ug/L		2	<2	<2	<2	<2	<2	<2	<2
Total Titanium	ug/L		2	4	3	<2	<2	<2	<2	<2
Total Uranium	ug/L	20	0.1	9.4	2.8	16.0	8.4	16.9	***23.0***	12.0
Total Vanadium	ug/L		2	<2	<2	<2	3	<2	8	2
Total Zinc	ug/L	[5000]	5	19	6	12	127	22	<5	45

Bold/Highlight: Parameter exceeds GCDWQ

*** Per NSE Guidelines**

3.5 Paired Wells

Wells at four locations throughout the study area were paired to attempt a direct comparison of the chemistry at each location. Each pair comprised a well with known or suspected deficiencies in well construction and a well of good construction. Differences in the water chemistry of each pair were intended to illustrate the effects of poor well construction. The data are presented in Table 3.5.

An older well at C1 was replaced by a newer well of improved construction. The water chemistry of the newer well reflected lower chloride and sodium concentrations, suggesting that the older well may have been affected by saline surface water.

The sample from R1 (poor construction) showed elevated turbidity, whereas the turbidity was minimal at C2 (good construction). Other parameters (including elevated chloride and arsenic) were comparable, suggesting that although the well at R1 could experience elevated turbidity as a result of construction problems, the poor water quality at this location is more directly attributable to the underlying Windsor Group bedrock.

Samples from W3 (poor construction) and C3 (good construction) were comparable. The manganese concentration at C3 was 55 μg/L (exceeding the GCDWQ of 50 μg/L), whereas the manganese concentration at W3 was just 9 μg/L. Both wells show water of generally excellent quality, and the relatively minor difference in the manganese concentration is attributable to variations in the formation water.

Water quality was likewise comparable in samples from wells at R2 (poor construction) and C4 (good construction). Notable differences were observed in the arsenic and uranium concentrations. Arsenic and uranium were elevated at both locations, but at R2 the GCDWQ was exceeded for these parameters and at C4 concentrations were below the GCDWQ. These differences are attributable to the aquifer conditions (e.g., depth, local mineral deposits).

The data collected does not allow for a definitive conclusion, but well construction appears to be a factor at select individual locations.

3.6 Drinking Water Guidelines

A complete summary of the data from the 2012 sampling program is provided in Appendix A. Data from 2004 are shown in Appendix B. Figure 3.4 shows the locations where health, taste, and operational parameters were exceeded under the GCDWQ. Mapping of parameter exceedances indicated that the Windsor Group bedrock is principally responsible for lower quality well water in the Pugwash area. Exceptions were noted at:

- PP1, where road salting and well construction could be a factor;
- R2 where the arsenic concentration was 16 μg/L (GCDWQ of 10 μg/L) and the uranium concentration was 21 μg/L (GCDWQ of 20 μg/L); and
- C3 where the manganese concentration was 55 μg/L (GCDWQ of 50 μg/L).

Exceedances at the latter two locations are attributed to localized effects in the Cumberland Group bedrock.

Table 3.5. Inorganic Chemistry Data (2012) for Selected Well Pairs*

			Inferred Well Construction	Poor	Good	Poor	Good	Poor	Good	Poor	Good
				Sample Location							
Parameter	**Unit**	**G / S**	**RDL**	**C1**	**C1**	**R1**	**C2**	**W3**	**C3**	**R2**	**C4**
pH		[6.5-8.5]		8.0	8.2	8.0	8.1	8.2	8.2	8.2	8.2
Reactive Silica as SiO2	mg/L		0.5	12.0	10.7	12.5	12.6	13.8	15.3	15.7	13.7
Bromide	mg/L		0.3		<0.3	0.69	<0.6	<0.3	<0.3	<0.3	<0.3
Chloride	mg/L	[250]	1	230	22	***508***	***507***	31	31	13	13
Fluoride	mg/L	1.5	0.1	0.1	0.1	0.1	<0.2	0.2	0.2	0.2	0.1
Sulphate	mg/L	[500]	2	18	8	40	37	36	21	10	10
Alkalinity	mg/L		5	110	122	101	120	153	156	130	122
True Color	TCU	[15]	5	<5	8	<5	<5	<5	<5	7	<5
Turbidity	NTU	[0.1-1]	0.1	***1.7***	***1.5***	***2.0***	0.2	0.6	0.4	0.4	0.3
Electrical Conductivity	umho/cm		1	900	313	1750	1780	446	418	285	284
Nitrate + Nitrite as N	mg/L		0.05	0.39	0.77	0.53	0.40	0.23	<0.05	0.17	0.17
Nitrate as N	mg/L	[10]	0.05	0.39	0.77	0.53	0.40	0.23	<0.05	0.17	0.17
Nitrite as N	mg/L	[1.0]	0.05	<0.01	<0.05	<0.05	<0.10	<0.05	<0.05	<0.05	<0.05
Ammonia as N	mg/L		0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Organic Carbon	mg/L		0.5	<0.05	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ortho-Phosphate as P	mg/L		0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Sodium	mg/L	[200]	0.1	110	13.1	162	***206***	51.0	44.2	9.4	27.2
Total Potassium	mg/L		0.1	1.9	0.8	9.3	15.8	5.6	6.9	4.2	4.9
Total Calcium	mg/L		0.1	59.0	36.4	117	131	38.0	40.2	36.2	25.6
Total Magnesium	mg/L		0.1	18.0	13.8	26.8	24.1	5.4	5.9	4.5	6.8
Total Phosphorous	mg/L		0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bicarb. Alkalinity (as CaCO3)	mg/L		5	110	122	101	120	153	156	130	122
Carb. Alkalinity (as CaCO3)	mg/L		10	1	<10	<10	<10	<10	<10	<10	<10
Hydroxide	mg/L		5		<5	<5	<5	<5	<5	<5	<5
Calculated TDS	mg/L	[500]	1	***509***	171	***926***	***995***	260	243	156	162
Hardness	mg/L	180**		***220***	148	***403***	***426***	117	125	109	91.9
Langelier Index (@20C)	NA			0.37	0.24	0.39	0.61	0.34	0.37	0.27	0.09
Langelier Index (@ 4C)	NA			0.13	-0.08	0.07	0.29	0.02	0.05	-0.05	-0.23
Saturation pH (@ 20C)	NA			7.66	7.96	7.61	7.49	7.86	7.83	7.93	8.11
Saturation pH (@ 4C)	NA			7.91	8.28	7.93	7.81	8.18	8.15	8.25	8.43
Anion Sum	me/L			9.0	3.28	17.2	17.5	4.70	4.43	3.19	3.03
Cation sum	me/L			9.1	3.55	15.3	17.9	4.71	4.59	2.70	3.15
% Difference/ Ion Balance (NS)	%			0.0	3.9	5.8	1.1	0.1	1.8	8.4	1.9
Total Aluminum	ug/L	[100]	10	<10	<10	<10	<10	<10	<10	<10	<10
Total Antimony	ug/L	6	2	<2	<2	<2	<2	<2	<2	<2	<2

Table 3.5. Inorganic Chemistry Data (2012) for Selected Well Pairs*

Inferred Well Construction				Poor	Good	Poor	Good	Poor	Good	Poor	Good
				Sample Location							
Parameter	**Unit**	**G / S**	**RDL**	**C1**	**C1**	**R1**	**C2**	**W3**	**C3**	**R2**	**C4**
Total Arsenic	ug/L	10	2	<2	<2	***10***	9	6	<2	***16***	8
Total Barium	ug/L	1000	5	240	409	207	204	52	60	206	90
Total Beryllium	ug/L		2	<2	<2	<2	<2	<2	<2	<2	<2
Total Bismuth	ug/L		2	<2	<2	<2	<2	<2	<2	<2	<2
Total Boron	ug/L	5000	5	9	24	25	53	45	51	7	19
Total Cadmium	ug/L	5	0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Total Chromium	ug/L	50	2	<2	<2	<2	<2	<2	<2	<2	<2
Total Cobalt	ug/L		1	<1	<1	<1	<1	<1	<1	<1	<1
Total Copper	ug/L	[1000]	2	10	20	5	5	8	<2	8	21
Total Iron	ug/L	[300]	50	150	148	72	<50	85	<50	<50	<50
Total Lead	ug/L	10	0.5	0.6	3.1	<0.5	2.6	1.0	0.7	3.7	1.9
Total Manganese	ug/L	[50]	2	6	3	9	10	9	***55***	<2	<2
Total Molybdenum	ug/L		2	<2	<2	<2	3	3	5	2	4
Total Nickel	ug/L		2	<2	<2	<2	3	<2	<2	<2	<2
Total Selenium	ug/L	10	2	<2	<2	3	3	<2	<2	<2	<2
Total Silver	ug/L		0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Strontium	ug/L		5	120	50	4610	6430	882	1450	960	769
Total Thallium	ug/L		0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Tin	ug/L		2	<2	<2	<2	<2	<2	<2	<2	<2
Total Titanium	ug/L		2	<2	<2	<2	<2	<2	<2	<2	<2
Total Uranium	ug/L	20	0.1	1.8	0.8	6.6	7.6	16.0	15.1	***21.3***	11.9
Total Vanadium	ug/L		2	<2	<2	<2	<2	<2	<2	3	2
Total Zinc	ug/L	[5000]	5	11	11	12	100	12	<5	<5	42

*Wells exhibiting poor water quality and/or poor construction were paired with a nearby newer well; drilling logs and/or field inspections indicated that the construction of the newer wells satisfied the NSE water well regulations.

Bold/Highlight: Parameter exceeds GCDWQ

**** Per NSE Guidelines**

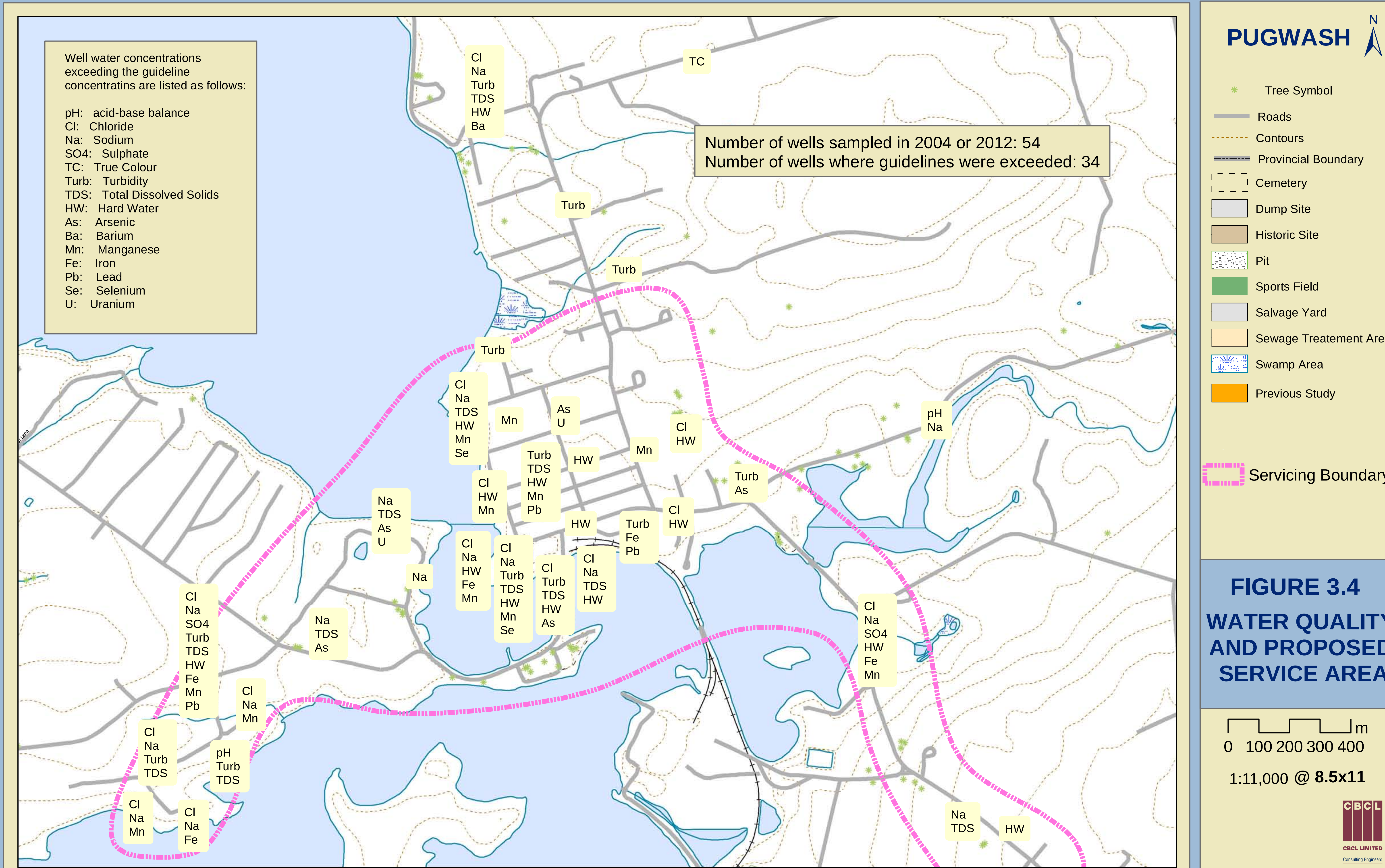


FIGURE 3.4

WATER QUALITY AND PROPOSED SERVICE AREA

3.6.1 Arsenic

Arsenic concentrations are show on Figure 3.5. The GCDWQ of 10 μg/L was met or exceeded at five locations.

3.6.2 Lead

Lead concentrations are shown on Figure 3.6. The GCDWQ of 10 μg/L was met or exceeded at three locations.

3.6.3 Uranium

Uranium concentrations are shown on Figure 3.7. The GCDWQ of 20 μg/L was met or exceeded at two locations

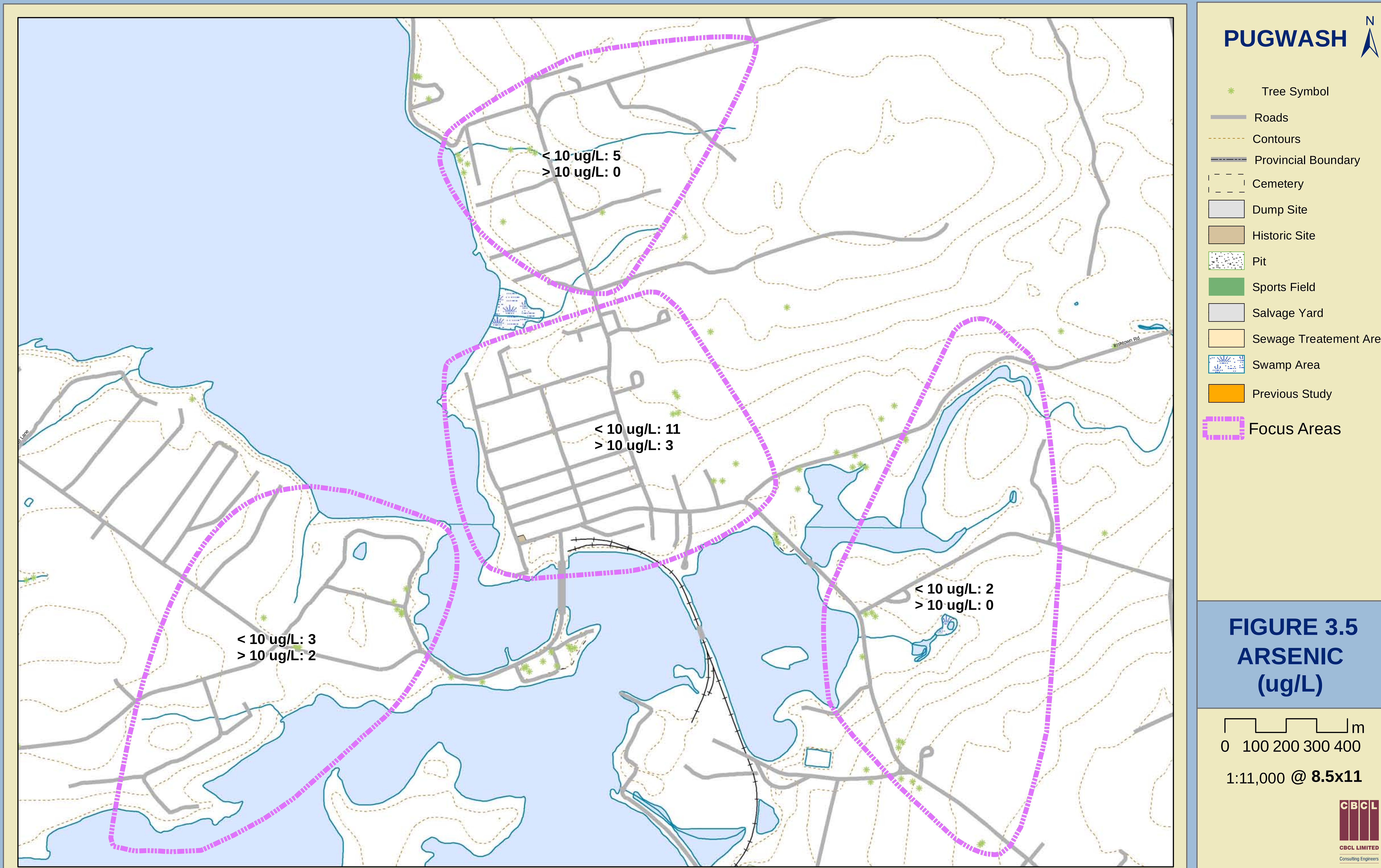
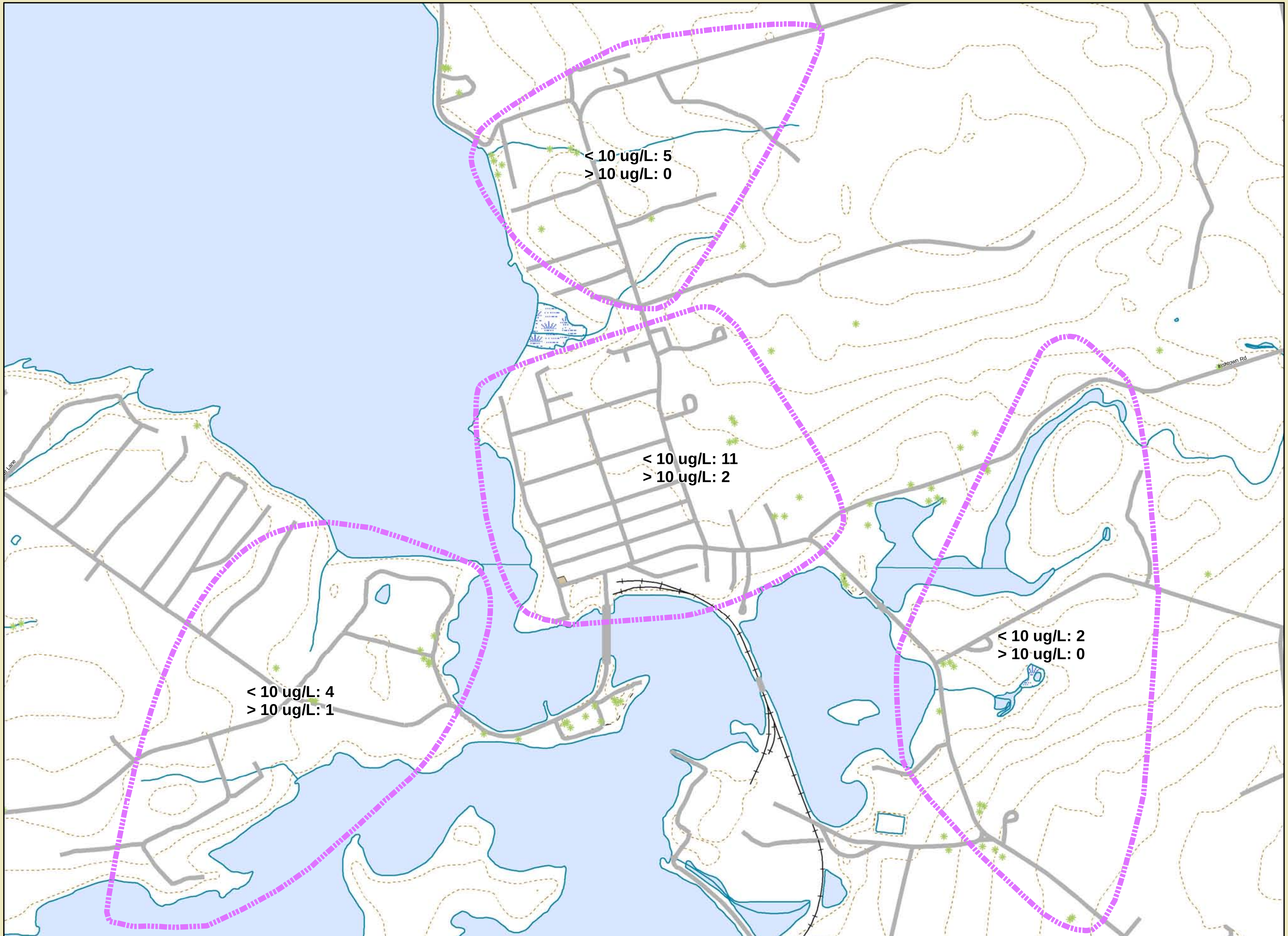


FIGURE 3.5 ARSENIC (ug/L)



PUGWASH

N

Tree Symbol

Roads

Contours

Provincial Boundary

Cemetery

Dump Site

Historic Site

Pit

Sports Field

Salvage Yard

Sewage Treatement Area

Swamp Area

Previous Study

Focus Areas

FIGURE 3.6 LEAD (ug/L)

0 100 200 300 400 m

1:11,000 @ **8.5x11**

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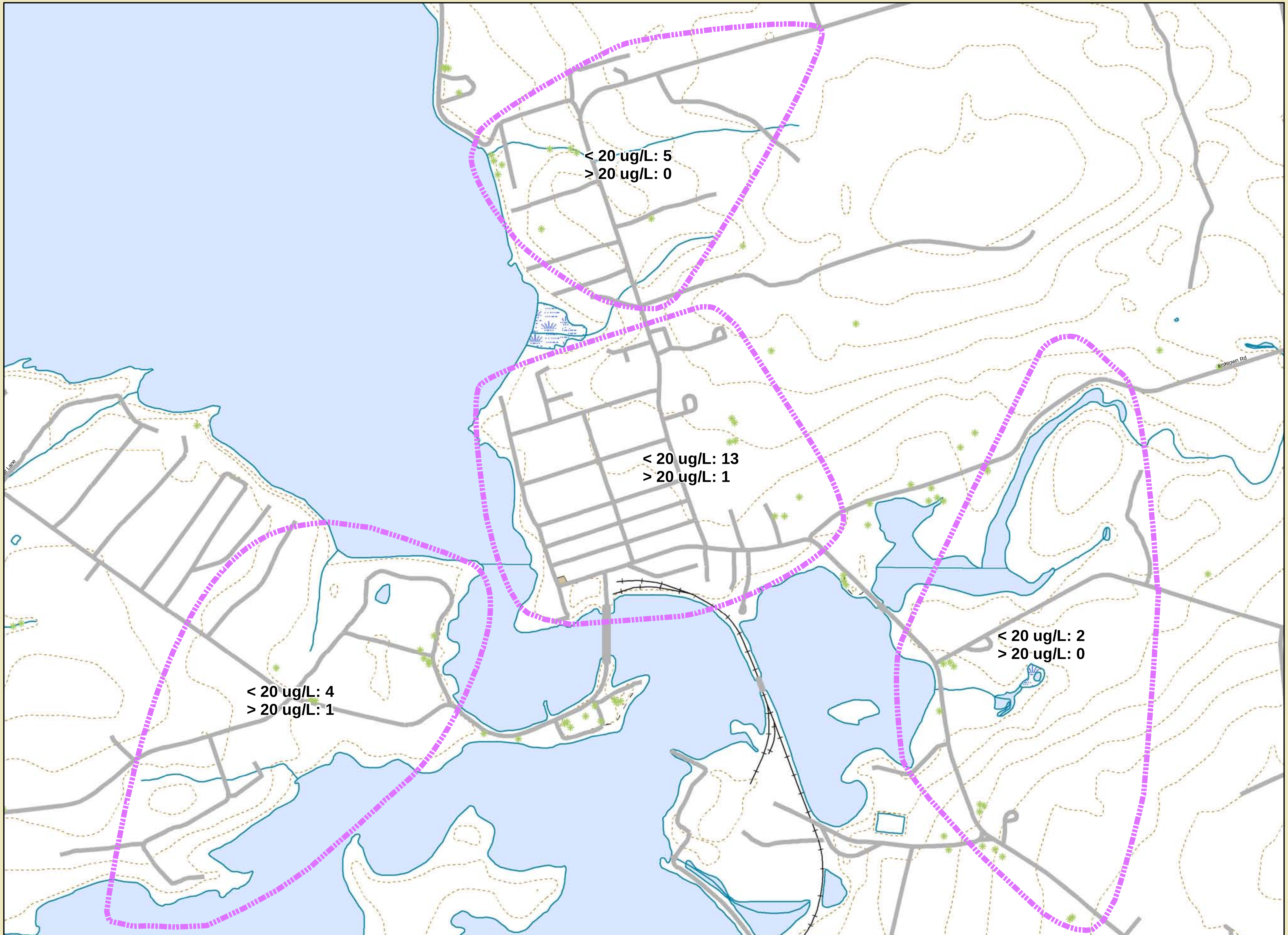

PUGWASH

N

- Tree Symbol
- Roads
- Contours
- Provincial Boundary
- Cemetery
- Dump Site
- Historic Site
- Pit
- Sports Field
- Salvage Yard
- Sewage Treatement Area
- Swamp Area
- Previous Study
- Focus Areas

FIGURE 3.7 URANIUM (ug/L)

0 100 200 300 400 m

1:11,000 @ **8.5x11**

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CHAPTER 4 REMEDIAL OPTIONS COSTING UPDATES

4.1 Remedial Options

Remedial options evaluated in the 2005 Study include the use of on-site and central groundwater. This project requires an update to the costing presented in the 2005 Study, and background discussions and updated data follows.

4.2 Individual Well/Water Treatment Improvements

In this option, residents and commercial users in Pugwash would be individually responsible for necessary well upgrades and for installing and maintaining on-site water treatment systems to improve water quality. Components of the process to follow include the following:

- Water Supply Assessment;
- Well Improvements;
- New Wells; and
- Water Treatment.

4.2.1 Water Supply Assessment

The water supply assessment program would involve the following:

- Water quality sampling;
- Visual assessment of dug wells; and
- Visual and video inspection of drilled wells.

Both dug and drilled wells would be assessed by persons qualified under NSE requirements to carry out such work.

Participants would be advised to search for a record of the construction of their well by contacting their well contractor. A raw water sample would be collected from the water supply system and analyzed for physical, chemical and microbiological parameters to characterize well water quality.

Recommendations for well upgrades and/or water treatment would be site-specific, and therefore information would be collected for each individual well water supply system to determine appropriate improvements. The construction of wells greater than 20 years old, and any well with identified water quality concerns (e.g., suspected surface water influence), would be inspected.

An inspection of a drilled well would involve a down-hole video inspection by a licensed pump installer, to assess and document the condition and depth of well casing, and the condition of the pitless adaptor (if applicable), driveshoe, and pump discharge line. A recommendation to continue the use of the well, to rehabilitate the existing well, or to install a new well would be made based on the results of the well inspection, appropriate cost considerations, the local hydrogeology, and the water quality results.

An inspection of a dug well would involve a visual inspection by a licensed pump installer, to assess and document the condition and depth of well liner and the apron, and to inspect the topography around the well. A recommendation to continue with the use of the well, improve the surface water drainage/seal around the well, or to install a new well would be made based on the results of the well inspection, appropriate cost considerations, the local hydrogeology, and the water quality results.

A decision by residents or commercial users to proceed with the recommended well improvements will be influenced by the scope of the improvements required, the cost of the proposed work, and by the ability of participants to fund the improvements.

4.2.2 Well Improvement –Drilled Wells

Drilled well rehabilitation may include one or more of the following:

- Improvement of seal between driveshoe and formation;
- Conversion to pitless adaptor system;
- Removal of well crock and the installation of annular seal around wellhead from bottom of crock (original) to grade surface and backfilling of well crock;
- Extension of well casing above grade;
- Re-grading around wellhead;
- New well cap; and
- Repairs to well casing and/or discharge line.

4.2.3 Well Improvement – Dug Well

Discussions with well contractors have indicated that the rehabilitation of a dug well to comply with current NSE requirements typically requires the removal of the well and the full construction of a new well. The rehabilitation of a dug well is therefore not generally considered a viable option. Improvements with respect to surface water drainage around the well crock, and the grouting of upper joints, however, can be readily made.

Well improvement options for dug wells therefore include re-grading around the well crock, grouting the upper joints, replacing the well cap, a new dug well, or a new drilled well.

4.2.4 New Well Installation

If rehabilitation of an existing dug or drilled well is not an option, the option of installing a new well may be considered. A new well should meet the requirements of the NSE Well Construction Regulations. It is recommended that new drilled wells should be constructed with 12.2 m of casing and an annular grout to adequately protect the well from shallow groundwater and surface water contamination.

Following the installation of a new well, the existing well would have to be abandoned in accordance with NSE regulations. If sufficient yield cannot be obtained from a new well, a water storage tank system may be considered.

4.2.5 Water Treatment

Water quality is influenced by well construction, and therefore the well water quality and required treatment (if applicable) would be evaluated following the installation of a new well or rehabilitation of the existing well. Qualified treatment equipment suppliers/installers should make recommendations for appropriate treatment based on the water quality results.

4.2.6 Magnitude of Costs

The costs for assessing and implementing the individual well improvements will vary with the number of participants and with the findings of the water supply assessment program. The costs provided herein are for residential wells and would increase for commercial high capacity groundwater supply assessment or development.

Participation in the assessment portion of the investigation would be voluntary. At a minimum the water supply assessment would include a water quality analysis and the identification of a well record. Where a well inspection is warranted, persons qualified under the requirements of NSE to carry out such work would assess both dug and drilled wells.

If well assessment indicates that the well construction is acceptable and water treatment is not required, the cost would be limited to the well inspection and water analysis costs. For the purposes of this report, it is assumed that the assessment of a dug well is $400, while the assessment of a drilled well is $600. The estimated cost of a well inspection may decrease if the same well contractor performs a number of well inspections. Water quality is assumed to be $50 annually for bacteria, and $200 every two years for chemistry and metals.

In the event that the assessment indicates that the construction of a dug well is not acceptable, it is assumed that a new well will be required. In the event that a drilled well is not acceptable, options include the rehabilitation of the well or the construction of a new dug well.

Tables 4.1 to 4.4 provide estimated costs based on the homeowner assuming financial responsibility for upgrading a drilled well and/or treatment system.

Tables 4.5 and 4.6 provide estimated costs based on the homeowner assuming financial responsibility for replacing a dug well and/or treatment system.

Treatment requirements may include arsenic, uranium, sodium, iron and manganese removal (Manganese Greensand followed by RO).

The 20 year life cycle costs are estimated as follows:

- Drilled Well Rehabilitation – treatment not required: $5,200;
- Drilled Well Rehabilitation – treatment required: $14,800;

Table 4-1: Magnitude of Cost Assessment Individual Well Improvement-Drilled Well Rehabilitation (Treatment Not Required)

Option	Pugwash
Typical Homeowner Costs	
Water Supply Assessment	$850
Well Improvement (worst case)	$2,250
Water Treatment	$0
Total	**$3,100**
Typical Water System Maintenance Costs	
Water Quality Sampling (Annual - bact, bi-annual - chemistry)	$150
Treatment Equipment	$0
Pump (annual reserve fund)	$50
Total	**$200**
Lifecycle Cost Analysis	
Interest Rate	7%
Period (Years)	20
Initial Capital Cost	$3,100
Treatment Equipment Replacement at Year 10	$0
Net Present Value on Capital Items	$3,100
Annual O&M Costs	$200
Net Present Value on O&M [1]	$2,119
Total Net Present Worth per Home [2]	**$5,219**

1 - Net Present Value represents the amount that would have to be invested now to earn the annual O&M costs

2 - Net present value on capital + net present value on O&M

Table 4-2: Magnitude of Cost Assessment Individual Well Improvement - Drilled Well Rehabilitation (Treatment Required)

Option	**Pugwash**
Typical Homeowner Costs	
Water Supply Assessment	$850
Well Improvement (worst case)	$2,250
Water Treatment	
Treatment Equipment	$2,900
Disinfection Equipment	$1,100
Total	**$7,100**
Typical Water System Maintenance Costs	
Water Quality Sampling (Annual - bact, bi-annual - chemistry)	$150
Treatment Equipment	$270
Pump (annual reserve fund)	$50
Total	**$470**
Lifecycle Cost Analysis	
Interest Rate	7%
Period (Years)	20
Initial Capital Cost	$7,100
Treatment Equipment Replacement at Year 10	$2,660
Net Present Value on Capital Items	$9,760
Annual O&M Costs	$470
Net Present Value on O&M [1]	$4,979
Total Net Present Worth per Home [2]	**$14,739**

1 - Net Present Value represents the amount that would have to be invested now to earn the annual O&M costs

2 - Net present value on capital + net present value on O&M

Table 4-3: Magnitude of Cost Assessment Individual Well Improvement - New Well (Treatment Not Required)

Option	Pugwash
Typical Homeowner Costs	
Water Supply Assessment	$850
New Well and Pump	$6,350
Water Treatment	$0
Total	**$7,200**
Typical Water System Maintenance Costs	
Water Quality Sampling	$150
Treatment Equipment	$0
Pump (annual reserve fund)	$50
Total	**$200**
Lifecycle Cost Analysis	
Interest Rate	7%
Period (Years)	20
Initial Capital Cost	$7,200
Treatment Equipment Replacement at Year 10	$0
Net Present Value on Capital Items	$7,200
Annual O&M Costs	$200
Net Present Value on O&M [1]	$2,119
Total Net Present Worth per Home [2]	**$9,319**

1 - Net Present Value represents the amount that would have to be invested now to earn the annual O&M costs

2 - Net present value on capital + net present value on O&M

Table 4-4: Magnitude of Cost Assessment Individual Well Improvement - New Well (Treatment Required)

Option	Pugwash
Typical Homeowner Costs	
Water Supply Assessment	$850
New Well and Pump	$6,350
Water Treatment	
Treatment Equipment	$2,900
Disinfection Equipment	$1,100
Total	**$11,200**
Typical Water System Maintenance Costs	
Water Quality Sampling	$150
Treatment Equipment	$270
Pump (annual reserve fund)	$50
Total	**$470**
Lifecycle Cost Analysis	
Interest Rate	7%
Period (Years)	20
Initial Capital Cost	$11,200
Treatment Equipment Replacement at Year 10	$2,660
Net Present Value on Capital Items	$13,860
Annual O&M Costs	$470
Net Present Value on O&M [1]	$4,979
Total Net Present Worth per Home [2]	**$18,839**

1 - Net Present Value represents the amount that would have to be invested now to earn the annual O&M costs

2 - Net present value on capital + net present value on O&M

Table 4-5: Magnitude of Cost Assessment Individual Well Improvement - Dug Well (Treatment Not Required)

Option	Pugwash
Typical Homeowner Costs	
Water Supply Assessment	$650
New Well and Pump	$5,000
Water Treatment	$0
Total	**$5,650**
Typical Water System Maintenance Costs	
Water Quality Sampling	$150
Treatment Equipment	$0
Pump (annual reserve fund)	$50
Total	**$200**
Lifecycle Cost Analysis	
Interest Rate	7%
Period (Years)	20
Initial Capital Cost	$5,650
Treatment Equipment Replacement at Year 10	$0
Net Present Value on Capital Items	$5,650
Annual O&M Costs	$200
Net Present Value on O&M [1]	$2,119
Total Net Present Worth per Home [2]	**$7,769**

1 - Net Present Value represents the amount that would have to be invested now to earn the annual O&M costs

2 - Net present value on capital + net present value on O&M

Table 4-6: Magnitude of Cost Assessment Individual Well Improvement - Dug Well (Treatment Required)

Option	Pugwash
Typical Homeowner Costs	
Water Supply Assessment	$650
New Well and Pump	$5,000
Water Treatment	
Treatment Equipment	$1,800
Disinfection Equipment	$1,100
Total	**$8,550**
Typical Water System Maintenance Costs	
Water Quality Sampling	$150
Treatment Equipment	$270
Pump (annual reserve fund)	$50
Total	**$470**
Lifecycle Cost Analysis	
Interest Rate	7%
Period (Years)	20
Initial Capital Cost	$8,550
Treatment Equipment Replacement at Year 10	$2,660
Net Present Value on Capital Items	$11,210
Annual O&M Costs	$470
Net Present Value on O&M [1]	$4,979
Total Net Present Worth per Home [2]	**$16,189**

1 - Net Present Value represents the amount that would have to be invested now to earn the annual O&M costs

2 - Net present value on capital + net present value on O&M

- New Drilled Well – treatment not required: $9,300;
- New Drilled Well – treatment required: $18,900;
- New Dug Well – treatment not required: $7,800; and
- New Dug Well – treatment required: $16,200.

It should be noted that the well rehabilitation estimates assume that the existing drilled well is in a well crock, and rehabilitation work would involve the removal of the crock, extending the casing, converting to a pitless adaptor system, and backfilling and re-grading around the wellhead. Wells that are buried, but are not located in a crock, should cost less to rehabilitate.

As an alternative option, a homeowner whose well construction assessment is not favourable may decide to purchase bottled water for drinking water and/or cooking purposes, and maintain the well for other uses.

The estimated cost of bottled water for drinking and cooking, not including taxes, is as follows:
- Cooler rental: $96 per year;
- Cooler purchase: $200; and
- Water purchase: $650 per year based on six bottles (18.9L) per month.

Over a 20 year period, the cost of using bottled water for drinking and cooking would therefore amount to an estimated $13,000 (excluding the cost of the cooler).

It should be noted that the following factors would influence the costs of bottled water:
- Use of bottled water (drinking and/or cooking);
- Volume of bottle purchased;
- Water source; and
- Delivery or pick up service.

4.3 Central Water

The TOR indicate that the Central Water option be updated assuming that that the groundwater source is located within 5 km from the distribution system and located in an aquifer where water quality meets the GCDWQ. The target aquifer comprises sandstone of the Balfron Formation, a member of Pictou Group sedimentary rocks. An alternative location was considered in 1982, near the centre of the Pugwash Point Peninsula. The quality of water from this location appears to be good, but previous studies suggested that the basin / aquifer yield is not sufficient to supply Pugwash with the required flow rates.

The following assumptions were therefore made for this system:
- The system is not sized to provide fire flows;
- The required yield can be obtained from a properly sited and constructed drilled well in Pictou Group sandstones;
- Water quality meets the GCDWQ;
- Water storage of 200,000 L, in a steel tank, would be provided along the transmission main;

- Water from the wells would be disinfected at the well field and pumped directly into the water storage reservoir;
- The required chlorine contact time would be provided in the transmission main;
- The well field would consist of a minimum of three 150 mm wells;
- Each wellhead would require a pitless adapter, fencing and three-phase power; and
- The pumps would pump the untreated groundwater to the treatment plant, which was assumed to be located in the vicinity of the wells.

At this phase of the investigation, cost components considered in the magnitude of cost assessment include the following:

- Establishment of a Water Utility;
- Groundwater Exploration and Aquifer Characterization Studies;
- Pre-Design Studies;
- Approvals, Plans and Permits;
- Wellfield Construction;
- Transmission Mains and Laterals; and
- Elevated Storage Reservoir.

4.3.1 Establishment of a Water Utility

The creation of a Water Utility would require the creation of an administration section that would be responsible to read the water meters and bill the customers.

4.3.2 Groundwater Exploration and Aquifier Characterization Studies

Groundwater exploration and aquifer characterization would include a desktop hydrogeological evaluation, test well construction, and aquifer testing including pumping tests.

The desktop hydrogeological evaluation would determine the optimum location and number of test wells to construct. Test wells would then be constructed and 72-hour pumping tests (or longer-term as required) would be performed. The number of test wells required depends on the program's success in locating groundwater resources with capacity sufficient to meet the requirements of the proposed water supply system. Groundwater exploration programs are therefore typically conducted as multi-phased work. The construction of test wells may involve road construction to provide access to sites for well drilling. If a suitable groundwater supply is located during the test drilling program, the test wells may be developed into production wells.

The primary objective of the exploration program would be to characterize the aquifer, including the safe yield and water quality characteristics, and to determine the suitability of the aquifer for groundwater supply development.

4.3.3 Pre-Design Studies, Approvals, Plans and Permits

The development of a groundwater supply would require a GUDI assessment, groundwater modelling (and capture zone delineation), application to the NSDEL for a groundwater withdrawal permit, and the development and implementation of a source water protection plan. To facilitate the implementation of the source protection plan, new wells should be sited in undeveloped areas.

4.3.4 Wellfield Construction

The development of the well field would involve the construction of an access road to the site, well field site development (land clearing, installation of fencing, etc.), the construction of high capacity groundwater wells to municipal standards, including a minimum of 12.2 m of casing with an annular seal, and the installation of well field yard piping to connect the wells to the treatment plant. It has been assumed that wells have been spaced at 150 m intervals.

4.3.5 Transmission Mains & Laterals

Cost estimates for transmission mains, watermains and laterals (within the ROW) also include piping to the well field, services, valves, and disinfection of mains.

4.3.6 Water Disinfection

Water disinfection will be conducted at the well field site, and the required chlorine contact time will be provided in the transmission main.

4.3.7 Storage Reservoir

Balancing requirements have been calculated based on maximum day demands. For the purposes of this report, it has been assumed that elevated steel storage reservoirs are best suited to this application. The optimum location for a storage reservoir would be identified as part of a pre-design study.

4.3.8 Estimated Capital Costs

The magnitude of cost assessment is provided in Table 4.7. Note that these figures include 25% engineering and contingency on construction items but do not include costs for HST or land acquisition. Data from the 2005 Study is included for comparison. The estimated costs represent the consultant's opinion of probable construction costs. The consultant has no control over the cost or availability of labour, equipment, materials, or over market conditions or the contractor's method of pricing. The consultant's opinions of probable construction costs are made on the basis of the consultant's professional judgement and experience. The consultant makes no warranty, express or implied, that the bids or the negotiated cost of the work will not vary from the consultants opinion of probable construction costs.

Servicing options are presented in Figures 4.1 and 4.2. Option 1 in Figure 4.1 (Pugwash 2012 in Table 4.7) provides for the servicing of "central" Pugwash, and is similar to the proposed servicing in 2005. Option 2 in Figure 4.2 extends the servicing boundary across the Highway 6 Bridge to approximately 40 homes in West Pugwash. The increase in capital cost is approximately $1,250,000, or $31,200 per serviced home. Overall, however, when all the homes are included, the incremental increase over Option 1 is approximately $1,500 per home. Figure 4.2 indicates the direction to a potential wellfield located to the southwest of West Pugwash.

Of note, however, is that although the capital costs have increased because a longer transmission main has been assumed, the operating costs will decrease because of the assumption that water quality meets the GCDWQ, and only disinfection is required. Capital costs are eligible for funding from other levels of government, while operations and maintenance costs are not.

Tables 4.8 to 4.10 indicate the estimated capital cost per connection using no funding, 33% funding, and 66% funding.

Table 4.7: Magnitude of Cost Assessment Central Supply Option

Option	Pugwash (2005)	Pugwash (2012)	Pugwash/ W. Pugwash (2012)
Capital Cost Components:			
Utility Setup	$20,000	$22,000	$22,000
Groundwater Exploration and Aquifer Characterization Studies	$165,000	$175,000	$175,000
Approvals, Plans and Permits	$35,000	$38,000	$40,000
Wellfield Construction	$400,000	$430,000	$500,000
Transmission Mains & Laterals	$2,430,000	$3,917,695	$5,023,399
Treatment	$1,480,000		
Disinfection		$150,000	$165,000
Storage	$525,000	$550,000	$605,000
Total	**$5,055,000**	**$5,282,695**	**$6,530,399**
Number of Homes	289	289	329
Cost per Home	**$17,500**	**$18,279**	**$19,849**

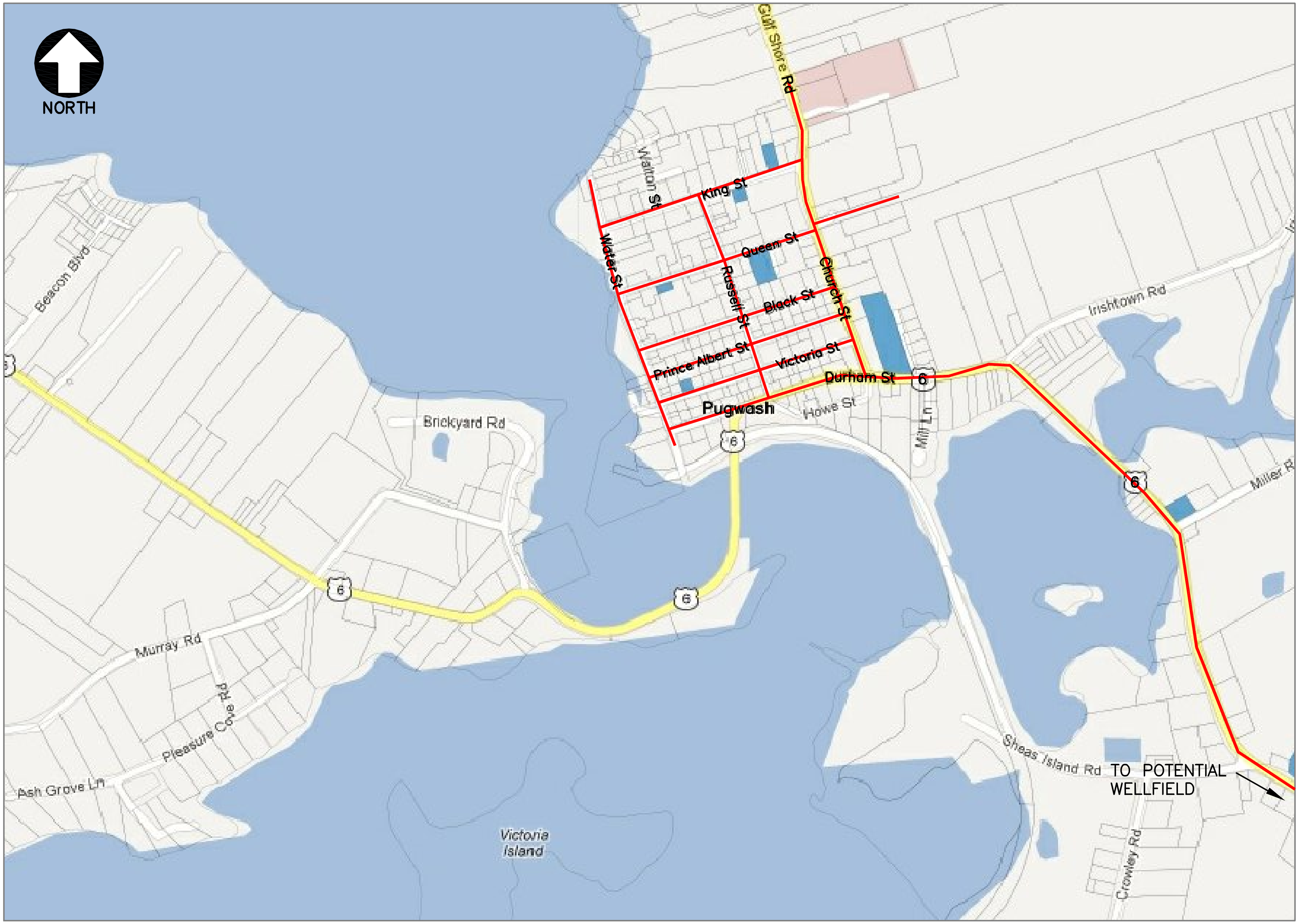

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FIGURE 4.1: OPTION 1

PUGWASH

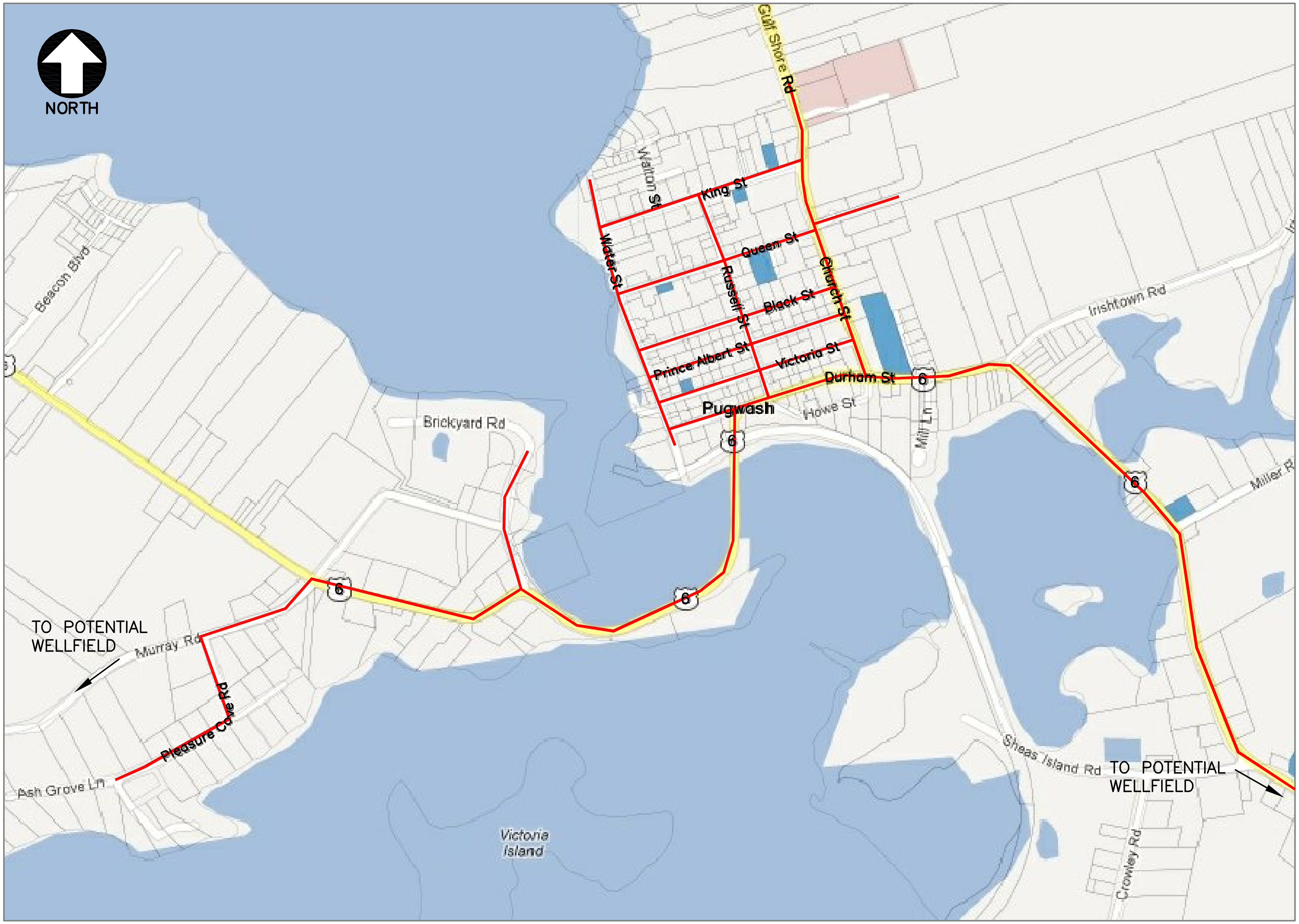

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FIGURE 4.2: OPTION 2

PUGWASH/WEST PUGWASH

Table 4-8: Estimated Capital Costs for Central Servicing (Option 2) (No Funding)

Option	Pugwash
Capital Cost (including Engineering & Contingency)	$6,531,000
Funding Allocation	0%
Capital Cost After Funding Allocation	$6,531,000
Capital Cost per Connection	$19,850

Table 4-9: Estimated Capital Costs for Central Servicing (Option 2) (33% Funding)

Option	Pugwash
Capital Cost (including Engineering & Contingency)	$6,531,000
Funding Allocation	33%
Capital Cost After Funding Allocation	$4,375,770
Capital Cost per Connection	$13,300

Table 4-10: Estimated Capital Costs for Central Servicing (Option 2) (66% Funding)

Option	Pugwash
Capital Cost (including Engineering & Contingency)	$6,531,000
Funding Allocation	66%
Capital Cost After Funding Allocation	$2,220,540
Capital Cost per Connection	$6,750

CHAPTER 5 CONCLUSIONS

5.1 Conclusions

Pugwash is underlain by two distinct geological formations, the Cumberland Group formation which generally provides suitable water quality, and the Windsor Group formation that in most cases does not provide potable water.

The results of this study are summarized as follows:

- Wells underlain by Windsor Group evaporite rock generally exhibited higher chloride concentrations, ranging to 3189 mg/L;
- The chloride concentration exceeded the GCDWQ of 250 mg/L at 14 of 23 locations underlain by Windsor Group bedrock, compared to only 1 of 30 wells underlain by Cumberland Group sandstone;
- Wells overlying the Cumberland Group sandstone generally showed chloride concentrations below 100 mg/L;
- Exceptions were noted at PP1 ([Cl]=1340 mg/L), and locations to the south and east of the Windsor Group contact ([Cl]= 159 and 191 mg/L);
- An alternative source aquifer was considered in 1982, located near the centre of the Pugwash Point Peninsula. The quality of water from this location appears to be good, but previous studies suggested that the basin / aquifer yield is not sufficient to supply Pugwash with the required flow rates;
- Br:Cl ratios in three wells indicate that the source of chloride is attributable to sea water or mineral formation water;
- Br:Cl ratios in four wells indicate that these wells may be affected by road salting, and that reduction of salting in these areas and upgrades to the wells should improve water quality with time;
- The water chemistry of samples collected from wells in 2004 was generally consistent with samples collected from the same wells in 2012;
- The quality of water from wells of good construction was generally good;
- Water from wells in the target areas of Water Street and West Pugwash showed results consistent with the underlying bedrock. Wells underlain by the Windsor Group were more likely to show elevated parameter concentrations whereas wells underlain by Cumberland Group were not;
- The well at PP1 showed elevated chloride concentrations. The Br:Cl ratio suggested that road salt affects the quality of water at this location;
- Paired well samples showed differences at two locations. Improved well construction at these locations appeared to result in a moderate improvement in water quality;

- The GCDWQ were frequently exceeded. Exceedances were often attributable to mineral water from the Windsor Group;
- The arsenic concentration exceeded the GCDWQ at five locations;
- The lead concentration exceeded the GCDWQ at three locations;
- The uranium concentration exceeded the GCDWQ at two locations;
- A potential source aquifer for a central water supply system for Pugwash was identified by the client, located south of the Village of Pugwash;
- The target aquifer is part of the Balfron Formation, a member of the Pictou Group sedimentary rocks;
- Alternative options to improve individual drinking water supplies include:
  - Well improvements / drill or dig replacement wells;
  - Treatment; and
  - External supply (refillable cistern or bottled water).

The findings of the investigation indicate that a central water supply from the Pictou Group Sedimentary rock provides the best option for the supply of the potable water to the Village of Pugwash. Development of a well field would require the installation of test wells, aquifer testing (pumping tests and water quality sampling), and additional hydrogeological investigations to ensure that the water supply will be secure for time frames exceeding 20 years. This phase of the work requires approval from Council and the availability of the required funding.

CHAPTER 6 REFERENCES

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APPENDIX A

Groundwater Quality Data from 2012 Well Sampling Program, Pugwash with Laboratory Analytical Reports

Table A1. Inorganic Chemistry Data for Wells Sampled in 2012

Parameter	**Unit**	**G / S**	**RDL**	***R1***	***R2***	***R3***	***R4***	***B1***	***B2***	***B3***	***B4***	***B5***
pH		[6.5-8.5]		8.0	8.2	8.0	8.5	8.2	8.1	8.2	8.1	8.2
Reactive Silica as SiO2	mg/L		0.5	12.5	15.7	10.6	9.5	15.0	14.0	10.4	13.0	14.6
Bromide	mg/L		0.3	0.69	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Chloride	mg/L	[250]	1	***508***	13	18	***301***	15	99	48	19	17
Fluoride	mg/L	1.5	0.1	0.1	0.2	<0.1	0.3	0.1	0.1	0.2	0.1	<0.1
Sulphate	mg/L	[500]	2	40	10	6	59	11	24	16	9	7
Alkalinity	mg/L		5	101	130	117	246	141	336	146	127	144
True Color	TCU	[15]	5	<5	7	<5	5	<5	9	5	<5	11
Turbidity	NTU	[0.1-1]	0.1	***2.0***	0.4	0.1	1.2	0.5	***1.9***	***57.2***	***1.8***	***2.8***
Electrical Conductivity	umho/cm		1	1750	285	279	1460	328	921	453	312	336
Nitrate + Nitrite as N	mg/L		0.05	0.53	0.17	0.88	<0.05	0.19	0.10	0.15	0.16	0.91
Nitrate as N	mg/L	[10]	0.05	0.53	0.17	0.88	<0.05	0.19	0.10	0.15	0.16	0.91
Nitrite as N	mg/L	[1.0]	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ammonia as N	mg/L		0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Organic Carbon	mg/L		0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.4	<0.5	<0.5	<0.5
Ortho-Phosphate as P	mg/L		0.01	<0.01	<0.01	0.01	0.02	0.01	<0.01	<0.01	<0.01	0.02
Total Sodium	mg/L	[200]	0.1	162	9.4	5.4	***330***	19.2	72.7	46.7	20.9	13.1
Total Potassium	mg/L		0.1	9.3	4.2	1.1	5.1	4.3	5.8	2.8	7.8	4.1
Total Calcium	mg/L		0.1	117	36.2	39.2	5.3	40.8	102	36.0	27.5	42.4
Total Magnesium	mg/L		0.1	26.8	4.5	4.1	0.7	6.6	27.4	8.6	6.7	8.3
Total Phosphorous	mg/L		0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bicarb. Alkalinity (as CaCO3)	mg/L		5	101	130	117	234	141	336	146	127	144
Carb. Alkalinity (as CaCO3)	mg/L		10	<10	<10	<10	12	<10	<10	<10	<10	<10
Hydroxide	mg/L		5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Calculated TDS	mg/L	[500]	1	***926***	156	148	***849***	182	***534***	251	168	182
Hardness	mg/L	180*		***403***	109	115	16.1	129	***368***	125	96.3	140
Langelier Index (@20C)	NA			0.39	0.27	0.06	-0.06	0.35	0.97	0.29	0.03	0.37
Langelier Index (@ 4C)	NA			0.07	-0.05	-0.26	-0.38	0.03	0.65	-0.03	-0.29	0.05
Saturation pH (@ 20C)	NA			7.61	7.93	7.94	8.56	7.85	7.13	7.91	8.07	7.83
Saturation pH (@ 4C)	NA			7.93	8.25	8.26	8.88	8.17	7.45	8.23	8.39	8.15
Anion Sum	me/L			17.2	3.19	3.04	14.6	3.49	10.0	4.62	3.27	3.57
Cation sum	me/L			15.3	2.70	2.56	14.8	3.53	10.7	4.76	3.04	3.48
Ion Balance (NS)	%			5.8	8.4	8.5	0.6	0.6	3.3	1.6	3.7	1.3
Total Aluminum	ug/L	[100]	10	<10	<10	<10	<10	<10	<10	<10	<10	16
Total Antimony	ug/L	6	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Arsenic	ug/L	10	2	***10***	***16***	3	4	6	<2	9	***12***	5
Total Barium	ug/L	1000	5	207	206	316	128	120	186	156	127	258

Table A1. Inorganic Chemistry Data for Wells Sampled in 2012

Parameter	Unit	G / S	RDL	*R1*	*R2*	*R3*	*R4*	*B1*	*B2*	*B3*	*B4*	*B5*
Total Beryllium	ug/L		2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Bismuth	ug/L		2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Boron	ug/L	5000	5	25	7	9	231	17	186	28	67	15
Total Cadmium	ug/L	5	0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Total Chromium	ug/L	50	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Cobalt	ug/L		1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Copper	ug/L	[1000]	2	5	8	20	16	31	287	47	25	15
Total Iron	ug/L	[300]	50	72	<50	<50	87	<50	222	***4330***	107	98
Total Lead	ug/L	10	0.5	<0.5	3.7	<0.5	2.6	0.8	***62.3***	***14.1***	4.0	3.4
Total Manganese	ug/L	[50]	2	9	<2	<2	37	<2	***598***	14	6	<2
Total Molybdenum	ug/L		2	<2	2	<2	10	<2	3	3	3	<2
Total Nickel	ug/L		2	<2	<2	<2	<2	<2	18	<2	<2	<2
Total Selenium	ug/L	10	2	3	<2	<2	<2	<2	<2	<2	<2	<2
Total Silver	ug/L		0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Strontium	ug/L		5	4610	960	153	116	764	1240	537	1750	427
Total Thallium	ug/L		0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Tin	ug/L		2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Titanium	ug/L		2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Uranium	ug/L	20	0.1	6.6	***21.3***	1.8	0.9	18.7	11.4	3.6	2.9	10.6
Total Vanadium	ug/L		2	<2	3	<2	<2	3	<2	<2	3	3
Total Zinc	ug/L	[5000]	5	12	<5	32	16	12	162	24	32	16

Bold/Highlight: Parameter exceeds GCDWQ

*** Per NSE Guidelines**

Table A1. Inorganic Chemistry Data for Wells Sampled in 2012

Parameter	Unit	G / S	RDL	*B6*	*B7*	*B8*	*B9*	*B10*	*W1*	*W2*	*W3*	*W4*
pH		[6.5-8.5]		7.9	7.5	8.7	8.2	8.5	8.0	8.1	8.2	8.1
Reactive Silica as SiO2	mg/L		0.5	12.9	10.7	9.4	9.7	9.0	11.5	8.6	13.8	11.1
Bromide	mg/L		0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<6.0	4.4	<0.3	<0.3
Chloride	mg/L	[250]	1	19	17	64	***672***	158	***1960***	***1190***	31	64
Fluoride	mg/L	1.5	0.1	0.1	0.1	0.6	<0.5	1.2	<2.0	<1.0	0.2	0.1
Sulphate	mg/L	[500]	2	7	6	49	***659***	36	175	152	36	12
Alkalinity	mg/L		5	137	61	268	189	313	186	165	153	138
True Color	TCU	[15]	5	***15***	<5	<5	<5	<5	<5	6	<5	<5
Turbidity	NTU	[0.1-1]	0.1	0.4	0.2	***1.6***	***1.3***	0.5	***1.4***	1.0	0.6	***2.0***
Electrical Conductivity	umho/cm		1	321	182	784	3440	1090	6060	4020	446	475
Nitrate + Nitrite as N	mg/L		0.05	0.48	0.58	<0.05	<0.05	<0.05	<0.05	<0.05	0.23	0.75
Nitrate as N	mg/L	[10]	0.05	0.48	0.58	<0.05	<0.50	<0.05	<1.00	<0.50	0.23	0.75
Nitrite as N	mg/L	[1.0]	0.05	<0.05	<0.05	<0.05	<0.50	<0.05	<1.00	<0.50	<0.05	<0.05
Ammonia as N	mg/L		0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Organic Carbon	mg/L		0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ortho-Phosphate as P	mg/L		0.01	0.02	0.03	0.05	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Total Sodium	mg/L	[200]	0.1	9.6	8.1	198	***725***	***263***	***973***	***755***	51.0	39.6
Total Potassium	mg/L		0.1	1.3	0.6	2.6	9.6	5.0	14.5	14.3	5.6	3.2
Total Calcium	mg/L		0.1	43.1	19.6	1.2	95.4	7.9	207	96.8	38.0	37.7
Total Magnesium	mg/L		0.1	7.9	5.1	0.1	7.5	2.0	87.2	36.4	5.4	16.5
Total Phosphorous	mg/L		0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bicarb. Alkalinity (as CaCO3)	mg/L		5	321	61	247	189	301	186	165	153	138
Carb. Alkalinity (as CaCO3)	mg/L		10	137	<10	22	<10	12	<10	<10	<10	<10
Hydroxide	mg/L		5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Calculated TDS	mg/L	[500]	1	172	96	***476***	***2280***	***660***	***3530***	***2340***	260	259
Hardness	mg/L	180*****		140	69.9	3.4	***269***	28.0	***876***	***392***	117	162
Langelier Index (@20C)	NA			0.06	-1.01	-0.45	0.73	0.22	0.84	0.58	0.34	0.19
Langelier Index (@ 4C)	NA			-0.26	-1.33	-0.77	0.41	-0.10	0.52	0.26	0.02	-0.13
Saturation pH (@ 20C)	NA			7.84	8.51	9.15	7.47	8.28	7.16	7.52	7.86	7.91
Saturation pH (@ 4C)	NA			8.16	8.83	9.47	7.79	8.60	7.48	7.84	8.18	8.23
Anion Sum	me/L			3.46	1.87	8.19	36.5	11.5	62.7	40.0	4.70	4.87
Cation sum	me/L			3.25	1.77	8.75	37.2	12.1	60.2	41.0	4.71	5.05
Ion Balance (NS)	%			3.0	2.7	3.4	1.1	2.8	2.0	1.2	0.1	1.8
Total Aluminum	ug/L	[100]	10	<10	<10	52	10	<10	<10	<10	<10	<10
Total Antimony	ug/L	6	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Arsenic	ug/L	10	2	<2	<2	8	2	3	6	6	6	6
Total Barium	ug/L	1000	5	167	159	16	13	55	67	68	52	179

Table A1. Inorganic Chemistry Data for Wells Sampled in 2012

Parameter	Unit	G / S	RDL	*B6*	*B7*	*B8*	*B9*	*B10*	*W1*	*W2*	*W3*	*W4*
Total Beryllium	ug/L		2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Bismuth	ug/L		2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Boron	ug/L	5000	5	25	59	141	127	101	161	83	45	30
Total Cadmium	ug/L	5	0.3	<0.3	<0.3	<0.3	<0.3	<0.3	1.6	<0.3	<0.3	<0.3
Total Chromium	ug/L	50	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Cobalt	ug/L		1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Copper	ug/L	[1000]	2	23	36	23	560	<2	36	10	8	7
Total Iron	ug/L	[300]	50	<50	<50	67	***931***	58	115	147	85	152
Total Lead	ug/L	10	0.5	<0.5	0.7	1.9	***19.8***	0.6	2.4	2.1	1.0	1.5
Total Manganese	ug/L	[50]	2	<2	<2	10	***573***	17	645	***103***	9	<2
Total Molybdenum	ug/L		2	<2	<2	22	9	23	<2	13	3	3
Total Nickel	ug/L		2	<2	<2	<2	6	<2	6	3	<2	<2
Total Selenium	ug/L	10	2	<2	<2	<2	<2	<2	***15***	***20***	<2	<2
Total Silver	ug/L		0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Strontium	ug/L		5	106	34	19	3100	300	2300	3020	882	474
Total Thallium	ug/L		0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Tin	ug/L		2	<2	<2	<2	8	<2	<2	<2	<2	<2
Total Titanium	ug/L		2	<2	<2	<2	9	<2	4	3	<2	<2
Total Uranium	ug/L	20	0.1	2.1	0.2	6.3	2.7	8.7	9.4	2.8	16.0	8.4
Total Vanadium	ug/L		2	<2	<2	<2	<2	<2	<2	<2	<2	3
Total Zinc	ug/L	[5000]	5	5	<5	37	219	6	19	6	12	127

Bold/Highlight: Parameter exceeds GCDWQ

*** Per NSE Guidelines**

Table A1. Inorganic Chemistry Data for Wells Sampled in 2012

Parameter	**Unit**	**G / S**	**RDL**	***PP1***	***WP1***	***WP2***	***C1***	***C2***	***C3***	***C4***
pH		[6.5-8.5]		7.9	8.4	8.4	8.2	8.1	8.2	8.2
Reactive Silica as SiO2	mg/L		0.5	13.3	8.2	10.2	10.7	12.6	15.3	13.7
Bromide	mg/L		0.3	<0.6	<0.3	<0.3	<0.3	<0.6	<0.3	<0.3
Chloride	mg/L	[250]	1	***1340***	148	132	22	***507***	31	13
Fluoride	mg/L	1.5	0.1	<0.2	0.6	0.6	0.1	<0.2	0.2	0.1
Sulphate	mg/L	[500]	2	18	87	74	8	37	21	10
Alkalinity	mg/L		5	180	224	248	122	120	156	122
True Color	TCU	[15]	5	<5	<5	<5	8	<5	<5	<5
Turbidity	NTU	[0.1-1]	0.1	***43.8***	0.6	0.6	***1.5***	0.2	0.4	0.3
Electrical Conductivity	umho/cm		1	3960	1020	989	313	1780	418	284
Nitrate + Nitrite as N	mg/L		0.05	0.45	0.44	0.05	0.77	0.40	<0.05	0.17
Nitrate as N	mg/L	[10]	0.05	0.45	0.44	0.05	0.77	0.40	<0.05	0.17
Nitrite as N	mg/L	[1.0]	0.05	<0.10	<0.05	<0.05	<0.05	<0.10	<0.05	<0.05
Ammonia as N	mg/L		0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Organic Carbon	mg/L		0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ortho-Phosphate as P	mg/L		0.01	<0.01	0.01	0.03	<0.01	<0.01	<0.01	<0.01
Total Sodium	mg/L	[200]	0.1	***376***	***241***	***236***	13.1	***206***	44.2	27.2
Total Potassium	mg/L		0.1	21.5	3.9	3.7	0.8	15.8	6.9	4.9
Total Calcium	mg/L		0.1	249	7.9	5.3	36.4	131	40.2	25.6
Total Magnesium	mg/L		0.1	83.0	1.3	0.6	13.8	24.1	5.9	6.8
Total Phosphorous	mg/L		0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bicarb. Alkalinity (as CaCO3)	mg/L		5	180	218	240	122	120	156	122
Carb. Alkalinity (as CaCO3)	mg/L		10	<10	<10	<10	<10	<10	<10	<10
Hydroxide	mg/L		5	<5	<5	<5	<5	<5	<5	<5
Calculated TDS	mg/L	[500]	1	***2200***	***625***	***601***	171	***995***	243	162
Hardness	mg/L	180*		***964***	25.1	15.7	148	***426***	125	91.9
Langelier Index (@20C)	NA			0.83	-0.02	-0.15	0.24	0.61	0.37	0.09
Langelier Index (@ 4C)	NA			0.51	-0.34	-0.47	-0.08	0.29	0.05	-0.23
Saturation pH (@ 20C)	NA			7.07	8.42	8.55	7.96	7.49	7.83	8.11
Saturation pH (@ 4C)	NA			7.39	8.74	8.87	8.28	7.81	8.15	8.43
Anion Sum	me/L			41.8	10.5	10.2	3.28	17.5	4.43	3.03
Cation sum	me/L			36.2	11.1	10.7	3.55	17.9	4.59	3.15
Ion Balance (NS)	%			7.2	2.7	2.1	3.9	1.1	1.8	1.9
Total Aluminum	ug/L	[100]	10	16	<10	12	<10	<10	<10	<10
Total Antimony	ug/L	6	2	<2	<2	<2	<2	<2	<2	<2
Total Arsenic	ug/L	10	2	<2	***20***	***34***	<2	9	<2	8
Total Barium	ug/L	1000	5	***3670***	21	17	409	204	60	90

Table A1. Inorganic Chemistry Data for Wells Sampled in 2012

Parameter	Unit	G / S	RDL	*PP1*	*WP1*	*WP2*	*C1*	*C2*	*C3*	*C4*
Total Beryllium	ug/L		2	<2	<2	<2	<2	<2	<2	<2
Total Bismuth	ug/L		2	<2	<2	<2	<2	<2	<2	<2
Total Boron	ug/L	5000	5	21	104	125	24	53	51	19
Total Cadmium	ug/L	5	0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Total Chromium	ug/L	50	2	<2	<2	<2	<2	<2	<2	<2
Total Cobalt	ug/L		1	<1	<1	<1	<1	<1	<1	<1
Total Copper	ug/L	[1000]	2	4	3	6	20	5	<2	21
Total Iron	ug/L	[300]	50	269	<50	78	148	<50	<50	<50
Total Lead	ug/L	10	0.5	0.7	<0.5	<0.5	3.1	2.6	0.7	1.9
Total Manganese	ug/L	[50]	2	43	13	19	3	10	***55***	<2
Total Molybdenum	ug/L		2	<2	21	36	<2	3	5	4
Total Nickel	ug/L		2	<2	<2	<2	<2	3	<2	<2
Total Selenium	ug/L	10	2	2	<2	<2	<2	3	<2	<2
Total Silver	ug/L		0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Strontium	ug/L		5	3220	271	146	50	6430	1450	769
Total Thallium	ug/L		0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Tin	ug/L		2	<2	<2	<2	<2	<2	<2	<2
Total Titanium	ug/L		2	<2	<2	<2	<2	<2	<2	<2
Total Uranium	ug/L	20	0.1	16.9	***23.0***	12.0	0.8	7.6	15.1	11.9
Total Vanadium	ug/L		2	<2	8	2	<2	<2	<2	2
Total Zinc	ug/L	[5000]	5	22	<5	45	11	100	<5	42

Bold/Highlight: Parameter exceeds GCDWQ

*** Per NSE Guidelines**

APPENDIX B

Groundwater Quality Data from 2004 Well Sampling Program, Pugwash

Table B1. Inorganic Chemistry Data for Wells Sampled in 2004

Parameter	**Unit**	**G / S**	O1	O2	O3	O4	O5	O6	O7	O8	O9
Calcium	mg/L		12.9	97.3	55.9	8.7	5.5	37.3	73.8	3.3	15.6
Magnesium	mg/L		3.5	25.2	6.8	1.6	0.7	7.3	18.4	0.7	2.3
Sodium	mg/L	[200]	74.6	74.2	40.8	***212.1***	***316***	8.8	93.4	***526.1***	***281.8***
Chloride	mg/L	[250]	42.5	***297.6***	20	138.2	***260***	12	159.5	***691.0***	***255.1***
Sulfate	mg/L	[500]	23.0	17.0	95	75.9	62	7	32.9	70.7	66.9
Iron	ug/L	[300]	78.6	33.8	< 50	18.9	80	< 50	29.1	***314.2***	155.4
Manganese	ug/L	[50]	5.6	3.7	5	14.4	38	2	0.7	41.5	***175.1***
Copper	ug/L	[1000]	0.6	0.3	3	2.3	10	15	6.1	< 20	< 20
Zinc	ug/L		14.1	< 10	6	3.8	9	14	11.0	1.6	4.3
Nitrate (as N)	mg/L	[10]	0.16	1.00	0.26	0.41	< 0.05	0.84	0.33	1.01	0.49
Alkalinity (as CaCO3)	mg/L		150	150	120	250	300	130	275	275	300
pH		[6.5-8.5]	8.1	7.7	7.7	8.3	***8.6***	7.7	7.7	8.3	8.0
Conductance	umho/cm		432	1166	534	1038	1580	289	989	2663	1412
Hardness (as CaCO3)	mg/L	180*****	46.5	***346.7***	168	28.2	16.6	123	***260.13***	11.2	48.3
Potassium	mg/L				4.2		5.6	1.9			
Aluminum	ug/L	[100]			10		< 10	< 10			
Reactive Silica (as SiO2)	mg/L				12		8.6	10			
Ortho Phosphate (as P)	mg/L				0.02		0.02	< 0.01			
Nitrite	mg/L	[1.0]			< 0.01		< 0.01	< 0.01			
Nitrate + Nitrite (as N)	mg/L				0.26		< 0.05	0.84			
Ammonia (as N)	mg/L				< 0.05		< 0.05	< 0.05			
Color	TCU	[15]			< 5		< 5	< 5			
Turbidity	NTU	[0.1-1]			< 0.1		0.2	0.2			
Bicarbonate (as CaCO3)	mg/L				119		289	129			
Carbonate (as CaCO3)	mg/L				< 1		11	< 1			
TDS (Calculated)	mg/L	[500]			308		839	166			
Cation Sum	me/L				5.23		14.2	2.9			
Anion Sum	me/L				4.96		14.6	3.14			
Ion Balance	%				2.71		1.39	4.09			
Langlier Index @ 4C	NA				-0.35		-0.10	-0.47			
Langlier Index @ 20C	NA				0.05		0.3	-0.07			
Saturation pH @ 4C	NA				8.05		8.7	8.17			
Saturation pH @ 20C	NA				7.65		8.3	7.77			
Antimony	ug/L	6			< 2		< 2	< 2			
Arsenic	ug/L	10			5		8	3			
Barium	ug/L	1000			53		140	160			
Beryllium	ug/L				< 2		< 2	< 2			

Table B1. Inorganic Chemistry Data for Wells Sampled in 2004

Parameter	**Unit**	**G / S**	O1	O2	O3	O4	O5	O6	O7	O8	O9
Bismuth	ug/L				< 2		< 2	< 2			
Boron	ug/L	5000			22		230	10			
Cadmium	ug/L	5			< 0.3		< 0.3	< 0.3			
Chromium	ug/L	50			< 2		< 2	< 2			
Cobalt	ug/L				< 1		< 1	< 1			
Lead	ug/L	10			< 0.5		0.5	0.7			
Molybdenum	ug/L				3		13	< 2			
Nickel	ug/L				< 2		< 2	< 2			
Selenium	ug/L	10			< 2		< 2	< 2			
Silver	ug/L				< 0.5		< 0.5	< 0.5			
Strontium	ug/L				750		97	170			
Thallium	ug/L				< 0.1		< 0.1	< 0.1			
Tin	ug/L				< 2		< 2	< 2			
Titanium	ug/L				2		2	< 2			
Uranium	ug/L				12		6.8	3.1			
Vanadium	ug/L				< 2		< 2	< 2			
Phosphorus	mg/L				< 0.1		< 0.1	< 0.1			
Total Org. Carbon (UV)	mg/L				< 0.5		< 0.5	< 0.5			

Bold/Highlight: Parameter exceeds GCDWQ

*** Per NSE Guidelines**

Table B1. Inorganic Chemistry Data for Wells Sampled in 2004

Parameter	Unit	G / S	O10	O11	O12	O13	O14	O15	O16	O17	O18	O19
Calcium	mg/L		18.2	33.2	12.6	697.8	111.3	142.9	80.4	62.6	22.6	23.8
Magnesium	mg/L		1.8	8.4	4.1	34.6	18.2	33.5	9.2	7.6	3.0	7.8
Sodium	mg/L	[200]	***454.6***	10.1	63.2	***835.9***	164.3	109.8	58.7	21.0	13.9	43.8
Chloride	mg/L	[250]	***584.7***	31.9	31.9	***1700.8***	***329.5***	***350.8***	170.1	106.3	31.9	42.5
Sulfate	mg/L	[500]	108.0	15.7	18.3	***1172.0***	46.1	22.7	10.9	10.4	9.5	15.7
Iron	ug/L	[300]	213.7	23.7	38.9	***10467.5***	250.1	154.9	12.6	31.8	16.6	237.4
Manganese	ug/L	[50]	***95.9***	2.2	41.1	***1060.3***	***330.2***	2.0	1.3	1.3	4.6	***98.6***
Copper	ug/L	[1000]	< 20	27.4	< 20	< 20	11.5	6.0	11.0	23.9	71.0	0.1
Zinc	ug/L		0.4	4.7	0.4	11.0	28.7	13.5	13.6	11.6	950.5	33.1
Nitrate (as N)	mg/L	[10]	0.85	0.76	0.15	2.38	0.68	2.90	1.18	1.48	0.98	0.23
Alkalinity (as CaCO3)	mg/L		225	100	150	175	275	275	175	100	75	150
pH		[6.5-8.5]	8.4	7.9	8.3	7.1	7.4	7.6	7.7	7.6	6.9	8.1
Conductance	umho/cm		2366	280	380	6920	1550	1575	816	527	221	405
Hardness (as CaCO3)	mg/L	180*****	52.8	117.5	48.6	***1884.9***	***352.6***	***494.8***	***238.8***	***187.3***	68.9	91.4
Potassium	mg/L											
Aluminum	ug/L	[100]										
Reactive Silica (as SiO2)	mg/L											
Ortho Phosphate (as P)	mg/L											
Nitrite	mg/L	[1.0]										
Nitrate + Nitrite (as N)	mg/L											
Ammonia (as N)	mg/L											
Color	TCU	[15]										
Turbidity	NTU	[0.1-1]										
Bicarbonate (as CaCO3)	mg/L											
Carbonate (as CaCO3)	mg/L											
TDS (Calculated)	mg/L	[500]										
Cation Sum	me/L											
Anion Sum	me/L											
Ion Balance	%											
Langlier Index @ 4C	NA											
Langlier Index @ 20C	NA											
Saturation pH @ 4C	NA											
Saturation pH @ 20C	NA											
Antimony	ug/L	6										
Arsenic	ug/L	10										
Barium	ug/L	1000										
Beryllium	ug/L											

Table B1. Inorganic Chemistry Data for Wells Sampled in 2004

Parameter	**Unit**	**G / S**	O10	O11	O12	O13	O14	O15	O16	O17	O18	O19
Bismuth	ug/L											
Boron	ug/L	5000										
Cadmium	ug/L	5										
Chromium	ug/L	50										
Cobalt	ug/L											
Lead	ug/L	10										
Molybdenum	ug/L											
Nickel	ug/L											
Selenium	ug/L	10										
Silver	ug/L											
Strontium	ug/L											
Thallium	ug/L											
Tin	ug/L											
Titanium	ug/L											
Uranium	ug/L											
Vanadium	ug/L											
Phosphorus	mg/L											
Total Org. Carbon (UV)	mg/L											

Bold/Highlight: Parameter exceeds GCDWQ

*** Per NSE Guidelines**

Table B1. Inorganic Chemistry Data for Wells Sampled in 2004

Parameter	Unit	G / S	O20	O21	O22	O23	O24	O25	O26	O27	O28	O29
Calcium	mg/L		32.6	57.6	289.0	34.1	38.0	48.4	28.2	54.7	334.1	404.7
Magnesium	mg/L		14.2	8.0	118.1	15.1	6.6	8.2	8.1	17.8	210.9	223.7
Sodium	mg/L	[200]	14.7	18.2	***398.4***	13.1	12.2	24.1	16.5	42.5	***1471.9***	***1580.7***
Chloride	mg/L	[250]	31.9	31.9	***1488.2***	31.9	31.9	31.9	10	85.0	***3189.0***	***3401.6***
Sulfate	mg/L	[500]	9.3	69.4	12.1	10.3	19.1	30.8	9	19.8	441.9	460.6
Iron	ug/L	[300]	65.4	30.4	***11640.1***	10.2	7.2	16.0	< 50	26.2	***549.0***	127.8
Manganese	ug/L	[50]	1.7	3.6	***381.6***	1.0	0.1	12.6	< 2	1.3	***1953.2***	***2485.6***
Copper	ug/L	[1000]	4.7	11.0	28.6	138.8	35.5	61.2	19	4.4	15.4	31.1
Zinc	ug/L		13.2	10.8	16.8	8.0	5.7	142.8	9	9.0	94.1	48.0
Nitrate (as N)	mg/L	[10]	0.26	0.28	2.36	0.75	0.38	0.72	0.20	1.35	4.83	4.97
Alkalinity (as CaCO3)	mg/L		150	125	175	150	125	150	140	200	150	150
pH		[6.5-8.5]	7.9	7.8	7.4	6.9	7.8	7.9	7.9	7.6	7.5	7.5
Conductance	umho/cm		343	433	4676	342	307	406	285	626	10680	11540
Hardness (as CaCO3)	mg/L	180*****	139.8	176.9	***1208.0***	147.3	121.9	154.5	104	***209.9***	***1702.5***	***1931.8***
Potassium	mg/L								6.6			
Aluminum	ug/L	[100]							10			
Reactive Silica (as SiO2)	mg/L								15			
Ortho Phosphate (as P)	mg/L								< 0.01			
Nitrite	mg/L	[1.0]							< 0.01			
Nitrate + Nitrite (as N)	mg/L								0.2			
Ammonia (as N)	mg/L								< 0.05			
Color	TCU	[15]							< 5			
Turbidity	NTU	[0.1-1]							0.5			
Bicarbonate (as CaCO3)	mg/L								139			
Carbonate (as CaCO3)	mg/L								1			
TDS (Calculated)	mg/L	[500]							178			
Cation Sum	me/L								2.96			
Anion Sum	me/L								3.28			
Ion Balance	%								5.11			
Langlier Index @ 4C	NA								-0.36			
Langlier Index @ 20C	NA								0.04			
Saturation pH @ 4C	NA								8.26			
Saturation pH @ 20C	NA								7.86			
Antimony	ug/L	6							< 2			
Arsenic	ug/L	10							14			
Barium	ug/L	1000							110			
Beryllium	ug/L								< 2			

Table B1. Inorganic Chemistry Data for Wells Sampled in 2004

Parameter	**Unit**	**G / S**	O20	O21	O22	O23	O24	O25	O26	O27	O28	O29
Bismuth	ug/L								< 2			
Boron	ug/L	5000							11			
Cadmium	ug/L	5							< 0.3			
Chromium	ug/L	50							< 2			
Cobalt	ug/L								< 1			
Lead	ug/L	10							< 0.5			
Molybdenum	ug/L								2			
Nickel	ug/L								2			
Selenium	ug/L	10							< 2			
Silver	ug/L								< 0.5			
Strontium	ug/L								870			
Thallium	ug/L								< 0.1			
Tin	ug/L								< 2			
Titanium	ug/L								< 2			
Uranium	ug/L								***20***			
Vanadium	ug/L								4			
Phosphorus	mg/L								< 0.1			
Total Org. Carbon (UV)	mg/L								< 0.5			

Bold/Highlight: Parameter exceeds GCDWQ

*** Per NSE Guidelines**

Table B1. Inorganic Chemistry Data for Wells Sampled in 2004

Parameter	**Unit**	**G / S**	O30	O31	O32	O33	O34	O35	O36	O37
Calcium	mg/L		28.3	4.7	28.0	23.3	30.6	32.9	102	84.7
Magnesium	mg/L		9.9	0.9	9.5	8.7	8.6	11.1	25.3	13.9
Sodium	mg/L	[200]	10.2	***210.6***	27.3	24.0	49.6	25.3	152	48.8
Chloride	mg/L	[250]	21.3	191.3	31.9	21.3	42.5	42.5	***430***	202.0
Sulfate	mg/L	[500]	8.0	24.9	11.6	10.1	19.0	11.1	29	19.3
Iron	ug/L	[300]	111.3	123.5	26.3	43.7	28.6	16.7	< 50	33.1
Manganese	ug/L	[50]	1.1	6.4	49.6	< 10	27.5	< 10	15	1.8
Copper	ug/L	[1000]	8.3	1.3	2.1	4	8.3	8.3	13	9.9
Zinc	ug/L		22.6	2.1	1.9	5.2	3.4	4.4	18	214.7
Nitrate (as N)	mg/L	[10]	0.28	0.48	0.15	0.22	0.25	0.32	0.35	2.60
Alkalinity (as CaCO3)	mg/L		100	150	125	100	150	125	89	125
pH		[6.5-8.5]	8.0	***8.8***	8.0	8.1	7.9	7.9	7.6	7.8
Conductance	umho/cm		268	1051	346	297	458	372	1760	839
Hardness (as CaCO3)	mg/L	180*****	111.4	15.5	109.2	94.0	111.6	127.8	***359.0***	***268.9***
Potassium	mg/L								12.7	
Aluminum	ug/L	[100]							10	
Reactive Silica (as SiO2)	mg/L								12	
Ortho Phosphate (as P)	mg/L								< 0.01	
Nitrite	mg/L	[1.0]							0.02	
Nitrate + Nitrite (as N)	mg/L								0.37	
Ammonia (as N)	mg/L								< 0.05	
Color	TCU	[15]							< 5	
Turbidity	NTU	[0.1-1]							0.5	
Bicarbonate (as CaCO3)	mg/L								89	
Carbonate (as CaCO3)	mg/L								< 1	
TDS (Calculated)	mg/L	[500]							818	
Cation Sum	me/L								14.1	
Anion Sum	me/L								14.5	
Ion Balance	%								1.48	
Langlier Index @ 4C	NA								-0.36	
Langlier Index @ 20C	NA								0.04	
Saturation pH @ 4C	NA								7.96	
Saturation pH @ 20C	NA								7.56	
Antimony	ug/L	6							< 2	
Arsenic	ug/L	10							12	
Barium	ug/L	1000							150	
Beryllium	ug/L								< 2	

Table B1. Inorganic Chemistry Data for Wells Sampled in 2004

Parameter	**Unit**	**G / S**	O30	O31	O32	O33	O34	O35	O36	O37
Bismuth	ug/L								< 2	
Boron	ug/L	5000							31	
Cadmium	ug/L	5							< 0.3	
Chromium	ug/L	50							< 2	
Cobalt	ug/L								< 1	
Lead	ug/L	10							< 0.5	
Molybdenum	ug/L								3	
Nickel	ug/L								< 2	
Selenium	ug/L	10							2	
Silver	ug/L								< 0.5	
Strontium	ug/L								3900	
Thallium	ug/L								< 0.1	
Tin	ug/L								< 2	
Titanium	ug/L								< 2	
Uranium	ug/L								7.7	
Vanadium	ug/L								2	
Phosphorus	mg/L								< 0.1	
Total Org. Carbon (UV)	mg/L								< 0.5	

Bold/Highlight: Parameter exceeds GCDWQ

*** Per NSE Guidelines**