Preliminary Groundwater Supply Assessment, Village of Chester Central Water System: Needs Assessment and Options Analysis

Final Report



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ISO 9001
Registered Company

Prepared for:

THE MUNICIPALITY OF CHESTER

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A Photographs of Dug Well Heads in the Chester Area

B Water Well Survey Template

C Water Well Survey Summary Table (files attached)

D Water Quality Data (files attached)

EXECUTIVE SUMMARY

The Village of Chester, Nova Scotia, is serviced by a municipal sewage collection system, but potable water is supplied by individual, private water wells. The Municipality of the District of Chester is seeking to determine whether the Village should be supplied with a municipal central water system. CBCL Limited has completed a Preliminary Groundwater Supply Assessment to determine the availability of safe, clean, and reliable drinking water to the community. Many of the wells in the Village centre are hand dug, rock-lined, and are over 50 years old. Both drilled and dug wells are common throughout the remainder of the community. The setting and construction of shallow wells in the Village suggests that individual water supplies could be prone to shortages and/or bacterial contamination. Bedrock aquifers in the area provide variable yields and are likely to supply water that requires treatment.

CBCL assisted the Municipality in administering a survey of well owners in the Village to determine the extent of potential issues. The survey response rate was 43% (431 of 992), providing a representative sample of conditions in the community. Interruptions to supply were reported by approximately one quarter of survey respondents. Factors contributing to water shortages included drought conditions and intensity of use. Many homeowners report that they rely on water conservation measures to avoid interruptions to supply. In some cases water conservation measures are insufficient, and delivery from outside sources is required.

Raw water samples were collected from 81 homes and businesses as part of the survey. Coliform bacteria were detected in 62% of the supplies sampled (50 of 81), and 100% showed one or more parameter exceeding the Health Canada Guidelines for Canadian Drinking Water Quality. Sixty percent of respondents (209 of 350) use a form of water treatment to provide potable water, and 77% of respondents (265 of 344) reported that they drink the water from their well. Eighty-five percent of respondents (292 of 343) reported that at least one water quality sample had been collected and analyzed prior to this assessment. The complete survey results will be made available by the Municipality under a separate cover.

The survey results and collected water quality data indicate that water quantity and quality problems are common throughout the Village of Chester, but that these issues are, with exceptions, managed at the household level. Clean, safe drinking water is available to Village residents who are diligent in maintaining treatment systems, well conditions, and conducting regular water quality sampling. Many

well owners are required to observe conservation measures, and several properties are without a consistent supply. Shortages show that water resources are stressed in localized parts of the community, and that the potential for further development or increased density within existing dwellings is limited.

Whereas there appears to be no imminent physical requirement, a central water system would improve the consistency and reliability of safe clean drinking water, and would benefit a portion of homeowners and businesses greatly. Conditions in the Village area are not conducive to development of a high capacity well field, however, there are aquifers in the Middle River that have the potential to provide the required yields. A groundwater supply in this area would require a six to seven kilometre pipeline to the Village. Test drilling would be required to determine whether development of a groundwater supply in this area is feasible.

CHAPTER 1 BACKGROUND

1.1 Purpose of Assessment

The Village of Chester is located within the Municipality of the District of Chester, in Lunenburg County, Nova Scotia. Figure 1.1 shows the Village boundary and surrounding communities. Homes and businesses in the Village draw water from private wells, and discharge sewage to a municipal collection system. The density of wells in the area is relatively high, particularly within the Village centre. Figure 1.2 shows property mapping of over 300 homes and businesses in this area, many of which are supplied by shallow unconfined aquifers using hand-dug, rock lined wells.

The Municipality is seeking to determine whether homes within the Village boundary require a municipal central water supply. A central supply would provide a clean, safe and reliable source of water to residents and businesses in the community. A demonstrated need for transition from individual supplies to central water would be based on the security, reliability and quality of existing water sources. This report describes the physical setting of aquifers within the Village and surrounding area, including information on the state of existing shallow groundwater resources, and the potential for development of a central supply.

1.2 Land Use

Land use within the Village boundary is predominantly residential, with the greatest density of homes located within the Village centre shown on Figure 1.3. Residential complexes to the east of the Village centre include the Shoreham Village senior's complex and the Chandler's Cove condominium complex. Light commercial activity (office and retail) is concentrated along Highway 3 / Lighthouse Route / North Street, and in the southeast part of the Village centre (Duke, Pleasant, and Queen Streets). Public facilities in the eastern part of the Village include three schools, a recreation complex, and the Chester Golf Club on the peninsula of Chandler's Cove. Open space, parkland, undeveloped wooded areas, and the southern tip of Stanford Lake comprise the outer parts of the Village, to the north, west, and east. There is light agricultural activity in the eastern-most part of the study area, and surrounding the communities of Marriott's Cove-Haddon Hill-Robinson's Corner.



Legend

Village Boundary

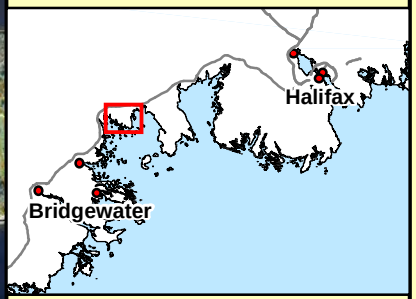


Figure 1.1. Study Area

Municipality of the District of Chester
Water Availability and Needs Assessment

0 0.25 0.5 0.75 1 km

1:35,000 @ 8.5x11

Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

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Legend

Property Boundary

Figure 1.2. Chester Village Centre

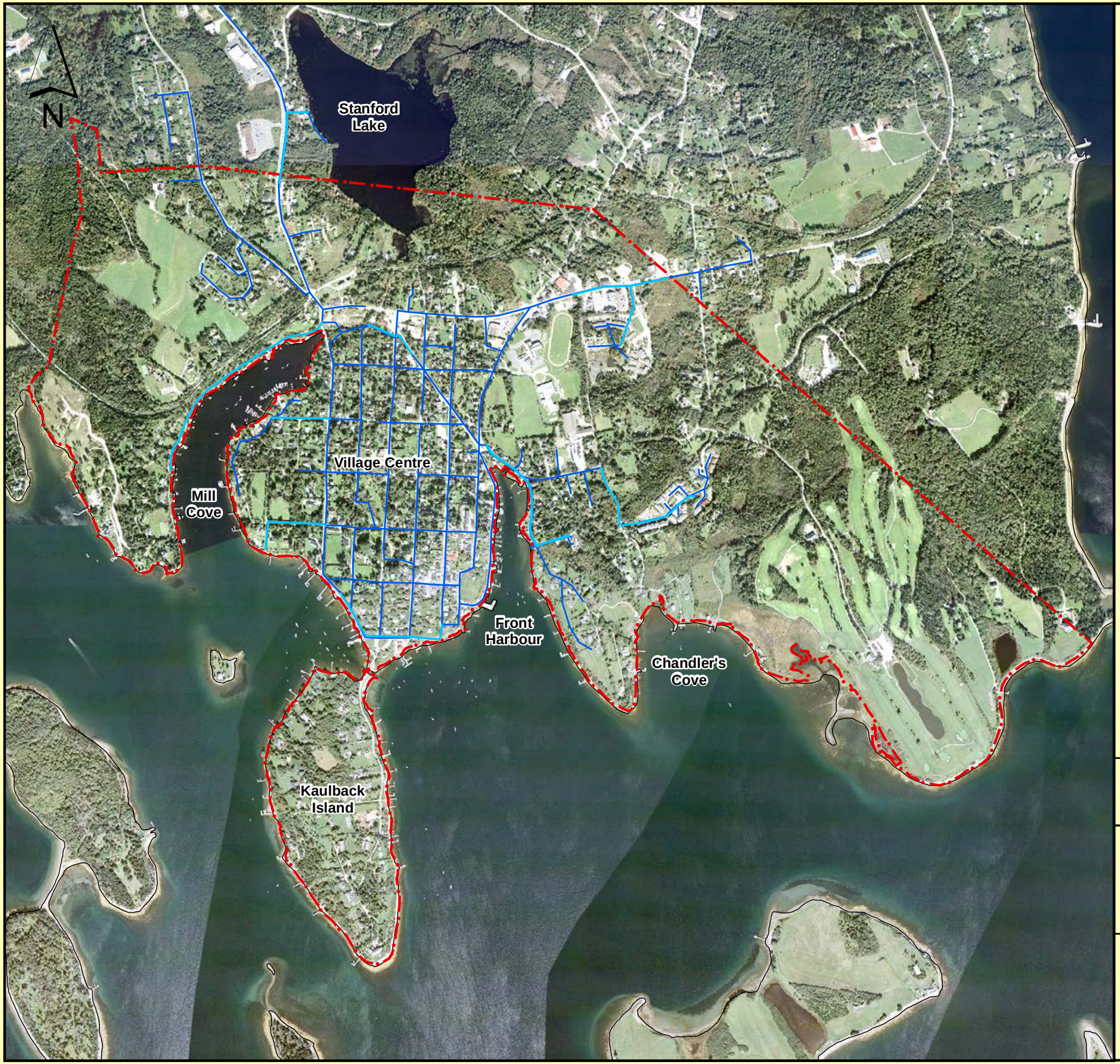
Municipality of the District of Chester
Water Availability and Needs Assessment

0 40 80 120 160 m

1:6,000 @ 8.5x11

Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

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Legend

- Sanitary Force Main
- Sanitary Sewer Line
- Village Boundary

Figure 1.3. Village of Chester

Municipality of the District of Chester
Water Availability and Needs Assessment

0 0.1 0.2 0.3 0.4 km

1:17,000 @ 8.5x11

Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

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CHAPTER 2 PHYSICAL SETTING

2.1 Watershed Mapping

The hydrological setting of the study area is primarily coastal, with local streams draining south into the coves surrounding the Village (Shown on Figure 2.1). The Spectacle Lake-Stanford Lake system drains south through the centre of the community and into Mill Cove. The Middle River watershed forms the western extent of the study area, traversing an area of potential interest (discussed below).

2.2 Geology Mapping

2.2.1 Quaternary Geology

Figure 2.2 shows quaternary geology mapping in the study area. The area is predominated by a hummocky ground moraine, which is reflected in the locally variable and hilly terrain. Larger, more regional ridges have been mapped as drumlins, and the regional upland to the east of the Middle River is mapped as glaciofluvial material. Much of the land underlying the Village centre and Kaulback Island peninsula is mapped as silty till.



Stony Sand Till, Evergreen Lane, Middle River

Figure 2.3 provides a more detailed map of till facies in the area. Occurrences of compact stony material (Hartlen Till) coincide generally with drumlinoid and silty till features shown in previous mapping, including much of the area within the Village boundary. Compact glacial till is not typically associated with aquifers of significant horizontal or vertical extent, but seams of granular material within this type of deposit can provide water sufficient to supply single households. Figure 2.3 indicates that zones to the north, west, and east of the Village are characterized by loose, sandy, stony material. These areas are potential targets for groundwater exploration work.



Legend

- Village Boundary
- Rivers and Streams
- Watershed Boundaries

Figure 2.1. Provincial Watershed Mapping

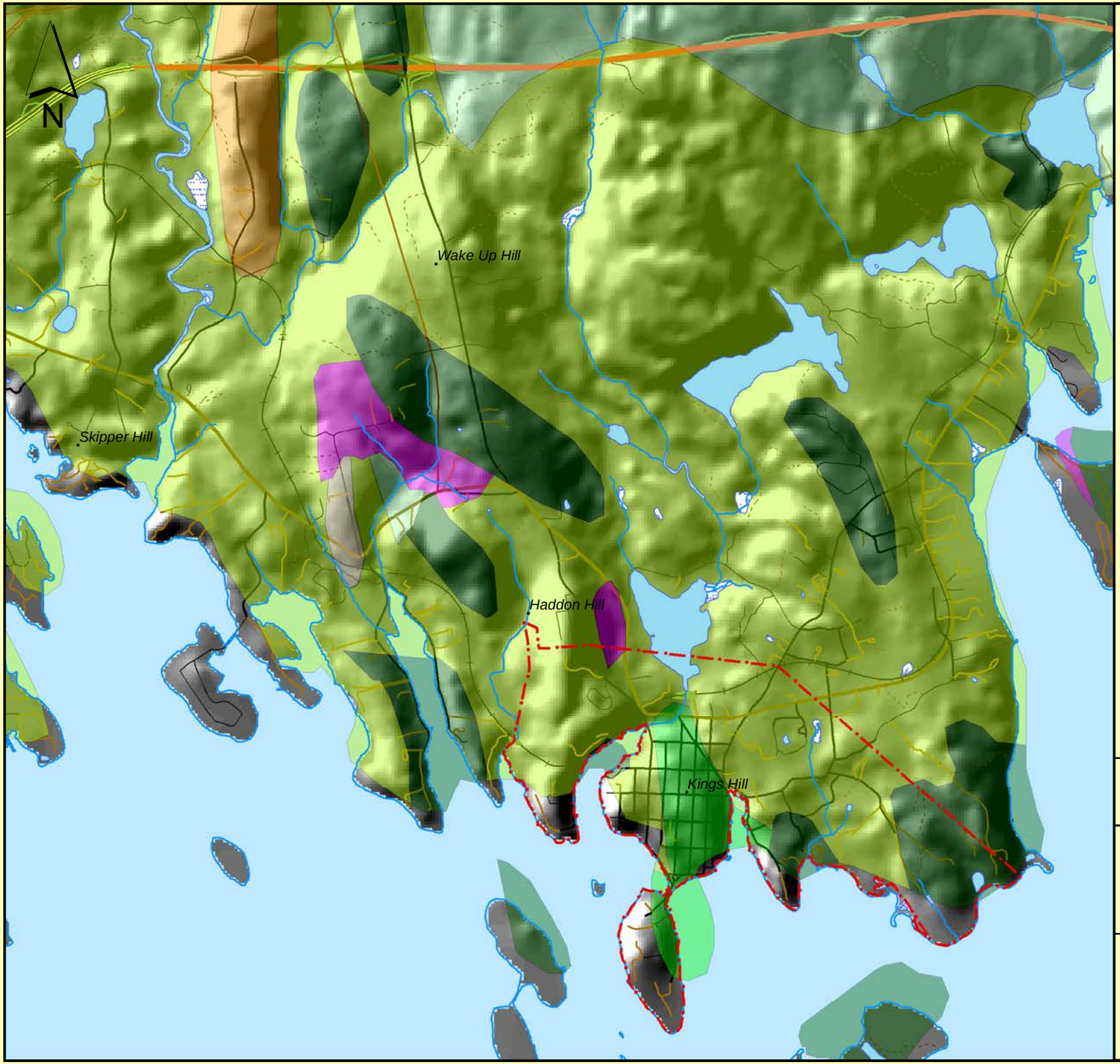
Municipality of the District of Chester
Water Availability and Needs Assessment

0 0.25 0.5 0.75 1 km

1:35,000 @ 8.5x11

Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

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Legend

- Village Boundary
- Alluvial Deposits
- Glaciofluvial Deposits (Outwash Fans)
- Hummocky Ground Morraine
- Stony Till Plain (Ground Moraine)
- Silty Till Plain (Ground Moraine)
- Silty Drumlin (Drumlin Facies)
- Exposed Bedrock

Figure 2.2. Quaternary Geology Mapping

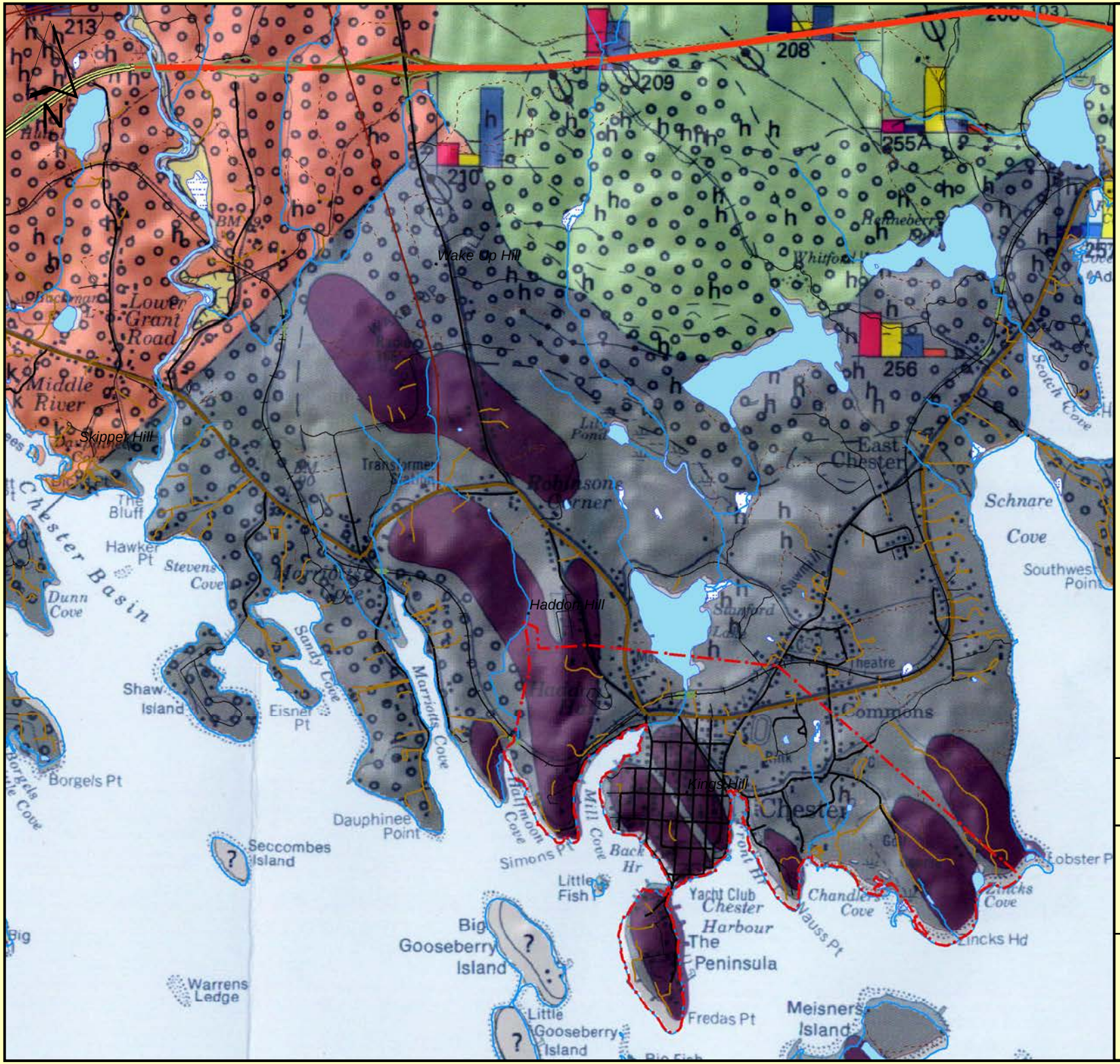
Municipality of the District of Chester
Water Availability and Needs Assessment

0 0.25 0.5 0.75 1 km

1:35,000 @ 8.5x11

Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

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Legend

- Village Boundary
- Granite Till C
  structured sandy matrix with bedded sand and gravel lenses
- Granite Till B
  loose to moderately compact sand with silt and clay
- Greywacke Till C
  bedded to massive sand and gravel lenses
- Slate Till C
  structured sandy matrix and interbedded sands
- Slate Till B
  loose stony sandy matrix
- Hartlen Till
  compact; stony; dark grey
- Alluvial Deposits

Figure 2.3. Till Facies Mapping

Municipality of the District of Chester
Water Availability and Needs Assessment

0 0.25 0.5 0.75 1 km

1:35,000 @ 8.5x11

Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

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2.2.2 Bedrock Geology

Figure 2.4 shows bedrock geology mapping for the study area. The Village is underlain predominantly by fine-grained metamorphic rocks of the Halifax Formation. The Feltzen Member, which underlies the Village Centre and areas to the west, exhibits sequences of metasandstone. To the west and within the zone underlying the Middle River there is Windsor Group rock, composed locally of limestone, gypsum and conglomerate. Anecdotal reports have suggested that there could be adequate thicknesses of limestone to provide moderate to good yields from wells drilled in this area.



Sandy Matrix of Area Tills

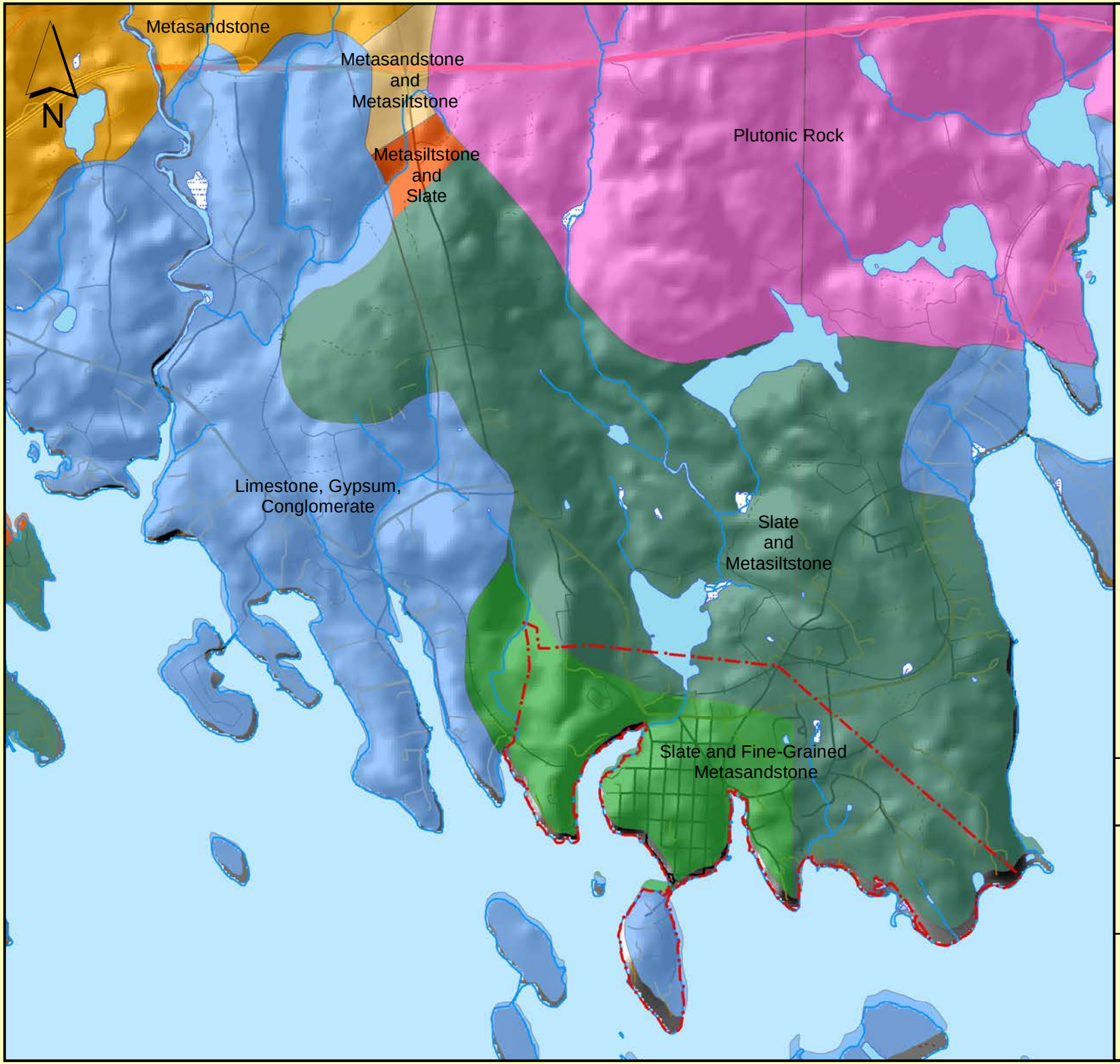
2.3 Provincial Well Data

2.3.1 Water Well Records

Figure 2.5 shows the locations of Water Well Records in the study area. The provincial database includes many of the drilled wells in the study area, but only a small subset of dug wells, particularly in the Village centre. A majority of the wells shown on Figure 2.5 are installed in slate bedrock. Table 2.1 provides a summary of drilled water well characteristics.

Table 2.1: Summary of Drilled Water Well Database Records

	Depth (m)	Casing Length (m)	Depth to Bedrock (m)	Depth to Static Water Level (m)	Airlift Yield (L/min)	Airlift Yield (m^3/d)
# Records with Data	233	195	182	147	217	217
Minimum	15	1.5	1.0	1.0	0.05	0
25^{th} percentile	55	9	3.0	3.0	11	16
Median	72	12	6.0	6.0	23	33
75^{th} percentile	91	28	24	12	45	65
Maximum	155	84	80	43	454	654



Legend

- Village Boundary

UNIT NAME

- Halifax Formation
- Cunard Member
- Feltzen Member
- Moshers Island Member
- Green Harbour Formation
- Tancook Member
- South Mountain
- South Mountain
- Windsor Group

Figure 2.4. Bedrock Geology Mapping

Municipality of the District of Chester
Water Availability and Needs Assessment

0 0.25 0.5 0.75 1 km

1:35,000 @ 8.5x11

Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

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Legend

Village Boundary

Well Logs Database

- Drilled
- Dug
- Pumping Test
- Water Chemistry

Figure 2.5. Provinical Well Records

Municipality of the District of Chester
Water Availability and Needs Assessment

0 0.25 0.5 0.75 1 km

1:35,000 @ 8.5x11

Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

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Wells in the area are generally between 15 and 91 metres deep, and are constructed with at least 9 metres of casing to seal off the overburden material. The till thickness varies significantly, and is generally from 3 to 24 metres thick, but reaches up to 80 metres in selected locations. Drillers report that some wells in the Middle River area have been constructed by installing a steel casing over the full depth of the overburden, and perforating the casing in zones where granular material was encountered. Wells of this nature may also be partially back-filled with pea gravel to discourage heaving of the formation into the well casing.

Reported airlift yields in bedrock wells are low to moderate, and should generally be capable of sustaining a single household. Figure 2.6 provides a summary of airlift yield information. The data suggest that more than half of the bedrock wells in the study area could provide 20 L/min or more. Reported short-term yields from dug wells are much higher, but are based on the driller's test pumping rate, and generally do not reflect longer term sustainability and water table effects. Additional information on dug wells is presented in Chapter 3.

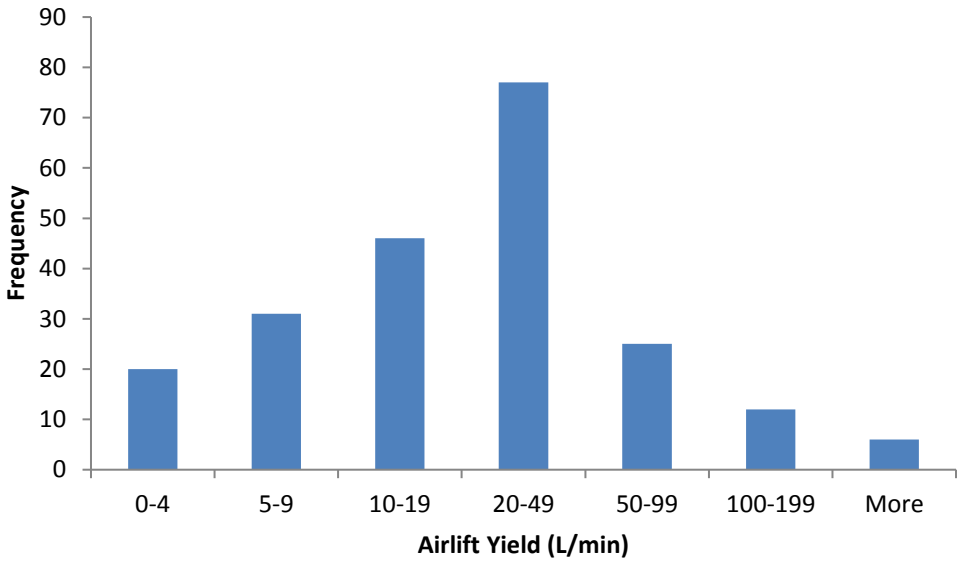


Figure 2.6: Histogram of Airlift Yields

2.3.2 Aquifer Tests

Aquifer testing data is available for 13 wells in the study area across 5 locations, summarized in Table 2.2. The aquifer transmissivity varied within and between the five locations. Whereas the majority of tested wells showed low to moderate potential for long-term yield ($T < 10\ m^2/d$), two wells in the area showed potential to supply facilities of moderate sizes ($T = 30$ and $43\ m^2/d$). One of these higher potential wells was installed in a surficial aquifer.

Table 2.2. Summary of Aquifer Testing Data

Pumping Test ID	NSE Well Number	Well ID	Test For	Test Start	Geology (HU)	Groundwater Region	Well Depth (m)	Static (m)	Pump setting (m)
LUN-14			The Old Wharf		WI	Carbonate/ Evaporite	74.7	-0.03	
LUN-24			Chester High School		M-HX	Metamorphic	110	6.50	
LUN-38.1	971737	Well #1	Chandlers Cove	9/20/1997	M-HX	Metamorphic	89.9	1.21	76
LUN-38.2		Well #2	Chandlers Cove	9/24/1997	M-HX	Metamorphic	45.7	1.02	39
LUN-38.3		TW3	Chandlers Cove	6/4/2003	M-HX	Metamorphic	61.9	2.38	47
LUN-39	970771		Tim Hortons		M-HX	Metamorphic	104	2.84	
LUN-41.1	011403	Well #1	Shoreham Village	4/26/2006	M-HX	Metamorphic	124	2.96	
LUN-41.2	011359	Well #2	Shoreham Village	4/26/2006	M-HX	Metamorphic	137	2.04	
LUN-41.3	030420	Well #3	Shoreham Village	4/26/2006	GLTPC	Overburden	6.10	2.56	
LUN-41.4	011358	Well #4	Shoreham Village	4/26/2006	M-HX	Metamorphic	128	1.69	
LUN-43.1	090526	Well #5	Shoreham Village	1/12/2010	M-HX	Metamorphic	122	2.40	64
LUN-43.2	090523	Well #6	Shoreham Village	1/19/2010	M-HX	Metamorphic	122	2.40	63
LUN-9	751349	Well #1	Shoreham Village		M-HX	Metamorphic	83.8	2.40	

M-HX Meguma Group-Halifax Formation (slate)
WI Windsor Group-Limestone, Gypsum, Conglomerate
GLTPC Glaciolacustrine, Till Plains, Colluvial

Table 2.2 (cont'd). Summary of Aquifer Testing Data

Pumping Test ID	Average Pumping Rate (m3/d)	Available Drawdown (m)	Max Drawdown (m)	Total Recovery (m)	Recovery (mins)	Hydraulic Conductivity (m/d)	Transmissivity (apparent, m2/d)	Specific Capacity (m2/d)	Long-Term Yield (Q20, m3/d)
LUN-14	56	66	8.5				3.3	6.7	118
LUN-24	33	94	44				0.5	0.86	27
LUN-38.1	177	75	9.4	9	840	5	43	18.8	39
LUN-38.2	31	38	2.6	2	60	2	12	12.0	
LUN-38.3	53	45	14.0	13	140	1	6.5	3.8	52
LUN-39	28	88	17.3			6	0.6	1.6	20
LUN-41.1	22	121	44	38	450	2	0.26		17
LUN-41.2	8	135	115			1	0.02		1
LUN-41.3	118	6	2.9	0	240		30		105
LUN-41.4	23	126	33	31	397	3	0.37		26
LUN-43.1	44	39	27	26	240	8	8.8	2.0	52
LUN-43.2	16	42	28	28	240	5	0.24	0.58	16
LUN-9	114	72	37			2	2.2	3.0	87

Transmissivity data support indications from the airlift yield data that well yields can be expected to vary significantly across the study area. Whereas the highest producing wells may be capable of supporting a larger business or residential complex, others may be capable of supporting only a small household. This is consistent with the presence of isolated individual fractures that may extend for some distance, but which are unlikely to be well interconnected, and which do not intersect all wells drilled on a given property. None of the wells tested would be capable of supplying the Village as a stand-alone well, however, the aquifer testing database did not include a well installed in the granular material in the Middle River area.

2.3.3 Water Quality Database

Table 2.3 provides a summary of water quality data available from the provincial database. The hardness of water in the area is low to moderate, and shows moderate concentrations of sulphate, chloride, and other dissolved solids. The dissolved solids content at one location was high ('Reg607'). Iron and manganese concentrations appear to be elevated in all but one well, and exceed the Guidelines for Canadian Drinking Water Quality (GCDWQ) of 300 ug/L and 50 ug/L respectively. Arsenic and uranium concentrations are below the GCDWQ in available sample data. Additional water quality data are discussed in Chapter 3.

2.4 Field Reconnaissance

2.4.1 Land Forms

A windshield survey of the study area confirmed the presence of many local topographic features associated with glacial activity. The landscape in and around the Village is dominated by numerous ridges, knobs, kettles, and drumlinoid features. The Village centre is situated on two drumlinoid features divided by central swale. Geology mapping indicates that the composition of many of these features is granular but poorly sorted material. Numerous borrow pits and exposures along roadsides confirmed the coarse-grained nature of the material in the Chester area. This is consistent with the reliance of most homes in the area on dug wells.



Borrow Pit on Evergreen Lane, Middle River

Table 2.3. Summary of Water Quality Data

Sample ID	Ptest252	Ptest253	Ptest254	Ptest537	Ptest538	Reg1798	Reg3220	Reg3222	Reg607	Reg761
Sampled Date	4/26/2006	4/26/2006	4/26/2006	1/14/2010	1/19/2010	9/11/2006	9/20/2010	9/20/2010	12/8/2003	2/2/2005
Groundwater Region	M-HX	GLTPC	M-HX	M-HX	M-HX	M-HX	M-HX	M-HX	M-HX	GLTPC
Alk (mg/L)	2.5	2.5	64	42	67	36	72	30	45	0.5
HCO3 (mg/L)	0.5	0.5	64	42	67	36	72	30	45	
CO3 (mg/L)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.21	
Na (mg/L)	41	42	21	22	44	110	162	95	224	34
K (mg/L)	2.5	2.5	1.3	1.6	1.7	1.3	0.84	0.36	3	1.3
Ca (mg/L)	22	22	27	49	46	40	7	0	7	11
Mg (mg/L)	3.9	4	2.4	4.5	4.7	4.3	4.6	0.16	6.1	2.9
SO4 (mg/L)	68	66	35	84	33	32	37	48	740	38
Cl (mg/L)	75	74	17	53	92	220	190	93	780	42
Hrd (mg/L)	70	73	76	140	130	120	25	3	53	39
TDS (mg/L)	225	226	149	254	278	471	449	264	885	156
pH	5	4	7	7	6	6	7	6	7	7
NO3 + NO2N (mg/L)	0.35	0.33	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.22
As (ug/L)	1	1	1	1	1	1	0	0	10	1
U (ug/L)	1.5	1.6	0.2	0.1	0.3	1.2	0.05	0.05	1	1
Fe (ug/L)	2900	3000	860	6200	7600	30 000	356	138	8143	391
Mn (ug/L)	650	660	51	150	250	800	66	11		64

M-HX Meguma Group-Halifax Formation (slate)

GLTPC Glaciolacustrine, Till Plains, Colluvial

Larger topographic features in the Middle River area are also consistent with quaternary geology mapping, including a possible glaciofluvial feature on the east side of the river, extending from south to north toward Highway 103. The terrain to the west of the river was also suggestive of extensive thicknesses of granular material, including a large terrace on Resby Lane. Land in this area has been cleared, and may be intended for residential development.



Terrace Overlooking Chester Connection Trail from Resby Lane, Middle River

2.4.2 Private Wells

Dug wells were identified at many of the homes in the study area, including all areas within the Village of Chester, Middle River, and much of the area to the northeast of the Village. In the Village centre dug wells were often ornamented with beach rock. Anecdotal reports of well construction suggest that some or most of these wells are hand dug and rock-lined below the ground surface. Wells of this type can be several decades old and in the study area many of the wells are covered with wood or metal plates that form an incomplete seal. Wells constructed with concrete crocks were also observed in varying apparent ages and conditions. Most dug wells in the study area have likely not been completed with a concrete apron below the ground surface, a feature which helps to block short circuit pathways between the ground surface and well bore. Examples of dug well heads in Chester are provided in Appendix A.

The NSE database contained two records of wells that were completed in an extensive thickness of granular material, and showed excellent airlift yields. The location of each of each well was confirmed during field reconnaissance. The first was located near McInnis Rd on the east side of the Middle River, and may be associated with the glaciofluvial feature shown in provincial mapping. The second well was located on Resby Lane, to the west of the Middle River on the terrace described in section 2.4.1.

2.4.3 Potential Sources of Contamination

Potential land uses of concern are limited to a cemetery located on the southwest part of the Village centre, and an Irving Fuel Station at the intersection of Highway 3 and Duke Street. Nova Scotia Transportation and Public Works operates a depot on Lighthouse Road, near the intersection with Marina Drive. The Village's sewage treatment plant is located on Nauss Point Road, 300 metres south of the recreation centre.

On-site sewage disposal systems have the potential to affect neighbouring down gradient wells, but the density of these systems is not expected to result in problems in most parts of the study area. The greatest densities of homes outside of the Village sewage collection system are noted on the Kaulback Island peninsula and in Marriott's Cove, Robinson's Corner, Chester Commons Road, Chester Downs Road, and Maple Street-Pine Street.

2.5 Hydrogeological Setting

Shallow flow systems in the study area are expected to be localized, drawing groundwater recharge from the zones in close proximity to each topographic high, and coinciding with local sub-watersheds. The granular nature of surface soils and underlying material is expected to facilitate infiltration, and result in local, shallow groundwater flow systems. Dug wells intersecting these shallow flow systems are not likely to be connected to source water or wells at distances greater than a few hundred metres. Groundwater use in the Village centre is expected to be influenced directly by fluctuations in the water table, which should respond readily to rain events, spring melt water, and seasonal changes in precipitation. Decreased precipitation and increased evapotranspiration are likely to result in measurable declines in the water table and availability of water to the wells that are shallowest, and/or which are located at the highest elevations of the Village Centre. The density of dug wells may be great enough to induce cumulative drawdown in some parts of the Village centre.

Geology mapping, landforms, and water well records in the Middle River area suggest that larger, more extensive surficial aquifers may be present in the Marriott's Cove-Middle River area. Mapping by the Nova Scotia Department of Natural Resources (NSDNR) has identified a zone that could represent a significant surficial aquifer, based on reported depths of granular material, and elevations of the regional bedrock surface (Kennedy, 2014). Figure 2.7 shows this zone and depths of granular material from water well records. This deposit may be continuous, or represent two or more linear features running from north to south through the study area.



Granular Material in an Abandoned Pit, Mapped as Glaciofluvial Outwash, Northeast Middle River

More regional flow systems are likely to be observed in the metamorphic and evaporite bedrock underlying area tills. The source of water to wells drilled in these bedrock systems would tend to be drawn from greater distances and/or larger catchments. Wells installed in Halifax Formation slates often rely on a limited set of fractures with limited connectivity to surrounding wells and/or features. The resulting yields and potential for cumulative interference is highly case-specific. Metasandstones underlying the Village centre could improve the yield and quality of water from wells that draw from the Feltzen Member. Wells drilled into the evaporite rock found in the western part of the study area should produce better yields than those in the slate, but may exhibit high dissolved solids content associated with gypsum rock.



Legend

- Granular Material Thickness (m) from Well Log
- Marriott's Cove Deposit(s), DNR

Figure 2.7. Potential Aquifer(s) in Marriott's Cove Area

Municipality of the District of Chester
Water Availability and Needs Assessment

0 0.2 0.4 0.6 0.8 km

1:30,000 @ 8.5x11

Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

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Many homes in the Chester area draw water from wells adjacent to the coastline. Whereas most dug wells will draw water from local, shallow catchments with low potential to be influenced by sea water, drilled wells in these zones are at higher risk. Mapping by NSDNR indicates that drilled wells in the Village Centre fall into a high risk category (Kennedy, 2012). Remaining properties within the Village have been categorized as 'medium' risk. The Village centre and Kaulback Island peninsula are surrounded by coastline; the risk of saltwater intrusion to these wells depends on cumulative extraction rates, connectivity of fracture sets, and the position of the saltwater interface in intermediate and regional flow systems. Saltwater effects can furthermore be difficult to distinguish from minerals imparted by the host rock for wells installed in Windsor Group rocks. Salt water intrusion effects are discussed further in Section 3.4.

Drought conditions prevailed in 2016 throughout southwest Nova Scotia (Kennedy *et al.*, 2017). Dry wells and water shortages were documented in many communities, and led to production by NSDNR of a groundwater drought index map (NSDNR, 2016). The drought index within the Village boundary was mapped as moderate, however, much of Lunenburg County to the southwest fell into the 'high risk' category. The risk of water shortage for Village residents is subject to additional local factors such as well construction, depth, intensity of use (individual and cumulative), and the thickness, catchment, and setting of each aquifer. For the purposes of this assessment, a water shortage is defined as an event when water is unavailable when a tap is turned on. In lieu of mechanical problems this is caused when the water level in a well drops below the pump intake and all available storage is drained. The length of a shortage may vary from hours to months. Whereas occasional shortages of several hours are due to overuse, longer or more frequent shortages tend to be related to depletion and/or reduced recharge of the aquifer.

Existing climate models suggest that the rate and frequency of extreme weather events is increasing in Nova Scotia, which would indicate that drought events such as those experienced in 2016 are likely to be repeated. Climate and well data compiled by NSDNR (Kennedy *et al.*, 2017) appears to support this likelihood. Periodic, intensive reductions in recharge to shallow aquifers in Chester are likely to continue to cause shortages, potentially with increased frequency and/or duration in future years.

CHAPTER 3 WELL SURVEY

3.1 Survey Design

3.1.1 Survey Goal

CBCL designed a homeowner well survey in collaboration with the Municipality. The survey was based on templates from Nova Scotia Environment (NSE) and Nova Scotia Transportation and Infrastructure Renewal (NSTIR), modified to meet the objectives of the current work. The primary goal of the survey was to determine the locations and density of dug and drilled wells, and to obtain self-reported data on water shortages, water quality issues, use of water treatment, well upgrades and repairs, and the condition/age of Chester wells. The survey also provided well owners with an opportunity to participate in a water quality sampling program, and to provide comments on their well system and/or the condition of water resources in the Village area. A tabulation of this data was used to assess whether there is a physical need to supply the Village with a municipal central water supply. An assessment of the socioeconomic benefits and costs of implementing central water was outside the scope of this work. Homeowner comments and opinions from the Water Well Survey have been processed under a separate cover.

3.1.2 Survey Responses

The well owner survey template is provided in Appendix B. The Municipality mailed the survey to each civic address / property owner within the Village boundary, in addition to advertising a web-based version of the survey. Responses were tabulated by the Municipality and analyzed by CBCL Limited.

Table 3.1 provides a summary of survey responses. A total of 431 landowners responded to the survey, of which 395 elected to complete the survey. The 43% rate of response is excellent, providing a representative sample of the Village as a whole. Respondents were provided the option to return the survey with comments, but without completing the survey. Thirty-six respondents selected this option. The Municipality allotted resources to collect water quality samples from up to 80 homes responding to the survey. A total of 255 homeowners were willing to participate in the sampling program. As some of the 395 questionnaires were more complete than others, percentages were calculated based on the number of responses that provided data for each individual parameter (i.e. blanks did not affect these calculations).

Table 3.1: Summary of Survey Responses

	No.	%
Total Surveys Mailed	992	
Responses Received*	431	43%
Opted Out of Survey	36	4%
Opted in for Water Quality Sampling	255	26%
Water Quality Samples Collected	80	8%

*does not include apparent responses from web survey that contained no data

3.1.3 Selection of Water Quality Sampling Locations

Wells were selected for water quality sampling based on survey responses. The following criteria were used to obtain a representative cross-section of available wells.



Typical Dug Well

Geology – The variability of the bedrock geology was assessed with respect to the location of drilled well respondents, and the variability of the surficial geology was assessed with respect to the location of dug well respondents. As responses were evenly distributed and covered all potential geology types within the Village, no filtering for geology was used in the selection process.

Well Construction – The proportion of drilled and dug wells within the Village boundary was maintained for the sampling program. Consequently, a higher proportion of dug wells was sampled, particularly in the Village centre (see Section 3.2.1).

Location/Distribution – Sampling locations were spaced across the Village area, with a density in proportion to well locations. Wells in each sub-watershed/local flow system were represented. Due to the vulnerability of wells in coastal locations, these wells received additional preference.



Dug Well Serving a Commercial Building

Building Use – All commercial buildings responding to the survey were included in the sampling program.

Substitutions – Wells that were initially selected for sampling but which could not be sampled (e.g. raw tap unavailable or owner not home) were

replaced with the closest well of similar construction.

3.2 Well Construction

3.2.1 Well Type

Figure 3.1 shows the locations of respondents with drilled and dug wells. More than half of the wells within the Village boundary were dug wells; this proportion increased to 77% of all wells in the Village centre and on the Kaulback Island peninsula.

3.2.2 Condition and Age

The condition and quality of water supplied by a well depends on the age and condition of the well. In particular the cap and condition of the casing above ground surface play an important role in preventing surface water from carrying bacteria into the well, the surrounding aquifer, and consequently to adjacent wells. The following comments provide indications of the well conditions in the Village.

Age – The median reported age of dug wells is 47 years, with several wells reported to be more than 100 years old. The age of over 100 other dug wells was reported as "unknown", suggesting that the age of these wells may also exceed 50 years. The median age of drilled wells is 18 years. Dug wells in the area that are more than 50 years old are likely to be rock-lined; rock-lined wells are commonly porous and/or cracked, providing openings and pathways that admit surface water and pathogens into the well. 54% of responding dug well owners described their well as rock-lined.

Cover – The covers of rock-lined wells are likewise seldom insect and rodent-proof, providing additional pathways for vermin and bacteria to enter the well. 62% of responding dug well owners (136 of 221) described the cover as concrete. Other covers are likely to be metal or wooden plates. Most drilled wells were reported as completed with a sealed metal or plastic cap.



Rock-lined Well with Concrete Cover, Unsealed

Surface Casing – Surface casings were generally reported to be visible, with some part of the casing sticking up above the ground surface. 31 wells were reported to be in pits, buried, or unknown. The ground surface around newer dug well installations is mounded to discourage run-off from contacting the well casing and entering the annular space between the well and formation. 61% of responding dug well owners (81 of 209) indicated that the ground is not mounded around their well.

Although well ages and conditions are variable, many dug wells in the Chester area are vulnerable to surface water and vermin. The potential for and presence of coliform bacteria in well water supplies is discussed further in Section 3.4.



Legend

Village Boundary

Well Type

- Drilled
- Drilled and Dug
- Dug
- Cistern
- Other / Communal
- No Well

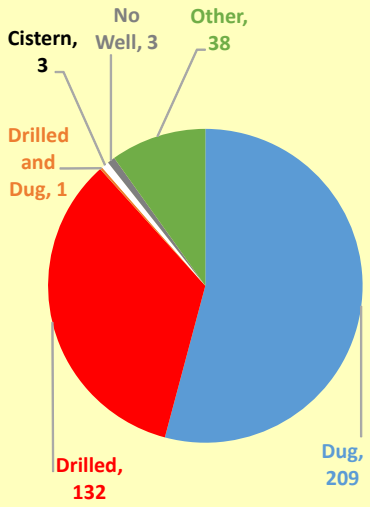


Figure 3.1.
Survey Responses: Well Type(s)

Municipality of the District of Chester
Water Availability and Needs Assessment

0 0.1 0.2 0.3 0.4 km

1:17,000 @ 8.5x11

Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

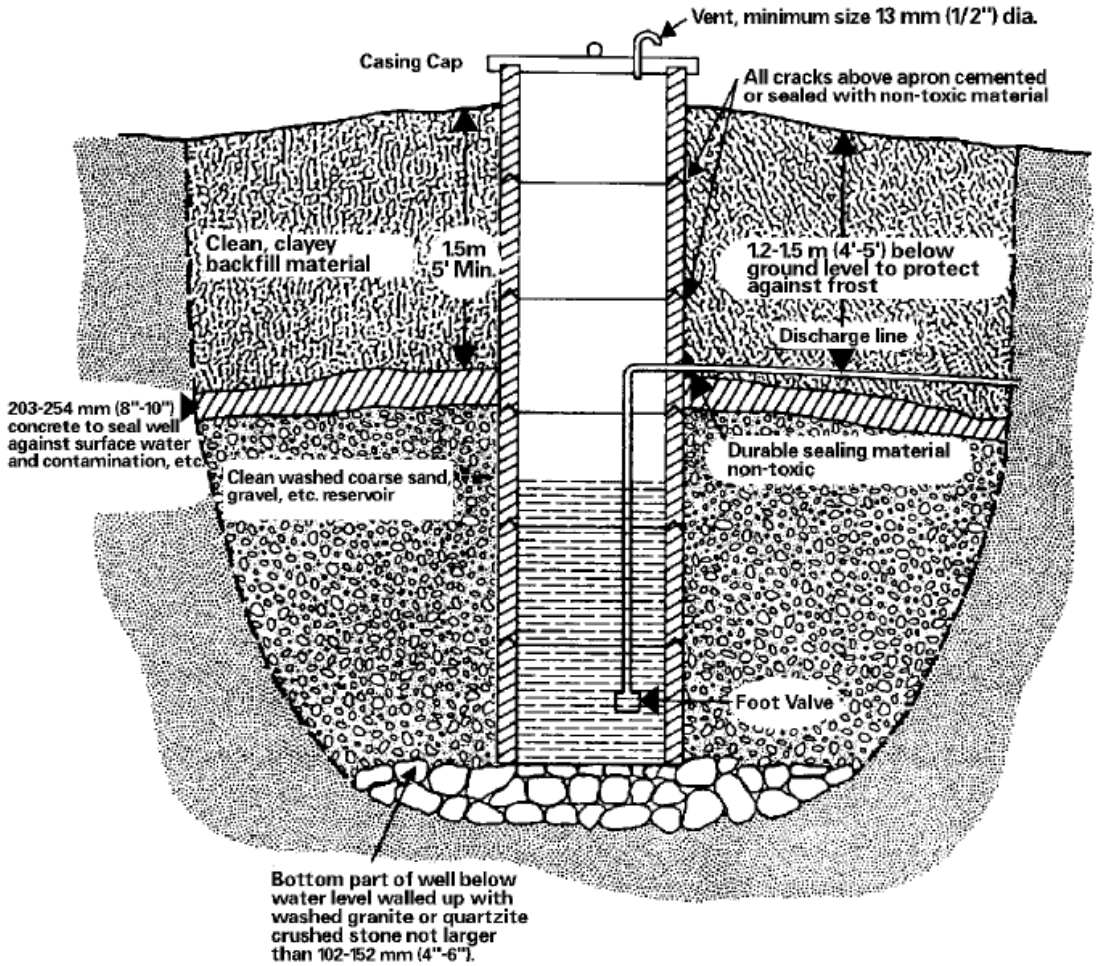
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Consulting Engineers

3.2.3 Water Well Regulations

Provisions for the construction of dug wells were incorporated into the Nova Scotia Well Drilling Regulations in 1972, with licensing for well diggers required by 1967 (Cross, 2017). Requirements for construction included:

- A sealed, water-tight well casing of at least 6 feet;
- A minimum of six inches of casing above the ground surface;
- Surface drainage to be directed away from the well head; and
- A six-inch thick concrete apron extending at least 3 feet away from the well in all directions.

In 1992 a requirement to place the apron below the frost line was introduced, and in 2007 additional material requirements were specified for the casing, joint sealant, apron, water for construction, cap/cover, and filter pack material. Dug wells older than 50 years and rock-lined wells installed after 1967 are unlikely to meet the basic requirements of the Water Well Regulations. Although there is no requirement for these wells to be upgraded, deficiencies imply that the quality of water drawn from these wells may be impaired.



Typical Dug Well Construction (NSE, 2004)

3.3 Water Quantity

3.3.1 User Types

Annual water use varies in the Chester area due to the number of seasonal homes and rental cottages. Figure 3.2 shows the division between part-time and full-time occupancy. Well owners reporting "other" include rental homes, businesses, and apartment/condo complexes. Approximately one quarter of the Village residents are part-time users, who would tend to increase demand during the summer months.

Commercial users that serve many customers per day tend to increase demand. Figure 3.3 shows the location of respondents reporting use of a well for a business. Businesses are concentrated along Highway 3 and in the Village centre. The most intensive water users are likely to be restaurants operating during the summer months. The effects of this increased demand on area aquifers are likely to be localized.

3.3.2 Water Shortages

Drought conditions in 2016 resulted in lowered water tables and water shortages for many private well owners (Kennedy and Drage, 2016). User-reported shortages are shown on Figure 3.4. 23% of responding well owners reported a shortage in 2016 (73 of 317). Reported shortages in years preceding 2016 were nearly identical. Of those reporting a water shortage, 10 homes were using drilled wells, and 63 homes were using dug wells or cisterns. Dug well owners reported extensive measures to conserve water; in spite of conservation measures some respondents experienced an interruption in supply for up to four months in 2016. Shortages show that water resources are stressed in localized parts of the community, and that the potential for further development is limited.



Legend

- Full Time
- Part Time
- Other
- Village Boundary

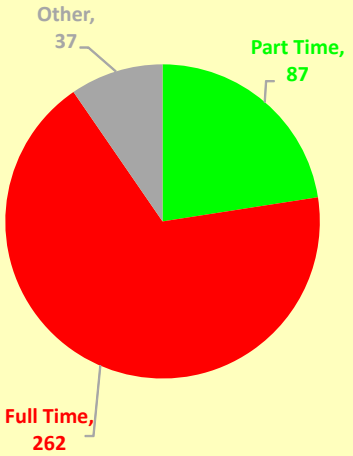


Figure 3.2.
Occupancy Type

Municipality of the District of Chester
Water Availability and Needs Assessment

0 0.1 0.2 0.3 0.4 km

1:17,000 @ 8.5x11

Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

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Legend

- Residential
- Residential-Commercial
- Commercial / Institutional
- Village Boundary

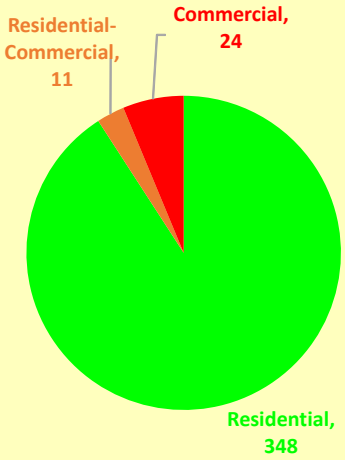


Figure 3.3.
Building Use

Municipality of the District of Chester
Water Availability and Needs Assessment

0 0.1 0.2 0.3 0.4 km

1:17,000 @ 8.5x11

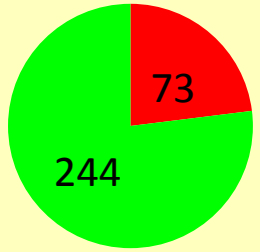
Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

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Legend

- Shortage in 2016
- No Shortage in 2016
- N/A
- Village Boundary



- Shortage
- No Shortage

Figure 3.4.
Water Shortages

Municipality of the District of Chester
Water Availability and Needs Assessment

0 0.1 0.2 0.3 0.4 km

1:17,000 @ 8.5x11

Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

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In periods of water shortage, homeowners may choose to have water delivered by a water hauler. In 2016 the Municipality also provided water to residents who experienced shortages. The use of outside water sources provides an additional measure of water shortages in a given year. Figure 3.5 shows the proportion of respondents who indicated that water was delivered in 2016, including those who registered with the municipality to receive water. 24% of homes required supplemental water, which is consistent with the reported rate of shortages. Eighteen respondents indicated that trucked-in water is their primary source of water.

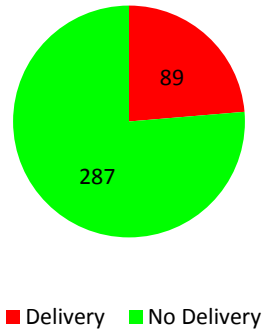


Figure 3.5: Respondents Receiving Water Deliveries from Private Haulers or the Municipality in 2016

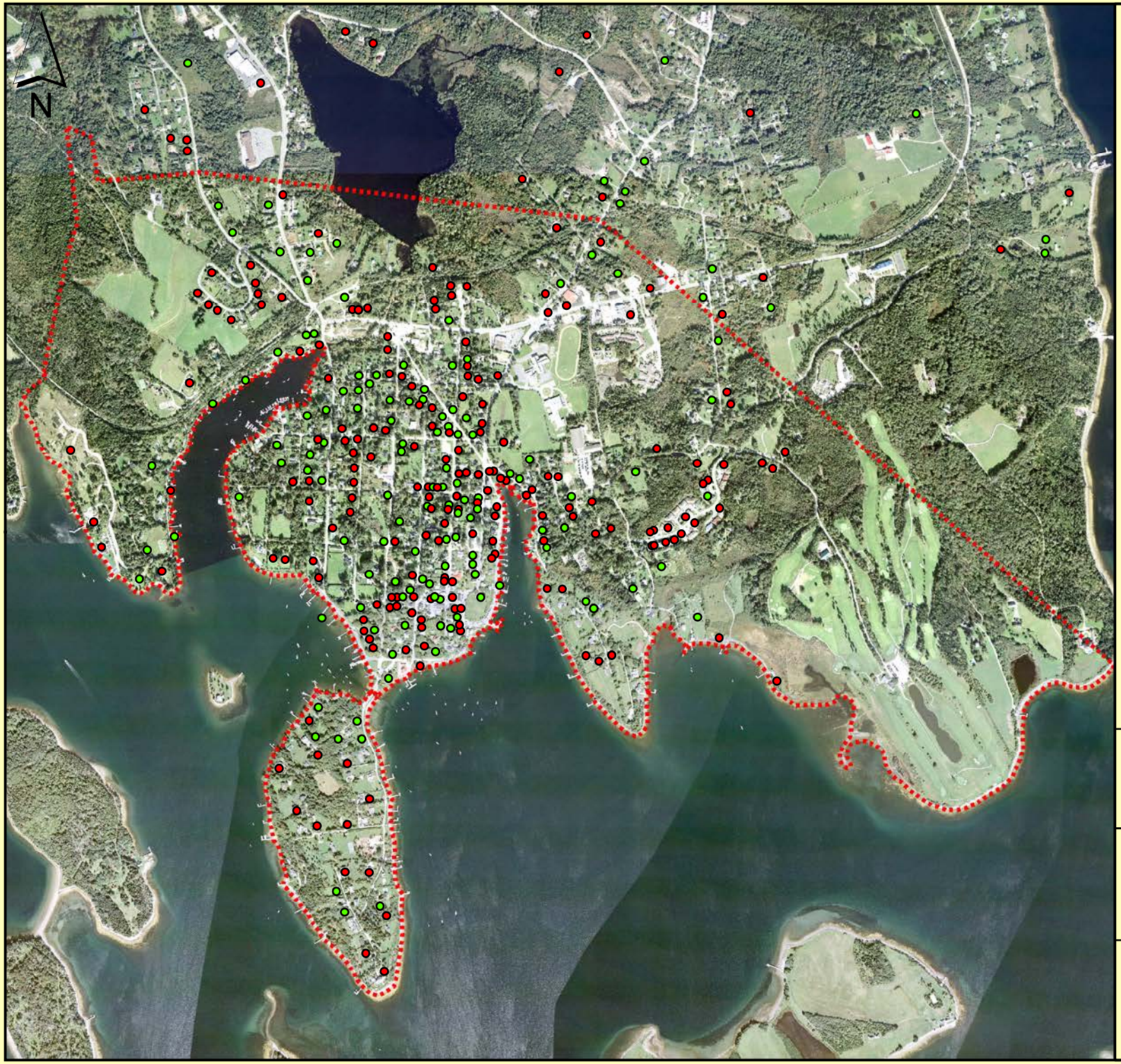
Many water deliveries are made directly into a homeowner's well. In periods of drought the porous formation that supplies water to the well is unsaturated. Water added to the well percolates downward through the formation until reaching the water table. A significant proportion of this delivered water is likely to become inaccessible by the well, and thus does not contribute to the homeowner's supply. 45% of respondents (28 of 61) indicated that water was delivered directly into a well. A preferred and more cost effective method is to have the water delivered into a properly maintained storage tank.

3.4 Water Quality Survey

3.4.1 Survey Responses

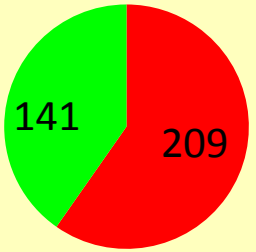
Figure 3.6 shows the locations of homes operating a treatment system. 60% of respondents (209 of 350) indicated that a treatment system is in use. Predominant forms of treatment were a UV light to eliminate pathogens (45), and softening to address hardness, including iron and manganese (41). Other technologies reported included point-of-use reverse osmosis systems, filtration, chlorination, and brand-name cartridge or integrated systems. A majority of respondents (77%; 265 of 344) reported that their well supplies the home's drinking water. Figure 3.7 shows the distribution of respondents who drink the water from their well.

The relatively high proportion of treatment systems suggests that raw water is frequently either unsuitable or not optimized for domestic use. Drilled wells obtaining water from bedrock in the area are likely to require softening to remove iron and manganese. Shallow hand-dug wells are likely to require chlorination, UV treatment, or reverse osmosis systems to provide a safe source of potable water.



Legend

- Treatment System
- No Treatment
- Village Boundary



Treatment System

No Treatment

Figure 3.6.
Water Treatment Systems

Municipality of the District of Chester
Water Availability and Needs Assessment

0 0.1 0.2 0.3 0.4 km

1:17,000 @ 8.5x11

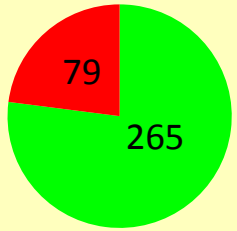
Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

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Legend

- Drink well water
- Do not drink well water
- Village Boundary



Drink well water

Do not drink well water

Figure 3.7.
Well Water Used for Potable Supply

Municipality of the District of Chester
Water Availability and Needs Assessment

0 0.1 0.2 0.3 0.4 km

1:17,000 @ 8.5x11

Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

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Consulting Engineers

Water quality supplies appear to be relatively well monitored. 85% of well owners (292 of 343) reported that at least one water quality sample was collected from the well.

31% of respondents (108 of 344) reported aesthetic issues with their raw water supply. The following issues were reported in equal proportion for drilled and dug wells:

- Odour: 43;
- Taste: 35;
- Sediment: 45;
- Cloudiness: 25; and
- Staining: 73.

Odour complaints are commonly associated with sulfur compounds/thiols. Taste and staining complaints are often related to iron and manganese. Issues with salty water were reported by three respondents.

3.4.2 Water Quality Sampling Program

Raw water samples were collected by CBCL limited from 81 sites, shown on Figure 3.8. At each home the sampler identified the line from the well into the home and identified treatment infrastructure (if any). The raw water tap was disinfected by swabbing with a bleach towelette, followed by flushing for 5 minutes. If a raw water tap could not be identified, the well was not included in the sampling program. Eight duplicate and three trip blank samples were collected for quality control and quality assurance. The sampling protocol adhered to industry and government standard procedures.

Water quality data from the sampling program are summarized in Appendix D. Full laboratory certificates are on file with the Municipality and were transmitted to each homeowner by the Municipality. A brief summary of the sampling program results follows. All data were compared to the Health Canada Guidelines for Canadian Drinking Water Quality (GCDWQ).

Total Coliform Bacteria - The presence of coliform bacteria provides indications that a well is influenced directly by surface water or inputs at the ground surface (i.e. dust, insects, rodents). Although coliform bacteria do not present a direct threat to human health, their presence indicates that the water supply is at an elevated risk to become affected by E. coli and other pathogens. The raw water of 50 wells (62%; 50 of 81) contained coliform bacteria. These locations were distributed evenly throughout the Village, and 48% (24 of 50) were dug wells.

The presence of coliform bacteria in dug well supplies is relatively common, particularly in wells with poor covers (metal, wood, or concrete with cracks/fissures) and/or rock-lined construction. Many dug well supplies in the Chester area are treated by the homeowner using chlorine, a UV light, or reverse osmosis.



Legend

- Drilled
- Dug
- Cistern
- Village Boundary

Figure 3.8.
Water Quality Sampling Locations

Municipality of the District of Chester
Water Availability and Needs Assessment

0 0.1 0.2 0.3 0.4 km

1:17,000 @ 8.5x11

Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

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E. coli – If present at any level, E. coli poses an immediate and direct threat to human health. Water supplies exhibiting E. coli require treatment, and should be examined for potential ways to reduce surface inputs to the well. Wells in this condition have the potential to affect other wells that are close by and installed in the same groundwater flow system, and are likely to be in contravention of the Nova Scotia Environment Act. E. coli was detected in one well water supply and one cistern supply (trucked water). Sampling data showed no evidence for systemic or wide-spread E. coli contamination.

Health Based Parameters – Water samples were analyzed for the parameters with health-based guidelines, shown in Table 3.2. Twelve raw water supplies (15%) showed arsenic concentrations above the guideline limit of 10 mg/L. Other parameters exceeding the GCDWQ in raw water were uranium (1 well) and fluoride (2 wells). Copper and lead exceeded the GCDWQ at one and six locations respectively. These parameters can be associated with corrosion of piping; the pH was below seven at 38 locations, which suggests that corrosion could be an issue. Several survey respondents were concerned about this issue.

Aesthetic Parameters – Water samples were analyzed for the parameters with aesthetic objectives (taste, odour, corrosiveness etc.), shown in Table 3.2. Turbidity exceeded 1 NTU at 48 locations (60%). Iron and manganese exceeded the GCDWQ in 33 and 26 samples respectively (41% and 32%). Iron and manganese contribute to poor taste, odours, staining, scale formation, and encrustation of screens, piping, and filters, and can increase turbidity and colour. Many of the aesthetic concerns reported on the well survey can be related to iron and manganese. Water softeners are generally sufficient to eliminate this issue. Use of water softeners was reported by 41 respondents (10%). Elevated chloride concentrations were observed in 3 samples, however, only one of these wells was within 120 metres of the coastline, and this well was a dug well.

Table 3.2. Summary of Water Quality Parameters with GCDWQ

Parameter	unit	GCDWQ	Type of Guideline	No. Samples Exceeding
Total Coliforms	P/A	ABSENT	AO	50
Escherichia coli	P/A	ABSENT	AO	3
Colour	TCU	15	AO	5
Total Dissolved Solids	mg/L	500	AO	3
Turbidity	NTU	1	AO	48
Chloride	mg/L	250	AO	3
Sulphate	mg/L	500	AO	0
Sodium	mg/L	200	AO	1
Iron	ug/L	300	AO	33
Manganese[1]	ug/L	50	AO	26
Aluminum	ug/L	100	OG	8
pH		7-10.5	*	38
Antimony	ug/L	6	Health	0
Arsenic	ug/L	10	Health	12
Barium	ug/L	1000	Health	0
Boron	ug/L	5000	Health	0
Cadmium	ug/L	5	Health	0
Chromium	ug/L	50	Health	0
Copper	ug/L	1000	Health	1
Fluoride	mg/L	1.5	Health	2
Lead	ug/L	10	Health	6
Selenium	ug/L	50	Health	0
Uranium	ug/L	20	Health	1
Zinc	ug/L	5000	Health	0
Nitrate	mg/L	10	Health	0
Nitrite	mg/L	1	Health	0

P/A - Presence or Absence
GCDWQ - Health Canada Guidelines for Canadian Drinking Water Quality
AO - Aesthetic Objective
OG - Operational Guideline
* - control of corrosion and effective treatment
Health - Parameter causes chronic toxicity to human health above guideline concentration
[1]proposed new manganese guideline is 20 ug/L (AO) and 100 ug/L (Health)

CHAPTER 4 GROUNDWATER RESOURCES

4.1 Preliminary Water Budget

A preliminary annual water budget for the study site is shown in Table 4.1. Using the average recharge rate for the Gold River watershed, groundwater resources do not appear to be stressed on an annual basis. Calculations suggest that, in the area of most intensive use in the Village Centre, 12% of available infiltration is used by private water wells. As all water used by homes is piped to a central sewage treatment plant, this represents a sustained reduction of recharge to serviced areas. This diversion of recharge is expected to cause local water tables to be depressed compared to background conditions that would prevail in the absence of widespread well use.

Preliminary budget calculations do not account for limitations to well yields attributed to the aquifer transmissivity, additional losses of infiltration area caused by impervious surfaces and storm water catch basins, or seasonal variations.

4.2 Reliability of Individual Wells

Responses to the water well survey showed that water table effects are most pronounced in the summer months. Well owners reported that wells were dry in 2016 and yielded no water for periods lasting from one week to four months. In many cases well owners reported these shortages in spite of concerted conservation efforts. Many other well owners reported temporary shortages from year to year stemming from intensive use of the well. Homeowners report that they are increasingly adding cisterns, rain water collection, and low-flow fixtures to their homes. In other cases drilled wells have been installed to replace dry or intermittently dry dug wells.



A Drilled Replaces a Rock-lined Dug Well in the Chester Area

Table 4.1. Preliminary Water Budget

Catchment	Area (m^2)	Civic Count	Usage (m^3/d)	Catchment Use (m^3/yr)	Catchment Use (m/yr)	Infiltration (m/yr)	Recharge (m^3/yr)	% Use
Village Centre	7 152 551	316	1	115 340	0.016	0.14	1 001 357	12%
Walker Road	1 819 876	13	1	4 745	0.003	0.14	254 783	2%
Kaulback Island	3 110 256	41	1	14 965	0.005	0.14	435 436	3%
Nauss Point	2 397 890	47	1	17 155	0.007	0.14	335 705	5%
Haddon Hill	6 609 777	99	1	36 135	0.005	0.14	925 369	4%
Target Hill	6 772 890	128	1	46 720	0.007	0.14	948 205	5%
Chandlers Cove	8 415 399	177	1	64 605	0.008	0.14	1 178 156	5%

Reports of intermittent shortages show that water resources are stressed zones local to each well or group of wells. Shortages are most likely to occur when the water table is low due to reduced precipitation and increased evapotranspiration, and may be affected by localized increased run-off due to slope or impervious surfaces (e.g. commercial centre of the Village). Use in these zones may be intensive due to individual practices, density of wells, and increased occupancy during the summer months. Delineation of these zones would require detailed seasonal monitoring and numerical modelling of the water table depth.

The following issues have the potential to limit the reliability of individual wells in the Village:

- Many dug wells do not meet current standards for construction;
- Water shortages, which have affected 23% of respondents;
- The cost and maintenance of water treatment systems, which are used by 60% of respondents;
- Aesthetic/other issues, which were noted by 31% of respondents and noted in 85% of water samples;
- Health related parameters, which affected 75% of sampled raw water supplies; including
- 62% of raw water supplies that contained coliform bacteria.

The results show that a consistent, reliable water supply is not available to a significant proportion of Village residents, but that the majority of concerns can be and are managed at the household level. Exceptions included several respondents who indicated that water was completely unavailable on their property due to quantity or quality issues, and that the only viable supply of potable water is through water delivery or bottled water. Several other respondents indicated concerns over excessive costs of treatment.

4.3 Potential for Central Servicing

4.3.1 Groundwater Sources

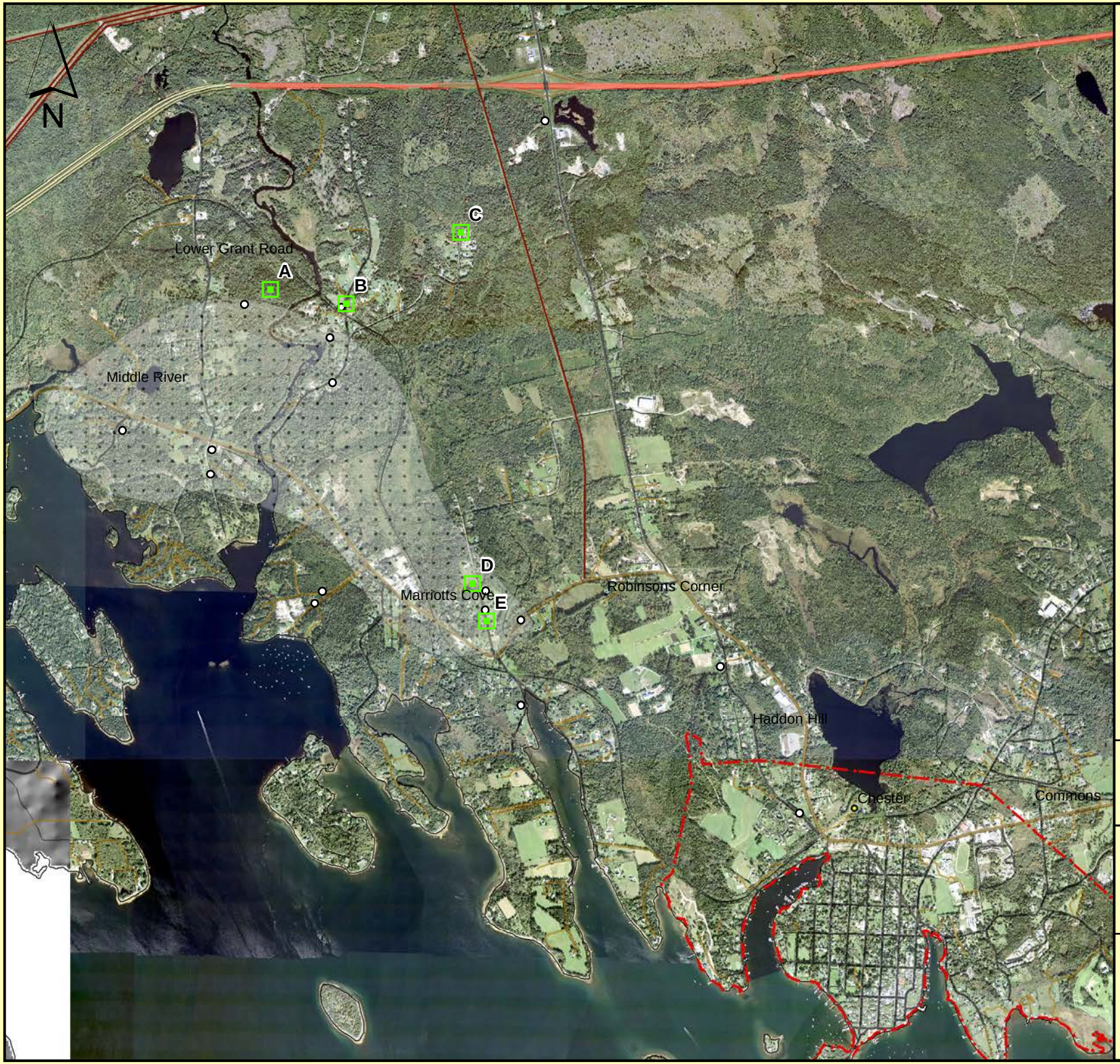
The average water demand for a central water supply system in Chester was estimated by KMV (2011) to be 739 m^3/d , reaching up to 1850 m^3/d during periods of peak usage. The KMV (2011) report did not include servicing to the Kaulback Island peninsula. The addition of Kaulback to the serviced area increases the average demand to 800 m^3/d and the maximum day demand to 2000 m^3/d, based on a peaking factor of 2.5. Based on the demands and service populations used in the KVM 2011 report a well field would need to be capable of producing up to 300 igpm, including redundant wells and water storage to meet peak demands. The demand and service population used in the KVM 2011 report should be reviewed and confirmed as part of the next steps. Metamorphic rock underlying the central and northern parts of the Chester area are not expected to be capable of providing yields on this order, and could be limited by salt water intrusion effects. Anecdotal evidence suggests that limestone beds within Windsor Group rocks in the west part of the Village (and further west), may be capable of providing moderate yields, however:

- Windsor Group rocks do not typically provide yields over 60 igpm; and
- Water pumped from Windsor group rocks is typically difficult and costly to treat, exhibiting elevated concentrations of iron, manganese, chloride, sulphate, and other scale forming minerals.

The hydrogeological setting of the Middle River area and preliminary mapping by NSDNR indicate that there may be potential to develop a well field. Extensive thicknesses of granular material supply productive wells to the west and east of the river. These deposits could be part of a buried regional valley feature, and to the east of the river are mapped as glaciofluvial outwash. These areas are well situated to provide adequate source water protection, but would require a six to seven kilometre pipeline to be connected to the Village.

4.3.2 Potential Test Drilling Sites

Potential test drilling sites were identified as part of field reconnaissance, shown on Figure 4.1. Potential drilling sites were selected based on geology mapping, thickness of granular material as indicated by water well logs, potential yield as indicated by the geology and airlift yields, and access for a drilling rig. Permission for access to these properties has not be investigated.



Legend

- Potential Test Drilling Site
- Significant Thickness of Granular Material
- Marriott's Cove Deposit(s), DNR
- Village Boundary

Figure 4.1. Potential Test Drilling Sites

Municipality of the District of Chester
Water Availability and Needs Assessment

0 0.2 0.4 0.6 0.8 km

1:30,000 @ 8.5x11

Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator

CBCL LIMITED
Consulting Engineers



Potential Test Site A



Potential Test Site B



Potential Test Site D



Potential Test Site E

CHAPTER 5 SUMMARY AND CONCLUSIONS

5.1 Summary

The physical setting of Chester area aquifers is as follows:

- Surficial material in the Chester area is predominantly stony sand till;
- Compact silty till may be found in the Village centre, where there are many dug wells;
- Bedrock underlying the study area includes metamorphic rock and Windsor group rocks;
- Metamorphic rock is typically not conducive to development of central water supplies due to insufficient yields and elevated concentrations of iron, manganese, and sulphur compounds;
- Windsor group rocks may exhibit adequate yields, but often supply water of poor quality with prohibitive treatment costs;
- Aquifer testing of bedrock wells within the Chester area showed yields that are not conducive to development of central supply wells;
- Well records indicate that there are thicker deposits of granular material adjacent to the Middle River; and
- Existing work by NSDNR suggests that water shortages and salt water intrusion could affect wells in the Chester area.

The water well survey provided the following additional information:

- A majority of homes in the Village centre and half of remaining homes are served by dug wells;
- Many dug wells in the area are rock-lined, 50 years old or more, and exhibit poor covers/seals;
- Approximately one quarter of homeowners reported shortages and/or are supplied by trucked-in/delivered water in times of shortage;
- 60% of homeowners use water treatment systems to remove bacteria, iron, and manganese from their water systems, and three quarters of homes use well water for drinking;
- The water quality sampling program showed that 62% of raw water supplies were affected by coliform bacteria, which is consistent with the construction and physical setting of wells in Chester;
- The water quality sampling program showed that 75% of raw water supplies exhibited parameter concentrations that exceeded health-based objectives under the GCDWQ;
- The water quality sampling program showed that 85% of raw water supplies exhibited parameter concentrations that exceeded other objectives under the GCDWQ; and
- The water quality sampling program showed that 100% of raw water supplies exhibited parameter concentrations that exceeded at least one objective under the GCDWQ.

Preliminary data and field reconnaissance indicate that there is potential to develop a central groundwater supply for the Village. Potential sources are six to seven kilometres from the Village distribution system. Several possible test drilling locations have been identified.

5.2 Conclusions

Individual water wells provide supplies that are inconsistent or of insufficient quality to at least half of the Village residents, however, the data further indicate that these issues can be and are being managed at the household level. Conservation measures are practiced by many dug well owners, and appear to be successful for most well owners most of the time. Individual households and businesses bear the costs of treatment and responsibility for the protection of shallow aquifers. Some homeowners report that trucked and bottled water are their only option for water supply. Shortages show that water resources are stressed in localized parts of the community, and that the potential for further development or an increase in population density is limited.

The introduction of central water would substantially improve the consistency, quality, and access to water for many residents of the Village, with improved monitoring and source water protection. Surficial and bedrock aquifers in the Chester Area show low potential for development of a central groundwater supply, but development of sand and gravel deposits in the Middle River Area may be feasible, pending test drilling work. A socioeconomic analysis of the benefits and costs of central water would further inform a decision to pursue test drilling work. A program of test drilling would provide physical data on whether central servicing via groundwater is feasible. An engineering report to compare surface water and groundwater supply options and to confirm water demands would also be required.

CHAPTER 6 REFERENCES

Alley, W.M., Reilly, T.E., and Franke, O.L., 1999. Sustainability of Ground-Water Resources. U.S. Geological Survey Circular 1186. Denver, Colorado.

Cross, H. 2017. Personal Communication.

Dillon Consulting Ltd., 2000. Recommendations on the Development of a Province Wide Strategy for the Protection of Municipal Groundwater Supplies in Prince Edward Island. 123p.

DP ME 43, Version 2, 2006, Digital Version of Nova Scotia Department of Natural Resources Map ME 2000-1, Geological Map of the Province of Nova Scotia, scale 1:500 000, compiled by J. D. Keppie, 2000. (Formerly DP ME D00-01).

DP ME 36, Version 2, 2006. Digital Version of Nova Scotia Department of Natural Resources Map ME 1992-3, Surficial Geology Map of the Province of Nova Scotia, 1:500 000, by R. R. Stea, H. Conley and Y. Brown, 1992. Digital product compiled by B. E. Fisher. (Formerly DP ME D92-03).

Driscoll, F.G., 1986. Groundwater and Wells, 2nd Ed. Johnson Screens, Saint Paul, Minnesota. Eighth Printing. 1089 p.

Freeze, R.A. and Cherry, J.A., 1979. Groundwater. Prentice-Hall, Inc., Englewood Cliffs, N.J.

Graves, R.M., and Finck, P.W., 1990. Till Clast and Glacial Geology of Chester, Nova Scotia. Nova Scotia Department of Mines and Energy Map 90-4, Scale 1:50,000.

Health Canada, 2012. Guidelines for Canadian Drinking Water Quality Summary Table. Water, Air, And Climate Change Bureau, Healthy Environments and Consumer Safety Branch, Health Canada. Ottawa, Ontario.

Kasenow, M., 2006. Aquifer Test Data: Analysis and Evaluation. Water Resources Publications, LLC, Highlands Rance, Colorado. 8th Printing. 382 p.

Kennedy, G.W., and Drage, J.D. and Check, G., 2017. Development of indices to assess the potential impact and risk of drought to private wells in Nova Scotia. Presentation at Geoscientists Nova Scotia Annual General Meeting/Continued Professional Development Session.

Kennedy, G.W., 2014. Potential Surficial Aquifers for the Western Region of Nova Scotia. Nova Scotia Department of Natural Resources, Mineral Resources Branch. Open File Map ME 2014-004, scale 1:200 000.

Kennedy, G.W., 2013. Identification and Preliminary Mapping of Surficial Aquifers in Nova Scotia. Annual Report of Activities, Mineral Resources Branch, Nova Scotia Department of Natural Resources.

Kennedy, G.W., 2012. Development of a GIS-Based Approach for the Assessment of Relative Seawater Intrusion Vulnerability in Nova Scotia, Canada. Nova Scotia Department of Natural Resources, Mineral Resources Branch. Presented at the IAH Congress, 2012, Niagara Falls, ON, Canada. 10 p.

Kennedy, G.W., and Utting, D.J., 2011. LiDAR, Surficial Geology Mapping, and Water Wells: Uncovering Potential Surficial Aquifers in Halifax, NS. Nova Scotia Department of Natural Resources, Mineral Resources Branch. Presented at geohydro 2011, Quebec City, QC, Canada. 8 p.

Keppie, J.D. (compiler), 2000. Geological Map of the Province of Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Energy Branch. Map ME 2000-1. Scale 1:500 000.

KVM Consultants Limited, 2011. Future Water Supply, Village of Chester and Area, Chester, NS. Prepared for The Municipality of the District of Chester. 20 p.

Neville, C.J., 2009. Critical Thinking in Pumping Test Interpretation. Short Course (Manual). 10th Joint CGS/IAH Groundwater Specialty Conference.

Nov Scotia Regulation 382/2007. 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.

Nova Scotia Environment, 2002. Protocol for Determining Groundwater Under the Direct Influence of Surface Water. Nova Scotia Department of Environment and Labour (NSE), 2011. Pumping Test Database (1973-present).

Nova Scotia Environment, 2004. Before You Construct a Water Well, Facts a homeowner should know. Report 68-3, Seventh Revision.

Nova Scotia Department of Environment and Labour (NSE), 2015. Water Well Database (1978 to Present).

Nova Scotia Department of Natural Resources, 2016. Potential Impact of Drought to Private Wells. Interactive Web Map: https://fletcher.novascotia.ca/DNRViewer/?viewer=DroughtIndex (accessed July 4, 2017).

Nova Scotia Department of Natural Resources, 2011. Nova Scotia Aquifer Properties Summary (MS Excel Spreadsheet).

Poehls, D.J., and Smith, G.J., 2009. Encyclopedic Dictionary of Hydrogeology. Elsevier Academic Press, Burlington, MA. 517p.

Rivard, C., Deblonde, C., Boivin, R., Bolduc, A., Paradis, S.J., Paradis, D., Liao, S., Gauthier, M.J., Blackmore, A., Trepanier, S., Castonguay, S., Drage, J., and Michaud, Y. 2007. Canadian Groundwater Inventory: Hydrogeological Atlas of the Annapolis Valley, Nova Scotia. Geological Survey of Canada, Open File 5541.

Rivard, C., Paradis, D., Paradis, S., Bolduc, A., Morin, R.H., Liao, S., Pullan, S., Gauthier, M.J., Trepanier, S., Blackmore, A., Spooner, I., Deblonde, C., Fernandes, R., Castonguay, S., Hamblin, T., Michaud, Y., Drage, J., and Paniconi, C. 2006. Canadian Groundwater Inventory: Regional Hydrogeological Characterization of the Annapolis-Cornwallis Valley Aquifers. Geological Survey of Canada.

Stea, R.R., Conley, H., and Brown, Y. (compilers) 1992. Surficial Geology of the Province of Nova Scotia; Nova Scotia Department of Natural Resources. Map 92-3. Scale 1:500 000.

Reilly, T.E., Dennehy, K.F., Alley, W.M., and Cunningham, W.L., 2008. Ground-Water Availability in the United States, A contribution of the Ground-Water Resources Program. Circular 1323, U.S. Geological Survey.

Van der Kaamp, G. and Maathuis, H. 2005. The applicability of "Q20" Methods for Determining Sustainable Groundwater Yields, 7 p. In: Proceedings of the 58th Canadian Geotechnical & 6th Joint IAH-CNC and CGS Conference, Saskatoon, SK, Canada.

Van der Kaamp, G. and Maathuis, H., 2006. The Q20 Concept: Sustainable Well Yield and Sustainable Aquifer Yield. Report prepared for The Water Research Users Group, Alberta Environment.

Velling, E.J.M., and Maas, C., 2010. Hantush Well Function Revisited. Preprint submitted to Journal of Hydrology, December 3, 2010.

Wireman, M., 2008. Aquifer-Based Ground-water Management. In Proceedings of the NWQMC 6th National Monitoring Conference.



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APPENDIX A

Photographs of Dug Well Heads in the Chester Area














29 QUEEN



APPENDIX B

Water Well Survey Template

VILLAGE OF CHESTER - WATER SUPPLY SURVEY

The Municipality of Chester is working with the Village of Chester Commission to determine if having a central water system in Chester is needed by enough properties to warrant installation. To aid the Municipality and the Village in this endeavour, we are requesting that every property owner within the Village Boundary take the time to complete this survey to get a clear picture of the need and desire for a central water system.

DEADLINE FOR SUBMISSIONS IS SUNDAY, APRIL 30, 2017.

Options to submit this survey:

- Online at www.chester.ca/centralwater
- Drop off at the Municipal Office at 151 King Street in Chester
- Via mail to Municipality of Chester, 151 King Street, P O Box 369, Chester NS B0J 1J0
- Fax to 902-275-3673
- Email to publicworks@chester.ca

What is your Civic Address:
(property/house number and street name (eg. 151 King Street)

_____

Are you interested in completing the survey? ☐ Yes ☐ No

If No, please explain why below. If insufficient space, feel free to attach further correspondence.

_____

_____

_____

_____

_____

If Yes, complete the questionnaire as outlined below.

Residential Users – This section is required to be completed by the Property Owner

Type of Residence:

☐ Permanent (12 months of the year)

VILLAGE OF CHESTER - WATER SUPPLY SURVEY

☐ Seasonal Months Occupied # _____ Specify Months - _____

☐ Rental Months Occupied # _____ Specify Months - _____

☐ Multi-Unit Apartments #_____ Condominium Unit #_____ Plex # _____

☐ Other _____

_____

Number of persons in residence #_____

Do you share a well with another property or residence ☐ Yes ☐ No

Number of units served by this well *(indicate if unknown)* # _____

Civic Addresses of units sharing well _____

_____

Commerical Users - This section is required to be completed by the Property Owner

Business name: _____

Type of business: _____

Number of employees _____ Number of customers per day _____

Days per week of operation _____

List months of operation _____

Estimated water use per day _____ ☐ Unknown

Is this a registered public drinking water supply? ☐ Yes ☐ No

If yes, NSE registration number _____

Do you share a well with another property or residence ☐ Yes ☐ No

Number of persons in residence *(indicate if unknown)* # _____

Number of units served by this well *(indicate if unknown)* # _____

Civic addresses of units sharing well _____

_____

Water Quality

When was the well-constructed? _____ ☐ Unknown

Name of well driller/digger? _____ ☐ Unknown

VILLAGE OF CHESTER - WATER SUPPLY SURVEY

Do you drink the water from your well? ☐ Yes ☐ No

Has the well water ever been tested for bacteria? ☐ Yes ☐ No

1. If yes, who did the testing? ☐ Owner ☐ Government Inspector ☐ Other
2. Approximate date tested _____
3. Is a copy of the results available *(attach if possible)?* ☐ Yes ☐ No

Has the well water ever been tested for chemical quality? ☐ Yes ☐ No

1. If yes, who did the testing? ☐ Owner ☐ Government Inspector ☐ Other
2. Approximate date tested _____
3. Is a copy of the results available *(attach if possible)?* ☐ Yes ☐ No

Have you experienced any water shortages? Pre-2016 ☐ Yes ☐ No

2016 ☐ Yes ☐ No

Describe: _____

_____

_____

Have you had water delivered to supplement or replace your well water? ☐ Yes ☐ No

- If yes, where was the water delivered? ☐ Into the well ☐ Storage Tank
- Is trucked water your main supply? ☐ Yes ☐ No

Have you had any other problems with your well water? ☐ Yes ☐ No

If yes, check any that apply: ☐ Odour ☐ Taste ☐ Sediments

☐ Cloudiness ☐ Staining

☐ Other_____

Do you treat your water? ☐ Yes ☐ No

If yes, indicate equipment: _____

Has the well been repaired or serviced by a contractor in the last 5 years? ☐ Yes ☐ No

If yes, describe problem and repairs: _____

_____

_____

VILLAGE OF CHESTER - WATER SUPPLY SURVEY

Well Information

☐ Drilled Well



Diameter ☐ 4 inch ☐ 6 inch ☐ Other

Which best describes your well?

☐ It sticks up out of the ground / it is in the yard.

How high above the ground (inches)? _____

☐ In the basement

☐ In a concrete chamber

☐ It is buried / I have never seen it

Describe well cap / quality of seal:_____

_____

Depth of Well_____

Depth of Steel Casing _____

Depth of intake / pump depth: _____

☐ Dug Well



Diameter ☐ 3 feet ☐ Other _____

How far above ground surface is the top of the well? _____

Does the well have a concrete cover (as shown above)? ☐ Yes ☐ No

Construction of well:

☐ Well Crocks ☐ Rocked wall

☐ Crock on top of rocks

Is the ground mounded around the well?

☐ Yes ☐ No

Are the joints between the crocks sealed?

☐ Yes ☐ No ☐ Unknown

Does the well have a concrete apron?

☐ Yes ☐ No ☐ Unknown

Depth of Well _____

Would you like to participate in the water quality sampling program? It is anticipated that the sampling program will be conducted over a two-week period in May 2017. ☐ Yes ☐ No

If yes, please provide your preferred contact information:

Name: _____

How would you like us to contact you?

☐ Phone _____ ☐ Text _____

☐ Email _____

General Survey Comments:

_____

_____

_____

_____

Thank you for taking the time to complete this survey!

Learn more about caring for your well at http://www.novascotia.ca/nse/water/privatewells.asp

Or try the province's new tool to help you understand your water quality results:

http://www.novascotia.ca/nse/dwit/Form

APPENDIX C

Water Well Survey Summary Table

(USB drive attached)

APPENDIX D

Water Quality Data

(USB drive attached)