DRAFT

WATER AND WASTEWATER FEASIBILITY STUDY
NORTH SHORE, PE

a

DRAFT report

submitted to

Engineering Technologies Canada Ltd.

by

TerrAtlantic Engineering Limited

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Ms. Kelly Galloway, P. Eng.
Engineering Technologies Canada Ltd.
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Dear Ms. Galloway:

RE: (DRAFT) WATER AND WASTEWATER FEASIBILITY STUDY, NORTH SHORE, PE

Enclosed is our report on groundwater aspects of the above study. It follows the review of available information and the assessment of four outlined sub-areas in North Shore.

From our evaluation of the hydrologic setting it is evident that bedrock in this area can provide adequate yields, but the long-term sustainability of groundwater withdrawals in the various parts of the community depends on other factors, and particularly on the density of development, the magnitude of recharge and the probability of water quality impacts.

Although it is unlikely that North Shore would consider servicing its small population from a central municipal wellfield, longer term development issues associated with some areas may require this. Two potential target locations for a central groundwater supply have therefore been identified.

Please contact the undersigned if we can clarify the content or otherwise be of further assistance.

Sincerely,

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PRINCIPAL HYDROGEOLOGIST

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1.0 INTRODUCTION

The Municipality of North Shore (NS) is located on the Gulf of St. Lawrence some 10 km north of Charlottetown. The community has a population of approximately 2,230 and comprises 825 or so private dwellings. Since there are many seasonal residents, the peak population during the summer can rise to as much as 2,840 people, living within approximately 1,051 equivalent dwelling units (EDUs). This translates to an average of roughly 2.7 persons per dwelling during the peak summer season.

Like many other communities on Prince Edward Island, North Shore relies on groundwater for 100 percent of its potable water requirements. The area is primarily serviced with individual water supply wells and on-site sewage disposal systems, but nine central (or cluster) water supplies exist throughout the municipality.

Wastewater management and water supply issues are closely linked but this part of the broader study focuses on the water supply component. From an examination of the hydrologic setting it became clear that individual domestic wells tapping the sandstone bedrock in this area can provide more than adequate yields. The bedrock is evidently transmissive, but the long-term sustainability of groundwater withdrawals depends on other factors, and particularly on the magnitude of recharge and on the probability of water quality impacts. These issues are therefore addressed in some detail.

In order to put both water supply and water quality issues into perspective, and to permit comparison of the challenges faced by different parts of the community, a groundwater availability / vulnerability map has been developed based on a series of factors that influence water quantity and quality in North Shore. Four sub-areas with differing servicing requirements are then identified, and for each, water needs are then assessed.

2.0 HYDROLOGIC SETTING

2.1 Topography and drainage

North Shore is in a rural, agricultural setting, with economic activity primarily revolving around farming, fishing and tourism. The area has increasingly become a "bedroom community" for those who commute to Charlottetown.

The topography comprises rolling hills with slopes of between 3 and 7 percent and rarely as steep as 15 percent. The surface elevation ranges from sea-level to the north, to a little over 60 metres on hill peaks in the south (refer to Figure 1).

Most of North Shore is located within the Brackley Bay - Covehead Bay watersheds, which collectively drain an area of nearly 73 square kilometres. There are five sub-watershed areas, these being (from east to west) Parsons Creek, Auld Creek, Bells Creek, Black River and McCallum Creek. Surface water within these sub-watersheds drains northwards into Brackley Bay (McCallum Creek and Black River) or Covehead Bay (Parsons Creek, Auld Creek and Bells Creek), and then discharges into the Gulf of St. Lawrence.

The southernmost part of the community (approximately 2.5 km^2) lies within the neighbouring Winter River Watershed. That surface water drains to the east and then north to discharge into Tracadie Bay and the Gulf.

The northern half of the Stanhope peninsula (a sand spit), and the adjacent area to the east, drain northwards into the Gulf.

2.2 Geology

2.2.1 Surficial

The bedrock in PEI is overlain by a variable thickness of glacial deposits of different types, with the overburden thickness being a function of topography, slope and elevation (refer to Figure 2 depicting the geology of North Shore). These deposits are generally derived directly or indirectly from local bedrock sources and comprise both unsorted till, and water-worked glaciofluvial and glaciomarine deposits (Francis, 1989).

Within the community limits, there are three main types of surficial sediments: (i) glacio-fluvial, (ii) post-glacial (re-worked) sediments, and (iii) till (ground moraine and ablation). Of these, ground moraine till is the predominant soil type. The soil cover is relatively thin with thicknesses ranging from zero on some of the higher ground to 6 metres or so in some flat and lower lying areas.

2.2.2 Bedrock

The bedrock on the Island consists of Upper Pennsylvanian to Middle Permian aged continental red-beds that dip to the northeast at about one to three degrees. The constituent granular material was transported by streams and rivers from highlands in present day New Brunswick and Nova Scotia and was deposited under oxidizing conditions in the low-lying area which is now Prince Edward Island (Francis, 1989).

The red beds comprise varying amounts of sandstone, siltstone, claystone, breccias and conglomerates, and exhibit rapid lateral and vertical facies changes and strong cross-bedding features. A complete review of the bedrock geology of Prince Edward Island was undertaken by Van de Poll who reports that the red bed units consist of an upwards fining series of cyclic deposits containing four ‘megacycles’ (Francis, 1989). North Shore is underlain by portions of Megacyclic

Sequence IV of the Lower Permian Pictou Group. This unit is dominantly comprised of coarse-grained conglomerates, and sandstones (with some interbedded siltstones at depth in places).

2.3 Bedrock groundwater system

2.3.1 Bedrock aquifer properties

The PEI red beds are a good example of a fractured porous aquifer. Most of the fluid in the aquifer is stored in the intergranular pore spaces of the bedrock, but, at least within the upper 35 metres of the rock, the dominant flow paths are within highly transmissive, and interconnected joints and fractures (Francis, 1989). Vertical to steeply dipping joints, with inclinations greater than 75 degrees, are widespread throughout the Island.

The typical bedrock porosity (n) and hydraulic conductivity (K) of the red beds has been reported to be about 0.17 and 3.5×10^{-5} m/s, respectively (Jiang, 2004). At depths greater than 35 metres, a decrease in both fracture frequency and fracture (aperture) width has been observed. As a result, a reduction in hydraulic conductivity by an order of magnitude for every increment of 60 metres depth has been reported. At depths greater than 100 metres, the matrix (primary) permeability rather than the fracture (secondary) permeability prevails (Francis, 1989).

2.3.2 Groundwater levels

On higher ground, depths to the static groundwater level can be significant, perhaps as much as 20 to 30 metres below grade, but close to the shore groundwater usually occurs at shallow depth. Seasonal fluctuations of the water table can be expected, with the lowest water levels occurring during those winter months following a fall of limited recharge. Water table fluctuations, particularly in these drier periods, would be less in the lower lying areas (Francis, 1989).

2.4 Water budget and sustainable withdrawals

2.4.1 Background

Most of North Shore lies within the Brackley Bay - Covehead Bay watershed. The neighbouring Winter River drainage basin to the southeast has been extensively studied, primarily because it is from that area that the City of Charlottetown presently withdraws water from three wellfields. Since the terrain and hydrogeologic settings are not dissimilar, a number of findings from Winter River basin can be applied to the Brackley Bay - Covehead Bay watershed.

Of the mean annual precipitation of 1200 mm, groundwater recharge has been estimated at between 400 mm (Jiang) and 685 mm (Francis). From numerical modelling, PEIDEEF concluded that groundwater withdrawals should not exceed 50 percent of this recharge. For the purposes of this study it is assumed that withdrawals should not exceed 200 mm/a[1]. If this value is applied over the complete watershed area of 73 square kilometres, it amounts to 15 million cubic metres per year or 40 ML/d (~ 6,000 igpm). Alternatively, if it is applied over the community area of 46 square kilometers, it amounts to 25.2 ML/d (or ~3850 igpm), or about 63 percent of the available capture area.

2.4.2 Domestic well use within the municipality

At present, groundwater is recovered from approximately 1,051 wells during the (peak) summer season. Details of some of these wells are available in the PEIDEEF well record, with other good information being provided by PEIDEEF hydrogeologists and from knowledgeable well drillers.

The domestic wells in the community tap the fractured sandstone bedrock at depth, although

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[1] Others have estimated lower values (e.g. 173 mm by CBCL in 2007 and 185 mm by the Covehead-Brackley Watershed Management Plan in 2009).

interbedded layers of claystone and/or siltstone may be present at depth. Depending on location, depth and diameter, individual wells tapping the sandstone bedrock in North Shore can reportedly yield between 23 and 230 L/m (5 to 50 igpm). Larger diameter wells sited at strategic locations can yield much more, but large-scale wells have not generally been developed in North Shore.

Typical well depths in North Shore range from 25 to 37 metres (80 to 120 feet) but there are some as shallow as 9 metres, and others as deep as 137 metres. Associated steel casing lengths are typically 13 metres (40 feet). The mean depth to the static water level is approximately 8 metres below grade (PEIDEEF WWIS Database, 2009).

The bedrock is evidently transmissive, but the long-term sustainability of groundwater withdrawals depends on other factors, and particularly on the magnitude of recharge and on the probability of water quality impacts.

Groundwater withdrawals must support the present (peak) population of approximately 2,840 or an equivalent 1,051 EDUs. If the typical water requirement per EDU is between 650 and 1,000 L/d, then the present daily withdrawal would be in the range 680 to 1,050 cubic metres (or 0.7 to 1.0 ML/d). This represents less than 3 percent of the (40 ML/d) sustainable yield of the bedrock aquifer. It should be noted that nearly half of the (peak) population is located on the Stanhope Peninsula, within an area of roughly 2 square kilometres. Not surprisingly, water supply issues are most often reported there.

Since the requirements of individual equivalent dwelling units (EDUs) are relatively small and the bedrock is transmissive, it would not be expected that well yield would be a limiting factor anywhere in the community unless the wells are sited very close to each other and interference becomes an issue. Well drillers report that a well will occasionally “go dry” but these are rare instances rather than commonplace ones.

If lower permeability claystones are intersected in the drilling process, domestic wells would simply be deepened so as to intersect coarser-grained, more transmissive sandstones or conglomerates at greater depth in the megacyclic unit. Deeper wells also have a greater storage capacity and can therefore function in an acceptable manner even if the yield is at the bare minimum. If two wells interfere with one another, one or both might be deepened to provide increased available drawdown and storage capacity.

Using the 200 mm/year sustainable withdrawal figure described earlier (Section 2.4.1), the recharge area required for an individual domestic well could in theory be as little as 1825 m^2 (i.e. 365 m^3/year divided by 0.2 m) which corresponds to a lot size smaller than even that considered viable from an on site wastewater servicing viewpoint. In practice, much larger lot sizes than this would be desirable if domestic wells are to be spaced far enough from each other to limit interference and to reduce the risk of contamination from a nearby septic system. This issue is discussed further in Section 2.5.

2.5 Water quality and contamination issues

2.5.1 General

Groundwater quality in North Shore is generally good. In some instances, the bedrock wells are cased to greater depths than those that might be considered usual so as to limit access to elevated nitrates that exist at shallower depth in the near-surface (i.e. Covehead Area). Elevated dissolved iron issues also exist in some of the groundwater wells located in the vicinity of the Stanhope golf course. Saltwater intrusion has also been reported on the Stanhope peninsula and on MacMillan Point. Isolated cases of bacteria contamination has also been reported in some wells on the Stanhope Peninsula. The issues reported from North Shore residents during a 2009 resident survey conducted by Engineering Technologies Canada are outlined below in Table 1, and summarized by subarea in the attached Figure 3.

TABLE 1 - SUMMARY OF RESIDENT SURVEY RESULTS - 2009

SUBAREA / ZONE	SURVEY DETAILS						
	Well contam. issues	Saltwater or high chloride	Total Coliform	Faecal coliform	E-coli	Nitrate	Other
COASTAL ZONE 1 - STANHOPE PENINSULA	31	2	20	1	1	0	7
COASTAL ZONE 2 - BALANCE OF COASTAL ZONE	8	0	4	0	1	2	1
AGRICULTURAL ZONE 1 - OUTSIDE WINTER RIVER WATERSHED	5	1	2	0	1	1	0
AGRICULTURAL ZONE 2 - INSIDE WINTER RIVER WATERSHED	0	0	0	0	0	0	0
TOTALS	**44**	**3**	**26**	**1**	**3**	**3**	**8**

Currently, water quality problems with residential wells in the community are dealt with on an individual, case-by-case basis. This generally involves re-drilling or deepening a well, by repairing or replacing leaking septic tanks or disposal fields, and/or by providing treatment for bacteria (e.g. home UV disinfection units). These approaches are considered to be less reliable methods of ensuring safe drinking water than would be the case with a professionally managed and monitored, central water supply.

2.5.2 Surface water

Routine water sampling at specific locations in both the Brackley and Covehead Bays has been conducted on an annual basis since 2000 as part of the PEIDEEF annual estuaries water quality survey (personal communication, PEIDEEF, Sept. 10, 2008). The water in the bays has routinely been “anoxic” (i.e. oxygen depleted). Water quality has been very poor in mid-summer as a result of nutrient inputs. The ambient tidal range in the area is small and there is only a narrow opening at the Brackely and Covehead Bay discharge point which restricts the tidal exchange capacity and encourages nutrient enrichment.

More recently, a number of freshwater monitoring sites further upstream within the watershed have also been periodically monitored for nutrient loadings. Freshwater nutrient loading from the five sub-watersheds is about average or slightly above average for the province. Nitrate levels in Covehead Bay have generally been higher than those for Brackley Bay, possibly on account of the larger contributing drainage area and the fact that there has generally been more agricultural land-use activity within the contributing Bells Creek sub-watershed than in any of the other sub-watersheds.

In 2002 the PEI Agricultural Crop Rotation Act was introduced. It stated that parcels of land larger than 1 hectare (2.5 acres) with slopes of 9 percent or more should either not be planted with a regular crop, or if planted, would require an approved management plan. It was reasoned that such land would be at greater risk of erosion during storm events than flatter ground. Such areas of greater erosional risk were identified along Bells Creek and Black River and may be a contributing factor to higher sedimentation rates to these watercourses (FCBB, 2009). In addition to sedimentation, fertilizers and nutrients may be mobilized in these areas as well, particularly where agricultural activity is in close proximity to the river banks, or ground infiltration is unimpeded. Resulting erosion of these river banks would therefore likely contribute to higher nitrate levels (and oxygen depletion) of the receiving Covehead and Brackley Bays as well.

Since surface waters can directly recharge to a groundwater aquifer (particularly where there are wells nearby), or alternatively be discharge points for groundwater, the quality of water in rivers, streams, groundwater and their receiving bays are intimately linked with one another, especially in Prince Edward Island.

For instance, in some areas of the municipality, elevated nitrate concentrations in groundwater correspond to areas where surface slopes are also greater than 9 percent (discussed later in Section 3.1.2 and 3.1.6). This groundwater may have been recharged from impacted river water (less likely), or may have resulted from the infiltration of highly concentrated (nitrate impacted) surface water run-off (most likely). Ultimately, the affected groundwater will eventually discharge to nearby streams and then the receiving bays, affecting the surface water quality there as well.

Additional nutrient loadings to these surface waters from municipal effluents would obviously be undesirable (Personal Communication, PEIDEEF, September 11, 2008).

2.5.3 Saltwater Intrusion

Given the topographic setting, and specifically the fact that the Stanhope Peninsula is surrounded on three sides by salt water, it was anticipated that salt water intrusion would already be an issue, and that it might become a significant challenge in future.

This hydrologic setting can be visualized as one of an "Ocean Island" whereby a lens of freshwater floats on the denser saline water. The thickness of the freshwater lens will depend on the hydraulic conductivity of the bedrock and on the net recharge to the aquifer occurring as a result of precipitation. The situation can be visualized in Figures 4 and 5. In Figure 4, all four hypothetical wells are located within the freshwater lens. In Figure 5, with the addition of wells and the resulting increase in the total withdrawal, the freshwater/salt water interface rises, causing wells C and D to yield salty water.

The situation is modeled quantitatively in Figure 6. In that figure it is assumed that: (a) the peninsula is 900 metres in width, (b) the annual recharge is equivalent to 241 mm, (c) the bedrock hydraulic conductivity is 1 x 10^{-6} m/s, and (d) each EDU draws 1 cubic metre per day from the aquifer. On these assumptions, prior to any development (i.e. 0 EDUs/ha), the maximum depth to the saltwater interface would have been close to 175 m. With the addition of 1, 2 and finally 3 EDUs per hectare, the salt water interface would respectively rise by 14 metres, then an additional 15 metres, then an additional 17 metres.

As shown diagrammatically in Figure 5 and quantitatively in Figure 7, a well can be located within the freshwater lens and yet still become impacted if the pumping rate is great enough to induce the upconing of salty water. From Figure 7 it is evident that, in this particular case, upconing is not likely to be an issue except in the case of larger-scale municipal wells, or for very marginal domestic wells located near the shore.

The original intent was to determine the maximum sustainable withdrawal rate beyond which saltwater intrusion would become the overriding issue of concern. In theory, shallow wells located in the middle of the peninsular could yield fresh water in the long term, even if the density of development increased by a factor of two. In practice, such an increase in withdrawal would likely cause many of the marginal wells, particularly those located close to the shore, to be adversely affected.

2.5.4 Nitrates

Nitrates occur naturally in the environment and are essential nutrients for plant growth. Excess nitrates can nevertheless contaminate groundwater and affect surface water quality. The key sources of nitrate pollution are agricultural practices (fertilizers and manure storage and spreading), and septic systems.

In recent decades Prince Edward Island has experienced a steady increase in the level of nitrates in both its groundwater and surface waters. Concern about this trend and the potential effects on health and the environment led to the creation of the Commission on Nitrates in Groundwater in July 2007. Work by the Commission included the analysis for nitrates on a province-wide basis. Six per cent of private wells were found to have nitrate-nitrogen levels above the Canadian Drinking Water Quality guideline of 10 mg/L.

The Commission report included six recommendations that were considered to be absolutely essential as follows:

- Improving Public Education on Protecting Water Quality
- Reducing Nutrient Loading from Sewage Treatment Systems
- Supporting Watershed-based Water Management Planning
- Mandatory Three-year Crop Rotation
- Matching Nutrients With Crop Needs to Reduce Nitrogen Leaching
- Identifying High Nitrate Areas (and taking corrective action)

The 182 nitrate records recovered from the PEIDEEF database for North Shore indicated that nitrate concentrations ranged from 0.2 mg/L to 13.1 mg/L and averaged about 1.7 mg/L. This compares with the 3 to 5 mg/L range for the broader Covehead-Brackley Bay Watershed. The nitrate data are mapped, both on a grid and property basis in Figure 8. These concentrations can be compared with background levels for the Province as a whole, which are in the range of 0.1 to 2 mg/L, and with the 10 mg/L drinking water quality guideline (CDWQG). Those areas within the municipality where nitrate concentrations approach or exceed the 10 mg/L CDWQG include Covehead, McMillan Point, and Stanhope, and are shaded red in the figure. In the case of the property map for nitrate concentrations, the entire property is labelled according to the highest nitrate concentration for that particular property, even if a very small portion of the assessed property is labelled as being higher than the rest.

Given the importance of nitrate impacts to water supply wells from point sources such as sewage treatment systems and distributed sources such as fertilized agricultural land, simple two-dimensional contaminant transport modelling was undertaken to evaluate the fate and transport of nitrate downgradient of a conventional domestic sewage treatment system. The objective was to estimate the likely limits of the contaminant plume at various time intervals, and the associated concentrations of the nitrate within the plume. The analytical model used was that developed by Domenico (1987). A number of assumptions were made about the hydrogeologic characteristics of the site as follows:

- the fractured bedrock setting can be modelled using an equivalent porous medium approach (the rock is relatively well fractured, and is in places weathered to resemble a weakly cemented sand);
- the hydraulic conductivity and hydraulic gradient in the horizontal direction are respectively 3.0 m/d and 0.01. The effective bedrock porosity is assumed to be 0.17 (the resulting average linear groundwater velocity would be a little less than 0.2 m/d or 65 m/a);
- the effective width of the source (perpendicular to the direction of groundwater flow) is 25 metres;
- the nitrate concentration at the source, C_0, is assumed to be 50 mg/L (the results can be pro-rated to accommodate other C_0 assumptions);
- the effective diffusion coefficient is 5×10^{-5};
- no allowance is made for the fact that some attenuation in nitrate concentrations will occur as impacted water soaks downwards through the unsaturated vadose zone, but would be representative of worst case situations in areas with a high water table or groundwater mounding issues;
- the longitudinal and transverse dispersivity are 10 metres and 1 metres respectively;

and,

- impacted water moves at the same rate as the groundwater (i.e. no retardation).

The modelling results are presented in Table 2. The modelling approach is somewhat simplistic, but the results are instructive.

Twenty and sixty-five metres directly downgradient of the source the nitrate concentrations were 33 mg/L and 10 mg/L respectively[2]. Given that the Health Canada Drinking Water guideline for nitrate-nitrogen is 10 mg/L, it follows that domestic wells should preferably be located no closer than 65 metres from an upgradient sewage disposal field and verifies that residential lot sizes in North Shore should be no smaller than about 4,200 m^2 (or approximately 1.0 acre) if the risk of well contamination is to be acceptably low.

TABLE 2 - TWO-DIMENSIONAL MODELLING RESULTS FOR NITRATE IN GROUNDWATER

Downgradient distance from source after 1 year	Dissolved Nitrate Concentration in Groundwater (mg/L)		
	Initial 40 mg/L	Initial 50 mg/L	Initial 60 mg/L
20 m	27	33	40
40 m	17	21	25
65 m	8	10	13

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[2] Although a modelling time of 1 year was used in this example, modelling results for larger time periods were found to give very similar results (i.e. near maximum concentrations had been achieved for these distances after 1 year).

2.5.5 Bacteriological contaminants

Bacteriological contamination of groundwater is not uncommon in North Shore: twenty two (22) instances were reported by residents of the Stanhope Peninsula (2009 ETC resident survey). Other historical information on bacteriological issues reported for the Stanhope and Covehead areas have been received from PEIDEEF and are outlined in Table 3 below.

TABLE 3 - SUMMARY OF BACTERIA RESULTS - COVEHEAD STANHOPE AREA

Year Sampled	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**revised 2007**	**2008**	**PEI Avg**
Total Number of Samples	334	278	242	314	307	192	207	265	
Zero bacteria	73.70%	65.50%	74.80%	73.20%	69.40%	69.80%	73.30%	77.70%	
Total Coliform 1-10 per 100ml	12.90%	15.80%	13.20%	15.60%	15.30%	16.10%	13.80%	14.00%	
Total Coliform greater than 10 per 100 ml	13.50%	18.70%	12.00%	11.10%	15.30%	14.60%	12.90%	7.90%	17.90%
Presence of e-coli	1.20%	1.40%	2.50%	0.30%	1.00%	0.00%	0.00%	0.37%	2.00%
Source: PEI Department of Environment,Energy and Forestry									

Although there is no real trend evident from this data, poorly maintained septic systems in close proximity to inadequately constructed wells are the typical causes of bacteriological problems. As a preventative measure to help reduce the risk of bacteriological contamination, an increasing number of cottages/homes have been using UV systems for water treatment.

For obvious reasons, domestic wells are usually sited upgradient of the associated waste disposal field. That disposal field becomes a potential source of groundwater and surface water contamination, but will more likely threaten the downgradient water wells rather than the (closer) well on the subject property. In addition to the depth to the water table, the vulnerability of wells to contamination therefore becomes a function of the topographic setting. If the distribution of wells and associated waste disposal fields is such that there are a number of septic fields located upgradient of domestic wells, the risk to the groundwater supply here would be greater than if lots were developed perpendicular to the groundwater flow direction.

2.5.6 Other issues

Local well drillers have indicated that wells drilled in the Stanhope Lane area (i.e. in the vicinity of the Stanhope Golf Course) yield hard water with elevated iron concentrations.

City of Charlottetown personnel indicate that elevated barium in water from some of the older, lower yielding “Winter River Basin” wells had been problematic. This was attributed to the presence of naturally occurring minerals in the rock. Given the similarity of the bedrock in North Shore, it is possible that barium concentrations in some domestic wells within North Shore could also contain elevated barium. The Health Canada Drinking Water Guideline for barium is 1 mg/L.

Most homes and businesses in the community are heated with oil, and there is therefore the potential for fuel oil releases to impact the associated groundwater resource. The situation is monitored by the PEIDEEF who maintain a database of such contamination events and document the remedial measures that are undertaken. The data are accessible for public review under the Freedom of Information Act, and such information is provided on a fee (per PID) basis. A response to a request for the total number of PEIDEEF ‘open’ and ‘closed’ files within North Shore had not been received at the time of reporting[3], but a web-based search of individual properties can be undertaken on the PEIDEEF web-page.

Given the confidentiality issue and the fact that some petroleum hydrocarbon releases may have gone unnoticed or unreported it is probably impractical to identify all problem areas. Suffice it to say that groundwater contamination is more likely to occur where development density is highest. Areas located immediately downgradient of properties where potentially hazardous chemicals are

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[3] Open files are those for sites currently under assessment. Closed files are those for sites that have been cleaned up to the satisfaction of the Department.

used or stored should be carefully evaluated before water supplies are developed there.

In addition to those homes heated by oil, approximately four commercial uses within the community may involve the storage and use of potentially contaminating chemicals. Road salt application in the area may also present a risk to groundwater wells within the community, particularly those wells that may have shorter than normal protective steel casings making these more vulnerable to near-surface contamination.

Drilling of test wells to confirm water quality and/or deepening of wells and casings, and/or adding treatment may help resolve these issues.

3.0 DEVELOPMENT OF A GROUNDWATER AVAILABILITY / VULNERABILITY MAP

3.1 Approach

It was resolved that a map should be developed to distinguish those parts of the community where groundwater supplies would likely be viable and those other areas where challenges might be expected for one or more reasons.

To accomplish this, a 50 m by 50 m grid was superimposed over the 10 km by 11.5 km study area in a GIS. Each of the resulting (46,431) grid points would be at the centre of a 0.25 hectare (square) piece of land. A database was then assembled with the easting, northing and elevation of each grid point. Six additional fields in the database were then generated, each of which could be represented graphically in the GIS as a separate layer. For each layer, the field in the database was populated with values ranging from low (negative or least preferred from a groundwater perspective, and highlighted in red in plan) to high (positive or most preferred, shaded green in plan). For each record, these values were then weighted and combined to produce a suitability index (refer to Table 4). Each of these factors is discussed briefly in turn.

3.1.1 Distribution of wells and sewage disposal systems [EDU]

Groundwater withdrawals will naturally be greatest in the more heavily developed parts of the community, where there is a greater chance that one well will interfere with its near-neighbour. The groundwater system in these parts of the community is also likely to be more vulnerable to contamination from sewage disposal systems or other chemical releases. To evaluate this, a point file was produced in the GIS, each point representing a building/EDU. The number of EDUs located within 250 m of each (50 m x 50 m) grid point was calculated. The number of EDUs assigned to each point ranged from 0 to 60, representing a density of development in the range 0 to 3 EDUs per hectare. The “EDU” layer is shown for both the grid assessment system, and for each property in the attached Figure 9. Those areas where development density is relatively high are shaded red in the figure, while sparsely developed areas are shaded green. All else being equal, water supplies would preferably be developed in the green (sparsely developed) rather than red (densely populated) shaded areas.

3.1.2 Nitrate concentrations in groundwater [NIT]

As discussed in Section 2.5.4, the presence of nitrates in groundwater occurring as a result of agricultural practices and sewage disposal is a serious issue. A file was developed identifying interpolated nitrate concentrations on the same 50 metre grid as noted earlier. The accuracy of these generated nitrate values and the associated contour plot will naturally be dependent upon the spatial resolution of the raw data, being more valid in areas with a larger number of tested wells. The “nitrate in groundwater” layer is shown in Figure 8. Those areas where nitrate levels are relatively high are shaded red in the figure, while nitrate concentrations are lower in the green shaded areas. All else being equal, water supplies would preferably be developed in the green rather than red shaded areas.

3.1.3 Bedrock type [BRT]

One bedrock type occurs in North Shore. This transmissive rock belongs to Megacyclic Sequence IV and is considered to be the most favourable from a water supply point of view. All grid points were therefore assigned 100 points in the database.

3.1.4 Overburden thickness and soil type [OST]

From surficial geology (GIS) data recovered from the PEIDEEF, the overburden over most of North Shore falls into one of three groups, with one main group being present. Given the relatively uniform surficial geology for the municipality, all soils were assigned a value of 100. Together, the bedrock and overburden soil type influence the transmissivity and recharge capability of an aquifer.

3.1.5 Elevation [ELE]

Elevation was included as a component of the groundwater availability map, it being reasoned that saltwater intrusion could be a factor where the surface elevation is close to sea level. The “ELE” layer is shown in Figure 10.

3.1.6 Slope [SLP]

As discussed in Section 2.5.2, areas with elevated nitrate concentrations in groundwater, and with surface slopes greater than 9 percent are at greater risk of surface erosion due to run-off and erosion during intense rainfall events. If fertilizer is being used in these areas, elevated dissolved nitrate concentrations could result in nearby groundwater, receiving streams and/or bays.

In some areas of the municipality, elevated nitrate concentrations in groundwater correspond to areas where surface slopes are greater than 9 percent. These areas may therefore be significant sources for surface and groundwater quality issues present in North Shore. Those areas where the slope was steeper than 9-percent were assigned zero points, based on their enhanced susceptibility to erosion (red on the mapping). Flat areas were assigned 100 points. The "SLP" layer is shown in Figure 10[4].

3.2 Findings

The six factors were combined and weighted as shown in Table 4 to produce a Groundwater Availability / Vulnerability Index Map (refer to Figure 11). This map distinguishes areas that would most likely provide groundwater of good quality and quantity (shaded green in the figure), from those areas considered to be at higher risk for groundwater issues, and less attractive from a groundwater supply point of view (shaded red in the figure).

4.0 GROUNDWATER ASSESSMENT BY SUBAREA

4.1 Coastal Zone 1 - The Stanhope Peninsula

In the longer-term, a central water supply may be warranted for the peninsula (particularly the outer 200 metre rim), since most of the peninsula has a relatively higher risk for water quality and quantity issues. The above mapping was taken into account in identifying target locations for the development of potential central water supplies. A possible site for a central wellfield to service the Stanhope Peninsula is identified as Area A in Figure 11. This location at the eastern edge of the community, south of the PEI National Park, is rated relatively highly (i.e. Groundwater

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[4] Please note that only the area within the municipal boundary is valid.

Availability/Vulnerability Index >80), and is sufficiently distant from the shore. Wellfield protection of this potential target location should be relatively easy to develop.

TABLE 4 - FACTORS UTILIZED IN DEVELOPING THE AVAILABILITY / VULNERABILITY MAP

FACTOR CONSIDERED / GIS LAYERS GENERATED		BASIS	POINTS	WEIGHTING FACTOR	SUITABILITY INDEX	
					MINIMUM	MAXIMUM
EDU	Distribution of wells and sewage disposal systems	EDUs within 250 m [EDUs per ha] 0 EDUs [0/ha] 20 EDUs [1/ha] 40 EDUs [2/ha] 60 EDUs [3/ha]	100 67 33 0	30 %	0	30
NIT	Nitrate concentrations in groundwater	Nitrate, mg/L <2 2 to 5 5 to 6 6 to 10 >10	100 75 50 25 0	30 %	0	30
BRT	Bedrock type	Megacyclic Sequence IV (most transmissive)	100	5 %	5	5
OST	Overburden thickness and soil type	thick, low permeability soils (e.g. clay) thin or highly permeable soil (e.g. sand)	100 0	5 %	5	5
ELE	Geodetic elevation	Sea level elevation 30 m elevation 60 m	0 5 100	15 %	0	15
SLP	Surface Slope (percent)	<3 3 to 5 5 to 6 6 to 9 >9	100 75 50 25 0	15 %	0	15
TOTAL				100 %	10	100

It should be noted that the prior recommended location for a central well to supply the Peninsula (i.e. near the south end of Stanhope Lane, as recommended by CBCL in 2007) is not considered appropriate due to two issues found during this assessment - (i) local well drillers indicate that there have been many cases of very high dissolved iron concentrations (i.e. very hard water) to the northeast of the golf course and along Stanhope Lane, and (ii) elevated nitrate concentrations in groundwater are known to occur to the south and east of Stanhope Lane, and this area may be within a capture / recharge zone of such a central well supply.

In the shorter-term for the Stanhope Peninsula, local groundwater supply problems could be resolved by: (a) drilling new wells, (b) connecting to neighbouring unaffected wells, (c) water treatment, and/or (d) trucking of water for onsite storage.

In order to establish an approximate time-frame for when development could (theoretically) increase to a level compromising groundwater quality in the area (i.e. high nitrate concentrations in groundwater in response to a growing number of septic systems), a simple modelling exercise was performed using a range of typical nitrate concentrations for septic effluent. Based on an equivalent number of EDUs, and a maximum build-out value for the peninsula (of 533 EDUs), the approximate (diluted) concentration of nitrate in groundwater was modelled. Modelling results are outlined in Table 5 and plotted in the attached Figure 12.

Using the drinking water guideline for nitrate (10 mg/L) as an indicator for when a Central Wastewater / Sewer System would be necessary, a central sewer system would probably not be considered until after 55 percent build-out is reached (i.e. when one-half the drinking water guideline is estimated to be reached in about 23 years). Due to the possibility for increased bacteriological issues and further saltwater intrusion prior to this time, it is likely that a central water supply would be required for the peninsula before this.

In practice however, the municipality may wish to wait longer before installing a central WWSS (at say 75 percent build-out). Using this approach, and based on current growth trends, a central WWSS would be necessary in about 56 years. Again, bacteriological problems may dictate the installation of a central (or cluster) WWSS sooner than this.

TABLE 5 - ESTIMATED NITRATE CONCENTRATIONS IN GROUNDWATER DUE TO INCREASED DEVELOPMENT ON STANHOPE PENINSULA

No. EDUs	% Build-out	Estimated [Initial] Nitrate concentrations from a Septic System and Approximate *Diluted* Nitrate Concentration in Groundwater due to Aquifer Recharge on Stanhope Peninsula, (mg/L)		
		[40]	[50]	[60]
173	33	*2.0*	*2.5*	*3.0*
267	50	*3.1*	*3.8*	*4.6*
400	75	*4.6*	*5.8*	*6.9*
533	100	*6.1*	*7.6*	*9.2*

The most conservative results of this modelling suggest that nitrate concentrations in groundwater could approach the 10 mg/L mark after full build-out[5]. Based on the current growth trend for the peninsula (of about 4 EDUs per year), an additional 360 EDUs would be expected in about 90 years.

It should be noted that the linear trend modelled would likely represent “best-case” conditions since the amount of aquifer recharge available for nitrate dilution would most likely decrease with added development (i.e. with the addition of paved roads, new culverts, ditches, parking lots, and more

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[5] This value assumes that typical nitrate concentrations from septic systems are 60 mg/L, and that 400 mm of recharge is available for dilution to the peninsula each year.

sophisticated site drainage systems) and with sea-level rise, making this relationship not truely linear, as portrayed, but curving upwards with time and added development.

4.2 Coastal Zone 2 - The balance of the outlined Coastal Zone

In the longer-term, the existing central water supply will need to be maintained for MacMillan point, with some (previously planned) lots being added to the current system as development increases. At full-build-out, it is planned that there would be about 150 homes on the current (three production well) system. It is understood that homes from the Eagle's Path area are not eligible to be connected to this supply in future. Should the current central water supply need to be expanded, and/or a central water supply eventually be sought for Eagle's Path, Area B (in Figure 11) might be considered.

Elsewhere within this zone, in the shorter-term, local problems could be resolved by: (a) drilling new wells, (b) connecting to neighbouring unaffected wells, (c) deepening wells or extending well casings, or (c) water treatment.

4.3 Agricultural Zone 1 - Outside the Winter River Watershed

Central (or cluster) water supplies are not likely required, even in the longer term.

Local problems could be resolved by: (a) drilling new wells, (b) deepening wells or extending well casings, or (c) water treatment.

Due to potentially high nitrate concentrations in this area, it may be advisable to drill test wells to confirm water quality before developing new lots.

4.4 Agricultural Zone 2 - Within the Winter River Watershed

Central (or cluster) water supplies are not likely required, even in the longer term, and might not be feasible for regulatory reasons.

Local problems could be resolved by: (a) drilling new wells, (b) deepening wells or extending well casings, or (c) water treatment.

Further domestic well development in the Winter River basin may also be restricted.

5.0 SUMMARY

In Table 6, the four subareas are classified based on water supply issues. The highest priority subarea should probably be serviced with potable water from an off-site source soon, or at least in the longer term. Off-site servicing of the “low to medium” priority subarea would be desirable but not essential (for the entire subarea) in the long term, as indicated. The two subareas falling into the “low” priority category could probably be serviced satisfactorily in the long term by domestic wells, although local problems may need resolution by well replacement, addition of casing or water treatment.

5.1 Recommendations for Groundwater Monitoring

So as to continue in a due-diligent manner, the municipality may wish to implement further proactive measures to keep current water quality / quantity issues in check, particularly for the Stanhope Peninsula. Some recommendations for a groundwater monitoring program for the Stanhope Peninsula include:

- Continue to obtain updates on groundwater test results from PEIDEEF (nitrate, bacteria, number of saltwater impacted wells drilled, status of petroleum release sites, etc).

- Sample and test a minimum of 12 well sites per year for general chemistry, trace metals, and microbiology (E. Coli and faecal coliform).

TABLE 6 - SUMMARY OF POTABLE WATER ASSESSMENT BY SUBAREA

SUBAREA	RELATIVE LEVEL OF NEED	DISCUSSION
COASTAL ZONE 1 - THE STANHOPE PENINSULA	1 MEDIUM TO HIGH	In the longer-term, a central water supply may be warranted for the peninsula (particularly the outer 200 metre rim), since most of the peninsula has a relatively higher risk for water quality and quantity issues. In the shorter-term for the Stanhope Peninsula, local groundwater supply problems could be resolved by: (a) drilling new wells, (b) connecting to neighbouring unaffected wells, (c) water treatment, and/or (d) trucking of water for onsite storage.
COASTAL ZONE 2 - SOUTH AND EAST OF BRACKLEY AND COVEHEAD BAYS	2 LOW TO MEDIUM	In the longer-term, the existing central water supply will need to be maintained for MacMillan point. Should an alternate central water supply eventually be sought for Eagle's Path, or to expand on the current system, Area B (in Figure 11) might be considered. Elsewhere within this zone, in the shorter-term, local problems could be resolved by: (a) drilling new wells, (b) connecting to neighbouring unaffected wells, (c) deepening wells or extending well casings, or (c) water treatment.
AGRICULTURAL ZONE 1 - OUTSIDE THE WINTER RIVER WATERSHED	3 LOW	Central (or cluster) water supplies are not likely required, even in the longer term. Local problems could be resolved by: (a) drilling new wells, (b) deepening wells or extending well casings, or (c) water treatment. Due to potentially high nitrate concentrations in this area, it may be advisable to drill test wells to confirm water quality before developing new lots.
AGRICULTURAL ZONE 2 - WITHIN THE WINTER RIVER WATERSHED	4 LOW	Central (or cluster) water supplies are not likely required, even in the longer term, and might not be feasible for regulatory reasons. Local problems could be resolved by: (a) drilling new wells, (b) deepening wells or extending well casings, or (c) water treatment. Further domestic well development in the Winter River basin may also be restricted.

- Monitor water levels (and conductivity if possible) on a continuous basis at a minimum of 3 well locations with automated dataloggers. These monitored locations would preferably be within cluster (or domestic) wells with relatively high daily discharge rates (two of the three monitored locations would preferably be located in the outer 200 metre perimeter of the peninsula with one in the inner core of the peninsula). This data should be downloaded routinely (say every six months) and reviewed periodically by a Hydrogeologist.

- A field conductivity meter can also be used once every two or three years to manually check all available wells for conductivity measurements (i.e. from which the degree of saltwater intrusion can be assessed on a routine basis). During this field work, residents could be surveyed / interviewed about any well (or septic) issues experienced.

REFERENCES

Anastasiadis P., and Latinopoulos P., 2002. Comparison Between Aquifer Solute Concentration and Monitoring Wells, Aristotle University of Thessaloniki, Greece.

Benson V. et al, 2006. Spatial Analysis of Land Use Impact on Groundwater Nitrate Concentrations, Technical Reports: Groundwater Quality, Madison, WI, USA.

Crane, C.S., Raymond, B.G., Thompson, J.W., Water Quality in Covehead/Brackley Bay, 2004.

Francis R., 1989. Hydrogeology of the Winter River Basin, Prince Edward Island, Department of the Environment, PEI.

Friends of Covehead-Brackley Bay (FCCB), Covehead-Brackley Area Watershed Management Plan, March 2009

Jiang, Y., Somers G., and Mutch J., 2004. Application of Numerical Modeling to Groundwater Assessment and Management in PEI, PEI Department of Environment and Energy, PEI.

Jiang, Y., Somers G., Paradis D., 2007. Estimation of Groundwater Residence Times in the Wilmot River Watershed on PEI - Implications for Nutrient Reduction, PEI Department of Environment, Energy and Forestry, PEI.

MacDougall J., Veer C., and Wilson F., 1988. Soils of Prince Edward Island, Research Branch Agriculture Canada, Charlottetown, PEI.

North Shore Official Plan, 2005. North Shore Municipality.

Somers G., Savard M., and Paradis D., 2007. Mass Balance Calculations to Estimate Nitrate Proportions from Various Sources in the Agricultural Wilmot Watershed of PEI, PEI Department of Environment, Energy and Forestry, PEI.

Somers G. et al, 2007. Evolution of Groundwater Nitrate Concentrations Under Various Climate Change Scenarios for PEI, Canada, PEI Department of Environment, Energy and Forestry, PEI.

Stanhope Water Studies, CBCL for North Shore Municipality, 2000 and 2008.

The GIS Centre, 2004. Nitrate Dilution Modeling of Montgomery Township, Somerset County, NJ

Van de Poll, H.W., 1983. Geology of Prince Edward Island, Department of Energy and Forestry, Charlottetown, PEI.

Van de Poll, H.W., 1988. Lithostratigraphy of the Prince Edward Island Redbeds, University of New Brunswick Department of Geology, Fredericton, New Brunswick.