Results of a Well Water Quality Survey in Eastern Shelburne County

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Introduction

The majority of residents in Shelburne County rely on private water wells for their drinking water. Many of these wells are located near the coast and have the potential to be affected by saltwater intrusion. Climate change is expected to increase the risk of saltwater intrusion into coastal aquifers because of rising sea levels and changes to precipitation patterns. As a first step towards managing this risk, a well water survey was completed in the summer of 2015 in eastern Shelburne County. The objective of the survey was to provide baseline information on salt levels in wells to help understand the current extent of saltwater intrusion since there are few sources of existing well water chemistry data in this area of the province. The results may also be used to compare to future surveys to determine if saltwater intrusion is increasing. The project was carried out as a partnership between the Nova Scotia Department of Natural Resources (DNR) and the Municipality of the District of Shelburne.

Background

Saltwater Intrusion

Saltwater intrusion (also called seawater intrusion) is the movement of ocean water into freshwater coastal aquifers. Under natural conditions the flow of fresh groundwater towards the coast prevents ocean water from moving inland, and the boundary between freshwater and saltwater remains near the coastline and far below the ground surface (Fig. 1). Saltwater intrusion occurs when the underground boundary between ocean water and fresh groundwater moves inland. It can be caused by any process that reduces or reverses the hydraulic gradient near the coast, including sea-level rise, increased water well pumping and declining groundwater recharge rates. Wells that are located near the coast where saltwater intrusion is occurring will experience higher salt levels and may become so salty that they must be abandoned.

Saltwater intrusion occurs in coastal areas throughout the world and is expected to become more widespread with climate change. In Atlantic Canada, the association between climate change and saltwater intrusion has been discussed by the Atlantic Climate Adaptation Solutions Association (Prince Edward Island Department of Environment, Labour and Justice, 2011) and case studies have been completed in each of the four Atlantic Provinces. This work has concluded that sea-level rise, extreme weather events, coastal erosion, changing precipitation patterns, warmer temperatures and the potential increased freshwater demand from coastal aquifers could all increase the risk of saltwater intrusion in Atlantic Canada. Additional scientific monitoring, assessment and collaboration has been recommended as a necessary first step in understanding and dealing with the issue of saltwater intrusion (Prince Edward Island Department of Environment, Labour and Justice, 2011).

In Nova Scotia, DNR has published a provincial saltwater intrusion risk map to help identify areas that are most vulnerable to saltwater intrusion (Kennedy, 2012). In eastern Shelburne County, the three municipal units (i.e. Town of Shelburne, Town of Lockeport, and Municipality of the District of Shelburne) have prepared Municipal

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Drage, N., Drage, J., Tipton, E. and Hartley, E. 2016: *in* Geoscience and Mines Branch, Report of Activities 2015; Nova Scotia Department of Natural Resources, Report ME 2016-001, p. 29-37.

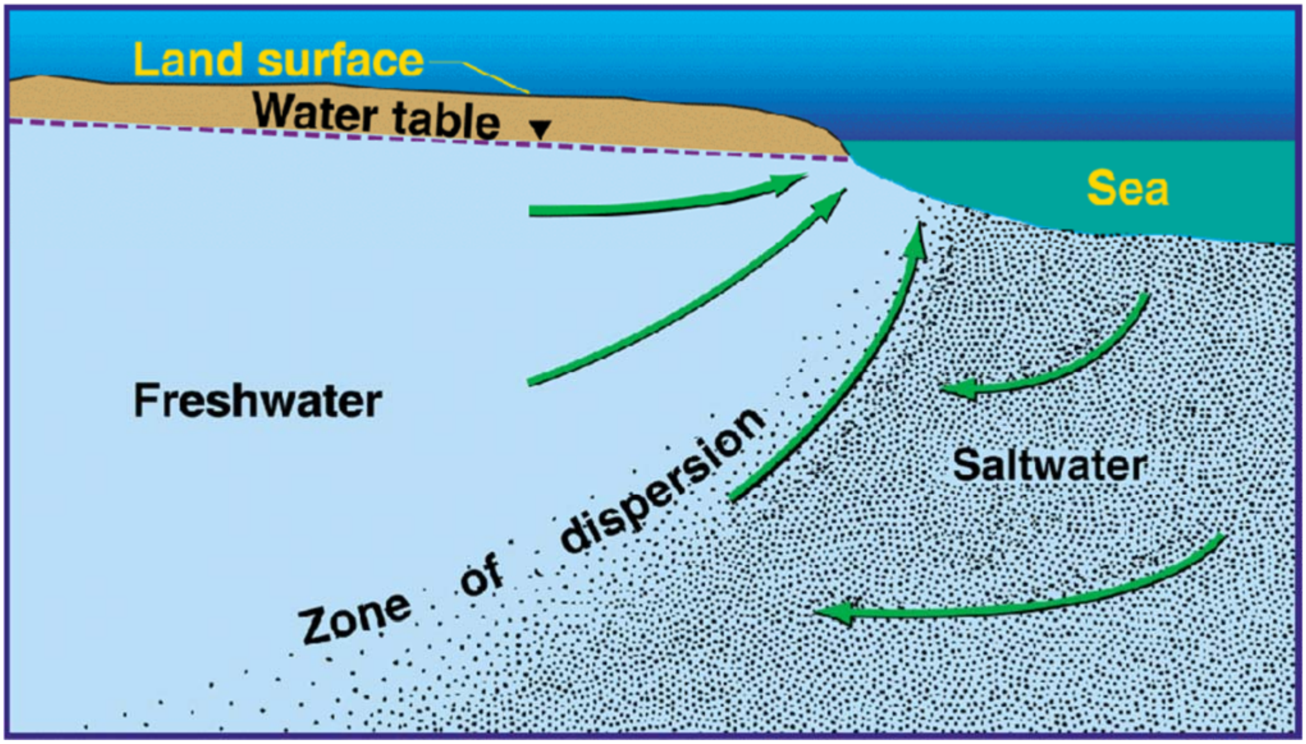

Figure 1. Groundwater flow under natural conditions in a coastal aquifer (Image provided courtesy of the U.S. Geological Survey, 2015).

Climate Change Action Plans, which include an assessment of the vulnerability of water resources to climate change. The plans identified potential climate impacts that include sea-level rise (approximately 1 m rise by 2100) and summer water shortages because of reduced rainfall. Both of these impacts have the potential to increase saltwater intrusion.

Water Supplies in Shelburne County

The population of Shelburne County is approximately 14,000, of which 12% live in population centres and 88% live in rural areas (Statistics Canada, 2011). Drinking water in the county is provided by both public water systems and private wells; however, the majority of Shelburne County residents (i.e. 99%) rely on private wells. The public water supplies include two municipal supplies (located in the Town of Shelburne and Town of Lockeport) and 68 registered public water supplies. In Nova Scotia, registered public water supplies are small water systems that have at least 15 service connections or regularly serve at least 25 people per day for 60 days of the year, including daycares, restaurants and commercial accommodations.

The Town of Shelburne water supply source is Rodney Lake. It was originally developed for the Shelburne naval base in 1942 and then expanded to service the Shelburne Industrial Park in the late 1960s and further expanded to service shopping centres and a fish processing plant in the early 1980s (CBCL Limited, 2015). It currently provides water to various commercial, industrial and institutional operations, and approximately 10% (170 people) of the Town's residents (CBCL Limited, 2015).

The Town of Lockeport water supply source is Hayden Lake. It was originally constructed in 1980 as a water supply for fish plants in Lockeport. It currently provides water to three residential homes and 12 commercial, industrial and institutional facilities (C. J. MacLellan & Associates Inc., unpub. rep., 2013).

The remainder of residents in Shelburne County rely predominantly on private wells. The NS Well

Log Database (Nova Scotia Environment, 2014) contains 2,137 water well records for Shelburne County. The database indicates that 1,378 (64%) of these are drilled wells and 759 (36%) are dug wells. However, based on the number of dwellings that are not serviced by municipal water supplies, it is estimated that there are approximately 8,000 water wells in Shelburne County. Approximately 75% of these wells are located within 500 m of the ocean.

The proportion of dug wells compared to drilled wells in Shelburne County is relatively high compared to the rest of the province (i.e. 36% versus 5%). Shallow dug wells are less likely to be affected by saltwater intrusion than drilled wells; however, they are more vulnerable to surface contamination and droughts. The development of surface water supplies to meet the demand of the largest water users in Lockeport and Shelburne has effectively reduced the demand for groundwater from coastal aquifers and helped to mitigate saltwater intrusion risk.

Previous Water Resources Studies

Prior to the development of surface water sources to meet industrial water demands in Lockeport and Shelburne, groundwater exploration programs were conducted in these areas to assess whether an adequate groundwater source could be obtained. Several reports were published in the 1960s and 1980s that include an assessment of the groundwater resources of eastern Shelburne County (NSDM, 1965; NSDM, 1967; Porter, 1982). With respect to saltwater intrusion, these reports suggest that problems may have been occurring in the 1960s in Lower Woods Harbour, Lockeport and the Town of Shelburne (NSDM, 1967). Industrial wells located near the coast in the Town of Shelburne were identified as possibly being affected by saltwater intrusion (NSDM, 1967). However, a water well survey completed in the Town of Shelburne in 1964 showed that salt levels in wells were low. The survey tested 53 wells and found that total dissolved solids (TDS) concentrations ranged from 28 mg/L to 252 mg/L with a median of 88 mg/L. None of the wells exceeded the aesthetic drinking water guideline for TDS of 500 mg/L.

Methods

Water Well Locations

Well water samples were submitted for testing by well owners who voluntarily chose to participate in the 2015 survey. The Municipality of the District of Shelburne advertised the well water survey in its 2015 summer newsletter and invited well owners to submit well water samples for testing. Water samples were also collected during a door-to-door survey carried out by DNR in the Lockeport area. A total of 33 samples were tested. The locations of the wells are shown on the map in Figure 2. The well locations were georeferenced using a handheld GPS during the survey (21 of 33 wells). For the samples submitted by the well owner, well locations were georeferenced using the NS Property Records Database via Property Online (Access Nova Scotia, 2015) and Google Earth (12 of 33 wells).

Water Testing Methods

The salt levels in the well water samples were estimated by measuring electrical conductivity and converting these values to TDS concentrations. TDS is composed of calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulphate and nitrate (Health Canada, 2014). Converting conductivity measurements to TDS allows the results to be compared to the Canadian Drinking Water Quality guidelines since there is a guideline for TDS but there is no guideline for electrical conductivity. The Canadian Drinking Water Quality guideline for TDS is 500 mg/L (Health Canada, 2014), which is based on aesthetic considerations (taste and excessive scaling) rather than health effects.

The well water samples were tested for electrical conductivity using a HACH portable meter (i.e. HACH SensION+ MM150 with 5048 multi-parameter electrode). This meter is reported to have an electrical conductivity measurement error of ≤0.5%. The meter was calibrated daily prior to taking electrical conductivity measurements. The HACH meter has a built in function for converting electrical conductivity to TDS, which is

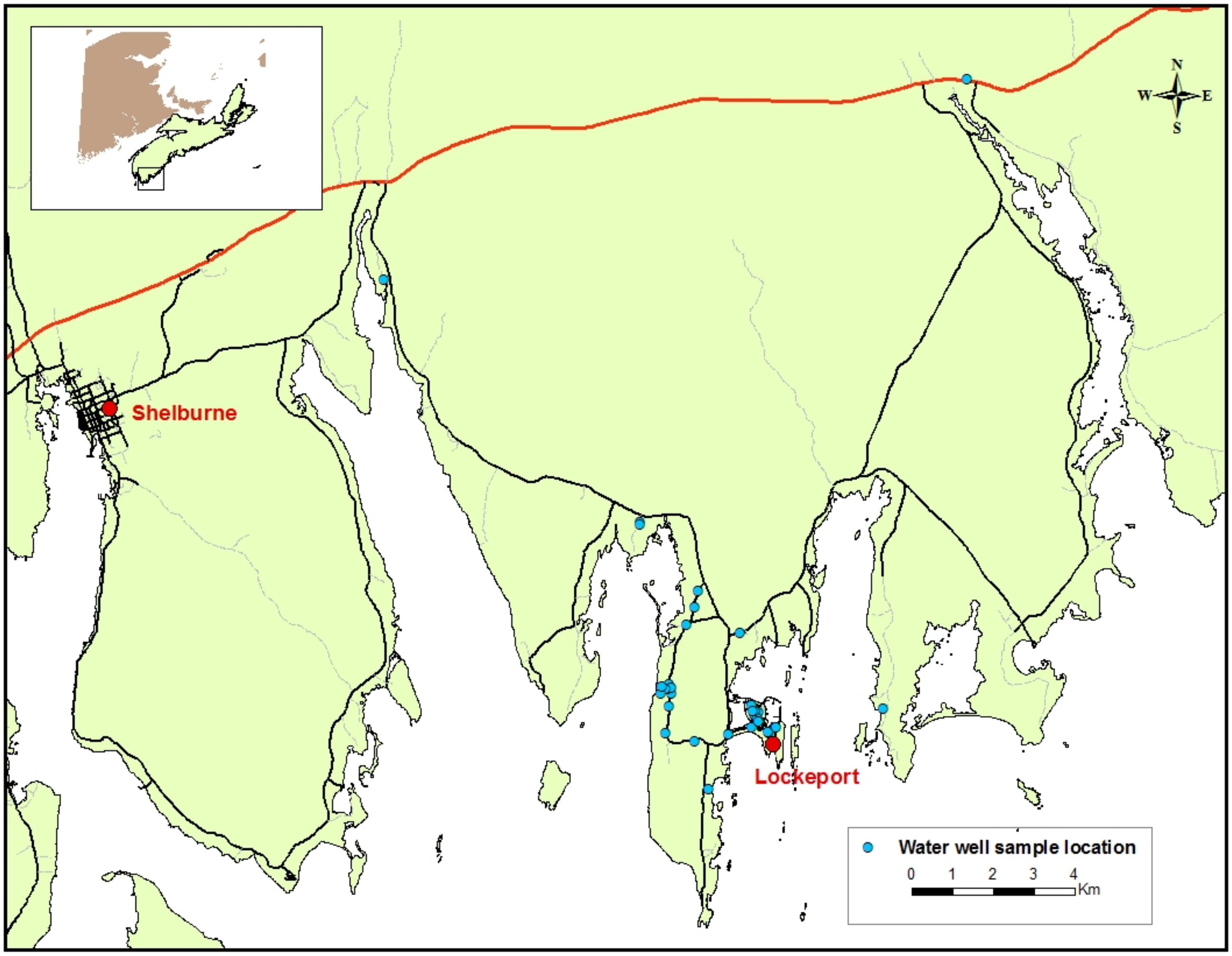

Figure 2. Map of well water sample locations.

based on a linear equation using a generic slope factor. In order to improve the accuracy of this conversion, a site-specific slope factor was derived using measured values of electrical conductivity and TDS from well water samples for Shelburne County from the NS Groundwater Chemistry Database (NSDNR, 2015).

Figure 3 shows a plot of the TDS versus electrical conductivity data for the 54 well water samples from Shelburne County in the NS Groundwater Chemistry Database. Using a linear regression model, the slope factor from the data in Figure 3 was calculated to be 0.57 with an R^2 value of 0.96. Therefore, a multiplier of 0.57 was used to convert all electrical conductivity measurements to TDS concentrations for the 2015 eastern Shelburne County well water survey.

Results and Discussion

The results from the 2015 well water survey are summarized in Table 1 and Figure 4. A total of 33 wells were tested. Twenty-two of these were dug wells (67%), four were drilled wells (12%) and seven were unknown well type (21%) (i.e. the well type was not reported by the well owner when the sample was submitted). The TDS concentrations ranged from 38 mg/L to 935 mg/L with a median value of 100 mg/L. Three of the well water samples (9%) had TDS levels above the drinking water guideline of 500 mg/L.

The TDS levels observed in the 2015 survey are slightly higher than those observed in the 1965 survey carried out in the Town of Shelburne; median concentrations are 100 mg/L and 88 mg/L

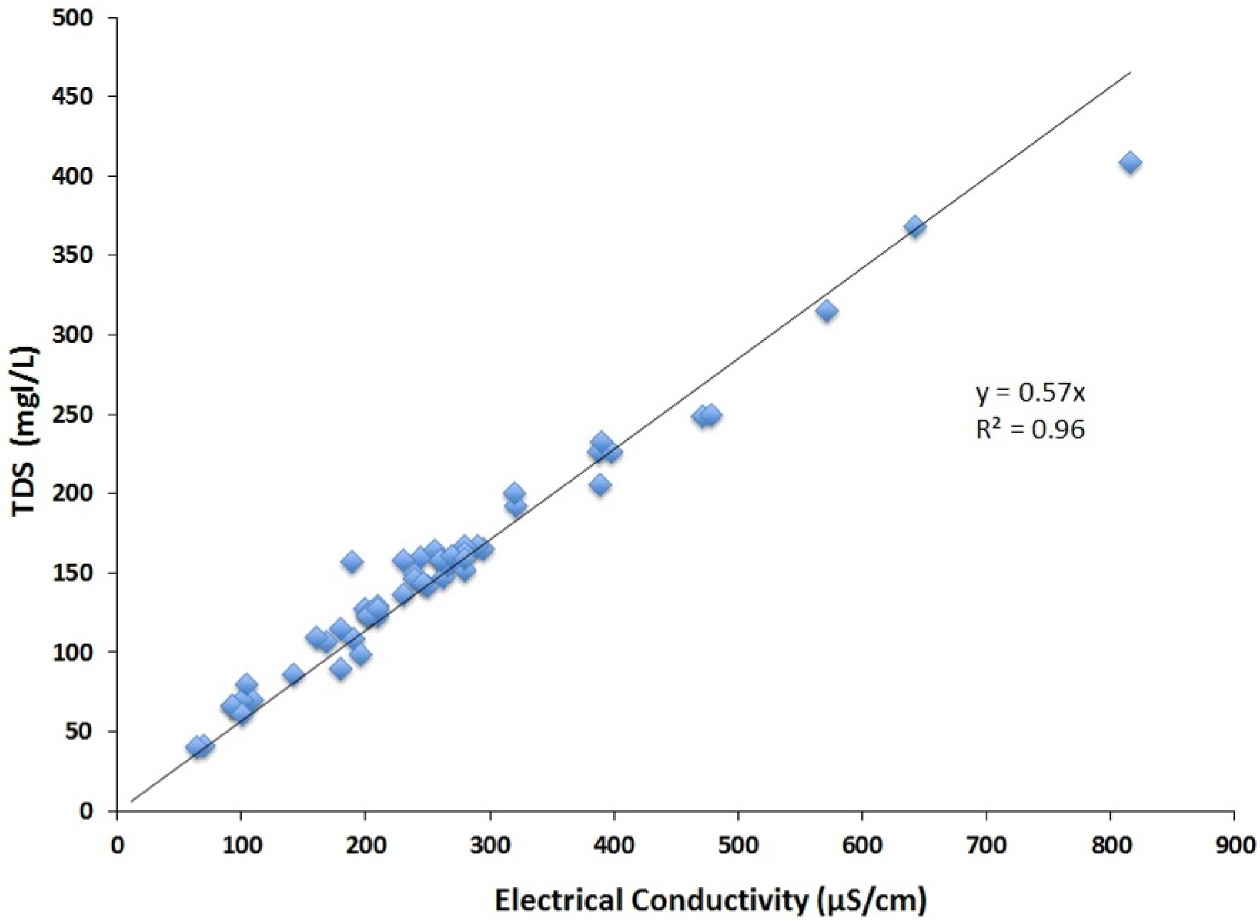

Figure 3. Electrical conductivity versus TDS measurements for well water samples from Shelburne County as reported in the NS Groundwater Chemistry Database (n=54).

Table 1. Summary of 2015 water well survey results.

	Electrical Conductivity (µS/cm)	TDS
No. of samples	33	33
Minimum	67	38
Maximum	1,640	935
Arithmetic mean	318	181
Standard deviation	347	198
Median	175	100
95^{th} Percentile	984	561
No. of samples above TDS drinking water guideline of 500 mg/L	NA	3 (9%)

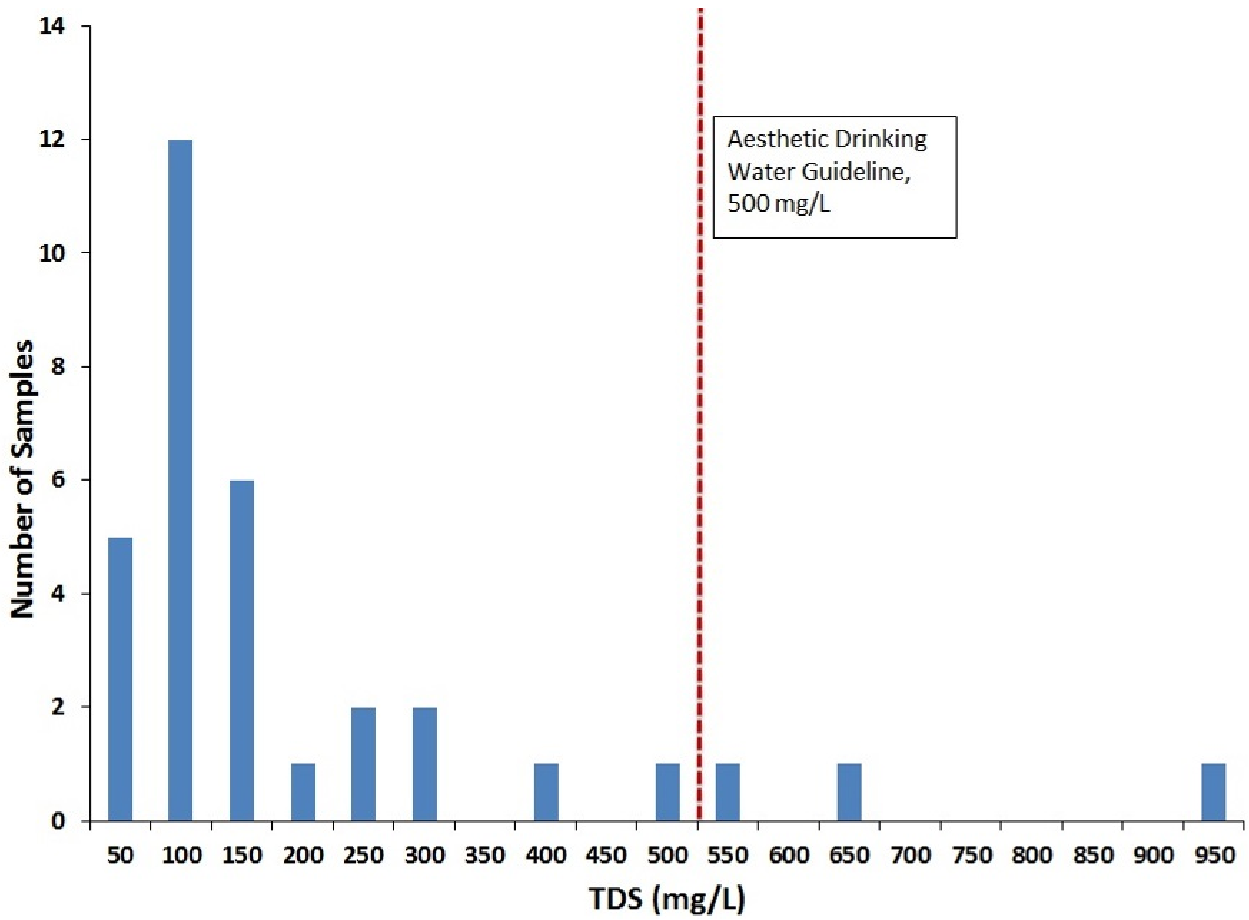

Figure 4. Histogram of TDS concentrations from the 2015 well water survey (n=33 samples).

from the 2015 and 1965 survey, respectively. In addition, 9% of the 2015 samples exceeded the TDS guideline, while none exceeded in 1965. It should be noted that these two surveys are not necessarily directly comparable because they were carried out in different areas using different wells.

There is no specific TDS threshold that can be used to indicate that a well has been impacted by salt. However, it is likely that the three samples from the 2015 survey that exceed the TDS drinking water guideline are affected by salt. Several of the other wells that had lower, but elevated TDS levels relative to background concentrations, may also be affected by salt.

It should be noted that there are several possible causes of salt in well water with the most common causes being saltwater intrusion and road de-icing salt. The 2015 survey data indicate that the wells with the highest TDS levels (i.e. >100 mg/L) were all located within 50 m of a road, and the majority of these were shallow dug wells. Given that these wells are shallow and close to roads, the elevated TDS levels are most likely related to road-salt impacts rather than saltwater intrusion.

The graph in Figure 5 shows the relationship between TDS levels and distance to the nearest road for the wells that were georeferenced using GPS (n=22). It is evident from the graph that the wells located closer to roads are more likely to have elevated TDS levels. Based on the data in Figure 5, the wells located less than 50 m from a road had an average TDS concentration of 218 mg/L (n=17), while the wells located greater than 50 m from a road had an average TDS concentration of 60 mg/L (n=5).

The graph in Figure 6 shows the relationship between TDS levels and distance to the coastline for the same wells used in Figure 5. In this case, there is no apparent relationship between TDS and distance to the coast (i.e. R^2 = 0.0002). This

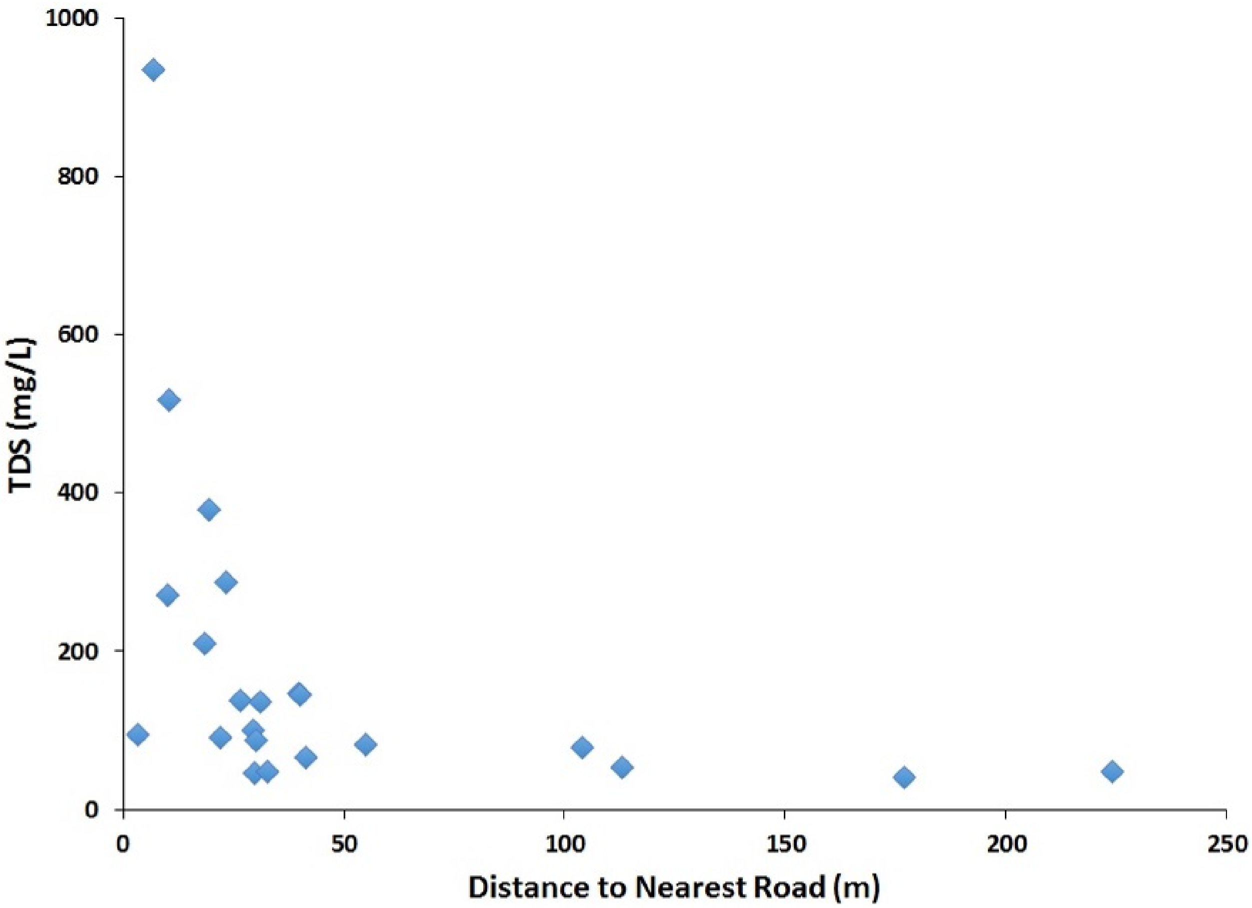

Figure 5. Distance from well to nearest road versus TDS concentration.

supports the conclusion that the observed TDS levels are more likely related to road-salt impacts than saltwater intrusion. Further work could be done to investigate the salt sources in these wells by collecting additional water samples and analyzing for chloride and bromide. The ratio of these two elements is commonly used to determine salt sources in well water (Briggins and Cross, 1995).

Conclusions and Recommendations

The results of the 2015 well water quality survey indicated that the majority of well water samples tested had low salt levels. However, 9% of the samples had elevated salt levels exceeding the TDS aesthetic drinking water guideline. The results also indicated that wells located near roads were more likely to have elevated salt levels and, therefore, the cause of the salt impacts is likely road-salt rather than saltwater intrusion.

Future work should include the testing of additional wells to increase the coverage of the current survey and testing for chloride and bromide to determine the source of salt in wells with elevated TDS levels. This work should target drilled wells near the coast, which are more vulnerable to saltwater intrusion. Additional work could also include the compilation and comprehensive review of existing groundwater quality data to help identify areas where saltwater intrusion has occurred. This should include data sources such as the NS Groundwater Chemistry Atlas, which includes a TDS map for the province (Kennedy and Finlayson-Bourque, 2011).

Given the high proportion of dug wells in the area (i.e. 67% of the sampled wells), local private water supplies are likely to be more vulnerable to shallow sources of contamination (e.g. road salt, bacteria) and summer drought conditions than saltwater intrusion. It is important that proper dug well construction methods are followed in the area to reduce the risk of impacts from surface

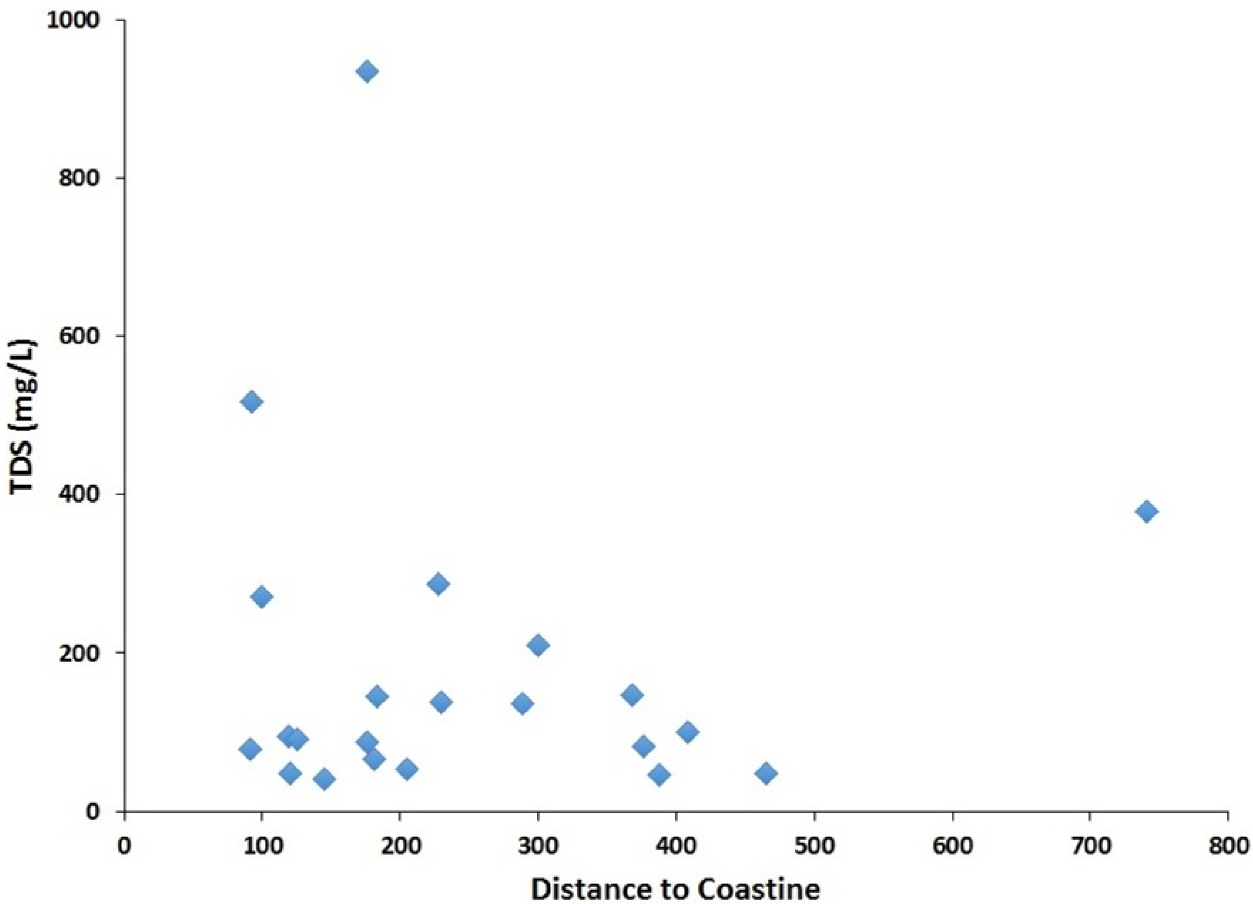

Figure 6. Distance from well to coastline versus TDS concentration.

contaminants. It is also important that potential contaminant sources (such as road salt, septic systems and petroleum products) are properly managed to reduce the risk of shallow groundwater contamination.

Acknowledgments

The authors would like to gratefully acknowledge all of the well owners who volunteered well water samples for the 2015 survey. Gavin Kennedy is also acknowledged for his thorough review, suggestions and contributions that greatly improved this manuscript.

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