Chapter 10 CONCLUSIONS AND RECOMMENDATIONS

10.1 Introduction

This chapter presents conclusions and a summary of recommendations for the current water systems for North and South Pender Islands. The recommendations have been divided on the basis of existing water supply systems, as well as for the islands as a whole. Both the conclusions and recommendations are then applied to other small island scenarios on a more global basis.

10.2 Conclusions: North and South Pender Islands

The findings of this dissertation provided an approach which assists in better defining the groundwater resources available for distribution on North and South Pender Islands, acquired information on groundwater consumption, recommended changes to the existing institutional framework with the goal of incorporating this information into the community planning process in a meaningful and cost-effective manner.

North and South Pender Islands represent a geologically complex environment to conduct groundwater assessment investigations. The bedrock dips vary significantly (19^0 to 89^0) and the bedrock is folded and faulted. The bedrock has low primary porosity and permeability but the faulting gives the bedrock localized increases in secondary porosity and permeability. Localized increases in secondary porosity and permeability also occur at stratigraphic boundaries within the bedrock.

The approach of integrating airphoto interpretation, geologic mapping, geophysical investigations, water well data, and climatic data was put forward to determine the physical characteristics of the islands as a means of cost effectively estimating the groundwater resources of the islands and incorporating that information into the community planning process. This approach followed recommendations made by Halstead and Treichel (1966).

The approach commences with the least expensive, most general investigative tools and works toward the most specific, expensive tools in a logical manner. The airphoto interpretation enabled the major faults to be identified as well as the bedrock lithology. The geological mapping and geophysical investigations enabled the delineation of faults and fracture zones within the bedrock that would assist in targeting water well locations to access zones of higher secondary porosity and permeability. The data acquired provide a means of improving the identification of areas at higher risk of both water shortage and decreasing water quality while improving estimates of the variables in the water balance equation. In short, the research undertaken to delineate the physical characteristics of the islands enabled a better understanding of the groundwater resources and providing useful information to improve management of these resources.

Geophysical investigations delineated the thickness of the freshwater column at several locations on the islands placing a lower limit on the depth for water wells. The geophysical investigations identified zones of increased fracturing within the bedrock that provided a better understanding of groundwater recharge and target locations for water wells. In low lying areas possessing soil cover, a perched water table appears to be common on the basis of the seismic refraction survey results, as well as observations of embankments along roadways. All of these results of the geophysical investigations exemplify the usefulness of the approach for groundwater exploration and development.

The climatic data from 1925 to 2002 were reviewed and incorporated into water balance equations. The water balance equations for the islands indicate the influence that climatic variability has on the groundwater resources. Water balance calculations indicate that there is a linear relationship between water available for groundwater recharge and the actual level of recharge. These calculations also indicate that minor increases or decreases in recharge can significantly change the volume of water available. Similarly, increases in secondary porosity may also correspond to increases in hydraulic conductivity resulting in an exponential increase in available water resources.

The current institutional and legal frameworks were reviewed with results illustrating a scenario in which there are many government agencies involved in the management of groundwater resources on the islands creating a scenario where too many agencies are involved in water management often with contradictory agendas. The islands were sub-divided on the basis of groundwater basins. Through a change in the current governance framework to groundwater basins versus islands as a whole, it is possible to have more local control over land use, water supply, water demand and water quality. The governance scheme proposed in Chapter 9 allows for the incorporation of the increased knowledge of the physical setting into the community planning process.

A water balance calculation for the Municipal Improvement District of Trincomali indicates the precarious nature of the water supply for the islands (Chapter 8). A similar approach for North and South Pender Islands shows the variability in supply based on relatively minor changes in groundwater recharge as a percentage of total annual precipitation and indicates that the islands may not have the carrying capacity for the estimated full build out populations (Chapter 8). In conjunction with groundwater vulnerability maps, it is important to utilize the information obtained to adjust community plans to minimize the risk of overtaxing the water supply in each groundwater basin (Chapter 9).

The estimated extractable groundwater resources are an important consideration in the overall water management (Chapter 7). The water consumption for North and South Pender Islands at full build out represents 8% and 6% respectively of the estimated extractable groundwater resources. Given the potential for water deficits for years with below average precipitation, groundwater mining would occur during these years.

10.3 Recommendations: North and South Pender Islands

In order for any of the following recommendations to be successful, there must be changes to the current management framework and a number of new, strictly enforced regulations. The recommendations are outlined for each of the current water supply systems, as well as for the islands as a whole.

10.3.1 Razor Point Road Improvement District (Groundwater Basin NP-VII)

As mentioned in Section 8.2.4.2, the Razor Point Improvement District is reliant on a single water well to meet the supply needs of the community. Threats to the water supply could come from contamination or natural disaster (drought, seismic activity). It is recommended that the community explore additional water well locations to provide a more secure water supply. The community should also ensure that any water wells are subject to regular testing for total coliforms and specifically *E. coli*. It is suggested that the Board of Directors for the district explore opportunities for funding the costs of drilling additional water wells. The Board of Directors should also explore the potential for funding installation of water-saving devices to assist in reducing water demand. A block pricing mechanism is recommended, one that differentiates between winter and summer water consumption.

10.3.2 Magic Lake Estates (Groundwater Basins NP-VI, NP-VIII, NP-IX, NP-X and a portion of NP-XI and NP-XII)

Magic Lake Estates encompasses part or all of six groundwater basins on North Pender Island. The prime focus of Magic Lake Estates should be the reduction of water demand through the use of water meters, block pricing mechanisms, and conservation practices. As discussed in Section 8.4.2.1, water meters could be used to the benefit of the community in the following ways:

- By identifying leaks in the distribution system;
- By identifying residences with abnormally high water consumption;
- For user pay system, by incorporating block pricing mechanisms.

The identification and repair of leaks in the water supply system not only results in increased supply but also in decreased energy costs. It is also recommended that water-saving fixtures be promoted (see Table 3.3), as this action could reduce water demand and as a result increase water supply.

The community should be concerned about changing land use around their water supply such as the potential sale of a large block of developable land adjacent to Buck Lake.

10.3.3 Municipal Improvement District of Trincomali (a portion of Groundwater Basins NP-XI and NP-XII)

At present, the Municipal Improvement District of Trincomali, as discussed in Section 8.2.4.3, represents the best approach to water management on North and South Pender Islands. The best recommendation that can be made for this district is that they continue their vigilance in managing their water resources. The Municipal Improvement District of Trincomali provides an example of a successfully managed water system.

10.3.4 Greenburn Lake (Groundwater Basin SP-III)

As mentioned in Section 8.2.4.4, there is limited development within Groundwater Basin SP-III. It is recommended that Parks Canada establish a means of monitoring withdrawals from the lake and impose rules on licencees requiring that they monitor consumption through the use of water meters. It is also suggested that a fee be charged to those with licenses to withdraw water. The fee should be aligned with seasonal demand so that higher rates are charged during the dry summer months. There should also be some form of block pricing during the summer months to ensure that any large withdrawals are charged at a higher rate.

There is no mention in any of the existing literature of water quality monitoring at Greenburn Lake. It is recommended that a water quality program be established; specifically for total coliforms and specifically *E. coli*.

10.3.5 Poets Cove (Groundwater Basin SP-III)

The Poets Cove development is reliant on water withdrawals from Greenburn Lake to meet all of its water requirements. It is recommended that the Poets Cove development establish alternate sources of water by drilling water wells, rainfall harvesting, using graywater, or small-scale desalination. Rainfall harvesting could provide water required to meet firefighting needs at the development. It could also be utilized to meet landscaping requirements, so that there would be reduced demands on the water supplied by Greenburn Lake.

As outlined in Section 8.2.4.4, it is recommended that each of the rooms, cottages, and condominiums be equipped with water meters to charge occupants on a water consumption basis. Educational information regarding the water shortages during the summer months should be made available to all guests. A block pricing mechanism should be in place, and occupants should be made aware of the costs associated with increased water consumption.

10.3.6 Individual Water Wells

If, as suggested in Section 9.2.2, a hydrogeologist is hired by Islands Trust, it is recommended that knowledge of the local geology be used to determine the optimal orientation of a water well (vertical versus directional). This same information could be utilized to target the optimal water well depth, enabling prediction of depth to geologic contacts and saline water. It can also be used to locate septic tanks or fields, so that potential for water well contamination would be minimized.

It is also suggested that each individual water well be equipped with a water meter and charged for water consumption through a block pricing mechanism. This system removes the perception of water as a free good while reinforcing the concept that the province owns the water. A charge for water consumed creates the potential that residents would install water-conserving fixtures.

10.3.7 North and South Pender Islands

From an island wide perspective, it is recommended that an integrated water management approach be undertaken. This would incorporate some of the following aspects:

- An island-wide water education program;
- An improved water well database;
- A new water well record format to provide more detailed information on the geology and water producing horizons;
- Local trustees push for groundwater legislation with provincial legislators;
- Election of provincial representatives supportive of groundwater legislation;
- Island-wide emergency response plan for drought, floods, and seismic activity;
- Encouragement for increased rainwater harvesting;
- Water meters for all residences as well as visitor accommodation;
- Promotion of use of directional drilling of water wells where appropriate;
- Water quality testing on annual basis for each water well;
- Limit number of tourists during dry summer months in times of water shortage;

- Adaptation of building codes to promote rainwater collection, use of water saving devices and use of gray-water;
- Strict enforcement of well head protection measures around best producing water wells;
- Regulation of pumping rates for water wells;
- Water balance calculations on a groundwater basin level.

An integrated approach requires application of a wide range of disciplines. This approach helps to avoid the scenario in which problems or issues are dealt with in isolation and the resulting solutions are formulated without an assessment of their impact on other aspects of water resource management (Frederiksen *et al.*; 1994). As is often the case, each discipline has its own jargon and set of rules, so that communications between disciplines is difficult (O'Grady and Henderson, 2005). Communications between scientists and decision makers is generally a difficult task and often occurs in a haphazard manner (National Research Council, 1999).

The integrated water resource management (IWRM) approach incorporates the concept of water as a common pool resource and the linkages between water and the ecosystem as a whole (Gleick, 2002). As Burger *et al*. (2001) discuss, the exploitation by humans of a common pool resource has the potential to result in unintended consequences for the ecosystem and ultimately for society. The exploitation of groundwater resources by humans can lead to a vicious circle, resulting in a downward spiral from both water quantity and quality perspectives. In addition, the notion of sustainability dovetails conveniently with the IWRM emphasis on the integration of human and natural systems. Loucks and Gladwell (1998) state that sustainability includes the future economic, environmental, physical and social impacts resulting from today's management practices.

10.3.7.1 Education

Education of residents and visitors alike would benefit the water management on North and South Pender Islands. As noted in Section 3.5, there can be a 10% reduction in water demand solely through education. This reduction could mean the difference between maintaining the current water supply system and requiring expenditure of significant capital to find alternative water sources. It is suggested that the Islands Trust hydrogeologist have regular town hall meetings and workshops to ensure that residents are aware of the water resources of the islands. Ammons and Rawls-Hill (2000) found that the more fully citizens understand issues, the more likely they are to assist in finding effective solutions.

An interactive web-site could be set up by Islands Trust that enables visitors to the web-site to actually use modeling software to investigate the impacts of reduced or increased precipitation over a given time frame, to observe the impacts of varying pumping rates of water wells, or to test the implications of a change in land use. This would provide a valuable focal point for the public to gain an appreciation of the responses to both naturally occurring and man-made events.

It is suggested that all tourist facilities provide visitors with an educational brochure that outlines the water issues on the islands. The brochures could be available on the B.C. Ferries that service the islands. It would be useful if the brochure were discussed at the time of check-in rather than simply being distributed to the visitors. Articles in the local newspapers such as the Pender Post and Island Tides would ensure that water issues were kept in the public eye.

10.3.7.2 Water Well Database

As discussed in Section 5.6, not all the water wells drilled or dug to date have been included in the B.C. Land, Water, and Air groundwater well database. The results, as presented in this dissertation, should be used as a guide only. The current database of water wells is of limited usefulness due to misinterpretation of bedrock types and inadequate information regarding water-bearing zones. The current database is also not very current since at the time of this research the most recent eight years of water well drilling were not included in the database. Useful information for a water well database would be the inclusion of the elevation of the water table enabling use of the Ghyben-Hertzberg relationship to estimate depth to saline water.

10.3.7.3 Water Well Records

As a means of removing some of the limitations associated with the water well database, it is suggested that a standard form be designed to ensure that there is some level of consistency. It would also be useful to have geophysical borehole logs included with new water well data, as the water-bearing zones would exhibit drastically different physical properties from the host rock. A minimum recommended level of borehole geophysics would include a combination of gamma logs to map variations in clay content and resistivity logs to map fractures, bedrock stratigraphy, and salinity variations. The increased cost to water well drilling would be minimal. The information gathered, if included in the water well database, would prove invaluable to the understanding of groundwater flow and resource assessment in the Outer Gulf Islands, and would consequently greatly enhance the planning and allocation of water resources. The additional information provided by borehole geophysical logs would also provide useful background data for monitoring variations in water quality with time, as the geophysical logs could be repeated at future dates.

10.3.7.4 Political Framework

In Chapter 9, an alternative local political framework is recommended based on groundwater basins rather than the islands as a whole. The recommended institutional framework places management of water resources in the hands of the Islands Trust and local residents. Whether or not this recommendation is followed, the local representatives must pursue other politicians at the provincial level to push for groundwater legislation. Without political support for groundwater management, it will be difficult to maintain a reasonable groundwater management plan.

The recommended institutional framework would replace an existing framework possessing too many government agencies having little or no coordination of activities between agencies. This recommendation follows the recommendation of the B.C. Auditor General (1999).

10.3.7.5 Emergency Response Plan

At present, there is no emergency response plan for any form of natural disaster that may occur on the islands. It would be prudent for residents and Islands Trust planners to establish emergency response plans for natural disasters that may impact water supply on the islands. The discussion of risk in Chapter 9 clearly outlines several potential natural disasters that may occur.

10.3.7.6 Water Meters

It has been recommended throughout this dissertation that water meters would be an asset rather than the liability that some residents perceive them to be. Henderson and Revel (2000) found that water meters in the Municipal Improvement District of Trincomali were useful in leak detection. Subsequent research for this dissertation found that the water meters in the Municipal Improvement District of Trincomali were an integral part of the water accounting for the water supply system. Water meters, on each water well, would provide information on pumping rates of the wells and on consumption, as well as establishing a basis for the implementation of block pricing mechanisms.

The use of water meters would promote the implementation of a user pay principle. Legislation could be enacted requiring water well drillers to install water meters upon completion of drilling.

10.3.7.7 Directional Drilling

When the bedrock geology possesses steeply dipping horizons, it may be advantageous to directionally drill water wells. This approach to drilling would encounter geologic boundaries between formations more quickly. It is known that at the geologic contacts between formations, there is often increased porosity and permeability that may contribute to enhanced water production.

Legislation to establish water rights and pumping rates is necessary prior to the routine use of directional drilling.

10.3.7.8 Water Quality Testing

It would be prudent for residents to have their well water tested annually. Because of the rapid development that has occurred on the islands (Henderson, 1998), there is an increased potential for reduced water quality due to contamination from septic fields and poorly maintained septic tanks.

10.3.7.9 Limit Tourism

During severe water shortages, it may be necessary to limit the number of tourists visiting the island at any particular time. Dovetail (1992) noted that the population of the island can triple during the warm, dry summer months. In times of severe drought, this level of short-term population growth may negatively impact water quantity and quality available for local residents.

10.3.7.10 Adapt Building Codes

A number of small islands have used building codes as a means of increasing rainfall harvesting and thereby decreasing reliance on limited groundwater resources. On North and South Pender Islands, building codes could be adapted to ensure that rainfall harvesting occurred at the individual property level. They could also be used to promote the use of gray-water for functions such as toilet flushing that do not require potable water.

10.3.7.11 Well Head Protection

Within groundwater basin SP-II, the best producing water wells are located along a fault with water production achieved from similar depths within the water wells (Figure 7.3), so that it is of the utmost importance to ensure that these wells are protected and to closely monitor and control land use operations in the vicinity of these wells. The location of the best producing wells along fault zones also indicates that there is an enhanced possibility for contaminant migration along the faults, due to increased secondary porosity and permeability.

10.3.7.12 Pumping Rates

To date, no documented pump tests or drawdown tests have been undertaken to determine the impact of several water wells producing from the same water-bearing horizons. Since some of the best producing wells occur close to one another and are apparently producing from the same water-bearing horizons, it is important to investigate the impact that production and pumping rates may have on adjacent wells. Septic fields and septic tanks should be placed at maximum distance from the producing wells to ensure that the water-bearing horizons are not contaminated. Regular water quality testing, on an annual basis, for *E-coli* and total coliforms, particularly for the wells with relatively shallow water-bearing horizons, should be undertaken to closely monitor water quality in the best-producing wells. Because the increased secondary permeability would be associated with the faulting (Domenico and Schwartz, 1998), contaminants would be able to travel quickly, potentially rendering the water from the fracture zones unfit for human consumption.

10.4 Conclusions: Global Perspective

It is important to consider the implications of water resource assessment from an island perspective, since the hydrodynamics of islands can be quite different from those typically encountered on large land masses. The physical setting can vary significantly between small islands, ranging from a relatively simple island atoll to the geologically complex islands such as South Pender Island. There is no panacea for applying the approach undertaken on North and South Pender Islands to a more global scale for small islands. In reality, the approach taken for North and South Pender Islands is fraught with assumptions and uncertainties, yet it represents the best interpretation of groundwater resources presently available. Each step of the water resource assessment process has limitations that will impact the reliability of the results. These limitations should not be hidden away; they should be presented in full view of all concerned. They represent a very important aspect in the design of the overall approach and ultimately on the usefulness of that approach for management purposes.

The approach put forward in this dissertation represents a simple formula that can be followed on any small island. Not all of the facets of the approach may be necessary. By using the approach as a guideline, a better understanding of the groundwater resources will be achieved that will allow for an improved community planning process.

For a small island atoll, the physical setting could be reasonably established by geologic mapping and two perpendicular geophysical survey lines through the centre of the island.

Information would be obtained on the presence of a perched water table, variations in soil type, depth to bedrock and depth to saline water. Knowledge of the depth to the water table would enable calculations of the thickness of the freshwater column.

For small islands with more complex geologic settings on which there is a reliance on secondary porosity and permeability for water supplies, it is recommended that if at all possible airborne magnetic surveys would be able to map the locations of faults. Knowledge of the location of faults would provide for better resource development, risk assessment, and community planning.

Water resources are often not available when and where they are required. A review of climatic variability in conjunction with existing water supply systems has the potential to provide additional options for water supply through increase rainwater harvesting, dew collection, desalination, or simply through education to decrease water demand.

The governance of small island water resources can also exhibit a wide range of approaches based on the complexity of the physical setting, the existing institutional frameworks and cultural norms. A review of the existing institutional and legal frameworks is required before any recommendations can be made to improve the existing framework. A review of the existing water supply systems present on an island will also play a role in the ability to re-shape water management practices.

Risk assessments have often been performed with little or no regard for the stratigraphic and structural geologic features that function as major controls for water well production on the islands. Through the performance of a water resource assessment on the basis of groundwater basins, a better understanding of the risks and uncertainties involved in water resource management can be achieved, and a framework for governance can be constructed.