Chapter 9 WATER MANAGEMENT PLAN: NORTH AND SOUTH PENDER ISLANDS

9.1 Introduction

This chapter presents a review of the groundwater conditions on North and South Pender Island and recommendations for improvements to the current water systems. It also presents a conceptual model for groundwater resource assessment and management for the case study area. In addition, the conceptual model has applicability to other small islands on a global basis. The physical setting, governance and risk aspects of water resource management for the islands in the case study area are addressed with recommendations that would enable water resource management to be incorporated into community plans. Since there is no such thing as a perfect approach (Kerr and Chung, 2001), the potential benefits and drawbacks to the water management plan are outlined.

9.2 Conceptual Model

The conceptual model for groundwater resource management is presented in a series of three schematics in Figures 9.1a, 9.1b and 9.2. The conceptual model is very simple which is a necessity if it is to be understood by all stakeholders. Figure 9.1a is analogous to wind chimes, with the community planning portion representing the top hook of the chimes with separate branches leading to the physical setting, governance and risk. The chimes themselves represent the parameters for each of the branches. In Figure 9.1a, the chimes represent a neat and orderly system, which is unlikely to occur in nature. In Figure 9.1b, the parameters are intertwined and more accurately reflect the interdisciplinarity of groundwater management from a community planning perspective. It is not only the parameters that are intertwined, as the branches above the parameters are also intertwined. Thus, the model illustrates the interdependence of physical setting, governance, and risk in the incorporation of water resource management into the community planning process.

Climate represents an example of the interdependence as a parameter that influences all of the branches in Figure 9.1b. As discussed in Chapter 4, the local climate provides the source water for groundwater recharge on small islands. Climatic conditions influence land-use patterns, which in turn impact surface runoff, infiltration and groundwater recharge, while drought and floods represent potential risks.

Previous researchers have stated that groundwater resource management requires a thorough understanding of climate, hydrology, hydrogeology, geology, topography, island size, and geographic location (Ozoray, 1977; Miloradov and Marjanovic, 1998). It would be foolhardy to attempt to manage a poorly understood and ill-defined resource or to make community plans on the basis of a poorly defined resource. In conjunction with the physical setting, the legal and institutional frameworks must be understood and adjusted to complete the governance aspect of groundwater resource management. Professionals responsible for understanding the physical setting must transfer their knowledge in a meaningful way to the policy makers responsible for governance of the resource, who must then pass that knowledge on to the users of the resource. Tidwell *et al.* (2004) found that system dynamics modeling provided a powerful platform for cooperative, community-based resource planning that integrated the disparate physical and social systems while providing an interactive environment for engaging the public.

The risks associated with the physical resource and developed policies must be fully evaluated and monitored. A critical aspect of water resource management is the temporal and spatial variability of the resource itself. An aspect of groundwater management, particularly risk management, should be a monitoring program that allows the resource base to be calculated at any time.

A different way of illustrating the conceptual model is by a number of interconnected gears similar to the workings of an old-fashioned watch (Figure 9.2). Since the physical setting, governance, and risk represent a unique temporal condition, the metaphor to an old-fashioned watch fits well. The gear concept also clearly shows the interdependence of the various parameters. Figure 9.2 also illustrates the circular perspective for groundwater management and the overriding need to monitor and adapt as conditions change through regular evaluation and re-evaluation.

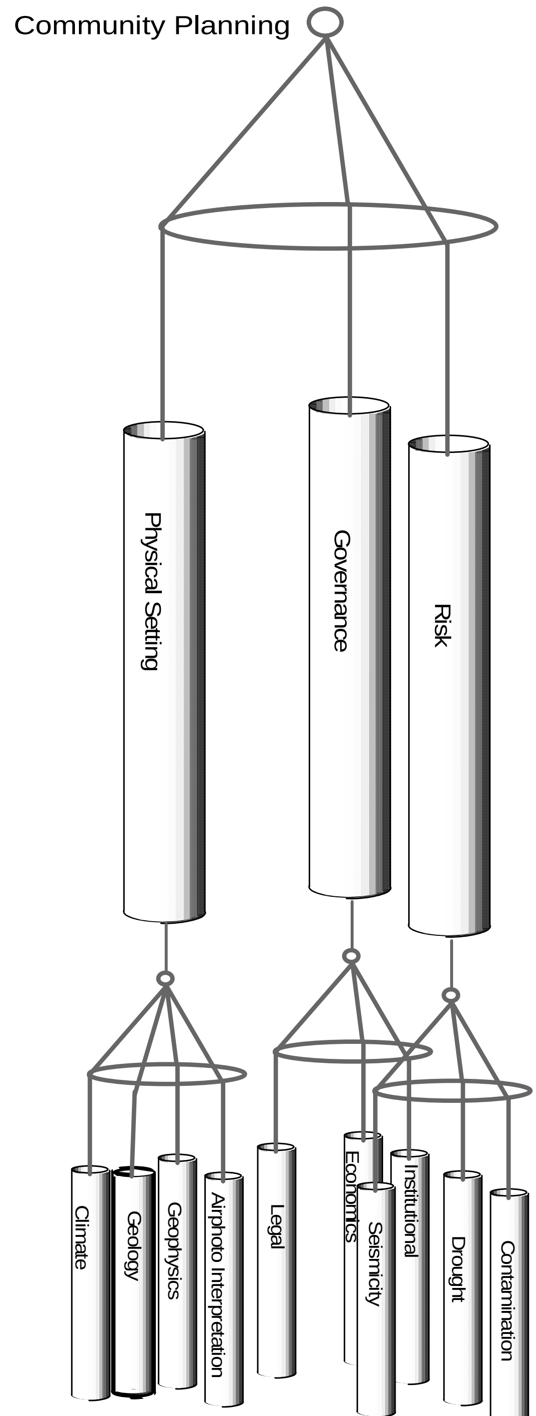


Figure 9.1a: Conceptual Model for Water Management and Community Planning

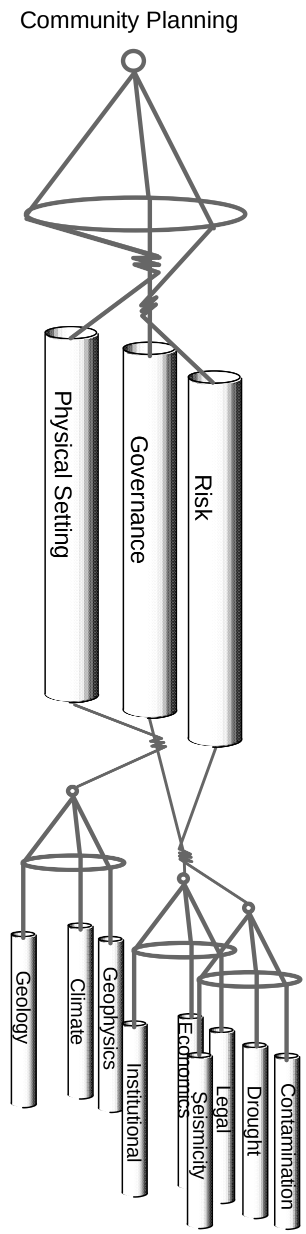


Figure 9.1b: Conceptual model for community planning and water management

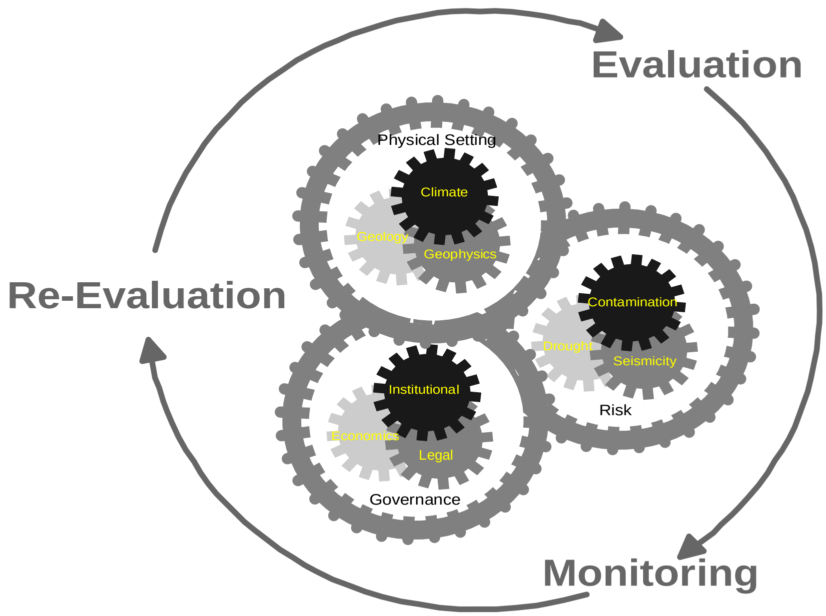


Figure 9.2: Conceptual model for community planning

9.2.1 Physical Setting

Chapter 4, 5, and 6 described the physical setting for North and South Pender Islands. Understanding of the physical setting was accomplished through the integration of airphoto interpretation, geologic mapping, geophysical investigations, climatic records, and a review of water well records. Heathcote (1998) states that a resource inventory provides the building blocks for modelling and evaluation, but it should be remembered that not all of the groundwater is actually a resource for human use, partially due to a lack of hydraulic conductivity within the host material. The porosity and hydraulic conductivity of the host material control the volume of water available. When dealing with aquifers in fractured bedrock, it is very difficult to assess the volume of water that may be available for extraction by humans and this volume of water may be changed by hydrofracing a bedrock zone to improve its hydraulic conductivity. In addition to the human requirements, there are also environmental functions played by the groundwater in support of the existing ecosystems; those functions are analogous to in-stream water requirements for surface water sources.

In oil and gas exploration and exploitation, there are strict definitions for the terms resource and reserve (Canadian Securities Commission, 2006). Reserves are defined (Canadian Securities Commission, 2006) as the estimated remaining quantities of oil and gas anticipated to be recoverable from known accumulations, from a given date forward, based on analysis of drilling, geological, geophysical and engineering data; use of established technology; and specified economic conditions, which are generally accepted as being reasonable, and shall be disclosed. Resources are defined (Canadian Securities Commission, 2006) as those quantities estimated on a particular date to be remaining in known accumulations plus those quantities already produced from known accumulations plus those quantities in accumulations yet to be discovered. Resources are sub-divided into discovered and undiscovered. Similar definitions are proposed for groundwater assessment. The groundwater resources would be in a constant state of flux on the basis of climatic conditions and groundwater extraction. There are obvious differences between groundwater and other resources, since groundwater is renewable and deemed a common good, having temporal and spatial components of extraction and recharge. In short, there will be significant variability over time in volumes of groundwater defined as a resource and volumes defined as a reserve.

With thorough understanding of the physical setting, one can begin to undertake a groundwater resource assessment and identify the options available for non-conventional water sources to either augment or replace groundwater supplies. A prescriptive approach to investigating the physical setting is outlined in Table 9.1. With the exception of the climatic data, which should be collected concurrently with all of the other stages, the approaches are listed in the recommended order of acquisition. The recommended order works from the most general and least expensive to the most specific and usually most expensive. Each approach builds on the results of the previous stage and acts as a means of confirmation of the data interpretation obtained during the previous stage.

Table 9.1: Prescriptive approach to physical setting investigations

Approach	**Objective**
Remote sensing	Vegetation types, geologic structure, bedrock lithology, geomorphology, surface water sources, topography, land use
Geologic mapping	Geologic structure, bedrock lithology, surficial geology, geomorphology, hydrogeologic properties
Geophysical investigations	Geologic structure, bedrock lithology, soil type, hydrogeologic properties, saline water delineation
Water well data	Soil type and thickness, bedrock lithology and thickness, water bearing horizons, groundwater flow rates, groundwater levels
Climatic data	Precipitation, temperature, evapotranspiration
Laboratory data	Water quality, bedrock porosity and permeability

9.2.1.1 Remote Sensing

As described in Chapter 2, the research encompassed all of the approaches listed in Table 9.1. Airphoto interpretation identified bedrock types, while geologic mapping identified the lateral and vertical extent of bedrock horizons, bedrock dip and strike for each formation. Locations of major structural features and an indication of the heterogeneity of the bedrock formations were also provided by airphoto interpretation. Airphoto interpretation proved useful in the identification of potential surface water sources, current land use, and general variations in topography for the islands.

9.2.1.2 Geologic Mapping

The major faults have been mapped with the use of a combination of airphoto interpretation, geologic mapping and geophysical investigations (see Figure 5.1). On

South Pender Island, most of the best-producing water wells occur along what appears to be the same fault while on North Pender Island one third of the best-producing water wells are located adjacent to faults (Figure 7.3). The location of the best-producing water wells along faults illustrates the influence of structural geology on the hydraulic properties of the bedrock. There is the potential risk of having the best-producing water wells located close to one another and being hydraulically connected.

The dip and thickness of each bedrock formation are important. For steeply dipping bedrock, it may be prudent to directionally drill water wells, since zones of higher porosity and permeability in the case study area occur not only in faults and fractures but also at the contacts of geologic formations. The cost of drilling a vertical well vary between $65/metre and $78/metre exclusive of mobilization and surface casing while directional drilling would average approximately $115/metre (Alliance Well Drilling, personal communication, 2008). There are other concerns when comparing vertical and directional water wells including the requirement for a larger site for directional drills, lining of directional water wells, and the requirement of a crane on site for a directional water well. Directionally drilling water wells, however, also raises the issue of whose groundwater is extracted if the bottom of a directional drill hole is located on neighbouring property. To date, this type of information has not been utilized in the planning of water wells. It is likely that such an approach would result in better water well production and a better understanding of drilling costs, since the depth to the geologic contacts could be estimated in advance.

In oil and gas regulations in Alberta, pumping rates from a particular field are regulated to ensure that companies having oil and gas rights in that field limit the impact on each others resources/reserves (Alberta Oil and Gas Conservation Act, 2002). Legislation in oil and gas also controls the drilling spacing and provides a framework for directional drilling and resource ownership. Similar regulations are required for directional drilling of water wells to ensure equitable water rights.

9.2.1.3 Geophysical Mapping

Geophysical investigations were limited by the existing level of development on the islands. A combination of complementary geophysical methods were used to provide information on the physical properties for each formation, identified a perched water table, variations in soil type, heterogeneity of bedrock formations, and depth to saline water.

The geophysical investigations provided information on water quality that is not available through other geoscience approaches without drilling water wells. The results of the time domain electromagnetic sounding interpretation, when inserted into the Ghyben-Hertzberg equation (Section 2.8), provide a means of estimating the depth to saline water at specific locations. This information provides a thickness of the freshwater column on the islands, and should be used to establish optimal water well depths and pumping rates to minimize potential for saline intrusion. Saline intrusion need not be restricted to areas adjacent to the coastline, although it may be most prevalent there. It can occur anywhere on the islands if the water well has been drilled to a depth approaching the base of the freshwater lens and the pumping rates are too high resulting in the upwelling of the underlying saline water.

The seismic refraction survey results identified zones having lower compression wave velocities and therefore the potential for a higher fracture density within the bedrock. Given the importance of secondary porosity and permeability, this information should be useful in optimizing water well locations.

A combination of the seismic refraction and electrical imaging results identified a potential paleo-channel on South Pender Island. Paleo-channels represent very good drill targets for water wells.

9.2.1.4 Water Well Data

The existing water wells have been summarized in Appendix D. The lack of any significant geological information within the water well database is a problem. This problem could easily be overcome for future water wells by simply having a water well data format that must be followed by water well drillers.

The existing water well database and responses to a water questionnaire distributed by the local trustees in 1992 indicated that there are a number of dug wells on the island used for water supply (Henderson, 1998). These dug wells rely on the presence of a perched water table as the source of potable water. Allen and Suchy (2001) state that in the Gulf Islands, groundwater recharge occurs in topographic highs and discharge occurs in topographic lows. Recharge may also be occurring in topographic lows as the geophysical investigations undertaken for this research indicate that the perched water table tends to occur only in portions of the islands having a soil cover overlying the bedrock. Soil cover of any significant thickness is typically restricted to low-lying areas. Water tends to flow down gradient close to the soil/bedrock interface (Henderson, 1998). In areas of soil cover, a portion of this water percolates downward and recharges bedrock even in topographic lows. The presence of a perched water table overlying bedrock has relevance to both local water supply and groundwater recharge. The Medicine Beach example (Section 6.3.1.11) indicates that there is groundwater discharge off island in the shallow marine environment.

At present, there are two observation wells located on North Pender Island; one in the Port Washington area (Paisley Road) and the other off Pirates Road southwest of Magic Lake Estates. These wells are not necessarily representative of the more general geology and hydrogeology of the islands. The observation wells are not located close to any of the major faults on the island. The observation well located off Pirates Road was drilled in the Extension Formation conglomerates which are not representative of the geology required for good producing water wells on the island. There are no observation wells located on South Pender Island.

9.2.1.5 Climatic Data

Climatic records are available for the years 1925 to 2002 at www.climate.weatheroffice.ec.gc.ca/advanceSearch_/searchHistoricDataStations_e.html. These records are currently almost six years behind and only contain data on monthly precipitation. The climatic data would be more useful if it contained daily precipitation records as well as records on daily variations in temperature. Temperature variations are important in calculating evapotranspiration. As has been discussed, (see Section 4.2.3), evapotranspiration is a major component of the water balance equation. If the stakeholders are to fully understand the physical setting and evaluate the impacts of policies on the physical setting, an up-to-date database for groundwater wells, climatic data, observation wells, and groundwater consumption should be maintained. This scenario has not been the case for the Gulf Islands.

9.2.1.6 Discussion

The prescriptive approach presented in Table 9.1 is recommended for use as the basis for estimating the physical groundwater resources and reserves available for distribution in small island environments. Thus, the approach fulfills a need identified at the outset of this dissertation. The prescriptive approach also provides the basis for future monitoring and evaluation of the groundwater resources and reserves once a baseline study has been completed.

The investigations undertaken for this dissertation have proven to be useful. Prior to this research, several attributes of the physical setting were either not known or not fully appreciated. These include the following:

- Distribution of a perched water table
- The fact that groundwater recharge occurs over the entire islands
- The existence of a possible paleo-channel on South Pender Island
- A thorough review of the water balance for the islands

- The depth to the underlying saline water and the implications for water well depths
- An estimate of the groundwater storage capacity

Foster *et al.* (2000) state that the characteristics of groundwater resources are often poorly understood by the public. Confusion arises partially because groundwater occurs in aquifers that are not homogeneous, so there is variable groundwater flow through heterogeneous units and structures (Burke and Moench, 2000). This is certainly the situation for the North and South Pender Islands case study. The results of the geological mapping and the geophysical investigations (see Table 6.2 and Sections 6.3.1 and 6.3.2) illustrate the high degree of variability in physical properties encountered within the same bedrock formation. The geological mapping provides an obvious expression of the heterogeneity while the geophysical investigations provide a downward extension of the geological mapping. This variability in physical properties translates into heterogeneity of hydraulic properties within a bedrock formation. The variability in physical properties may be due to several factors, including degree of bedrock weathering, changes in bedrock type, and degree of fracturing.

As Bachmat *et al.* (1980) point out, direct observation of groundwater resources in itself is not enough. There must also be a means of temporally and spatially interpolating between a limited, economically feasible set of observation points (water wells) with some consistency and reliability. The prescriptive approach outlined in Table 9.1 allows this to happen, with the added requirement that data from water wells (specifically water levels and water quality) be acquired at regular time intervals. A person or group needs to be responsible for collating, integrating and interpreting the data and putting the data into a useful, comprehensible format for the end user as has been successfully completed in the Municipal Improvement District of Trincomali.

The water resources of the islands are directly connected to annual precipitation, which varies from year to year and exhibits significant variability on a seasonal basis. Because the precipitation and the resulting groundwater resources can vary both spatially and temporally, limitations in the number of options available for resource management exist. Through the division of the islands into groundwater basins, it became clear that each groundwater basin had a different groundwater storage capacity based on a complex combination of areal extent, topography, variable geology, thickness of freshwater column, and level of development.

Knowledge of the groundwater resource base and the implications of interactions between groundwater basins are of little value if this knowledge cannot be used to provide a basis for community planning. Knowledge of the groundwater resource base also provides a different perspective on alternative potable water sources. If the groundwater resource base is limited, it may be of much greater importance to evaluate alternative sources than is the case if supplies are abundant.

There is overlap between the physical setting, governance and risk with the requisite legal and institutional frameworks needed in place to support the physical settings and reduce the risks associated with policy decisions. This point is stressed since unfortunately, there can be a significant time lag between policy implementation and visible impacts on the physical setting (Bellamy *et al.*, 2001). This time lag further emphasizes the need to be proactive by conducting baseline studies and continual monitoring and evaluation. System dynamics modelling has the ability to allow both the scientific experts and the public to visualize potential long-term impacts prior to their occurrence.

9.2.2 Governance

The concept of community interest versus self-interest can be viewed as the overriding framework for governance of water resources. At the centre of the community interest versus self-interest issue are a number of complex concepts including sustainability, common pool resources, hydrogeology in fractured bedrock, legal framework and institutional frameworks. The community being considered must be defined. It could represent the permanent residents within a specific groundwater basin, the permanent residents of the islands or the visitors plus residents of the islands, the residents of British Columbia, or the residents of the surrounding land masses encompassing the centres of Victoria, Vancouver, and Seattle. For the purposes of this dissertation, we will consider the community to include the islands' residents and visitors. This community comprises groups of people with diverse backgrounds and interests; it will be a difficult task to have them agree on a groundwater management plan having a single course of action (National Research Council, 1999). The technical issues involved will be interwoven with broader societal structures, demands and issues that will complicate development of a groundwater management plan (Loucks *et al.*, 1998). The ability to undertake social marketing to achieve community acceptance of a groundwater management plan is a very important aspect in the ultimate success of the plan. It should be remembered that any management plan would need to be dynamic rather than static, due to the temporal nature of groundwater resources.

As the OECD (1998) so aptly points out, the most effective approach for altering water consumption patterns is to combine top-down measures (i.e., regulatory controls, pricing) and bottom-up strategies (i.e., education, information), with both occurring within a favourable context (infrastructure). Within the Outer Gulf Islands, there is no one effective government agency responsible for water issues (see Section 8.3.2). The favourable context recommended by OECD needs to be developed if the top-down and bottom up strategies are to be integrated. On North Pender Island, the residents of Magic Lake Estates have consistently shown their disregard for community interest by voting to avoid the use of water meters. Some form of strong governance is required to ensure that the interests of the community are placed ahead of the interests of any individual or group of individuals.

Heathcote (1998) states that sustainability implies the consideration of the needs of the entire community rather than the needs of the individual. According to OECD (1998), this can be achieved through the promotion of user "ownership" of water issues. As

Henderson and Revel (2000) pointed out, the Municipal Improvement District of Trincomali presently places the needs of the community as a whole above those of any individual within the community. The Municipal Improvement District of Trincomali was awarded a Stewardship Award for its water management practices by Islands Trust in 2004. Communities, such as Magic Lake Estates, represent the other end of the spectrum by blocking initiatives that would enable a more efficient water accounting system within the community. As discussed in Chapter 8, Sections 8.2.4.1 and 8.2.4.3, there are a number of other differences between Magic Lake Estates and Trincomali. Magic Lake Estates is the most heavily populated development in the Gulf Islands while Trincomali has only 104 lots of which only 71 have been developed. Trincomali has very strict regulations regarding water consumption and water use while Magic Lake Estates have very few regulations. Both of these differences may contribute to the increased level of community involvement in water issues for Trincomali versus Magic Lake Estates.

A development such as Poets Cove represents another scenario, which involves visitors to a specific resort, as opposed to permanent residents. It may be difficult to have short-term visitors accept ownership of water issues, since they have little or no apparent self-interest in the long-term water resources.

There are, however, barriers to implementation of policies and regulations that may be based on knowledge of the islands groundwater resources. These barriers include the following:

- Lack of technical expertise of policy makers;
- Lack of communication between earth scientists and policy makers;
- Disciplinary versus interdisciplinary viewpoints;
- Lack of understanding of politics by earth scientists;
- Lack of acceptance by all stakeholders.

9.2.2.1 Institutional Framework

Currently governance of groundwater resources on North and South Pender Island are stuck in a quagmire of interagency conflict as discussed in Chapter 8. There is no one agency with control over groundwater management, although the creation of such an agency was recommended by Henderson (1998) and the B.C. Auditor General (1999). To make matters worse, there are three levels of government involved in groundwater management (see Chapter 8). There are costs associated with development of a new agency to oversee groundwater management. It is recommended that Islands Trust be given the mandate to manage groundwater resources. This would require the hiring of knowledgeable groundwater specialists; the benefit would be the placement and retention of that knowledge base within the governing body for the Gulf Islands.

Cooperative arrangements would be required to ensure that communications with other agencies and levels of government be maintained or initiated. These cooperative arrangements reflect the interdisciplinary nature of groundwater management. Since it is not reasonable to expect a groundwater professional for example, to be an expert in health, transportation, or planning issues, input of other specialists and the integration of results will be required on a regular basis to solve ever more difficult problems.

One of the major barriers to governance from a groundwater perspective is the wide range of water supply systems currently in use. These systems encompass everything from ad hoc individual water wells to large urban style water supply networks such as Magic Lake Estates. Clearly, there will have to be mechanisms in place to balance the needs of each. For the Improvement Districts and Magic Lake Estates, there should be legislation that requires water meters in each residence. Metering represents the only means of monitoring water consumption and enabling estimates of the resource available for consumption. The use of water meters also enables the development of a water accounting system, such as the one currently employed by the Municipal Improvement District of Trincomali. Water meters have proven to be an effective means of identifying disruptions in the supply network. Early leak detection results in minimization of water losses from the system as well as lower energy costs. Reduction of leaks from the system would increase the water supply. Water meters would provide a useful means of exercising some form of control over the supply, demand and allocation of water resources while enabling calculations of water budgets when combined with population and water supply data. Burke and Moench (2000) note that emerging groundwater problems are related to use efficiency, allocation and understanding; each of which could be assisted through the use of water meters.

Figure 9.3 presents a schematic for the proposed institutional framework for groundwater resource governance on the Gulf Islands. It is recommended that Islands Trust become the lead agency with responsibility for groundwater. The Gulf Islands represent a small portion of the areal extent of British Columbia and with the Islands Trust's knowledge of the islands, it is the logical choice to be the lead agency. One current drawback to this proposed approach is that Islands Trust does not currently have a hydrogeologist on staff. The hiring of a hydrogeologist would be a prerequisite for their assuming the role of lead agency. This administrative structure would consolidate both land and water planning under the auspices of the same agency, so the potential for inter-agency conflicts is reduced. The staff at Islands Trust would be responsible for interacting with other agencies that have a legislated authority over some aspects of groundwater management. The proposed approach for the governance of groundwater management follows the recommendation of Pigrim (1988), who states that comprehensive restructuring of administrative arrangements and legal and political systems are required.

With a hydrogeologist on staff at Islands Trust, Gulf Islands planners would become more educated regarding the implication of planning decisions and policies on the islands groundwater resources. It is envisioned that the role of the hydrogeologist would encompass conducting water resource assessments, up-dating databases, assisting in defining problems and evaluating solutions, disseminating information, raising public awareness, and engaging stakeholders. In short, the hydrogeologist would be both an educator and resource person to planners, policy makers, and groundwater users.

Since there are currently both provincial and federal jurisdictions on North and South Pender Islands, Islands Trust will need to report to and have the support of both levels of government. This is not an ideal scenario but it is part of the reality of the current legal and institutional frameworks. Islands Trust's having full responsibility for groundwater management on the islands does, however, provide the potential to have a level of integration that has not been present in the past.

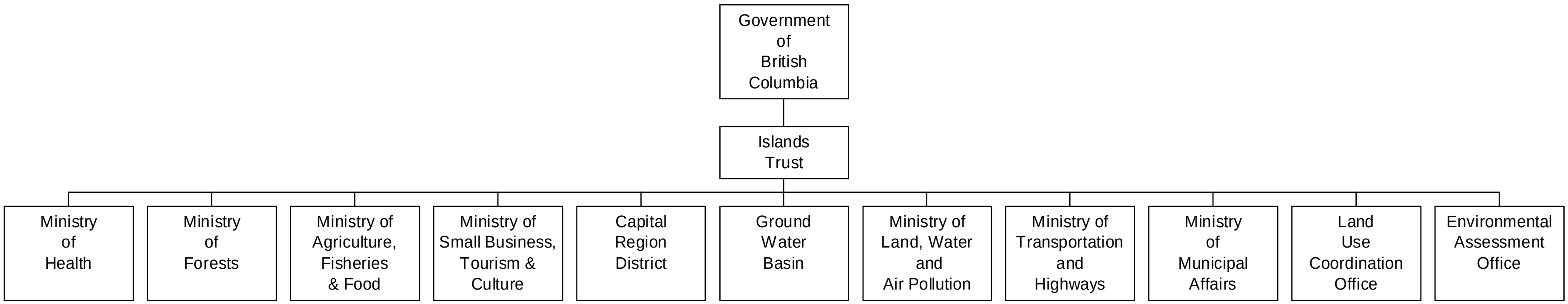


Figure 9.3: Schematic for proposed institutional framework for governance of groundwater resources in the Gulf Islands.

There are drawbacks to any management approach. On the basis of the research of Viessman (1988), one of the potential drawbacks to this recommended approach is that the traditions and philosophies of the institutions previously involved with groundwater issues and management, along with the legal framework and social norms, are deeply entrenched and can be highly resistant to change. A significant effort, by all involved, will need to be expended to ensure that these barriers are removed.

One of the recommended major changes to the current institutional framework is the inclusion of the Groundwater Basins for North and South Pender Islands at the same level as other government agencies (Figure 9.3). This change has the added benefit of placing ownership for the governance of the islands in the hands of the local population. Swallow *et al.* (2001) recommended the devolution of authority for natural resources from large government bureaucracies to smaller community groups. The Municpal Improvement District of Trincomali represents an example of the success of this approach from the case study area. Like watersheds, the groundwater basins represent the natural division of groundwater resources from a management perspective (Kerr and Chung, 2001). Burke and Moench (2000) suggest that the feasibility of establishing institutions capable of effective management is influenced by: 1) clearly defined resource boundaries, 2) adequate information on resource conditions and dynamics, 3) a clearly defined (and generally small) group of users, and 4) the ability to control and exclude free-riders. Management at a groundwater basin level for small islands fulfills the requirement of having clearly defined resource boundaries and a clearly defined small user group.

Islands Trust would require an institutional framework that would enable them to design rules and regulations; give them the authority to enforce; and provide them with the financial wherewithal to implement the rules and regulations. Islands Trust would also have to provide the hydrogeologist with access to MODFLOW, WaterWare and other complementary software to enable the hydrogeologist to prepare reasonable models of groundwater flow and predict future water resource conditions. Model building is a difficult process requiring considerable expertise. The hydrogeologist will require access to system analysts for support and will require training from software providers.

The schematic presented in Figure 9.4 provides a more detailed description of the interrelation of the groundwater basins, with South Pender Island as an example. That island has been selected simply because there are fewer groundwater basins than on North Pender Island. It is proposed that there be a Board of Directors for each groundwater basin. The board members would represent the major stakeholders within each groundwater basin as well as adjacent groundwater basins. Table 9.3 presents the recommended representation for the Board of Directors for each groundwater basin on South Pender Island. The directors would be required to reach a consensus on all water management issues. Additionally, no one board member should have any greater power than any other. This model represents the application of the collaborative planning process to groundwater management at a groundwater basin level.

In case unanimity cannot be achieved, or a stakeholder group does not feel that it has been adequately represented, it is necessary to have an appeal process in place. It is suggested that the best mechanism would be a review panel consisting of representatives from off island, to reduce any potential for bias or conflict. The review panel should include a representative of Islands Trust, another from the provincial government, and the third member from a groundwater basin on a different Gulf Island.

Table 9.2: Composition of governing bodies for groundwater basins, South Pender Island

Groundwater Basin	**Composition of Governing Body**
SP-I	Two residents SP-I
	One resident SP-II
SP-II	Two residents SP-II
	One resident SP-I
	One resident SPIII
SP-III	Two residents SP-III
	One resident SP-IV
	One resident SP-II
	One representative of Parks Canada
SP-IV	Two residents SP-IV
	One resident SP-III

Frame *et al.* (2004) indicate that the British Columbia government has significant experience using collaborative planning because of their involvement in the Commission on Resources and the Environment. The collaborative planning process involved a facilitator and sought consensus through face-to-face negotiations, while ensuring that all participants were heard and respected (Frame *et al.*, 2004). The same approach is recommended for management of groundwater basins. The collaborative planning process should, under ideal circumstances, provide the necessary flexibility and adaptability required to manage groundwater resources within a local context (Moore and Koontz, 2003). Johnson *et al.* (2001) state that water management should be participatory to be successful and that the process of being participatory includes the following:

- Stakeholders work together to set criteria
- They identify priority constraints

- They evaluate possible solutions
- They recommend technologies and policies
- They monitor and evaluate impacts

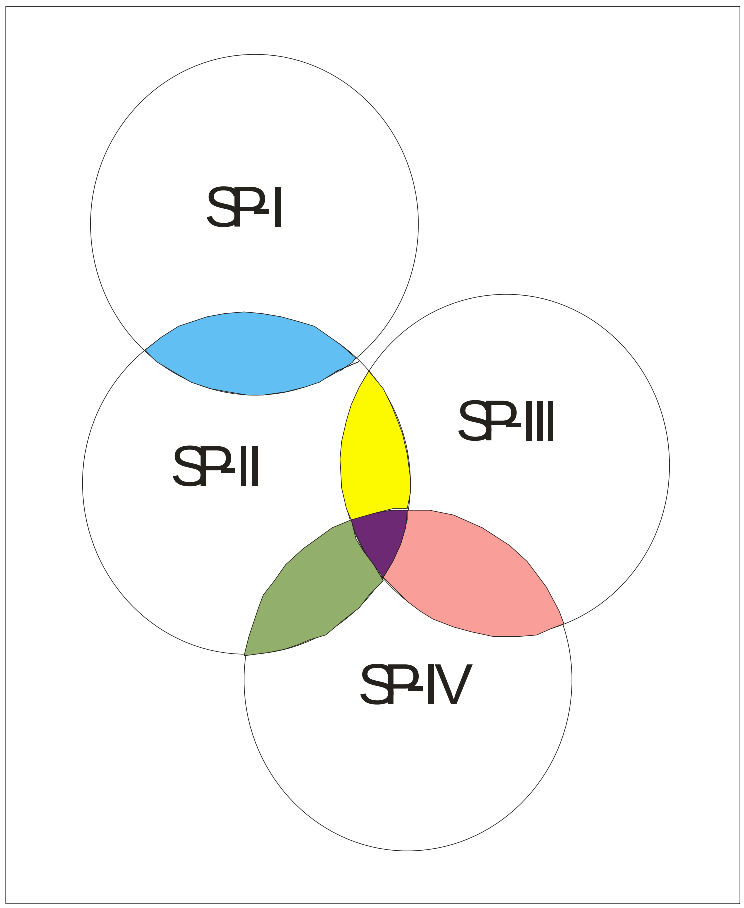


Figure 9.4: Schematic of groundwater resource management at the groundwater basin level for South Pender Island.

On the basis of these tenets, the process will work effectively only if the hydrogeologist fulfills his or her role in disseminating information. One of the hydrogeologist's many challenges will be to communicate with participants about a complex groundwater system in simple terms while explaining the key elements that control the system response to decisions or policies (Stave, 2003). Frame *et al.* (2004) also point out that the community (in this case, each groundwater basin) must have the capacity to participate actively. For an island with a limited population, the population base must be large enough that people are willing to be stakeholder representatives.

A benefit of the collaborative planning process is that it should result in decisions that will benefit both the groundwater basin and island communities. That is one of the basic cornerstones of sustainability (Heathcote, 1998). This community advantage of collaborative planning essentially compels individuals to work for the collective good of the community in order to reach consensus on issues.

In the natural setting, the direction of flow of groundwater is not necessarily constant, particularly at the boundaries between basins. Excessive water well pumping, changes in land use, or prolonged drought could easily result in a change of groundwater flow direction close to the basin boundaries. For this reason, adjacent groundwater basins should have representation on each other's Boards of Directors.

It is currently not known if groundwater recharges the man-made lakes on North and South Pender Islands or vice versa. Surface water and groundwater withdrawals have the potential to strongly influence one another. Decisions should be made that integrate both surface water and groundwater knowledge, and there should be a means of monitoring and evaluating the impacts of those decisions.

9.2.2.2 Legislation

The lack of any groundwater legislation in British Columbia presents a problem, particularly in areas such as the Gulf Islands reliant to a great extent on groundwater resources for domestic water supply. There have been discussions regarding designation of groundwater management areas, but to date, none has been so designated. The lack of any legislation translates to the right of first capture for groundwater. Legislation should be enacted that clearly defines the use of groundwater for domestic purposes in critical areas such as the Gulf Islands, as well as establishing parameters for wellhead protection, pumping rates, well interference. There should be specific legislation encompassing wellhead protection, particularly for the better producing wells, methods of determining extraction rates to avoid drawdown of neighbouring wells, and a means to monitor water well production rates. In the example of directional drilling of water wells, there is a need for technological advances to be accompanied by parallel changes to the legal framework. There is a need to determine if a well could be started on one property and completed on an adjacent property. As stated previously, there are regulations for the exploration and production of other natural resources that could be readily applied to directional drilling of water wells (Alberta Oil and Gas Conservation Act, 2002). The presence of groundwater legislation does not by itself accomplish anything unless there are mechanisms in place to ensure that the legislation is enforced.

For individual well users, drilling a water well on either island generally will have very little impact on the groundwater resources. The drilling of a number of water wells close to each other and producing from the same fracture network or stratigraphic contact can have a dramatic effect on the quantity and quality of groundwater resources for each individual well owner.

B.C. Ministry of Management Services (2005) predicted significant population growth of the metropolitan centres located close to North and South Pender Islands, and it is safe to assume that there will be a corresponding increase in the number of visitors. There is a limit to the sustainable water resources for each groundwater basin on the islands. From a planning perspective, it is recommended that the island be subdivided into groundwater basins, but it is highly unlikely that visitors to the islands will be aware of these basins or the implications of their own presence, so there is the potential for stressing groundwater resources. In the future, it may be necessary to limit the number of visitors to maintain some semblance of the “preserve and protect” mandate of Islands Trust. Currently reservations are often made at tourist accommodations on the islands and the number of tourist accommodations is controlled through building and development permits. During times of water shortage in the future, it may be necessary to reduce the number of tourist accommodations. This may be either a temporary or permanent reduction dependent on the severity of the water scarcity.

In order to meet the requirements suggested by Burke and Moench (2000), it is recommended that a questionnaire be distributed to residents and property owners on North and South Pender Islands. A questionnaire has been prepared that is modeled after similar documents distributed in Australia which were designed to provide more information regarding the resource conditions and dynamics (Table 9.2). In conjunction with the questionnaire, it is recommended that Islands Trust be given the task of checking the elevation of the water table in each well on the islands. The elevation of the water table could then be used to estimate the thickness of the fresh water column using the Ghyben-Hertzberg Equation.

Table 9.3: Questionnaire on water supply and water conservation

This questionnaire has been sent to every address on North Pender Island and to all registered North Pender Island tax payers. We would like this questionnaire to be completed by both permanent and non-permanent residents irrespective of whether they are home owners or tenants. A similar questionnaire was sent to property owners/tenants of North Pender Island in 1991 in response to concerns regarding adequacy of water supply. Given the development on the island since the initial questionnaire, concerns regarding adequacy of water supply are still relevant. It is important that as many property owners/tenants as possible respond to this questionnaire as possible to enable preparation of community plans that do not overtax the water supply of the islands.

1. Please indicate which of the following applies to you (check as many boxes as may apply)
    - I live on North Pender Island in my own home
    - I live on North Pender Island in a rental property
    - I visit North Pender Island frequently to stay in my holiday/weekend home
    - I own rental property on North Pender Island
    - I own tourist accommodation property on North Pender Island

2. What is your primary source of water supply for the property?
   - o Water well
   - o Dug well
   - o Water supply system
   - o Rainwater
   - o Other (please specify)

3. If your primary source of water supply is a dug well or water well, does your supply last most years?
   - o Yes, I rarely have to source additional water
   - o No, it runs out most years
   - o Don’t know

   Do you have any comments?

4. Do you know the flow rate of your well?

   Winter

   Summer

5. How many persons reside in your household?

6. How do you rate your water supply?
   - o Good
   - o Fair
   - o Poor
   - o Don’t know

7. Check if your water supply is:
   - o Brackish (salty)
   - o Discolored
   - o Sulphurous
   - o Hard
   - o Soft
   - o Visibly contaminated
   - o Other

8. Have you ever had to purchase water as a direct result of your water supply being inadequate?
   - o Yes
   - o No

9. Has your water supply ever failed?
   - o Yes
   - o No

10. Over the past few years has your supply:
    - o Increased
    - o Decreased
    - o Remained Constant
    - o Don't know

11. Are you worried about your future water supply?
    - o Yes
    - o No

12. In general, how important is water conservation on North Pender Island to you?
    (please check only one box)
    - o It is extremely important.
    - o It is important but I could do more.
    - o I don't think about it much.
    - o It is not important.

13. What methods do you currently use to conserve water? (please check as many boxes as apply to you)
    - o Low flush toilet
    - o Water efficient appliances
    - o Short showers
    - o Use a plug rather than allow taps to run
    - o Use of greywater
    - o Use of rainwater
    - o Low-flow showerheads
    - o Flow-regulating devices on faucets
    - o Other (please specify)

14. Do you have a cistern?
    - o Yes
    - o No

    If yes, what is your cistern's storage capacity?

15. Do you have any comments concerning water use, water supply, and water conservation on North Pender Island?

9.2.2.3 Discussion

To recover the cost of administration and the salary of the hydrogeologist, it is suggested that a water fee be charged annually to each property owner. This is a fair and equitable means of recovering costs. The same approach would be recommended for the other Gulf Islands so that the hydrogeologist could be shared by all of the islands; thus, the potential water fee would be lower than it would if North and South Pender Islands paid water fees and the other Gulf Islands did not.

It is also recommended that all residences on the islands, including those reliant on individual water wells, have water meters. The requirement for water meters on individual wells, as well as in the water systems, would allow for accurate measurement of consumption for the islands which would in turn lead to improved water balance calculations. It would be a simple matter to have regulations in place requiring water well drillers to install water meters as they are completing wells. There should be a block pricing mechanism implemented within each water distribution system. The price for the basic water requirements on a per household basis should be similar to rates currently charged by Magic Lake Estates, Trincomali, and Razor Point Road community water supply systems. Water consumption above the basic volume required should be charged at a significantly higher rate in an attempt to dissuade over-consumption. This increased rate could also be referred to as an impact fee. The Province of British Columbia has stated unequivocally that it owns all groundwater resources so that individual water well users are accepting some risk when they drill water wells. The government would then have every right to charge for consumption of a resource that it has ownership of.

Since tourists consume greater quantities of water than permanent residents (Falkland, 2003), it is recommended that all tourist accommodations be equipped with individual room water meters and that tourists be charged for water consumption. This system would raise the level of public awareness in the hopes of reducing the overall levels of water consumption, particularly during the dry summer months when tourist levels are at their highest. This would encourage accommodation owners to reduce overall water consumption by installing low-flush toilets, low-flow showerheads, and flow-regulating faucets. Accommodation owners should also be encouraged to provide educational information on the necessity to conserve water on the islands and how tourists could help in this conservation. Brochures on limited water resources could be prepared by Islands Trust for distribution to tourists upon check-in. An analogous scenario occurs in the Maldives where a desalination plant has been employed to provide bottled water to tourists. The bottled water is sold at a significant mark-up to cover the cost of the desalination plant. There has not been any decrease in tourism noted with the associated cost of water.

The legislation should clearly set out that individual well owners are not charged for the quantities of water required to meet their basic needs. The determination of basic needs could be based on guidelines put forward by the World Health Organization, Environment Canada or more locally by the Municipal Improvement District of Trincomali. They should, however, be charged the same impact fee as other residents for over-consumption. The use of impact fees would also assist in covering the costs of administration, implementation and enforcement. A user-pay system would be in effect.

With water meters, it would also be possible to have a water accounting system to measure consumption and estimate the resource base at any particular time. Water meters would provide accurate information on the volume of water produced by any given well during a specific time period. This information would be part of a monitoring program to ensure that wells are being pumped at a reasonable rate to reduce the risk of saline intrusion and interference with other water wells. If water levels in the water wells were recorded at the same time then variations in the depth to the water table could be monitored to provide more of an island-wide representation of the thickness of the zone of potable water. Knowledge of the resource base in a time sensitive scenario would be important in the use of predictive models in times of water scarcity. Water meters also represent an ideal mechanism for identification and remediation of any leaks in water distribution systems. To remove the potential barrier to resistance to the installation of water meters in each residence, the installation could be deemed voluntary and paid for by the provincial government. This incentive could be offered in light of the proven resistance to water meters by Magic Lake Estates residents. An impact fee equivalent to the cost of installation would be charged on an annual basis to each resident who is unwilling to voluntarily have a water meter installed. Fees generated from this revenue stream would be used to offset the cost of water meter installation. Another alternative would be to simply legislate that by a particular future date, water meters will be mandatory and then follow the same approach as listed above using the voluntary system until that future date arrives. This alternative approach would ensure that at the future date, collection of data to regulate the water resource use would occur.

It is possible to have an automatic meter reading system in place. The system can be used to compile the latest consumption figures and trends over time (www.radio-tech.co.uk). With additional firmware, it is also possible to use the system to identify and pinpoint leaks.

Islands Trust would be responsible for collecting and analyzing the water meter data. It would be possible to set up a data base that could be easily maintained by an Islands Trust staff member. At present, the Municipal Improvement District of Trincomali records water consumption on a weekly basis during summer months and informs residents if their consumption levels are higher than recommended levels. It would require a coordinated effort, given the existing water systems on the islands, but it should not be a difficult or expensive task to compile water meter data into a database.

The use of a block pricing mechanism in conjunction with water meters would also promote the use of rainfall harvesting and water re-use as a means of supplementing water supply, while potentially reducing costs to the individual. The proposed system would make individual property owners accountable for their water consumption through the use of economic measures to raise their awareness of water resources.

9.2.3 Risk

As stated previously, there is no perfect approach to the management of groundwater resources. Few of the parameters for even a simple water balance approach to groundwater assessment can be measured accurately, so there is potentially a high degree of uncertainty. For the Gulf Islands, risks that may impact groundwater encompass both water quantity and quality and would include the following:

- Drought
- Saline intrusion
- Water well interference
- Other contamination
- Seismicity
- Lack of alternative natural water sources
- Time frame
- Changing legislation

There is currently no drought management plan for either North or South Pender Island. Since the climatic data for the islands indicate that droughts of varying degrees of severity have occurred in the past (see Section 4.2.5), it would be prudent for each groundwater basin to develop a drought management plan. It is recommended, as part of the drought management plan, that the best-producing wells become community wells under the supervision of the Islands Trust hydrogeologist, and that levels of extraction and water quality be closely monitored. A means of equitably distributing water from these wells during time of scarcity would need to be established.

Saline intrusions can be a result of overpumping of water wells or a natural response to prolonged drought conditions. In the case of overpumping of water wells, there should be strictly enforced regulations within the governing institutional framework to provide a level of control for pumping rates. The installation of water meters for each residence would provide a means of monitoring pumping rates. This same approach can also be applied to minimize the impact of water well interference, which is also a result of overpumping. Saline intrusions can also occur as a result of water wells being drilled to depths encroaching upon the base of the freshwater lens. Prior knowledge of the depth to saline water would be of benefit in the determination of optimal water well depths.

In the absence of much industrial activity on North and South Pender Islands, there is limited potential for other contaminant sources. There is, however, agricultural activity, including a vineyard on North Pender Island (personal observation). There are currently no irrigation systems for agricultural activity in place on North or South Pender Island. The use of pesticides and herbicides should be limited, monitored and strictly enforced to eliminate the potential for groundwater contamination.

Removal of the natural vegetative cover can impact the water balance equation by changing the evapotranspiration, surface runoff and soil moisture. Decisions regarding changes in land use should be closely scrutinized to determine the potential impacts on each groundwater basin. A recent ruling by the B.C. Farm Industry Review Board (2007) placed blame for contamination of an organic garden squarely on the approval of a vineyard by Islands Trust. The B.C. Farm Industry Review Board (2007) noted that the steep slope of the vineyard had the potential to cause drainage issues on downslope neighbouring properties.

The most likely contaminant source on the islands is from septic fields or poorly maintained septic tanks. There are currently no regulations for testing individual water wells on a regular basis to measure total coliforms and the presence of *E-coli*. Such regulations should be put in place, with the test results becoming part of the groundwater database. With this system in place, reduced water quality would be detected and responded to quickly to reduce health risks. At the same time, the system would allow for speedy and less expensive remediation than if contamination were undetected and travelled greater distances. Septic fields should not be located near major faults and in areas lacking soil cover since contaminants would have ready access to zones of increased secondary porosity and permeability. Because of the increased secondary porosity and permeability in these areas, contaminants could travel large distances in short time frames before being detected. Input from the Islands Trust hydrogeologist during the development approval process could help reduce this risk.

One service station, located on North Pender Island, provides gas. The storage tanks are located above ground and are double walled to reduce the risk that a leak will impact the soil and groundwater resources (personal observation). This is an important aspect; the service station is located close to the Pender Fault and any spill could have major repercussions on some of the best-producing water wells on the island. If the proposed management plan had been in place at the time of the application for siting the service station, it is likely that it would have been located farther from the Pender Fault.

The other potential contaminant source on the islands is the disposal of household and farm wastes in an inappropriate manner by individuals. Regulations controlling waste disposal are currently in place (Islands Trust, 2003), but there is little in the way of monitoring or enforcement. Increased public awareness of the negative impact that waste disposal can have on the groundwater resources may assist in reducing this risk.

North and South Pender Islands are located in a seismically active area. Montgomery and Manga (2003) have noted that earthquakes can impact water wells in a negative manner by changing groundwater levels and reducing flow rates. There is also the potential that an earthquake could positively impact a water well by increasing flow rates similar to hydrofracing an aquifer. These impacts can be of short or long term duration (Montgomery and Manga, 2003). It is recommended that an emergency response plan for major seismic events be established and that the plans include alternate water supply options for impacted residents.

There are a number of community-run water distribution systems on North and South Pender Islands (see Section 8.2.4). The Razor Point Road Municipal District represents an example of a community that is reliant on a single water well to meet its water supply needs. If water quality were to deteriorate in this well or if flow rates were reduced by a major seismic event or drought, there is presently no alternative water supply for this community. Each community-run system should have an emergency response plan, which would consider alternative sources of water supply in both the short and long term. For the Razor Point Road Municipal District, it would be prudent to have an additional water well to provide greater security of supply.

One of the most difficult risks to assess is that of the temporal scale. As mentioned earlier, Bellamy *et al.* (2003) point out that the impacts of decisions and policies may take a long time to be realized and may only become apparent after monitoring and evaluation have been completed. The temporal scale can also impact the participatory aspect of the collaborative planning process. It may be difficult to maintain participation of the community when the outcome of the participants' efforts are not readily visible in a short time (Johnson *et al.*, 2001).

Without knowledge of the physical setting and the appropriate governance scheme, it is not possible to minimize any of the potential risks to the security of the water supply. If these risks are to be reduced, there is a need to understand the physical setting and establish an institutional and legal framework based on this understanding that is supported both politically and financially.

Investigations have considered aspects such as risk assessment to the water resources but with no base information as to the actual water resources of the islands and little regard to the structural controls on groundwater flow. The incorporation of the approach outlined in Table 9.1 will provide the necessary information to determine the relative risk to groundwater resources on the islands. Each of the previous investigations on groundwater resources on the islands has concluded that the water resources are limited. However, no plan has been put forward as to how a water resource assessment should be conducted and then incorporated into community plans to provide an effective means of managing the resources of the islands, while following the "preserve and protect mandate" of the Islands Trust. The approach put forward in Table 9.1 provides a reasonable basis for commencing groundwater assessments on the islands, but as Loucks *et al.* (1998) stated, anyone involved in water resources planning and management must contend with risk and uncertainty. Hence, the following two questions arise:

- What are the sources of risk?
- How can these be overcome or reduced to acceptable levels?

Figure 9.5 presents a groundwater vulnerability map produced by Denny *et al.* (2006) for North Pender Island. A number of areas have been delineated as having high contamination vulnerability. The basis for the classification is not presented in the North Pender Island Community Plan. Denny *et al.* (2006) used DRASTIC-FM, which consists of the depth to the water table, (net) recharge, aquifer media, soil media, topography slope, aquifer conductivity, fractured media and the impact of the vadose zone, to develop the susceptibility map. The DRASTIC-FM approach does not, however, include current land use nor does it include all of the existing faults on the island that play a significant role in groundwater production and recharge. The groundwater vulnerability map is much more useful when viewed in combination with the sub-division potential map for North Pender Island (Figure 9.5). There are several regions of North Pender Island possessing both a high degree of groundwater vulnerability and sub-division potential. An example is in the vicinity of Port Washington and is indicative of the lack of integration of groundwater resources into the community planning process.

The water improvement districts of Razor Point and Trincomali are in regions of generally moderately high susceptibility to groundwater contamination. Within Magic Lake Estates, there is a range from low to moderately high susceptibility to groundwater contamination. The location of the vineyard on North Pender Island is in a zone of moderate susceptibility and its location adjacent to Razor Point should be a cause for concern. The combination of the groundwater susceptibility map and the current land use map should be utilized to ensure that portions of the island currently legislated as agricultural and having moderate or greater susceptibility never be allowed to change their land use status to enable land development.

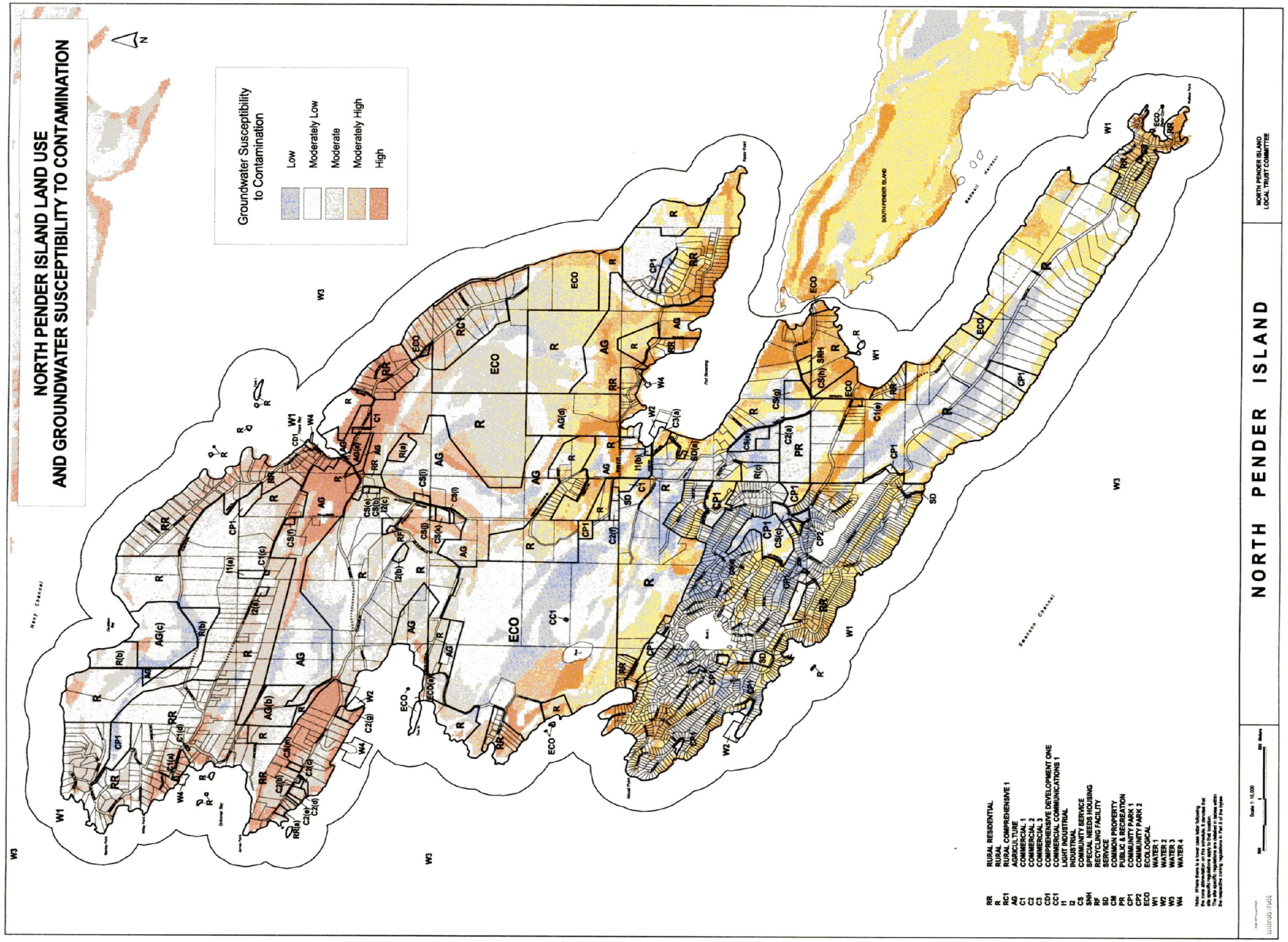
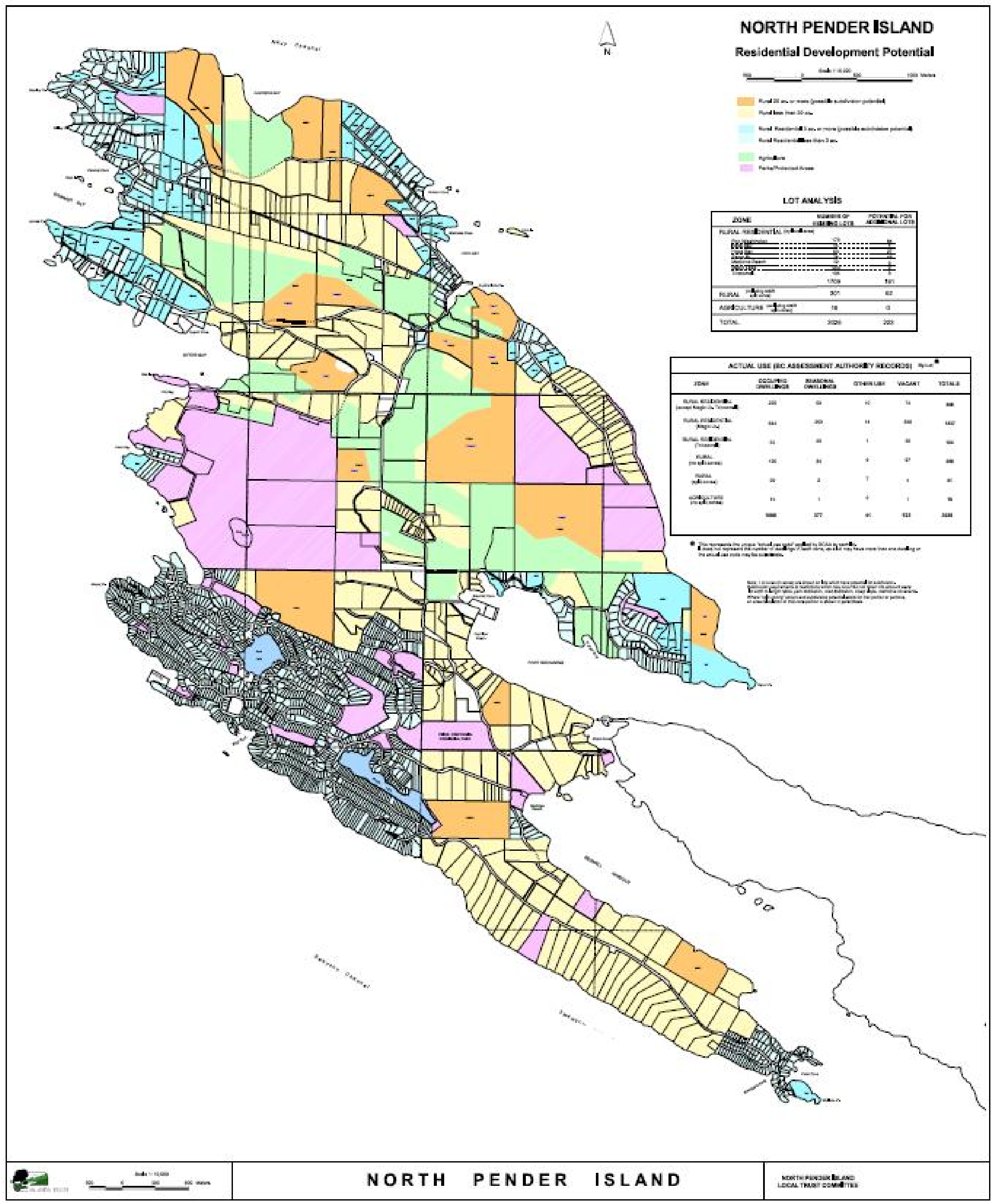


Figure 9.5: Groundwater vulnerability map (Denny *et al.*, 2006)

Figure 9.6: Sub-division potential map for North Pender Island (Islands Trust, 2006b)



One of the risks associated with maps is that the information presented may be accepted as factual, when in reality, it is not. The groundwater vulnerability map is an example, in that it does not indicate significantly high risk in the vicinity of known faults. It is well established that secondary porosity and hydraulic conductivity may increase substantially in the vicinity of major faults, enabling migration of contaminants and therefore increased groundwater vulnerability. The maps also do not include areas of known water quality issues as presented by Mordaunt (1981) and Henderson (1998); those areas should be shown as having increased groundwater vulnerability.

Relatively simple issues such as lot size have been determined more by market demand than by water availability, although a direct correlation between the two is expected. The lot areas for ocean frontage and without ocean frontage clearly illustrate this point (Islands Trust, 2006a). Ocean-front lots are more susceptible to salt water intrusions and because of their smaller lot size, there is an increased likelihood of well interference between neighbouring lots. This situation is accentuated by the lack of guidelines or regulations pertaining to the distance between water wells on neighbouring lots and pumping rates for water wells.

It is also the case that water wells in low-lying areas have a much greater potential for encountering saline water. This fact is simply related to the location of the water table above sea level and the Ghijben-Hertzberg formula presented in Section 3.3. Salt water intrusion could occur simply through the drilling of a water well that is too deep or through overpumping from a well completed close to the freshwater/salt water interface. Each of these situations could be circumvented by knowledge of the depth to the water table and the depth to the fresh water/salt water interface.

Fresh water occurs in a manner somewhat analogous to a bowl floating on salt water, due to the lower density of the fresh water. Removal of the freshwater would enable the salt water to migrate upward and such movement would destroy the equilibrium that has developed over time. It would likely take considerable time to enable sufficient build up of freshwater to depress the underlying salt water to its present position, once disturbed.

Additionally, risk deals with security of supply. It has already been established that natural conditions such as climatic variations and seismicity may change water resource availability. For better management of these risks, it would be sensible to develop an emergency response plan focusing on water supply and allocation during natural disasters, such as droughts and earthquakes.

Contamination from sources other than salt water should always be a concern. The most likely source of contamination on the islands is from *E-coli* emanating from septic tanks and fields. The current regulations are designed to deal with such groundwater contamination in a reactive manner once contamination has taken place. This approach does little to remove the risk of contamination or reduce the time frame and cost of remediation. A more proactive community-based approach is required to minimize risk of contamination. This will require a number of steps including educating residents about possible sources of contamination and the implications of a contaminated aquifer, and establishing a monitoring program. The education aspect could be accomplished through stakeholder involvement in computer modeling, specifically through model simulations using MODFLOW. A more stringent water sampling program for water wells has the potential to lead to the early identification of contaminants and to provide a warning system to limit the impacts of contaminants through that early detection. Contamination from septic fields and tanks is a good example of where the interaction between natural setting, governance and risk will arise.

The potential exists for there to be a lack of consensus between stakeholders on both a groundwater basin level and inter-groundwater basis. The stakeholders may have diverse and conflicting interests. A means of dealing with lack of consensus has been prescribed in Section 9.2.2.

The last potential risk to be discussed is the possibility that changing legislation will over time result in changes to lot size and thereby increase sub-division potential or alter current land-use. The groundwater basin governance scheme proposed in Section 9.2.2 could go a long way to reducing this risk by requiring the approval of adjacent groundwater basins prior to any such changes taking place.

9.3 Discussion

The research undertaken for the case study of North and South Pender Islands did not occur under ideal circumstances. The ability to locate geophysical survey lines in optimal locations was limited by the level of development already existing on the islands, as well as by the rugged topography of the islands. When the results of the geophysical investigations were combined with the geologic mapping and airphoto interpretation, an approach to groundwater resource management was developed. This proposed approach has a number of potential benefits:

- Reduction of inter-agency conflict;
- Development of emergency response plans (including drought management plans);
- Following of user pay principle;
- Promotion of sustainability;
- Use of a natural division for resource management (groundwater basins);
- Logical approach to community planning (collaborative process);
- Promotion of community interest over self-interest.

To accompany the benefits, there also exist some potential barriers to implementation of the proposed approach. These potential barriers include the following:

- Lack of inter-agency cooperation;

- Resistance to water meters, water fees, impact taxes and block pricing schemes (user pay principle);
- Possibility that consensus may not be achievable;
- Requirement for an additional management level;
- Requirement for regular involvement of a hydrogeologist;
- Lack of political will;
- Lack of community involvement.

The proposed groundwater management approach requires that sufficient time and financing be available; that there is an education and public awareness component; that there are changes to the legal and institutional frameworks; that there is a requirement for both political and stakeholder participation in order for the approach to be successful. This approach represents a long-term commitment to the integrated management of groundwater resources and community planning on North and South Pender Islands.

A major portion of the research for this dissertation emphasized the development of an approach to provide a cost-effective means of estimating the groundwater resources for North and South Pender Islands. The use of university researchers is generally a cost-effective approach. The cost of the geologic mapping and geophysical investigations was $0 but if undertaken by consultants would have been on the order of $100,000. Even if undertaken by consultants the cost would represent the equivalent of drilling 9.5 water wells to a depth of 150 metres. It would not be possible to gain an island-wide overview of groundwater resources on the basis of this limited number of water wells.

An emergent strategy from this research approach resulted in the application of the information obtained on the islands physical setting in the establishment of a conceptual model for groundwater resources governance, as well as the identification of potential risks to these groundwater resources.

In the past, community plans have been developed in the absence of sufficient knowledge of the groundwater resources. Clearly, since some of the existing water wells do not meet the minimum production requirements proposed by the North Pender Island Community Plan, there has been essentially no reliance on groundwater information in the enforcement of the guidelines put forward by Islands Trust. The proposed conceptual model, although over simplified, illustrates the interdisciplinary nature of groundwater management. It is simple enough that stakeholders should be able to visualize the interaction between all of the variables. The proposed conceptual model represents a move from a purely reactive approach to a more proactive approach to groundwater resource management and, ultimately, community planning.

The approach presented in Table 9.1, combined with the suggested governance and potential risks, provides a logical progression, while offering a means of enacting recommended changes. There exist both benefits and limitations to the approach presented and it may be more important to be aware of the limitations than the benefits of the approach.