Chapter 1 INTRODUCTION

1.1 Problem Statement

Islands surrounded by saline water are self-contained freshwater systems possessing limited freshwater supplies that differ temporally and spatially due to changing climatic conditions and geologic setting. There is a need to better understand the groundwater resources and management of these resources to aid in the planning for development of the islands and for planning for potential times of water shortage. Given that groundwater is an invisible resource, residents tend to be unaware of groundwater problems until they happen. This dissertation provides an approach for better defining the groundwater resources available for distribution in small island environments, acquiring information on groundwater consumption, planning for the education of stakeholders in a concrete and comprehensible manner, and changing the institutional framework to streamline responsibility for groundwater management. Historically, the planning process has involved predominantly the development of policy to determine for example lot size, land use, location of septic systems, and has not been related to the available groundwater resources.

Water is currently being treated as more of a commodity than a social good. This dissertation develops a scheme to better understand groundwater resources and reserves in a manner similar to the method used in determining oil and gas resources. The method of estimating groundwater resources and reserves is also used to establish a reasonable governance scheme.

The research examined the complementary application of geological mapping, geophysical investigations, and climate monitoring to develop an island water balance. North and South Pender Islands, two of the Gulf Islands on Canada's west coast, were selected as a case study. The goal was to provide a cost effective, consistent approach, which had been sorely lacking. The islands selected encompass the range of water resource issues encountered on small marine islands and are therefore ideal as a research

venue. Previous research on North and South Pender Islands by Mordaunt (1981) and Henderson (1998) indicate that there have been concerns by residents about both water quantity and quality. Denny *et al*. (2006) note that seasonal precipitation fluctuations in combination with increasing population has resulted in significant delines in water quality, increased numbers of abandoned wells and contributed to saline intrusions on the southern Gulf Islands. Similar concerns were found on neighbouring Saltspring Island (Hodge, 1995).

The islands in the study area possess a mixture of water distribution systems developed within a complex legal and institutional framework. Through knowledge acquired concerning the physical groundwater resource base, it was possible to develop a conceptual groundwater management model. North and South Pender Islands possess a relatively complex geologic and hydrogeologic setting; through the use of specific islands (local) at the complex end of the spectrum, generalizations to the more global small island water issues can readily be made.

1.2 Objectives

The primary goal of this dissertation is to develop an approach for quickly and economically understanding the physical groundwater resources and reserves on small islands. The objectives of the dissertation have application on both a local and global scale. Physical resource knowledge will enable the development of logical, clear and concise community plans that meld with the concepts of sustainability in a cost- effective manner. It is from this perspective that the dissertation brings new knowledge to the existing scientific basis for water management. The global objectives for the research include the following:

General Objectives

- Review existing groundwater resource and reserve assessment practices and develop a conceptual approach for groundwater resource and reserve assessment on small islands.
- Provide a quick and economical approach for groundwater assessment using a combination of airphoto interpretation, climate monitoring, geological mapping and geophysical investigations.
- In the context of groundwater assessment, investigate water supply and water demand in small island environments and propose a groundwater monitoring scenario that can be applied cost-effectively.

Water Supply Objectives

- Determine water quantity, quality and distribution for groundwater assessment.
- Provide a review of the impact of variability of climatic and hydrogeological parameters related to water supply.
- Present information in a format that can be readily incorporated into a community planning process.

Water Demand Objectives

- Investigate the existing water management systems and their impacts on water demand.
- Review existing groundwater modeling packages.

From a local perspective, the research for this dissertation used North and South Pender Islands, British Columbia as a case study to achieve these general objectives:

- Review the existing groundwater resource assessment practices undertaken for these islands.

- Review the climatic conditions and the relationship to groundwater resources by combining the water balance equation, geophysical data and geological information.
- Evaluate geophysical methods and demonstrate their role and usefulness for groundwater resource assessment by correlating the geophysical data with groundwater well information.
- Determine the hydrogeological parameters and their influence on water supply.
- Define groundwater basins.
- Review current institutional and legal frameworks for groundwater resource management.
- Conduct a review of the existing water supply systems, identify the problems and provide recommendations for the current water management framework.
- Review socio-economic aspects of water management and propose water demand options as a means of increasing water supply.
- Investigate the role of education in both water supply and water demand management.
- Develop a cost-effective approach to groundwater resource assessment.
- Present information in a format that can be readily incorporated into the community planning process.
- Develop a conceptual model for a data base that would enable improved planning, designing, monitoring and implementation of policies and actions for water resource management and community planning.

1.3 Background

From a physical perspective, water resource management on small islands is based on the hydrologic cycle, which encompasses a complex interaction between surface water and groundwater (Fitts, 2002). Small islands commonly do not have significant surface water sources and residents must rely on groundwater and rainfall capture (Falkland, 1991). A number of landowners often have access to the same surface water or aquifer. As a result,

water resource management presents issues of common pool resource management, with the added complication that groundwater is invisible and often poorly understood by the non-specialist (Berardinucci and Ronneseth, 2002; Fitts, 2002). In addition, there may be a wide range of water allocation systems on any given island, further complicating the resource management. The water allocation systems range from individual wells to complex water distribution systems commonly found in urban environments. This range in water supply systems couples with the constantly changing, unpredictable nature of water resources, both temporally and spatially.

Water issues are interdisciplinary and multi-faceted, encompassing spatial, temporal, physical science and socio-economic dimensions (National Research Council, 1997; Burke and Moench, 2000; Gleick, 2002). As a subset of water issues, groundwater management can be extremely complex; nowhere, is this more evident than on small islands (Deschenes and Chartow, 2004).

There are many approaches to groundwater resource management, which typically consists of a series of trade-offs between water supply and water demand. Water sources on small islands generally comprise groundwater, small lakes, intermittent streams and rainfall harvesting (Falkland, 1991). For small islands, geologic and hydrogeologic conditions can differ dramatically from simple to extremely complicated. The small size of islands also contributes to the water demand issues as population growth and development pressures increase (Dovetail, 1992). Generally, community plans are developed on small islands with little prior knowledge of the groundwater resource base for the particular island in question (Falkland, 2003).

There is also a need to investigate the socio-political and socio-economic aspects that can control the allocation of the water resources. Within this context, fact-based natural science and value-laden social sciences are blended in an effort to deal with water supply, demand and allocation issues.

Groundwater resource assessment has typically not been utilized as a means of assisting in governance and community planning on small islands. An assessment of groundwater resources seems to be a logical first step in the ultimate development of management plans for the resource (Ozoray, 1977). Geophysical investigations represent a reasonable approach to cost-effectively assess groundwater resources. There are many geophysical texts and articles dealing with the application of geophysical methods to hydrogeologic mapping (Kelly and Mares, 1993). Falkland (1991) discusses the applicability of geophysical methods as a means of meeting specific objectives but not as a major contributor to groundwater assessment and management. This dissertation explores the applicability of geophysical methods in mapping subsurface geology to assist in estimating the groundwater resources on small islands and in developing a scheme for governance of the resource.

1.4 Motives for Research

The basic motivation for the research resulted from an investigation undertaken during the preparation of my Masters Degree Project within the Faculty of Environmental Design at the University of Calgary (Henderson, 1998). I was puzzled by the lack of groundwater resource base knowledge incorporated into community plans for the Gulf Islands of British Columbia. The importance of groundwater resources has been recognized by researchers in island environments and by the Government of British Columbia. The lack of information therefore raised many questions that research has attempted to address (Ozoray, 1973; Falkland, 1991; B.C. Environment 1993a, b, c, d, 1994a, b; South Pacific Applied Geoscience Commission, 1998; Khaka, 1998; Falkland, 1998; Gossling, 2001). I saw that if I were to develop a cost-effective approach for groundwater resource assessment, as well as an easily understood description of the resource base and the factors affecting it, I might contribute significantly to the community planning process.

1.5 Importance of Research

The concept of sustainability and its viability for resource management, especially for future generations, lies at the heart of the research. It can be argued that the approach taken here is reductionist in view of the emphasis on understanding the physical nature of the resource base. To a certain extent, that argument is justified. The physical resource base represents a snapshot in time, since the resource base varies both temporally and spatially. The resource base represents the physical reality, but it can be argued that the primary barriers to resource management are social, economic and political factors (Burke and Moench, 2000). Many water-related terms such as water scarcity have social, economic and political definitions. Knowledge of the resource base does, however, allow for improved decision-making. Decisions based on such knowledge are educated and informed rather than being made in relative ignorance. Ultimately, educated decisions lead to greater good for more people. As decisions are made in the course of water resource management, potential future options may disappear, so that there is less flexibility in future decision-making. The possibility of influencing the decision-making process in a positive way was one of the driving forces behind this dissertation.

1.6 Contribution of Research to Knowledge

The significant contribution of this dissertation is a conceptual framework for groundwater resource assessment on small islands that will enable improved decision-making in the community planning process. The dissertation also provides a revised approach to the governance of groundwater resources and reserves on small islands. The integration of geologic mapping, geophysical surveys, and climate monitoring as a physical basis for community planning represents a departure from the standard planning process.

1.7 Overview of Document

Chapter 1 introduces the dissertation by presenting the problem statement and the objectives of the research. Chapter 2 describes the research approach and methods. Chapter 3 reviews the background information on water resource assessment on small islands. Chapter 4 describes the climatic conditions for the case study area. Chapter 5 provides an overview of the geology of North and South Pender Islands. The results of the geophysical investigations are presented in Chapter 6. Chapter 7 provides an overview of current land use on the islands and divides the area into groundwater basins providing estimates the groundwater resources available in each groundwater basin. Chapter 8 presents the existing legal and institutional frameworks in the study area. Chapter 9 discusses the results of the case study and presents a conceptual model for groundwater management on North and South Pender Islands. Finally, Chapter 10 presents recommendations for dealing with water issues on North and South Pender Island. The global applicability of the prescribed approach is also discussed.