An Overview of Environment Canada's Groundwater Research Activities at Point Pelee National Park, Ontario

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Abstract

Most of Point Pelee National Park is comprised of a massive marsh consisting of cattails and open water ponds. The marsh is completely separated from Lake Erie by two barrier bars along the east and west sides of the marsh. Elevated concentrations of phosphorus, nitrate and ammonia were detected in a few of the open water ponds within the marsh. These high concentrations and continued nutrient loadings may lead to the deterioration of the health and natural biodiversity of the marsh. Because the highest concentrations of nutrients are located along the western barrier bar, which is also the main area of human activity within the park, it is suspected that nutrients from the septic system tile beds are leaching to the water table, and then into the marsh via groundwater flow. To enable Parks Canada to make informed decisions about water quality issues within the park, Environment Canada is undertaking a multi-disciplinary series of research and monitoring studies. These studies endeavour to characterize the following:

1. the sedimentology and glacial stratigraphy of the barrier bars;
2. the groundwater flow regime and its connection to Lake Erie and the marsh;
3. the relative contributions of the hydrologic components to the groundwater regime;
4. the fate and transport of septic system derived nutrients;
5. the historical impact of land use;
6. nutrient cycling within the marsh; and,
7. modelling groundwater flow and contaminant transport.

Introduction

Point Pelee National Park is located on the southern portion of a spit extending 15 km southward into the western end of Lake Erie. Approximately 70% of the park is comprised of a massive marsh consisting primarily of cattails and open water ponds (Figure 1). The marsh is completely separated from Lake Erie by barrier bars which run along the west and east sides of the marsh. The convergence of the barrier at the south gives Point Pelee its distinctive triangular shape. The park is internationally known as a sanctuary for migratory birds because of its southward projection into Lake Erie and its large marsh. In addition to its highly diverse bird population, the Point Pelee marsh is a highly productive ecosystem, supporting many species of aquatic and terrestrial plants, fish, mammals, reptiles and amphibians.

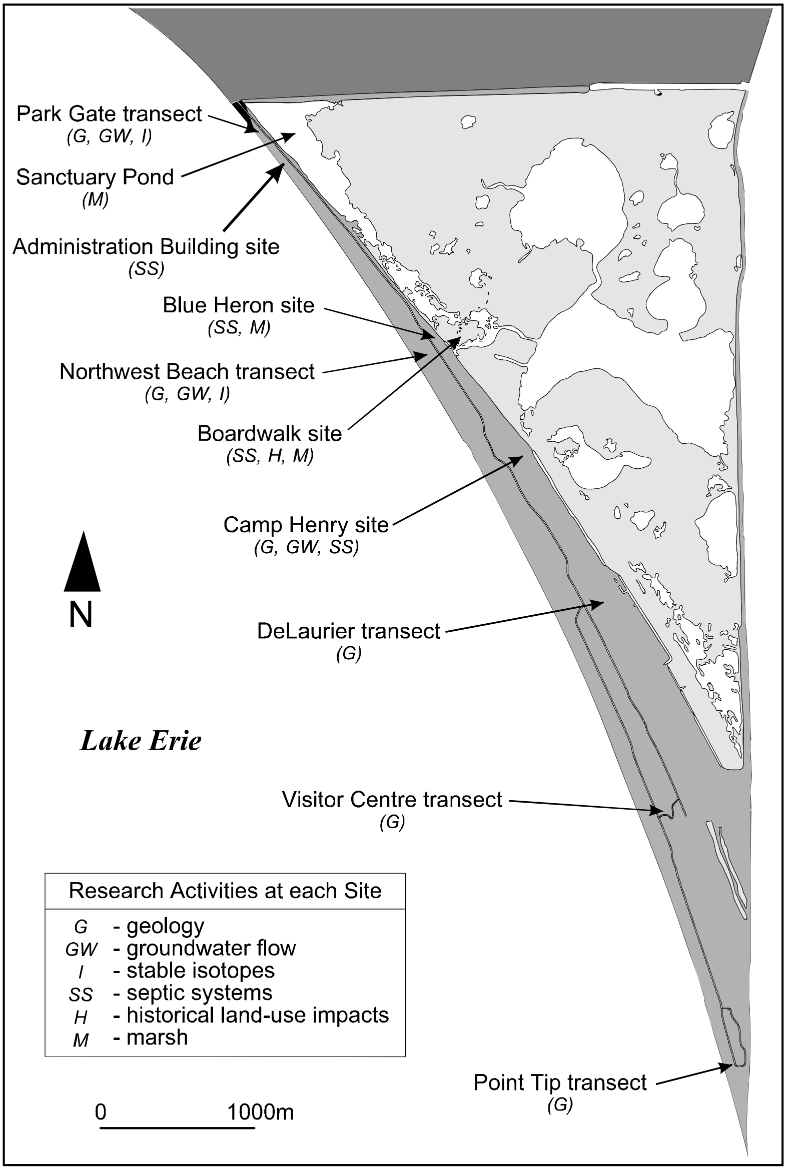

Figure 1: Location of groundwater-related activities at Point Pelee National Park

The Point Pelee marsh also acts as a metabolic regulator of contaminants, nutrients and organic matter that enter the system. Although plants within a marsh consume phosphorous which enters the marsh, too much phosphorous will overload the system, leading to the deterioration of water quality and natural biodiversity. The Ecosystem Health Division of Environment Canada detected elevated concentrations of phosphorous in a few of the open water ponds. Sanctuary Pond, located in the northwest corner of the marsh, has experienced excessive seasonal algal growth which has resulted in the pond presently experiencing hypereutrophic conditions. Phosphorus concentrations in the ponds near the Marsh Boardwalk area are not as high as at Sanctuary Pond, but are still sufficiently high to warrant concern about its water quality and ecosystem. These ponds are located immediately adjacent to the western barrier bar, which is also the area of the park accessible to visitors and contains services for the visitors, including washrooms. It is very common to have waste water from septic system tile beds migrating downward to the water table causing high concentrations of nutrients, including phosphates, nitrates and ammonia, in the groundwater. Because of the numerous septic system tile beds located relatively close to the marsh, and the very sandy nature of the soil in which the tile beds are placed, it was suspected that the park's septic systems may be a potential source of the nutrient loading via groundwater flow and discharge to the marsh.

Point Pelee National Park (Parks Canada) and the Ecosystem Health Division (Ontario Region - Environment Canada) asked the Groundwater Remediation Project (National Water Research Institute - Environment Canada) to help address this issue. The principal objective was to determine if nutrients from the park's septic systems were entering the marsh and contributing to the increased concentrations of phosphorus, nitrate and ammonia presently observed in the marsh. This objective was divided into two primary tasks:

1. understanding the groundwater flow regime in the western bar; and,
2. characterizing the nutrient discharge from the park's septic system.

Initially, addressing these tasks seemed like a relatively simple groundwater flow and contaminant transport problem. The septic systems are within a few 10's of metres of the marsh; tile beds are constructed in very sandy and permeable soil; the water table is quite shallow; and, the septic systems are situated between the marsh and an upland dune area. However, as the study progressed, it became apparent that the groundwater flow regime and the geochemistry of the septic-system nutrients in the subsurface were very complex. Further, it became apparent that undertaking this study over a few months or even 1 - 2 years would not provide an accurate understanding of the system, nor would it adequately address the objectives of the study.

The study has become long-term and is now entering into its fifth year. It has also adopted a multi-disciplinary perspective. Various components of the study now underway include:

1. understanding the groundwater flow regime;
2. developing a hydrologic budget of the groundwater flow regime;
3. characterizing the nutrient geochemistry of three septic system tile beds;
4. investigating the historical land-use impacts;
5. identifying sources of phosphorus in the marsh;

6. interpreting the sedimentary structure and geological evolution of Point Pelee; and,
7. developing a numerical model for groundwater flow and contaminant transport.

This paper presents an overview of these seven research activities. Some of these activities have been completed and some are currently being conducted at Point Pelee National Park.

Geological Setting of Point Pelee

The sediments and sedimentary structure in the subsurface largely control groundwater flow. Groundwater flow, and corresponding contaminant transport, favour sediments which offer the least resistance to flow. Sand and gravel are most conducive to groundwater flow, while clay and till are least conducive. Identification of those sedimentary zones – or hydrostratigraphic units – which are most likely to be the main pathways for groundwater flow as well as those which are least likely to permit groundwater flow, is required in order to focus efforts and resources in areas most likely to contain contaminants. In addition, characterization of the sedimentary structure, geometry, and extent of these hydrostratigraphic units aids in interpolation between boreholes and wells. The present subsurface structure is a direct result of past deposition and erosion of the sediments. Thus, a geological investigation of Point Pelee is an integral component of the park's groundwater study. The specific objectives undertaken as part of the geological interpretation of Point Pelee are to:

1. identify subsurface sediment types (e.g., sand, gravel, till, clay);
2. define the structure, geometry and lateral extent of the hydrostratigraphic units;
3. interpret the geological evolution – depositional and erosional history – of Point Pelee; and,
4. determine the post-glacial shoreline evolution of western Lake Erie.

An extensive drilling program was undertaken to install wells and groundwater sampling devices along the western barrier bar at the Park Gate transect, the Northwest Beach transect, and the Camp Henry site. This drilling program provided valuable subsurface information which was used in the geological interpretation of Point Pelee. Subsurface sediments were brought to the surface for observation, collection and analysis, and yielded considerable information relevant to the interpretation of the type of sediments and lateral geometry of sedimentary units below Point Pelee. Additional drilling, specifically for the geological investigation, was undertaken along three additional transects: the De Laurier transect, the Visitor Centre transect and the Point Tip transect (Figure 1).

Four major sedimentary units were identified, three within the barrier bar and one within the marsh. The lower-most unit encountered was a clay-rich till which forms the main structural feature on which Point Pelee was formed. Fine-grained, gray glacio-lacustrine sand was encountered on the clay-till but it is present only south of the Marsh Boardwalk site. The uppermost sediment comprising the barrier bar is a medium-grained sand and gravel unit. It is subdivided into two sub-units. The first is a poorly sorted shoreface sand, composed of essentially the same material found along the present beach. It varies in thickness from 7 m at the beach to 1 m adjacent to the marsh. The second is an aeolian (dune) sand derived from the shoreface sand. It varies in thickness from 0 m at the beach to 8 m within the largest dunes, and overlies the shoreface sand. The base of the marsh is composed of an organic marsh deposit of gyttja and peat, which sits on top of the clay-till.

The formation and evolution of the marsh and barrier bars at Point Pelee National Park is related to the depositional history and subsequent sedimentary processes that occurred at Point Pelee. As the last glacier melted and retreated northward, water began to fill the Lake Erie basin. Sediments were carried by the melt water into the western basin of Lake Erie. Subsequent reworking of these sediments altered the coastline and eventually resulted in the present shape of Point Pelee. Although there was an overall rising trend in Lake Erie levels from 10,000 years before present, two major intervals in which the lake levels were at a stand-still are documented by the sediments at Point Pelee. First, the surface of the till below the south end of Point Pelee was eroded by waves to a planar surface at about 164 m above sea level. Second, the upper portion of the glacio-lacustrine sand was also eroded by wave action forming a planar surface at an elevation of approximately 169.5 m above sea level. Radiocarbon dates on basal marsh deposits indicate that marsh formation was initiated around 3,200 years ago. The initial deposition of the sands forming the barrier bar at Point Pelee commenced at the same time as the formation of the marsh.

Groundwater Flow Regime at Point Pelee

Groundwater flow through the barrier bar is the principal mechanism through which contaminants would be transported from the septic system tile beds to the marsh. Thus, before an accurate assessment of whether the septic systems are impacting on the marsh, an accurate understanding of the groundwater flow regime is necessary. Further, because the groundwater flow regime is one component of the hydrologic cycle occurring at Point Pelee, an assessment of the groundwater flow regime must also address the relationship of groundwater flow to the marsh, Lake Erie, infiltration of precipitation and spring snowmelt, and evapotranspiration. The specific objectives of this phase of the project are to determine:

1. the direction of groundwater flow, that is towards the lake or marsh, or both;
2. the velocity at which groundwater moves through the barrier bar;
3. the nature and the extent of the link between groundwater, the lake and the marsh;
4. the importance of infiltration and evapotranspiration in the groundwater regime; and,
5. the potential for groundwater to transport contaminants to the marsh.

The groundwater flow regime at Point Pelee was investigated along two transects extending from Lake Erie to the marsh (Figure 1). The Park Gate transect is representative of a narrow portion of the barrier bar (80 m) with relatively low relief. The Northwest Beach transect represents a wider portion of the barrier bar (320 m) with considerably higher relief. Additional information was obtained from the Camp Henry site, located on a very wide portion of the barrier bar (420 m) with moderate relief. Transects were instrumented with shallow water table wells and deeper groundwater wells (piezometers). Multilevel bundle samplers were installed along the transects which enable groundwater samples to be collected at 1 m intervals vertically through the groundwater flow system. Water levels were taken at least monthly at these wells. Water level measurements of the surface of the marsh (measured by Parks Canada) and Lake Erie (measured by the Canadian Hydrographic Survey), and meteorological information (measured by Parks Canada) is also required as part of this assessment. By observing the changes in the water levels at an individual well and along a transect, and comparing these to changes in the lake, the marsh, and precipitation, a conceptual model of the groundwater flow regime can be developed.

Long-term monitoring of these data is required because the groundwater flow regime fluctuates on both a short-term and long-term basis. On a short-term basis, the groundwater flow system is affected by infiltration from the surface after major rainfall events and daily removal of water through evapotranspiration. On an annual basis, the groundwater flow regime changes due to seasonal fluctuations of Lake Erie and the marsh, as well as the major spring recharge event caused by the infiltration of melting snow. On a long-term basis, periods of very high lake levels – as is presently occurring – or very low lake levels – as occurred during the mid-1960s and late 1980s – also has a major impact on the groundwater flow regime.

Large changes in elevation of the water throughout the barrier bar occur due to infiltration of precipitation and spring melt and annual changes in the elevation of Lake Erie. A reversal in the direction of groundwater flow occurs twice each year in response to larger changes in the elevation of Lake Erie versus those in the marsh. Although there is considerable groundwater recharge each year, there is also a considerable loss of this recharge water throughout the summer and fall through evapotranspiration. The width of the barrier bar, which increases southward, governs the hydraulic gradient across the barrier bar. Thus, groundwater velocities, groundwater travel distances, and inflow of lake and marsh water into the barrier bar, all decrease southward. Where the barrier bar is 450 m wide, there is a negligible seasonal reversal in the direction of groundwater flow because of the very low hydraulic gradient across the barrier bar and the dominance of infiltration (Figure 2). Groundwater flows from the central portion of the barrier toward the marsh at a rate of only a few metres per year. Where the barrier bar is 300 m wide, groundwater flow exhibits a reversal in the direction of flow at a rate of 5-10 m per year towards the lake and 1-4 m per year towards the marsh, for a net annual travel distance of about 3 m (Figure 2). Hence, there is little movement of groundwater from the barrier bar into the lake and the marsh, and little corresponding movement of marsh and lake water into the barrier bar. The small net annual extent of movement due to the reversal in flow will result in long residence times. Where the barrier bar is 80 m wide, a strong seasonal reversal in groundwater flow towards the lake and marsh of 30-40 m and 20-30 m, respectively, occurs. This allows considerable discharge of groundwater into the lake and the marsh, as well as considerable inflow of water from the marsh and the lake. As a result of the reversal of groundwater flow and high rate of evapotranspiration, water from Lake Erie never flows through the barrier bar to the marsh, or vice versa.

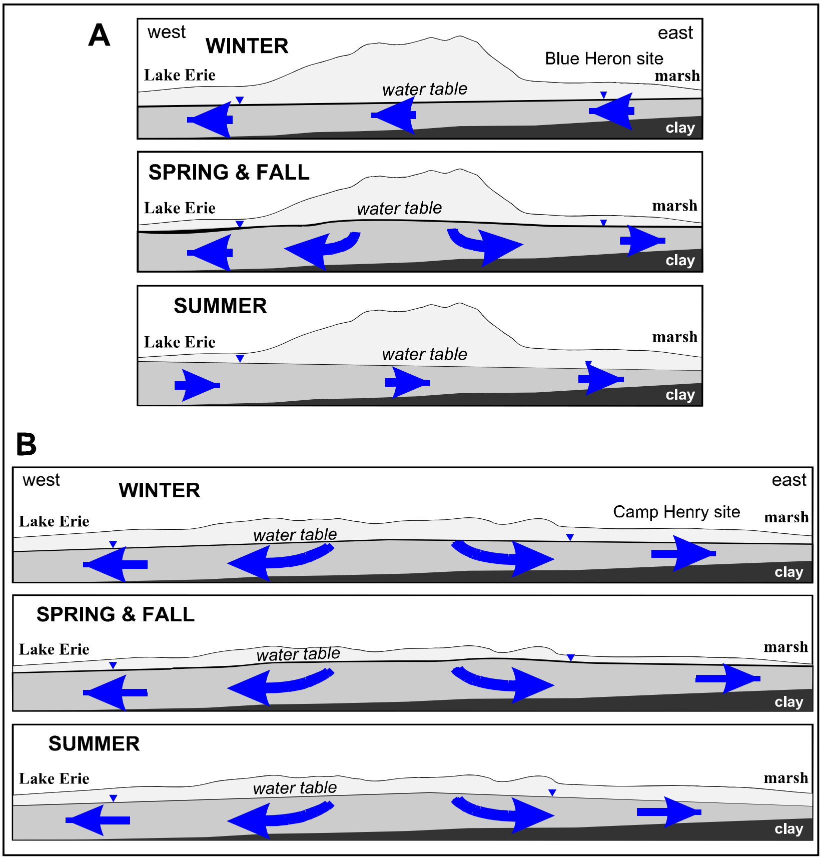

Figure 2: Conceptual model of seasonal changes in the direction of groundwater flow at (A) the northern part of Point Pelee(e.g., Northwest Beach/Blue Heron area), and (B) the southern portion of Point Pelee (e.g., Camp Henry site).

Stable Isotope Analysis of the Groundwater Flow Regime

Stable isotopes are naturally occurring elements with the same number of protons but a different number of neutrons and consequently a different atomic mass. Hydrogen and oxygen each have two useful stable isotopes. These are: ^{1}H (common or light) and ^{2}H or D (rare or heavy), ^{16}O (common or light) and ^{18}O (rare or heavy). The most common water molecule is $^{1}H_2{}^{16}O$; heavier $^{1}HD^{16}O$, $^{1}HD^{18}O$ and $^{1}H_2{}^{18}O$ are rare. The process of evaporation causes an isotopic fractionation that affects the relative proportions of these isotopes in waters. Water comprised of the lighter isotopes of oxygen and hydrogen are preferentially evaporated. Hence water vapour is relatively enriched in the lighter isotopes and the remaining surface water is enriched in the heavier isotopes. The effect of this fractionation on the isotopic composition of the remaining body of water depends on its overall volume relative to the amount of water evaporated and the time in which the surface water has been exposed to evaporation. These factors make it possible to distinguish between different sources of water that exist in the groundwater flow regime, including the marsh, Lake Erie, infiltrating rainfall, and snowmelt. The isotopic composition of the Point Pelee marsh and Lake Erie are quite similar in the winter. As the weather warms, evaporative processes cause marsh water to become isotopically heavier because the volume of water lost through evaporation represents a large portion of the volume of water in the marsh. The isotopic composition of Lake Erie remains relatively constant, because the volume lost through evaporation is small relative to the lake's total volume. The isotopic signature of the lake and marsh become increasingly different during the summer months, making it possible to distinguish them. Local precipitation also has a unique isotopic composition that is much lighter than either the lake or marsh. The isotopic composition of precipitation vary predictably during the year in response to local air temperatures.

As a result of these isotopic differences, isotopic characterization of water samples taken from groundwater, the marsh, Lake Erie, and precipitation can be used to aid in the interpretation of the groundwater flow regime. The objectives for this study are:

1. to determine the relative contributions to groundwater by each of the sources over time;
2. to track the extent of movement of lake and marsh water into the barrier bar; and,
3. to observe the seasonal changes to the groundwater flow regime.

Water samples from the marsh and Lake Erie, as well as groundwater from the multilevel samplers along the Park Gate and Northwest Beach transects (Figure 1) were collected six times during the first year and seasonally since. Total monthly precipitation samples were also collected. All samples were analyzed for oxygen and hydrogen stable isotope measurements at the University of Western Ontario's Stable Isotope Laboratory. There was similar isotopic evidence of infiltration into the shallow groundwater (0-2 m) at both transects. The isotopic compositions of deeper groundwater samples differed between transects, suggesting that the relative contribution to the groundwater flow regime from Lake Erie and the marsh are significantly different. A considerable proportion of the groundwater at the Park Gate transect is composed of marsh and the lake water. For example, during the winter of 1994, water from the marsh moved up to 27 m westward into the barrier bar, and during the summer of 1995, lake water moved up to 42 m eastward into the barrier bar. In contrast, water from neither the lake nor the marsh moved more than a few metres into the barrier bar at the Northwest Beach transect, thus groundwater here has essentially no marsh or lake component.

Characterization of the Park's Septic Systems

Although Point Pelee National Park is Canada's smallest National Park, it receives over 500,000 visitors each year. The park currently has more than 30 active septic systems along the western barrier bar to service the park's staff and visitors. Given the proximity of the septic systems to the marsh – many are within a few 10's of metres of the marsh – and the favourable hydrogeological conditions for contaminant transport – tile beds constructed within highly permeable sand, and a shallow water table – it is conceivable that nutrients derived from the septic systems are moving towards the marsh. Most of the park's septic system tile beds are installed directly into the native barrier bar sand. The objectives of this study are:

1. to determine whether or not nutrients reach the water table;
2. to characterize the extent of contamination spatially and in concentrations;
3. to identify processes controlling the contaminant migration, retention, and transformation; and,
4. to determine if septic system derived nutrients are entering the marsh.

Three sites were instrumented with water table wells, multilevel bundle samplers, mini-piezometers, and seepage meters (Figure 1). The Camp Henry site is representative of a septic system which has moderate and mainly seasonal use, is located at a very wide portion of the barrier bar (420 m), and was decommissioned in 1995. The Blue Heron site is one of the most heavily used septic systems within the park. It is used throughout the year and is located at a moderately wide portion of the barrier bar (300 m). A third site, at the Administration Building, has recently been instrumented. This is a moderate but continuous use site, located where the barrier bar is narrow (90 m). Extensive groundwater sampling was undertaken from over 400 sampling points at over 50 locations. The groundwater samples were analyzed for nutrients (NO_3, NH_3, PO_4), dissolved organic carbon, major ions, trace metals, dissolved oxygen, pH, Eh, alkalinity, electrical conductivity, and temperature.

Plumes of contaminated groundwater, containing elevated concentrations of nutrients, including NO_3, NH_3 and PO_4, and other dissolved constituents were observed below the tile beds at the Blue Heron and the Camp Henry sites. At the Camp Henry site, located where reversals in groundwater flow are negligible, a uniform plume has developed in one direction away from the tile bed and towards the marsh (Figure 3). The plume contains high concentrations of NO_3 (to 80 mg/L N) and NH_4 (to 50 mg/L N), and moderate concentrations of PO_4 (to 1.5 mg/L P). It is likely this plume will be eventually flushed to the marsh by continuously infiltrating water. At the Blue Heron tile bed site, located where strong seasonal reversals in groundwater flow direction occur, a bimodal plume has developed in both east and west directions of the tile bed (Figure 3). The bimodal plume contains high concentrations of NO_3 (to 30 mg/L N) and moderate concentrations of NH_4 (to 2 mg/L N) and PO_4 (to 1.5 mg/L P). This plume is likely to expand because of recharge, and will have a long residence time because of the reversals in flow. Near the Blue Heron site, nutrient-rich groundwater was observed to be discharging from the barrier bar into a marsh open-water pond. The discharge of this water is likely contributing to elevated nutrient concentrations observed in the adjacent open-water pond. One implication of the strong reversals in groundwater flow direction is that discharge of effluent to the marsh is expected to be less than if the groundwater flow was directed toward the marsh year-round. A second implication is that septic-system effluent is expected to remain in the barrier bar longer than if groundwater flow was in one principal direction year-round.

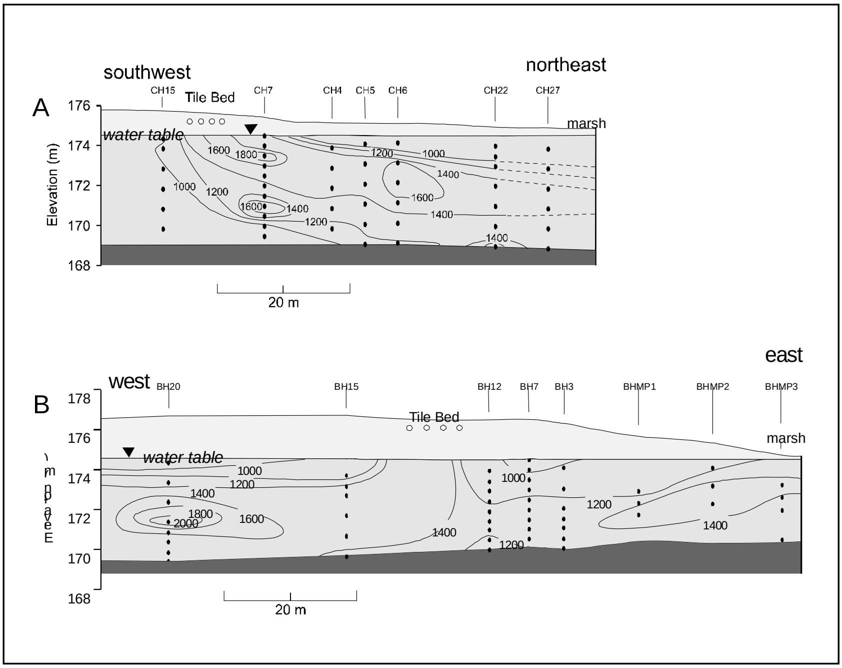

Figure 3: Cross sections showing electrical conductivity (μS/cm) originating from the tile beds at the (A) Camp Henry and (B) Blue Heron sites, during the summer of 1994.

Historical Impacts of Land Use

The recent investigation of groundwater contamination from the park's septic systems has revealed the presence of septic system derived nutrients in the groundwater flow regime. At the Blue Heron site, the reversal in the direction of groundwater flow has led to widespread contamination both east and west of the tile bed. Additional geochemical studies, groundwater flow calculations, and age dating of the groundwater, indicate that the deeper groundwater here dates to the early 1970s. Thus, there is neither a continuous movement of contaminant towards the marsh or the lake, nor is there a reasonably rapid flushing. The implication of this is that once contaminants enter the groundwater flow regime, they remain there for a long time.

Before the present parking lot, boardwalk, snack concession, and washrooms were constructed at the Blue Heron - Marsh Boardwalk area, a variety of buildings and activities occupied this site. A survey of past land use revealed that a store, a barn, a gun club, boat houses, a garage, and numerous permanent houses, summer cottages, hunting cabins and fishing cabins were situated here up until the mid 1970s. It can be assumed that most of the buildings would have had a sewage disposal system, either permanent or temporary. The efficiency of these waste disposal systems to attenuate phosphate and oxidize ammonia is questionable due to the shallow water table and the construction practices of the time. Thus, it is highly probable that groundwater contamination occurred and that this contamination still exists. A study is currently being conducted to determine whether past land use is responsible for present groundwater contamination. Specific objectives are:

1. to identify phosphate in the groundwater flow regime that originated from past land use;
2. to identify processes responsible for long-term retention and lack of mobility of phosphate;
3. to investigate geochemical processes occurring at these locations; and,
4. to quantify discharge to, and inflow from, the marsh at these sites.

Indications of past sewage disposal practices in the marsh boardwalk area were detected during drilling when pieces of tile were brought to the surface, and during a search of historical records and photographs which indicated that vault-styled toilets existed here. The presence and extent of sewage derived contaminants were assessed through analyses of groundwater collected from multilevel bundle samplers installed at the boardwalk site. Phosphate and ammonia were detected in the groundwater where there are not any present septic system tile beds but where former buildings were located. Very large areas have elevated concentrations that are similar to those found in the groundwater beneath the present tile beds. In addition, there are isolated areas close to the edge of the marsh which have concentrations of phosphate and ammonia even higher than untreated waste water.

Phosphorus Cycling within the Marsh

Marshes function as natural sinks for nutrients, including phosphorus. Benthic sediments – sediments at the base of the marsh – and plants represent important storage compartments of phosphorus within a marsh. There is a substantial cycling of phosphorus between the benthic sediments, water and the plants. Marshes typically exhibit a balance between the phosphorus consumed by plants and the phosphorus released by sediments. However, a major introduction of phosphorus from external sources would upset this balance and result in a steady deterioration in water quality and subsequent reduction in species biodiversity. Because many of the septic systems at the Point Pelee National Park are close to the marsh, it is conceivable that nutrients from these septic systems can enter the marsh. The main focus of the groundwater studies was to determine whether nutrients from the septic systems are entering the marsh via the groundwater flow regime. These studies, however, could not provide evidence that the septic system-derived nutrients actually enter the marsh, nor could they document their impact on the nearshore zone of the marsh. To determine if septic system-derived nutrients contribute to the natural loadings in the marsh, a marsh-focused study was undertaken having the following objectives:

1. identify differences in sediment phosphorus concentrations spatially and with depth;
2. relate sediment phosphorus concentrations to the chemistry of sediment pore water; and,
3. relate sedimentary phosphorus distributions to the sewage-specific marker, coprostanol.

Two areas of the marsh were investigated (Figure 1). Sanctuary Pond, which is the most eutrophic pond in the park, and the Blue Heron - Marsh Boardwalk site which has poor water quality, but is not yet eutrophic. Sediment cores were collected at these two sites from locations near the shore of the marsh and further offshore. The sediments were analyzed for phosphorus and organic content. Blue Heron - Marsh Boardwalk sediments were also analyzed for coprostanol, a substance indicative of sewage input. The pore water within the benthic sediments at the Sanctuary Pond, which influences the distribution and the dynamics of dissolved nutrients in the water column, were also analyzed. No differences in phosphorus concentrations in sediments or pore water were found between the nearshore and offshore locations in the Sanctuary Pond, suggesting that either there are no external sources of phosphorus to the Sanctuary Pond, or the annual increase in nutrient concentrations from the contaminated groundwater is a small component of the overall nutrient budget in the well-mixed system of the Sanctuary Pond. At the Blue Heron - Marsh Boardwalk site, concentrations of phosphorus and coprostanol at the nearshore locations were significantly higher than those offshore, suggesting input of sewage-derived nutrients to the marsh. However, these analyses can not distinguish between nutrients entering the marsh from the present septic systems, or through past waste disposal practices.

Computer Simulation of Groundwater Flow and Contaminant Transport

Groundwater flow in the vicinity of coastal wetlands is often complex and can exhibit reversals in flow direction. Due to the complexity of both groundwater flow and hydrostratigraphy, the field studies required to adequately assess groundwater conditions require considerable instrumentation, several years of monitoring, and can be very expensive. Numerical models offer a cost-effective and rapid means of obtaining considerable insight into the groundwater flow regime at wetlands. A numerical model of the groundwater flow regime in the barrier bars between Lake Erie and the marsh at Point Pelee National Park is currently being developed. This model will extend the present studies beyond the characterization of what is presently being observed, to being able to predict what could happen to the system as a result of natural or man-made changes to the park. The objectives for the modelling study are:

1. to provide insight into present hydrologic processes;
2. to investigate the impact of long-term changes to the system;
3. to quantify groundwater discharge to the marsh;
4. to investigate contaminant transport in the groundwater regime; and,
5. to assess potential remedial scenarios.

Although there are numerous groundwater flow models, these models can be limited with respect to numerical and conceptual accuracy in their application to coastal wetlands and groundwater flow within barrier bars. The groundwater-wetlands model being developed will overcome limitations of existing models. The model is designed to simulate groundwater flow and contaminant transport in a two-dimensional cross section with a wetland and/or lake located at either end of the cross section. The model will account for a fluctuating water table, the formation of seepage faces, a heterogeneous sedimentary sequence, and time-varying shorelines between the groundwater regime and the wetland and marsh. These can fluctuate both vertically and laterally in response to changes in the size and shape of the wetland, or annual lake level cycles within Lake Erie. Initial modelling results show hydraulic heads respond relatively rapidly to lake-level fluctuations, and the direction of the groundwater flow rapidly undergoes a reversal in response to the relative elevations of the lake and the marsh. However, the width of the barrier bar is the main factor controlling the extent and timing of the reversal.

Summary

Many parks located along coastal areas of the Great Lakes use septic system tile beds as their primary means of waste-water disposal. Because many of these systems are located in sandy soils, there is a high probability that septic-system derived nutrients will contaminate the underlying groundwater. Further, because many of these tile beds are relatively close to marshes, ponds or a lake, contaminated groundwater may discharge to these adjacent waters and detrimentally impact on the water quality and natural biodiversity. The complex nature of the groundwater flow regime in these coastal areas makes tracking of contaminants, determining the extent of contaminant, and understanding the geochemical processes occurring very difficult. At Point Pelee National Park, the groundwater flow direction within the northern portion of the barrier bar undergoes a complete reversal in the direction flow – towards the lake during the winter and towards the marsh during the summer. In some areas, the contaminants may be flushed from the barrier bar, but elsewhere the reversal causes the contaminants to remain trapped for decades. Because of the complexity of these coastal areas, understanding the nature of groundwater flow, the migration and persistence of contaminants, and their impact on an adjacent marsh or pond, cannot be accurately resolved over a few months or even 1 - 2 years. As experience at Point Pelee has shown, long-term monitoring and assessment are necessary. Further, all components of the system are closely inter-related including the geological setting of the park, the hydrology of groundwater and surface waters, the siting of the septic system, the characterization of contaminant migration and persistence, and nutrient cycling within the surface waters. Thus, a multi-disciplinary approach is essential for fully understanding processes before undertaking remedial action.

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