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# Surface Water Vulnerability Analysis for Goderich Intake

**August 14, 2007**
**11066.000**

Navigating New Horizons

# Surface Water Vulnerability Analysis for Goderich Intake

*Prepared for*

**Town of Goderich**

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## TABLE OF CONTENTS

## TABLE OF FIGURES

# 1.0 INTRODUCTION

## 1.1 Background

The Clean Water Act received Royal Assent on October 19, 2006. It ensures communities are able to protect their municipal drinking water supplies through developing collaborative, locally driven, science-based protection plans. The Act establishes a framework for the development and implementation of source protection plans across Ontario.

Source protection is a watershed based, locally driven program that uses scientifically sound methods for assessing risks to drinking water and is an approach to decision-making that emphasizes information sharing, consultation and involvement by interested members in the watershed communities. Under the Act, source protection plans are to be developed on a watershed basis. To facilitate efficient use of resources and coordination of source water protection planning, regulations under the Act group individual conservation authorities into source protection regions. The Act mandates that source protection plans be developed to address threats to all municipal residential drinking-water systems within these source protection regions.

The framework for source protection, as set out in the Act, requires the development of a watershed based assessment report. This assessment report includes a watershed characterization, a water budget, municipal long term water supply strategies (aligned with the municipal residential systems), a groundwater and surface water vulnerability analysis, a threats assessment and issues evaluation, and a risk assessment for water quality and quantity. Once the assessment reports are complete and risks to drinking water have been identified, source protection would focus on the development of the source protection plan. This plan is to set out locally based risk management measures to reduce or eliminate significant risks to drinking-water supplies, and set out a strategy to implement these measures.

In October 2006, the Town of Goderich in partnership with the Ausable Bayfield Conservation Authority (as lead authority for the Ausable Bayfield Maitland Source Protection Region) retained the team of Baird & Associates in association with BMROSS to undertake a surface water vulnerability analysis for their intake on Lake Huron. This draft report describes the work undertaken and presents our findings.

## 1.2 Scope of Work

The primary purpose of the vulnerability analysis is to delineate the Intake Protection Zones (IPZs) around the drinking water intake and assign vulnerability scores that reflect the comparative likelihood of a contaminant reaching the intake. This information will ultimately feed into the Water Quality Risk Assessment (MOE, 2006) where vulnerable areas will be ranked based on the threat to drinking water.

The general approach used on this project is based on the methodology outlined in Assessment Report: Draft Guidance Module 4 (MOE, 2005). The document was updated in October 2006, after this project started, and the work presented herein is based on the earlier version. Future phases will be based on the updated document. Specific tasks included:

- Data collection and analysis;
- Intake characterization including characterization of coastal processes in the surrounding area;
- Development of the modeling approach considering available data, intake location and characterization;
- Model selection and setup;
- Delineation of IPZ-1s and preliminary IPZ-2s;

- Assignment of vulnerability scores and level of uncertainty;
- Threats identification and inventory;
- Issues evaluation;
- Identification of data gaps related to delineation of Intake Protection Zones; and
- Recommendations for additional work.

It is important to note that the scope of work does not include calibration of the model used to delineate the IPZs. This is discussed further in Section 4.

# 2.0 DATA COLLECTION AND ANALYSIS

## 2.1 Bathymetry

Bathymetric data required to develop the model grid was extracted from Canadian Hydrographic Service (CHS) Field Sheets (mylar copies of the original, detailed survey soundings). This is the best source for complete & accurate bathymetry information. For the deep water areas, historic data from CHS and the US National Ocean Service (NOS, of the National Oceanic and Atmospheric Administration (NOAA)) from 1899 & 1946 surveys were incorporated. The historic deep water data were derived from two NOAA surveys. For Field Sheet 3936 a digital version was not available so a sampling of points were digitized. The table below summarizes the individual datasets used in developing the bathymetry for the model domain. All depths were verified or adjusted to Chart Datum (IGLD85). Figure 2.1 shows the individual datasets used to develop the model grid. Each dataset is colour coded.

**Table 2.1**
**Summary of Bathymetry Data Used to Develop Model Grids**

| Title | Field Sheet/ Survey ID | Date | Map Scale | # Data Points |
|---|---|---|---|---|
| Goderich Harbour Approaches | 1200150 | 1995 | 2,500 | 11,272 |
| Goderich Approaches – Shoal Investigation | 4003283 | 1991 | 5,000 | 4,112 |
| Goderich to Kincardine (portions superceded by FS 1200146) | 3936 | 1977 | 50,000 | 4,033 |
| Goderich to Point Clark | 8144 | 1982 | | 11,750 |
| Point Clark to Poplar Beach | 1200146 | 1991, 1994, 1995 | 20,000 | 19,822 |
| **Deep Water Surveys** | | | | |
| NOAA, Lake Huron East | 03L11037 | 1946 | 120,000 | 3,033 |
| NOAA, Lake Huron South | 03L11038 | 1946 | 120,000 | 4,663 |

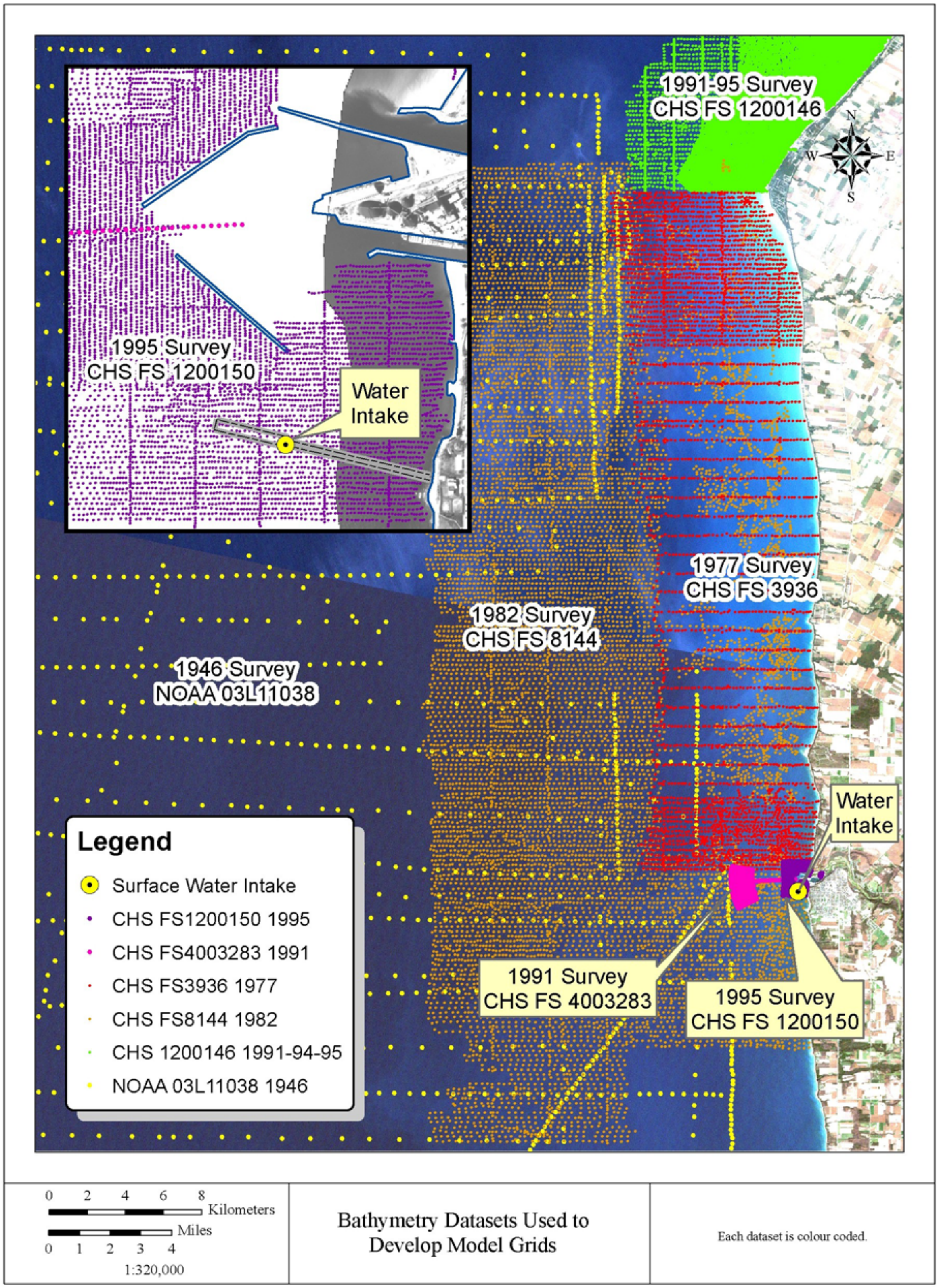


**Figure 2.1 Bathymetric Survey Data Used to Develop Model Grids**

## 2.2 Wind

Wind data was obtained from the Lake Huron Operational Forecast System (LHOFS), which utilizes the Princeton Ocean Model (POM) to generate nowcast and forecast winds for Lake Huron and Georgian Bay. LHOFS was developed and is maintained by the U.S. National Oceanic and Atmospheric Administration (NOAA).

The POM wind data is generated from many meteorological stations located around the lake, in Canada and the United States. Values are interpolated for the model domain; secondary influences such as water temperature are also included. Output from the LHOFS showing wind velocity vectors for a sample time step are provided in Figure 2.2. Hourly data for the period 2003 to 2005 were used in the modeling for the Phase 1 work. Comments on the limitations of the data set are provided in Section 4.5.

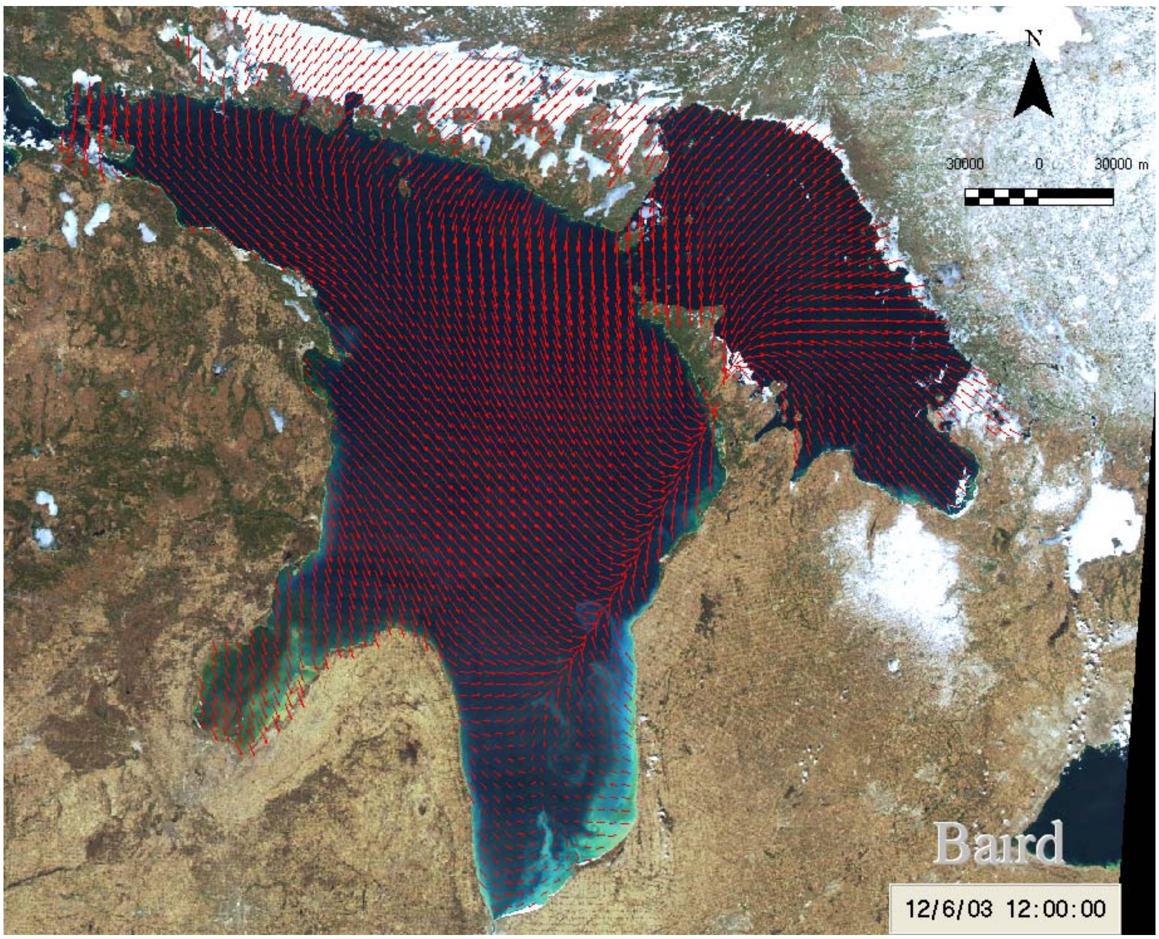


**Figure 2.2 Example of Wind Vectors on Lake Huron from LHOFS Model**

Wind data in the immediate vicinity of the intake was extracted from the LHOFS. Wind data was also collected from the Goderich Airport to confirm the POM results. The wind roses for 2003 for Goderich are shown in Figure 2.3. The LHOFS wind data was an input for the boundary conditions in the Delft3D model used to delineate the IPZ-2, as described in detail in Section 4.

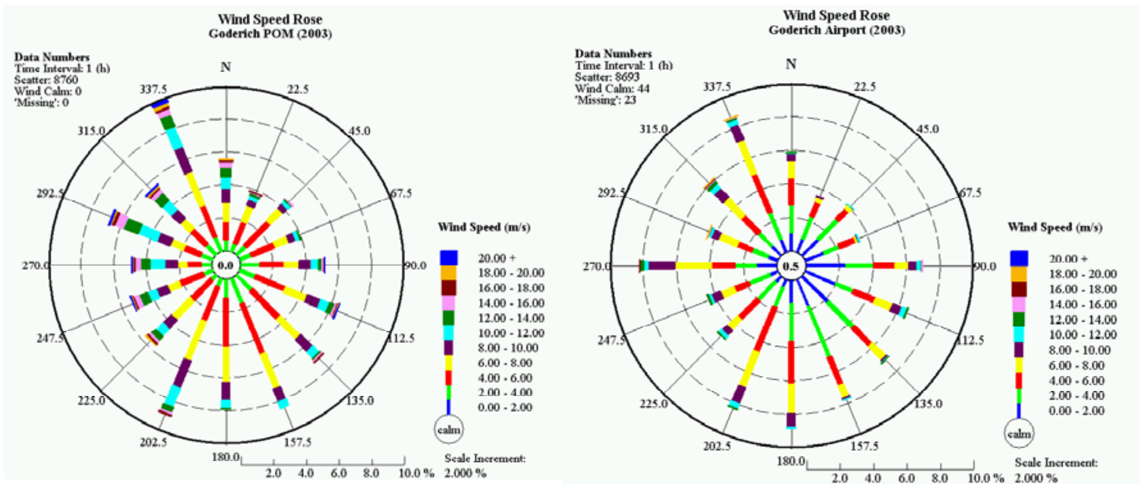


**Figure 2.3 Wind Data from LHOFS and Goderich Airport for Goderich (direction is "from")**

Figure 2.3 confirms that the wind data from the POM is consistent with observed winds in the Goderich area. Primary differences between the data show lower velocities at the airport, which would be expected since it is over the land, at a 10 m elevation – likely still within the turbulent boundaries created by on-land roughness elements (trees, buildings, etc.) Some differences in directionality occur, likely as a result of the grouping of the wind data into "bins". For example, the Airport data seem to indicate a higher number of occurrences from the west than the POM data. However if the WNW and W bins are combined, the total number of occurrences in the two data sets is very similar. It is also worth noting that the most frequent wind direction is from the NNW, however large events occur from the WSW, north through to the NNW. These are onshore winds and these wind events could push river contaminants south towards the intake.

Seasonally there is a significant variation in the wind speed. In Figure 2.4, it is clear that the events through the colder months (October to April – the wind rose on the left) are much more severe than the events through the warmer months (May to September – the wind rose on the right).

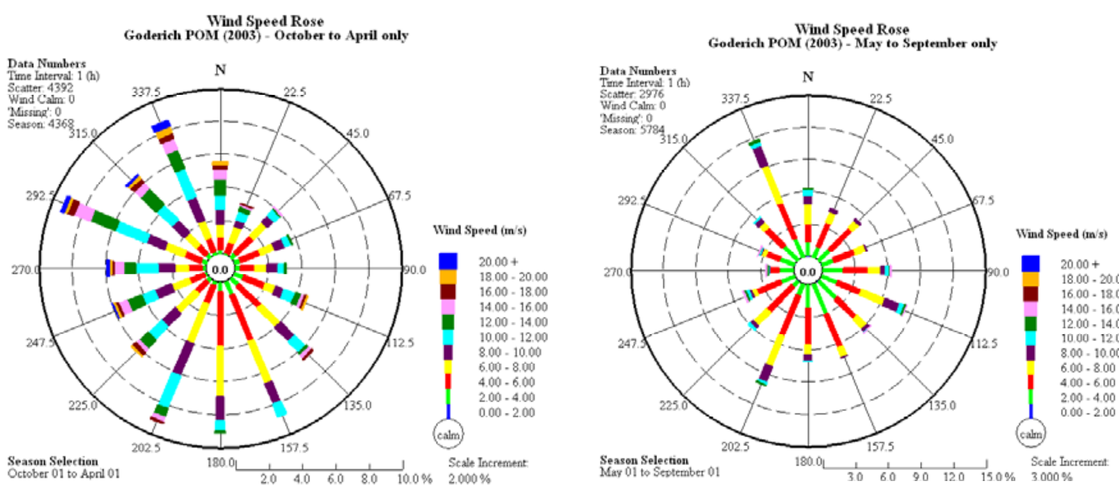


**Figure 2.4 Seasonal Winds from LHOFS (direction is "from") for Winter (left) and Summer (right)**

## 2.3 Currents

Two sources of current data were reviewed: modeled data (from the LHOFS model) discussed in Section 4, and measured data (described in this section).

Acoustic Doppler Current Profilers (ADCPs) were deployed by the Ontario Ministry of Environment (MOE) in 2003 as part of MOE's Great Lakes Nearshore Monitoring Program overseen by Dr. Todd Howell. These instruments measure the current magnitude and direction through the water column from the lakebed to the lake surface. Eight ADCPs were deployed at the locations shown in Figure 2.5, for the period from May through November 2003. The instruments measured data every 7.2 s and recorded the average of these measurements every half hour.

Current velocity data for the ADCPs deployed offshore of the Maitland River in 2003, are shown in Figure 2.6. The currents are shown for approximately 3m below the surface (top row), and approximate 3-4 m above the lakebed (bottom row). The nearshore ADCP (located 1.2 km from shore) was in a depth of 9 m, and the offshore ADCP (located 6.8 km from shore) was in a depth of 15 m. The ADCP data indicate that the currents are normally moving parallel to the shoreline, however at the offshore ADCP, the currents are stronger. The currents closer to shore are more variable in direction. The increased speed and variability in direction near the surface demonstrates the increased significance of wind and wave influences.

Figure 2.7 demonstrates the spatial variability in currents as well as the variability with depth. The figure shows currents at one point in time, at various depths through the water column (the ADCP location is indicated by the red dot at the bottom of the staff). The arrows indicate current direction and speed. This figure clearly demonstrates the variability in currents through the water column in the lake and the need for a three dimensional hydrodynamic model to evaluate the IPZs (two dimensional models use one depth averaged velocity to represent currents through the water column).

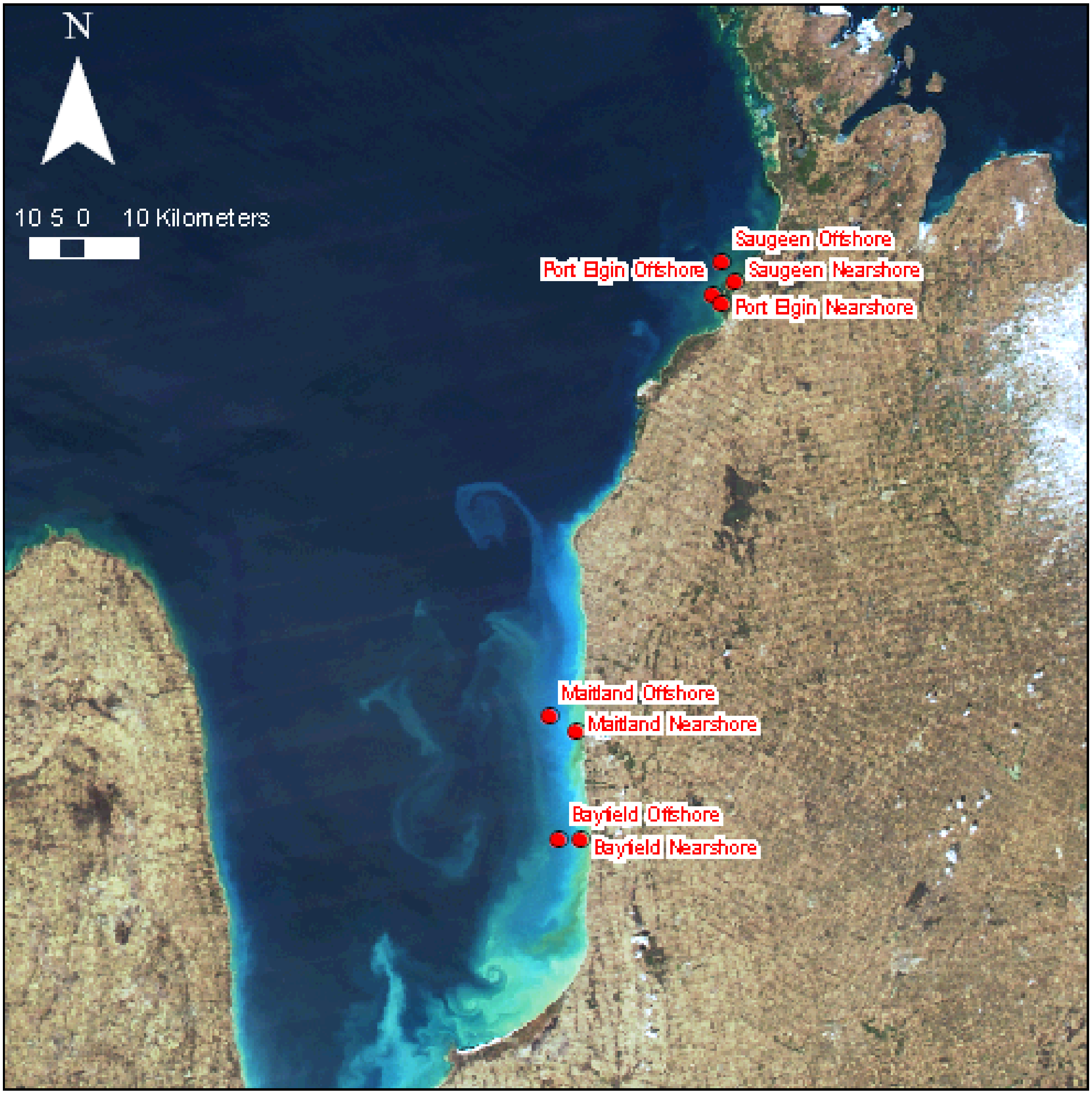


**Figure 2.5 MOE ADCP Deployment Locations on Lake Huron for May to November 2003**

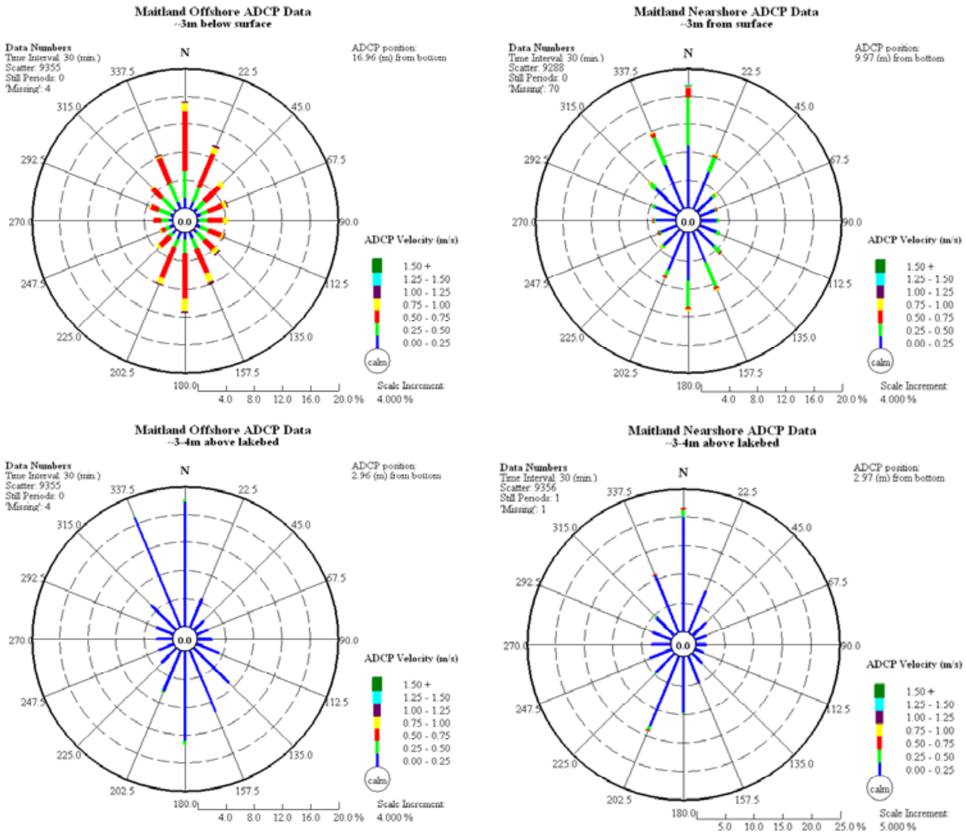


Figure 2.6 MOE ADCP Data for Maitland Offshore and Nearshore (directions are "heading to")


**Figure 2.7 ADCP Data at Goderich Showing Current Variability Spatially and with Depth**

## 2.4 Tributary Flow

Stream flow discharge data for the Maitland River were obtained from Environment Canada and from the Maitland Valley Conservation Authority (MVCA). The river is gauged at Benmiller, approximately 16 km upstream of the river mouth. The station identifier, location and period of data collection is:

Maitland River at Benmiller (02FE015)

Latitude 43° 43' 03" N Longitude 81° 37' 34" W

Data Available: Daily 1989-2005 (Environment Canada)

Data Available: Daily 2003-2006 (Maitland Valley Conservation Authority)

A comparison of the data collected by Environment Canada and MVCA for the period of overlap (2004) is shown in Figure 2.8. Although the station identifier indicates that the station locations are the same, the data are not identical. The MVCA data contains more peaks, and in most cases the peaks are higher.

A Peaks Over Threshold (POT) analysis was undertaken for both data sets to determine the 2-year return period discharge for use in the modeling and IPZ-2 delineation. The data collected by MVCA provided more conservative results, even though the data set covers a shorter period of time. The more conservative results of the POT analysis for the MVCA data were therefore used. The graph of the POT analysis is shown in Figure 2.9 and the extreme events from the POT analysis are summarized in Table 2.2. The values in Table 2.2 are based on the gauge data. No adjustment has been made to account for the input to flow from the watershed downstream of the gauge, however the increase would be less than 2%, based on the size of the watershed (approximately 2,500 $km^2$) and the relatively close proximity of the gauge to the river mouth (estimated area of the watershed downstream of the gauge is less than 40 $km^2$).

**Table 2.2**
**1- and 2-year Return Period Flows for the Maitland River at Benmiller**

| River | 1 Year Return Period ($m^3/s$) | 2 Year Return Period ($m^3/s$) | Daily Average ($m^3/s$) |
|---|---|---|---|
| Maitland | 442 | 534 | 48.9 |

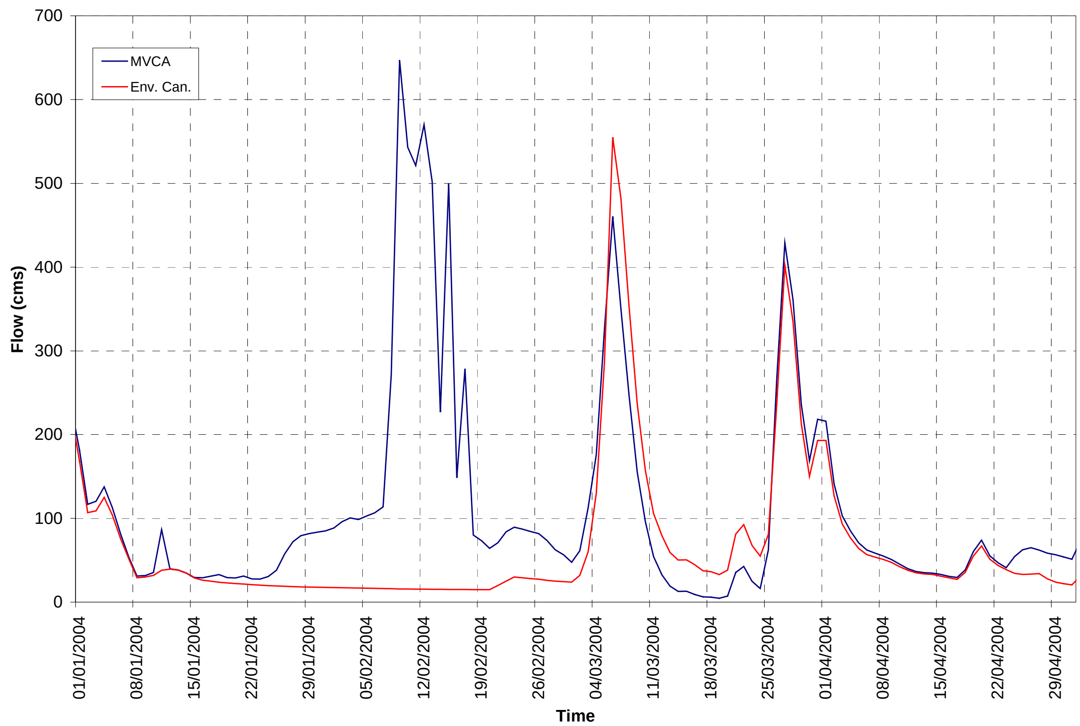


**Figure 2.8 Comparison between Environment Canada and MVCA Flow Data for the Maitland River at Benmiller (2004)**

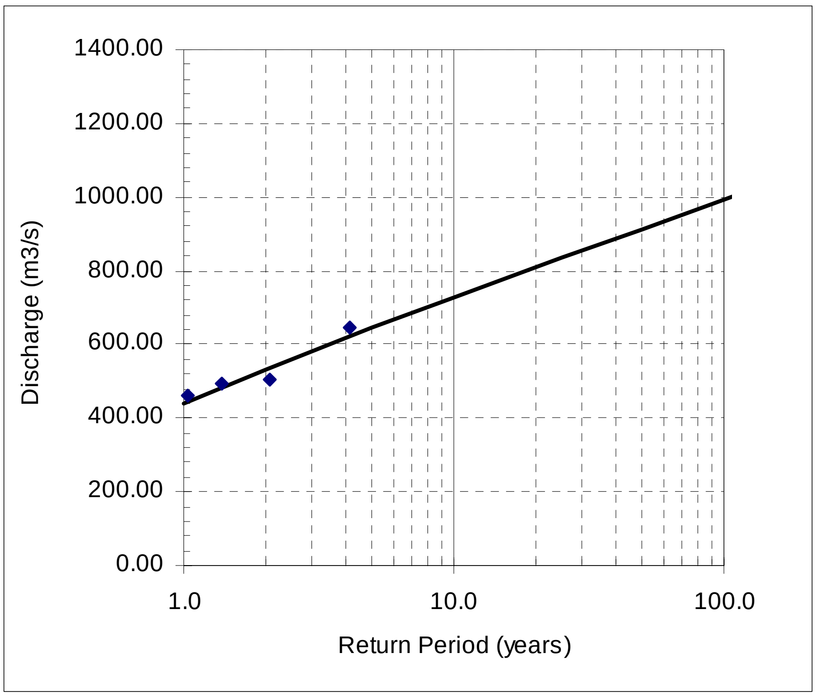


**Figure 2.9 Return Period Plot for Maitland River**

## 2.5 Water Sampling

Existing raw water quality data collected in the vicinity of the water intake was reviewed. Data sets from the Maitland River and Lake Huron were reviewed for the presence of trends and potential drinking water threats. Additional analysis was conducted by comparing water quality results in conjunction with stream flow and rainfall data to assess potential relationships between storm sewer and river discharges and raw water quality at the water treatment facility. The following data sets were used:

1. Provincial Water Quality Monitoring Network Data - Monthly sampling program collected in the Maitland River at Hwy. 21
2. Ontario Drinking Water Surveillance Program - Collected at Water Treatment Plant Intake
3. Goderich Water Treatment Plant Raw Water Quality - Monitored internally at the Treatment Plant

Table 2.3 summarizes the data available from each source, including parameters that were reviewed, sample frequency, and years of record. An analysis of the data and discussion is provided in Section 3.6.

**Table 2.3**
**Water Quality Data Overview**

| Source of Information | Years of Record | Parameters Available (# of Parameters) |
|---|---|---|
| Provincial Water Quality Monitoring Network Data | 2003 to 2005 | • Alkalinity, turbidity, temperature<br>• General Chemistry (15)<br>• Metals (16) |
| Ontario Drinking Water Surveillance Program | 1990 to 2006 | • Alkalinity, turbidity, temperature<br>• Chlorides, Nitrates, Phosphorus, Sodium<br>• General Chemistry (17)<br>• Bacteriological (2)<br>• Metals (26)<br>• Volatile Organics (26)<br>• Chloromatics (14)<br>• Chlorophenols (6)<br>• Herbicides and Pesticides (48)<br>• Phenolics (1)<br>• Polynuclear Aromatic Hydrocarbons (17)<br>• Radionuclides (7) |
| Goderich Water Treatment Plant Raw Water Quality | 2003 to 2006 | • Alkalinity, turbidity, temperature - daily<br>• E. Coli - weekly |

## 2.6 Sediment Sampling

At the outset of the study, it was determined that historic sources of sediment data would be investigated, rather than undertaking the collection of new data. Generally, there are limited sources of sediment data available for review, as this data is not typically collected by provincial or local authorities. Historic municipal and BMROSS files were examined for the presence of reports or studies, which might contain relevant data.

### 2.6.1 Dredging

The Ministry of the Environment (MOE) routinely requests that sediment collected in conjunction with harbour dredging projects be analyzed for the presence of contaminants. Material must be free of contaminants before open lake disposal or disposal on land. BMROSS was involved in three recent dredging operations within the harbour area. These occurred in 1995, 2001 and 2003. A review of files indicated that sediment sampling occurred in 1995 (results discussed in 2.6.2) but has not occurred in conjunction with a dredging project since. Dredging that occurred in 2001 was predominantly comprised of cobble and gravel; therefore the MOE determined that sampling was not required. Dredging in 2003 also did not require sampling of sediments because the MNR determined that it was a maintenance project and, based on background data from the 1995 sampling of the outer harbour, potential contamination was not a concern. In the most recent dredging operation (2003) open lake disposal of the sediments occurred.

### 2.6.2 Environmental Reports

Several environmental reports were examined for the presence of sediment sampling results. Two studies conducted in the mid-nineties are summarized below. Executive summaries from both are included in Appendix A.

*Goderich Federal Harbour – Environmental Audit*

Phyper & Associates Ltd. conducted an environmental audit of the Goderich Harbour in 1995, prior to transfer of the facility to local municipal ownership. The audit was undertaken to establish the current environmental condition of the property and to determine the degree of compliance of the subject properties with applicable federal and provincial regulations and criteria.

Sediment sampling was conducted within the inner and outer harbour areas in January of 1995 in conjunction with a Public Works pre-dredging survey. Borehole sampling of areas north and south of the harbour was also undertaken as well as the establishment of groundwater monitoring wells. These locations are illustrated on Figure 2.10.

The results of the analysis revealed the following:

1. Soil samples collected south of the harbour contained elevated levels of Total Petroleum Hydrocarbon (TPH) (oil and grease) indicating that it has been impacted by historical industrial/commercial operations in the area.
2. Analysis of sediment samples collected from the inner harbour revealed that copper, lead, total organic carbon (TOC), Polycyclic Aromatic Hydrocarbons (PAH's) and Total Kjehldahl nitrogen (TKN) concentrations exceeded those collected in the outer harbour. It was determined that open lake disposal of dredged material from the inner harbour, would have an adverse effect and would therefore not be permitted.

3. Leaching pit disposal operations associated with the Sifto Salt Mine may be contributing to elevated TPH (oil & grease) concentrations found within soil samples collected on the north side of the harbour.

The report concluded with a series of recommendations categorized as ‘high’, ‘medium’ and ‘low’ priority. Of these, only two are related to soil sampling results; the open lake disposal of dredged material from the inner harbour; and the discharge of mine water to leaching pits, north of the harbour.

### *St. Christophers Beach – Property Transfer Assessment*

Angus Environmental Limited conducted an assessment of the beach area south of the water treatment facility in 1996 in conjunction with the development of St. Christopher’s Beach, which is located between the harbour quay and the water treatment facility. Four borehole samples were collected and analyzed for the presence of organic and inorganic compounds, potentially associated with former coal storage facilities located in the area from the turn of the century until the early 1960’s.

Subsurface sampling revealed elevated concentrations of Polycyclic Aromatic Hydrocarbons (PAH’s), which are commonly found in coal and thought to be associated with former coal storage facilities. Based on the intended use of the property, passive recreational, and the depth and location of the detected contaminants, it was determined that the material presented minimal risk to the area.

### *Additional Investigations*

In June of 2004, Watech Services Inc. was retained by the Goderich Port Management Corporation (GPMC) to conduct an inspection of the lake bottom immediately north of the Sifto Salt Mine north dock. Sifto staff had noticed gas discharges from this area of the lake bottom and, as the salt caverns are located beneath this area, an investigation into the source of the discharges was deemed necessary.

The inspection involved a visual and tactile examination by divers of the lake bottom in the vicinity of the discharges.

The inspection revealed that the discharges were a result of rotting organic matter (leaves, branches, etc.), which had become trapped beneath soft silt sediment in the bed of the lake. The material was likely deposited following spring run-off events within the Maitland River and was not related to activities within the mine.

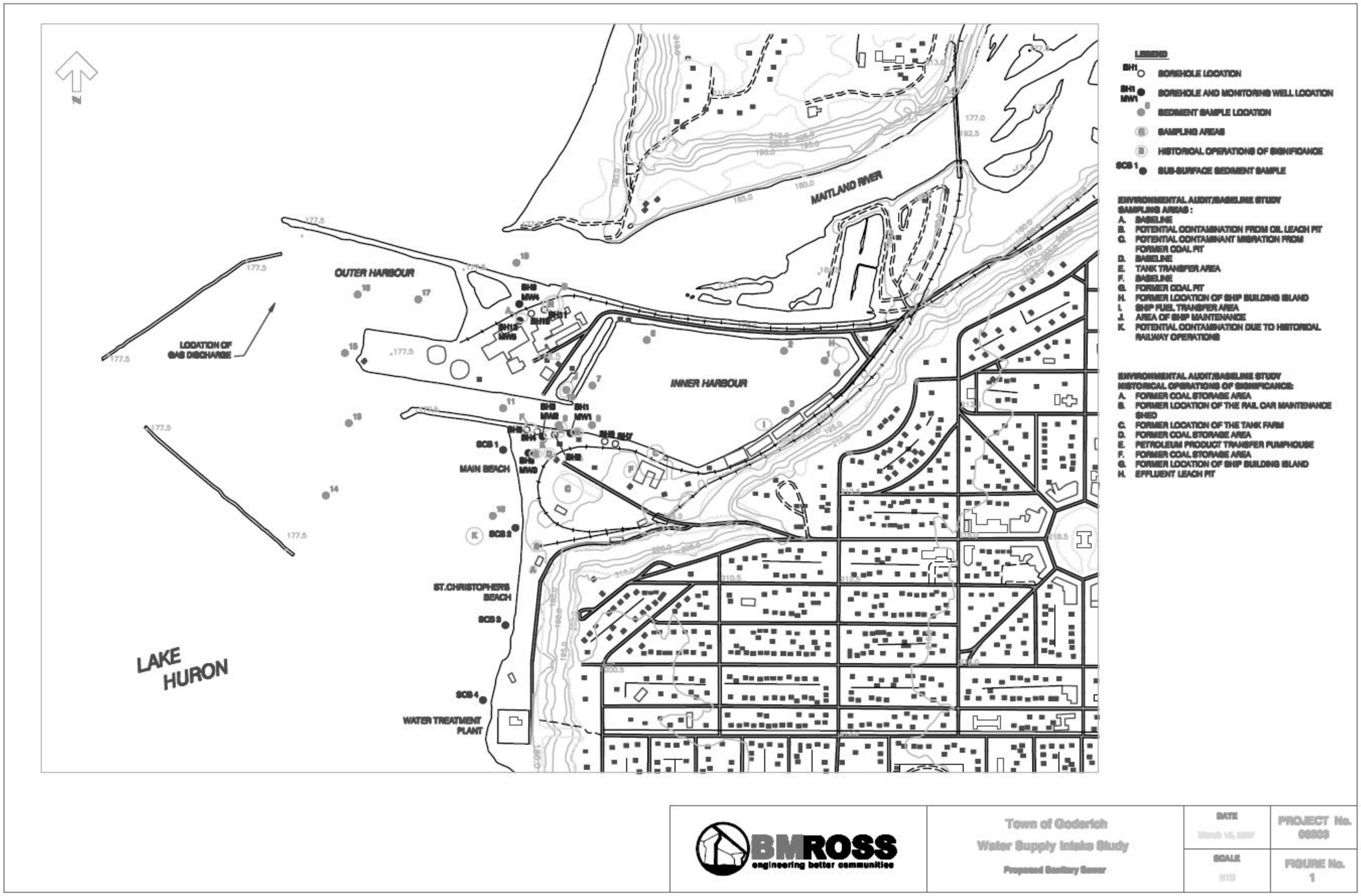


**Figure 2.10 Sampling Sites from Angus Environmental Ltd. (1997) and Phyper and Associates (1995)**

# 3.0 INTAKE CHARACTERIZATION

## 3.1 Technical Characteristics

The water treatment plant and associated intake pipe were constructed in 1961. Major upgrades were completed in 1986 and 2004, although neither upgrade affected the depth or location of the intake pipe or altered the plant's treatment capacity.

The existing municipal water supply system serves the Town of Goderich, the Bluewater Correctional Facility (a provincial young offenders facility located approximately 4 km. south of Goderich), and a large commercial plaza located just east of the municipal boundary in the former Township of Goderich (now the Municipality of Central Huron). The population, based on 2006 Canada census data, is 7,563. The water treatment facility is designed with a maximum flow rate of 165 l/s and a maximum daily flow volume of 12,000 m3/day.

Three primary sources of information were reviewed with respect to the physical characteristics of the existing intake. These were historical BMROSS files, information obtained from the Town of Goderich and legal plans provided by a local Ontario Land Surveyor (OLS).

The original construction plans for the intake, obtained from BMROSS files were reviewed to determine the exact location and depth of the intake crib. In addition, drawings pertaining to more recent upgrades to the intake crib contained useful data that was utilized as a cross-reference. Based on this material, it was determined that the existing intake is located approximately 518 m from the water treatment plant structure, extending in a northwesterly orientation from the facility. The intake pipe is a nominal 750 mm diameter concrete pipe that follows the lake bottom from the plant to the intake crib. The pipe turns upwards at the crib and widens to a diameter of approximately 1000 mm. A chlorine diffuser is located near the mouth of the intake to deter colonization by zebra mussels.

There is some discrepancy in the depth of the intake, reported in the various data sources and reports reviewed. It is difficult to read the depth on the drawings. The Engineer's Report states that the water depth over the intake in 2001 was "believed to be" approximately 4.5 m. The Certificate of Approval dated 2004 states that the intake is located in an approximate depth of 5.5 m. Based on the most detailed (and most recent) CHS survey of the area, Field Sheet 1200150, completed in 1995, the depth is 7.0 m. Since the latter is based on actual data, this is considered to be the most reliable estimate, however the depth should be confirmed. Plans of the intake are included in Appendix B.

The Town of Goderich provided several underwater videos of the intake. These had been collected at various times in conjunction with inspections or upgrades to the intake crib. A summary of these is included in Appendix C. Based on the three videos, it was determined that the lake bed surrounding the intake consists of a relatively flat, silty bottom with no rock or vegetation present. The exterior of the intake is covered with silt and encrusted with zebra mussels, though the interior is clean of obstructions due to the presence of a chlorine line, which discourages mussels and other natural growth within the mouth of the inlet pipe.

Upgrades to the intake crib were undertaken in the late 1990's, consisting of reinforcements to the crib supports and roof of the structure.

## 3.2 Operator Interview

The Water Treatment Plant Operator (employed by Veolia Water Canada Inc.) was interviewed by BMROSS staff on October 26, 2006. The intent of the interview was to determine standard operating procedures for the facility, historic raw water quality issues and concerns, past problems with the facility, and standard shut down time frames and procedures. A copy of the entire interview is provided in Appendix D. The following key information was obtained through the interview:

- Daily water quality data is available for January 2003 to September 2006
- Data includes temperature, turbidity, pH, alkalinity
- WTP can be shut-down immediately upon notification ("*a flick of a switch*")
- Ships turning in the vicinity of the intake have impacted raw water quality
- No raw water conditions are alarmed

The following are issues/concerns potentially impacting the operation of the facility:

- Turbidity
- Ice Jamming
- Microbial Contamination
- Taste and Odour (generally thought to relate to algae)
- Temperature
- Alkalinity

These conditions can be caused or aggravated by wind and wave action, storm events, seasonal conditions and activity within the river and harbour, and discharges from storm sewers in the vicinity of the water treatment plant.

There have been no conditions within the past 5-6 years that have required the plant to be shut down. At times, conditions make raw water challenging to treat, but water quality conditions at the intake have never exceeded the capabilities of the facility.

Based on the Water Treatment Plant Operator's experience and opinion, the following are potential threats/concerns to the facility:

- All agricultural activities via the Maitland River;
- Goderich STP discharge to shore, south of WTP, including by-passes caused by (combined sewage overflows) CSO's;
- Storm sewer discharges north and south of WTP;
- Marinas in the Maitland River;
- Mining activities and salt storage at the mouth of the Maitland river and adjacent to the harbour; and
- Commercial shipping and recreational boating.

## 3.3 Hydrodynamic and Hydrologic Conditions

The primary factors affecting lakewide circulation patterns are hydraulic currents, wind, and gradients resulting from temperature differences. In Lake Huron, the hydraulic currents are created by the inflows from the St. Mary's River from Lake Superior and the Straits of Mackinaw from Lake Michigan, and the outflow to the St. Clair River.

The prevailing winds that generate wind driven currents along the southeast shore of Lake Huron are from the northwest through southwest as described in Section 2.2. There are also seasonal variations in the current patterns as discussed in Section 4.3.2. During the winter months (December through February) the currents typically follow the shoreline and flow in a northerly direction in response to strong alongshore winds. The currents are also stronger than in other seasons. In the spring (March through May) southerly currents dominate. In the summer (June through August), there is a roughly equal distribution between north flowing and south flowing currents and the current speeds are notably less than in other seasons.

Currents also result from temperature differences and the development of thermoclines in Lake Huron. In the summer months, the water near the surface becomes warmer. Density differences between the warm water at the surface and the colder, deeper water results in stratification and limited mixing, producing currents along the thermocline that divides the layers, as well as pressure gradients that result in water movement from high to low pressure areas.

Water temperature differences can also be established between offshore and nearshore waters. Thermal bars develop in the spring when temperatures rise in the shallow waters near to shore, more quickly than in the deeper offshore waters. The reverse occurs in the fall when temperatures along the shoreline drop faster than in the deeper water. The thermal bars result in reduced mixing (due to density differences) and nutrients and suspended solids may become trapped in the nearshore (Howell, 2006). In this context, nearshore and offshore waters are not linked to a specific depth or distance from shore, as they vary temporally.

The Goderich intake is located approximately 650 m south of the mouth of the Maitland River. The Maitland River watershed covers an area of approximately 2540 $km^2$ with daily average flows in the range of 49 $m^3/s$ as described in Section 2.4. Howell et al. (2006) has linked nearshore water quality in the Goderich area to discharge rates in the Maitland River.

## 3.4 Lakebed and Sediment Processes

Sediment, substrate characterization and sediment processes can have an impact on water quality in the nearshore and at the intake. The Lake Huron shoreline in this area is characterized by sand and cobble beaches backed by glacial till bluffs. The beaches are often narrow and not sufficient to protect the bluffs from erosion. The largest input to the sediment budget is from erosion of the glacial till bluffs.

Sediment transport, deposition, erosion and re-suspension can also affect water quality. The intake lies in a littoral cell that extends from the northern limit of Goderich Harbour to Kettle Point (Reinders, 1988). The net direction of transport along this shoreline is from north to south. A significant beach has accumulated on the north side of Goderich Harbour and the harbour breakwaters are reportedly a complete barrier to sediment transport (Reinders, 1989) though maintenance dredging is undertaken (interview with Harbour Master October 24, 2006 – Appendix D). The shoreline south of the harbour, extending south of the intake is protected, reducing the natural sediment supply that would have resulted from shoreline erosion. Christophers Beach is a sand/cobble beach developed south of the harbour, using dredge spoil.

Sediment can play a significant role in the transport of contaminants and Phosphorus as described in Veliz (2007). The Lake Huron Centre for Coastal Conservation (2004) reported that studies conducted by MOE in 1984 showed a relationship between sediment re-suspension (and associated increase in pathogen concentrations) linked to the nearshore lakebed slope and the grain size of the nearshore lakebed material. At

Goderich, a relatively steep nearshore (1 vertical: 30 horizontal) resulted in higher suspension rates, however the coarse sand in the nearshore supported lower concentrations of bacteria.

## 3.5 Shoreline Development

The Goderich intake is located approximately 650 m south of the Maitland River mouth and the entrance to Goderich Harbour, in the Town of Goderich. The Town of Goderich represents the largest urban settlement in the County of Huron, with a permanent population of approximately 7,600 persons. The community is situated along the Lake Huron shoreline at the mouth of the Maitland River. Goderich contains well-developed residential, commercial and industrial sectors as well as extensive tourism-related activities attributable in part, to the Town's proximity to Lake Huron and its historic downtown core. The community also includes a variety of public amenities, in addition to a well-developed recreational/commercial harbour.

The Goderich Harbour, located immediately north of the intake, historically developed as an important commercial shipping port due largely to its strategic location along the eastern shore of Lake Huron at the mouth of the Maitland River, its relative proximity to key primary industries (i.e., agriculture, mining) and the scale of its loading and off-loading facilities. Early activities, including shipbuilding and lumber shipping, were located in areas of the harbour that were naturally protected. The facilities currently include a series of linear offshore and shore connected breakwaters designed to protect the harbour from wave action. Recent work includes an extension to the south pier, and further modifications and improvements are proposed over the next 5 to 7 years (see Appendix B). The harbour accommodates a diverse range of commercial shipping, fishing boats, pleasure craft and other users (e.g., Coast Guard vessels). With respect to commercial shipping, approximately 200 freighters dock within the port facilities annually (most shipping activity is associated with the salt mine situated in the harbour or the grain elevators situated at the eastern end of the harbour basin).

South of the intake, the shoreline has been developed as a recreational beach destination with picnic areas, a boardwalk, a supervised beach and playground. The Goderich Sewage Treatment Plant is located approximately 1 km south of the intake, with the discharge pipe located south of a 260 m long groyne constructed to protect the recreational beach area. The sewage treatment plant provides secondary treatment. Several urban storm sewers discharge in the vicinity of the current water intake facility and into the Maitland River.

## 3.6 Raw Water Quality

### *3.6.1 General*

As part of the intake study, historical raw water quality data obtained from sources listed in Section 2.5 was reviewed for parameters that would indicate the presence of point source pollution (e.g. metals, hydrocarbons). The concentrations of several common inorganics (chlorides, sodium, nitrates, phosphorus), as well as pesticides and herbicides, were also reviewed.

Raw water data for alkalinity, turbidity, temperature, and E. Coli were also examined. Parameter concentrations were compared in order to identify potential relationships (e.g. to determine if an increase in alkalinity is accompanied by increases in turbidity, etc.). Such relationships would assist in identifying the source(s) of contaminants.

As mentioned in Section 2.5, alkalinity and turbidity in the raw water is monitored at the Water Treatment Plant. Both alkalinity and turbidity are monitored on a daily basis; therefore, data for these parameters provide a sufficient basis for investigating trends in the intake raw water quality. The Treatment Plant data were reviewed, and alkalinity events, defined as an increase in alkalinity of at least 30% during a one-day period, were identified. High turbidity, defined as the turbidity value that was exceeded 10% of the time, was calculated. High turbidity events were then identified. Alkalinity and turbidity events were used as indicators for overall raw quality. Where alkalinity or turbidity events occurred, flow data for the Maitland River, wind data and rainfall data, were also reviewed. The purpose of this review was to determine if a relationship between river flow, wind direction and raw water quality, or between rainfall quantity and raw water quality, could be identified.

### *3.6.2 General Comments on Raw Water Quality*

Data from the Ontario Drinking Water Surveillance Program were reviewed for trends in concentrations of various metals, hydrocarbons, and herbicides and pesticides. During the period of 1992 to 2006, concentrations of each parameter remained low (metals on the order of μg/L, and pesticides on the order of ηg/L). No identifiable trends were recognized.

Concentrations of four common inorganic parameters were also analyzed for trends. Table 3.1 summarizes the average concentration of each parameter during the 1990 to 2006 period. The relatively low sampling frequency of 1 to 8 samples per year did not allow any definite trends in water quality to be identified.

**Table 3.1**
**Common Inorganic Concentrations in Raw Water**

| Parameter | Average Concentration During 1990 – 2006 (mg/L) | Maximum Concentration (mg/L) | Minimum Concentration (mg/L) | No. of Values in Average Concentration Calculation |
|---|---|---|---|---|
| Chloride | 8.74 | 18.4 | 6.2 | 42 |
| Total Nitrate as N | 0.41 | 3.05 | 0.3 | 43 |
| Total Phosphorus as P | 0.03 | 0.15 | 0.002 | 43 |
| Sodium | 5.03 | 10.69 | 3.8 | 43 |

Raw water quality records were also obtained from the Water Treatment Plant. These records provided daily raw water data for alkalinity, turbidity, and temperature, during the 2003 to 2006 period. E. Coli data was provided on a weekly basis. The following relationships were investigated for trends:

- E.coli vs. alkalinity
- E.coli vs. turbidity
- Turbidity vs. alkalinity

Table 3.2 provides a summary of all raw water data from the Water Treatment Plant that was used in the analysis.

**Table 3.2**
**Summary of Water Treatment Plant Raw Water Data**

| Parameter | Average Value During 2003 - 2006 | Maximum Value | Minimum Value | No. of Values in Average Value Calculation |
|---|---|---|---|---|
| Alkalinity | 107.8 mg/L | 194 mg/L | 78 mg/L | 1093 |
| Turbidity | 13.8 NTU | 168 NTU | 0.45 NTU | 1367 |
| Temperature | 9.9 °C | 25 °C | 0.5 °C | 1362 |
| E. Coli | 18 cfu/100 mL | 700 cfu/100 mL | 0 cfu/100 mL | 189 |

Figures 3.1 and 3.2 provide samples of graphs used in the analysis. Figure 3.1 displays alkalinity and turbidity in raw water during 2005. Figure 3.2 provides a graph of turbidity vs. alkalinity throughout the 2003 to 2006 period.

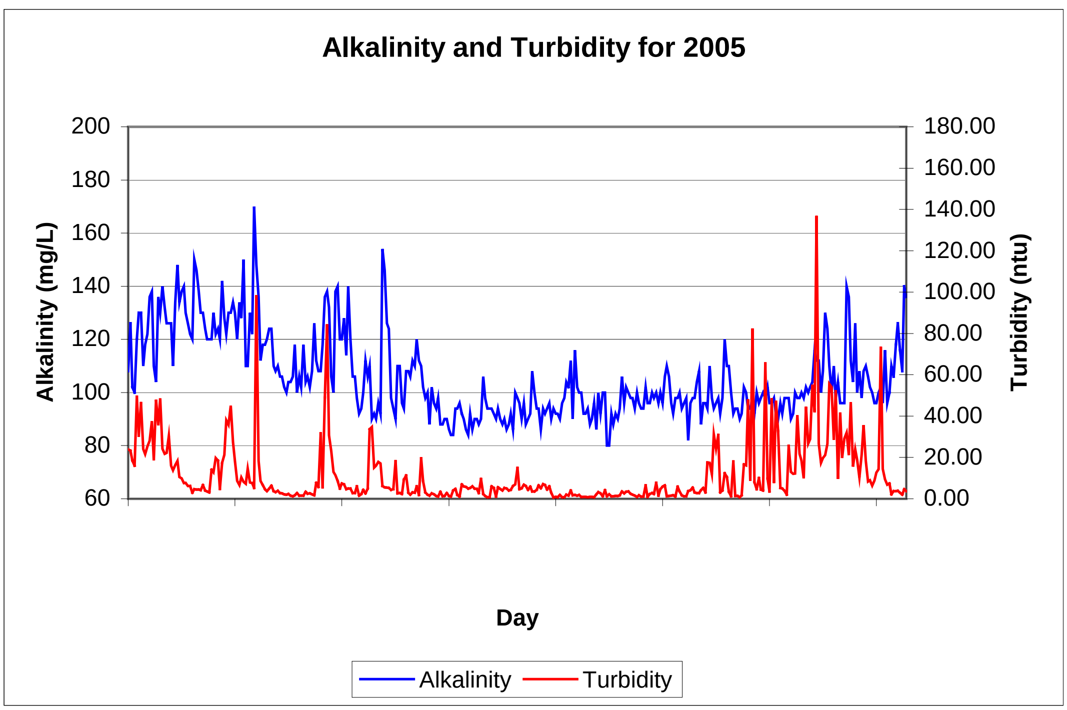


**Figure 3.1 Alkalinity and Turbidity for 2005**

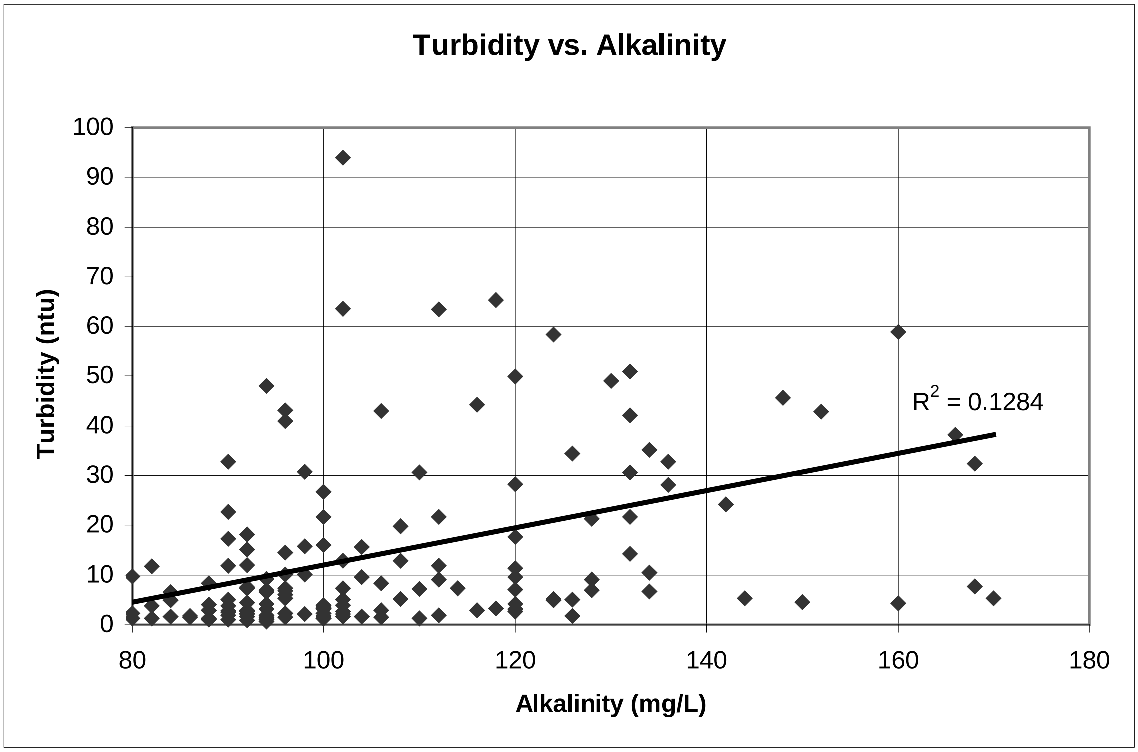


**Figure 3.2 Turbidity vs. Alkalinity**

Linear regressions were obtained for the E.Coli vs. alkalinity, E.Coli vs. turbidity, and turbidity vs. alkalinity graphs, and corresponding $R^2$ values of 0.0122, 0.0082, and 0.1284, respectively, were found. These low $R^2$ values indicate that there is no linear relationship between these parameters.

In conclusion, no relationship in parameter values could be determined from the linear regression analyses of raw water alkalinity and turbidity, alkalinity and E. Coli, or turbidity and E. Coli. It was noted that alkalinity and turbidity levels were more consistent during the summer months (June to September).

### *3.6.3 Analysis of Influence from Maitland River*

#### a) Based on Raw Water Alkalinity

An analysis was conducted to determine if a relationship between flow from the Maitland River and raw water quality at the intake, expressed as alkalinity, was identifiable. River alkalinity was compared to intake raw water alkalinity for the years 2003 to 2005. River discharge was compared to intake raw water alkalinity for the years 2003 to 2006. The following relationships were analyzed for trends:

- River alkalinity in 1984 vs. river alkalinity in 1990
- Raw water alkalinity vs. river alkalinity
- Raw water alkalinity vs. river flow
- Daily % change in raw water alkalinity vs. daily % change in river flow
- Daily % change in raw water alkalinity vs. river flow

Comparing river alkalinity in 1984 to river alkalinity in 1990, values throughout both years were very similar. Seasonal changes were also similar, with the lowest alkalinity occurring during August and September at approximately 153 mg/L, and the greatest alkalinity concentrations occurring in January and December at approximately 264 mg/L. This comparison suggests that trends in river alkalinity have not changed over the years.

For the years of 2003 to 2005, intake raw water alkalinity was compared to river alkalinity. Only the raw water data for days on which river alkalinity was measured were used. River alkalinity was, on average, 216 mg/L. River alkalinity was consistently greater than intake raw water alkalinity, which was, on average, 100 mg/L. There were insufficient river alkalinity data to determine a definite relationship between river alkalinity and intake raw water alkalinity, although some trends were observed.

Figure 3.3 provides a sample graph used in the analysis. This figure shows raw water alkalinity and river discharge during 2005.

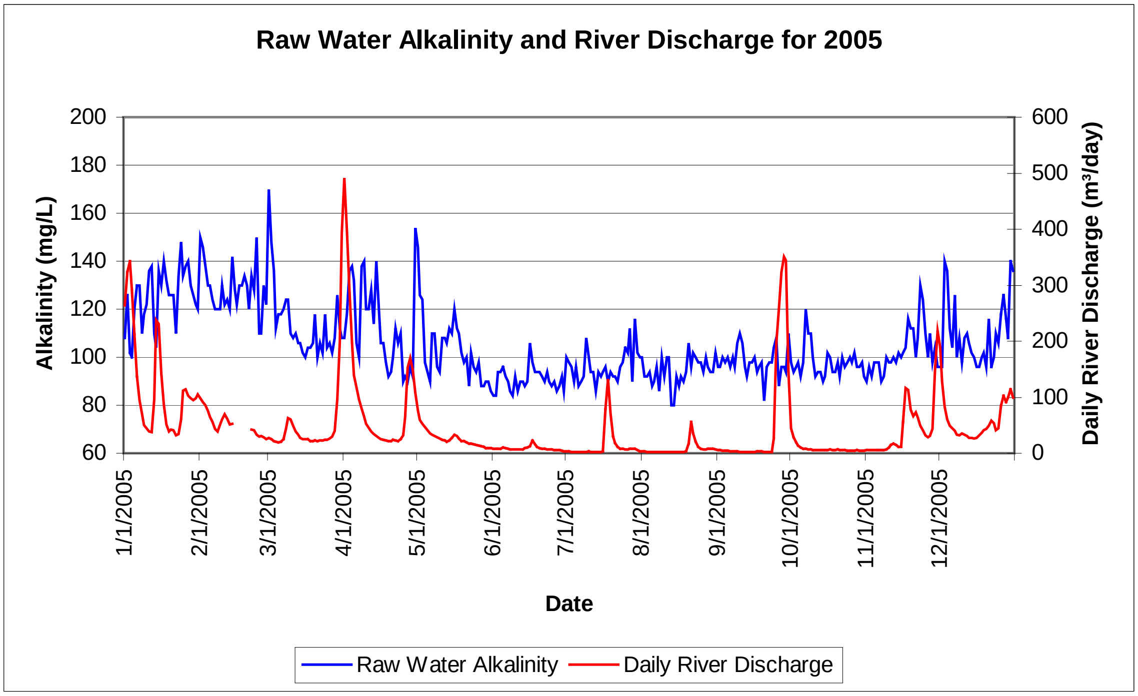


**Figure 3.3 Raw Water Alkalinity and River Discharge for 2005**

Graphical representations of intake raw water alkalinity vs. river flow, and daily percent change in intake raw water alkalinity vs. daily percent change in river flow, were produced. These graphs did not show a consistent relationship between river flow and alkalinity in raw water at the intake.

Events where alkalinity in raw water at the Treatment Plant increased by more than 30% in a single day were identified. River flows during the days leading up to such events were examined to look for a relationship between river flows and raw water alkalinity. Table 3.3 provides examples of two specific events used in this comparison.

**Table 3.3**
**Example of Alkalinity Events and River Discharge**

| Day | WTP Alkalinity (mg/L) | Daily River Discharge ($m^3$/sec) | % Change | | Comments |
|---|---|---|---|---|---|
| | | | WTP Alkalinity | Daily River Discharge | |
| 25-Nov-03 | 116 | 59.94 | -6.45 | -0.33 | River flows doubled over the week. Alkalinities at intake are high. Implied delayed effect of 2 to 3 days. |
| 26-Nov-03 | 104 | 55.98 | -10.34 | -6.61 | |
| 27-Nov-03 | 108 | 49.84 | 3.85 | -10.97 | |
| 28-Nov-03 | 106 | 50.26 | -1.85 | 0.84 | |
| 29-Nov-03 | 128 | 89.51 | 20.75 | 78.09 | |
| 30-Nov-03 | 124 | 114.74 | -3.13 | 28.19 | |
| 1-Dec-03 | 118 | 109.82 | -4.84 | -4.29 | |
| 2-Dec-03 | 158 | 100.04 | 33.90 | -8.91 | |
| 5-Dec-03 | 178 | 51.03 | 23.61 | -19.36 | Intake alkalinities are consistently high. High river flows on Dec 12/13 had no apparent effect. |
| 6-Dec-03 | 180 | 45.63 | 1.12 | -10.58 | |
| 7-Dec-03 | 156 | 42.61 | -13.33 | -6.62 | |
| 8-Dec-03 | 148 | 37.1 | -5.13 | -12.93 | |
| 9-Dec-03 | 140 | 31.82 | -5.41 | -14.23 | |
| 10-Dec-03 | 160 | 31.2 | 14.29 | -1.95 | |
| 11-Dec-03 | 110 | 72.77 | -31.25 | 133.24 | |
| 12-Dec-03 | 154 | 120.68 | 40.00 | 65.84 | |
| 13-Dec-03 | 150 | 105.85 | -2.60 | -12.29 | |
| 14-Dec-03 | 148 | 70.87 | -1.33 | -33.05 | |
| 15-Dec-03 | 166 | 54.13 | 12.16 | -23.62 | |
| 16-Dec-03 | 134 | 46.8 | -19.28 | -13.54 | |
| 17-Dec-03 | 118 | 60.05 | -11.94 | 28.31 | |
| 18-Dec-03 | 174 | 71.27 | 47.46 | 18.68 | |

(yellow box) - Denotes a raw water alkalinity increase of at least 30% in a one day period

The analysis of raw water alkalinity events, defined as an increase of at least 30% in a one-day period, with respect to river flow indicated a weak connection between increasing river flow and increasing WTP alkalinity. The lag between river flow increases and raw water alkalinity events ranged between 1-6 days, with a typical value of 2 to 3 days. Raw water alkalinity events only occurred during the winter, late fall, and early spring.

For days in which a raw water alkalinity event was observed, percent change in raw water alkalinity was plotted against river flow (Figure 3.4). A linear regression and associated $R^2$ value of 0.002 was obtained for this graph. The low $R^2$ value does not indicate a linear relationship between raw water alkalinity and river flow. A second-order polynomial regression was also obtained which gave an $R^2$ value of about 0.19, however this is still too low to conclude any relationship between raw water alkalinity and river flow.

The reason for the lack of correlation may be linked to the need to consider wind speed and direction in the analysis. Alkalinity and river flow were also analyzed with wind data. Wind speed and direction influence the currents and they are therefore a consideration. The data indicate some instances where alkalinity did increase following a high flow event, particularly when winds were from the north. There is a lag in the range of several days between high flow events and increases in alkalinity at the intake. This is well beyond the 2-

hour response time identified by the WTP Operator for delineation for the IPZ-2. A more detailed analysis would be required to better understand the processes.

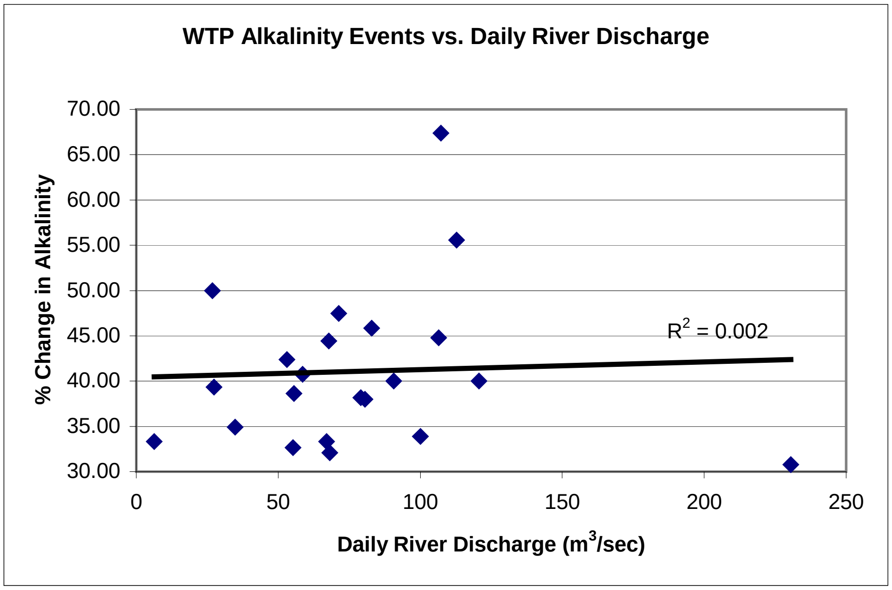


**Figure 3.4 WTP Alkalinity Events vs. Daily River Discharge**

## b) Based on Raw Water Turbidity

An analysis was also conducted to determine if a relationship between flow from the Maitland River and raw water quality at the intake, expressed as turbidity, was identifiable. It is our experience that high turbidity at intakes can be explained by a combination of one or more of the following factors:

1. Local re-suspension/lakebed erosion of sediment by wave generated orbital velocities and to a lesser extent currents;
2. High turbidity sediment transported to the intake from regional resuspension/lake bed erosion through large scale circulation patterns (this is a longer term impact that 1); and/or
3. River plumes.

Frequency graphs showing river flow and intake turbidity for the period 2003 to 2006 are provided in Figures 3.5 and 3.6 respectively. High flow was defined as the river flow rate that was exceeded 10% of the time. High turbidity was defined as the turbidity value that was exceeded 10% of the time. From the frequency analysis, a river flow rate of 106.6 $m^3$/s was exceeded 10% of the time. An intake turbidity of 40 NTU was exceeded 10% of the time. Specific days with high river flow and/or high intake turbidity were identified for further analysis.

- High flow occurred on 132 days.
- High turbidity occurred on 128 days.
- On 25 days (approx. 19% of the time), both high flow and high turbidity occurred on the same day.

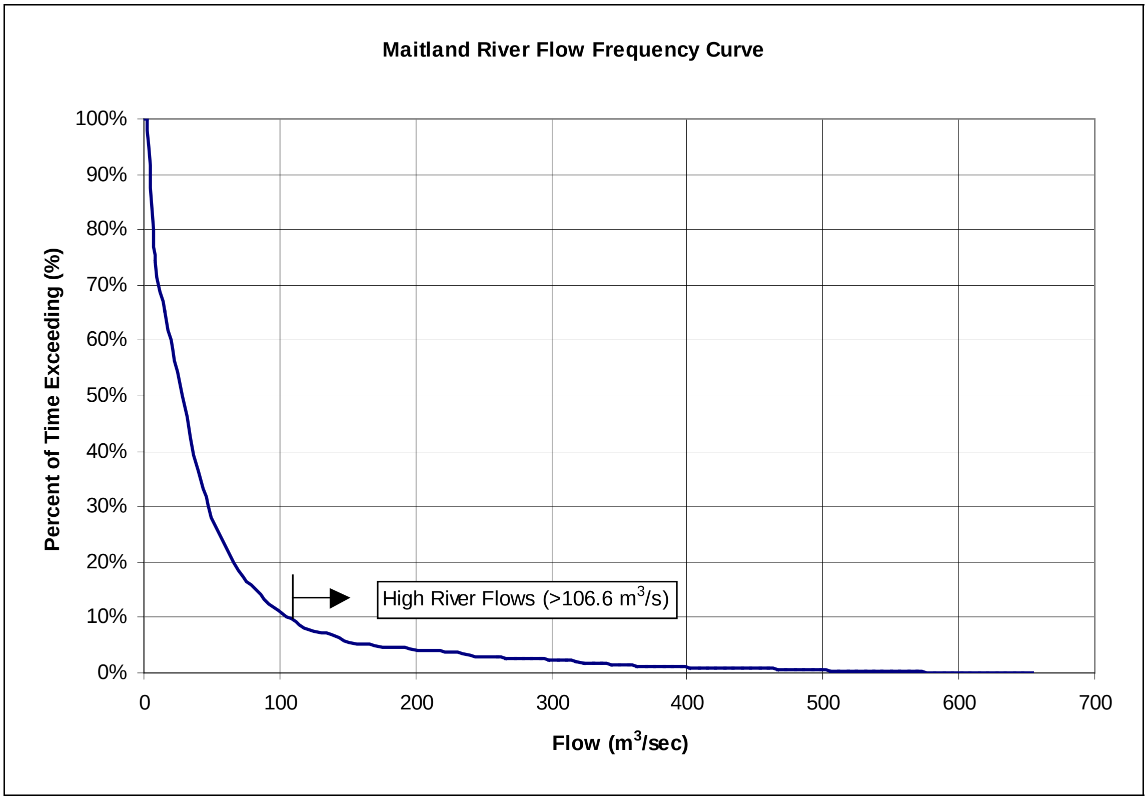


**Figure 3.5 Maitland River Flow Frequency Curve (2003 to 2006)**

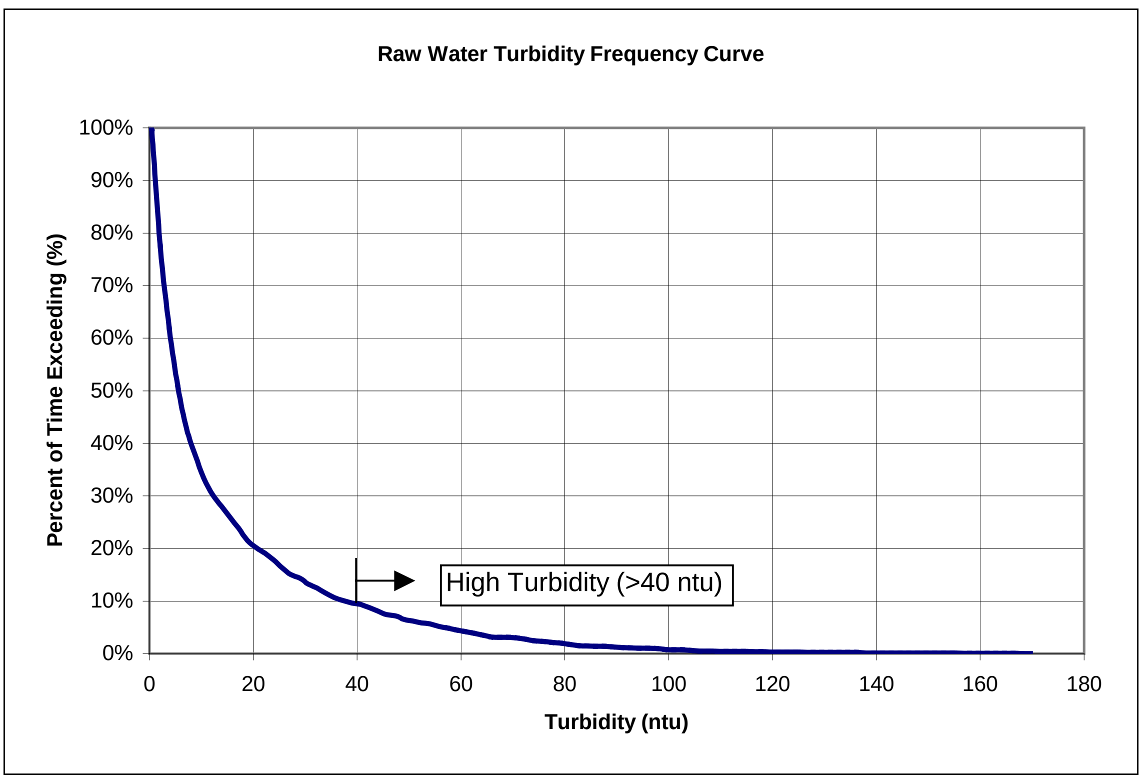


**Figure 3.6 Raw Water Turbidity Frequency Curve (2003 to 2006)**

For days with high intake turbidity, the turbidity value was initially plotted against river flow for the same day (Figure 3.7). Similarly, high flows were plotted against intake turbidity (Figure 3.8). Each graph also displays a linear regression and the associated $R^2$ values. From the graphs, the following is observed:

- High Turbidity vs. River flow
  - Of the 16 days with highest turbidity, only 1 day also had high river flow
  - $R^2$ value of 0.0105
- High River Flow vs. Turbidity
  - Of the 29 days with highest river flow, not one day also had high intake turbidity
  - $R^2$ value of 0.0456

This highlights the fact that high turbidity is due to several factors (i.e. high winds, waves), that high flow alone may not result in high turbidity at the intake (currents are necessary to transport the plume to the intake), and that the lag between a high flow event and high turbidity at the intake must be considered. The linear regression lines and low $R^2$ values for the high flow vs. turbidity and high turbidity vs. flow graphs also demonstrate this.

Table 3.4 provides a summary of the total number of high turbidity and high flow events that occurred during each month. More than 60% of high turbidity events occurred during the November to December period, and more than 60% of high flow events occur during the January to March period.

**Table 3.4**
**Summary of High Turbidity and High Flow Events (2003 to 2006)**

| Month | High Turbidity Events | | High Flow Events | |
|---|---|---|---|---|
| | Number of Events | % of Total | Number of Events | % of Total |
| Jan | 19 | 14.8 | 24 | 18.2 |
| Feb | 7 | 5.5 | 20 | 15.1 |
| Mar | 3 | 2.3 | 36 | 27.3 |
| Apr | 10 | 7.8 | 15 | 11.4 |
| May | 1 | 0.8 | 6 | 4.5 |
| Jun | 0 | 0 | 0 | 0 |
| Jul | 0 | 0 | 1 | 0.8 |
| Aug | 0 | 0 | 0 | 0 |
| Sep | 1 | 0.8 | 6 | 4.5 |
| Oct | 8 | 6.3 | 0 | 0 |
| Nov | 32 | 25.0 | 12 | 9.1 |
| Dec | 47 | 36.7 | 12 | 9.1 |
| **Total** | **128** | **100** | **132** | **100** |

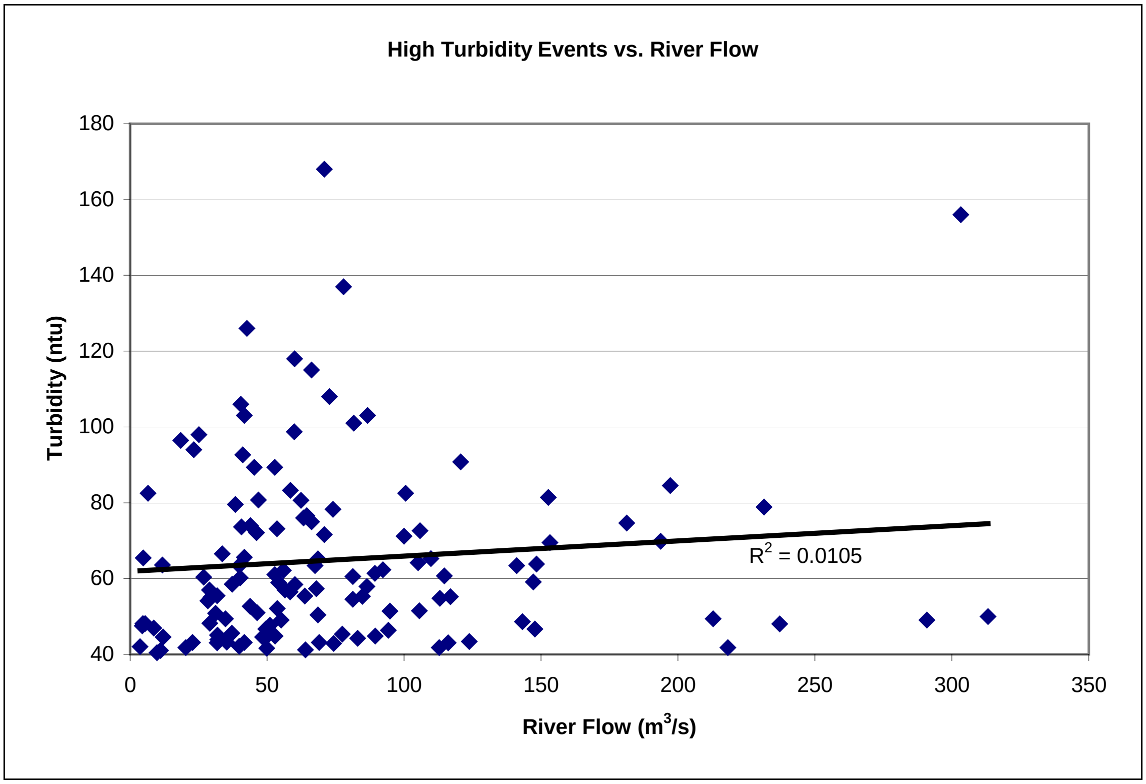


**Figure 3.7 High Turbidity Events vs. River Flow (2003 to 2006)**

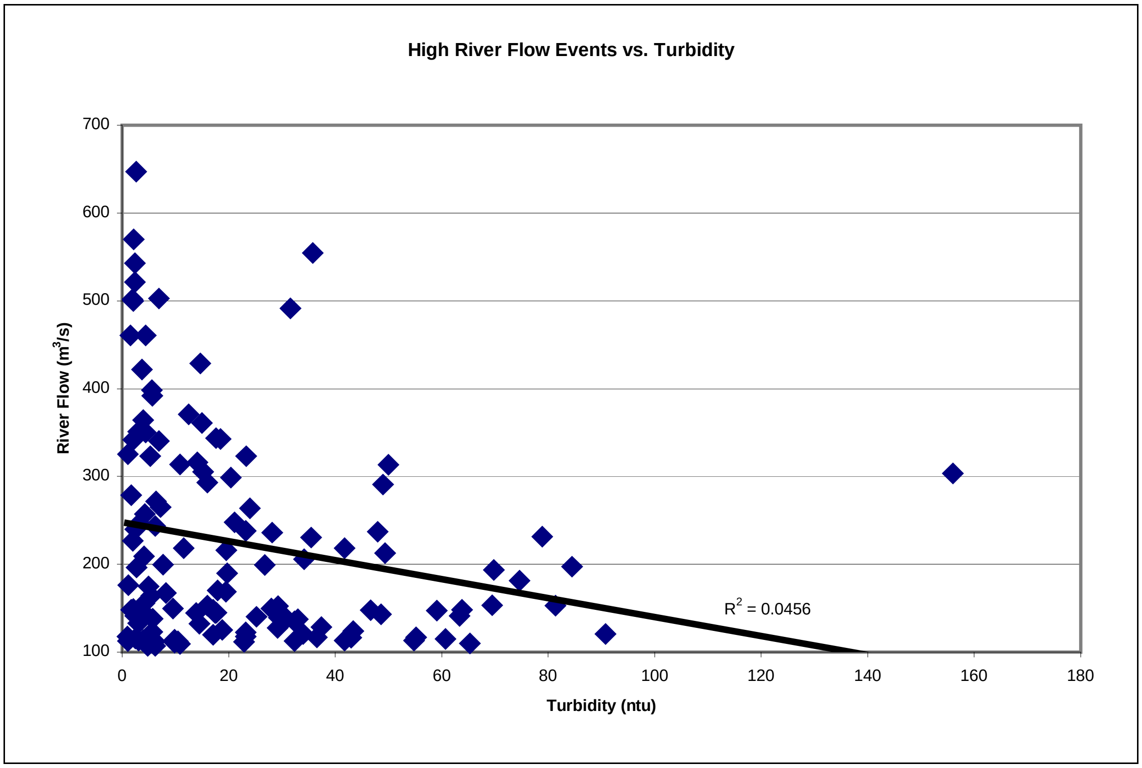


**Figure 3.8 High River Flow Events vs. Turbidity (2003 to 2006)**

Further analysis was undertaken to investigate the role of wind and current velocity, and turbidity at the intake. In particular, the WTP Operator identified the following conditions, corresponding to high turbidity readings at the intake (see Appendix D):

1. When there is high river flow accompanied by low winds, turbidity levels only increase slightly. Readings in the 30 to 40 NTU range would be typical for high flow events with calm winds.
2. Turbidity values increase when the winds are offshore, from the south or southeast, and further increase (above 100 NTU) when there is significant flow from the river.
3. High winds alone do not typically lead to the highest turbidity levels, however during high onshore winds (e.g. from the northwest) turbidity values can reach 50 to 60 NTU caused by gritty, sandy material.

The 2003 turbidity, wind speed, wind direction, and discharge data for the Maitland River were plotted and analysed. The data sets used in the analysis are described in Section 2.

The initial analysis of turbidity and flow presented previously, supports Operator Observation 1. When there is a high flow event that is not accompanied by significant winds, turbidity values do not generally exceed 40 NTU (the 10th percentile exceedance value). An example of a high flow/low wind event is shown in Figure 3.9. Although the flow exceeded 300 $m^3/s$, turbidity did not rise above 20 NTU.

The analysis shows that turbidity increases above 100 NTU when high flow events coincide with high wind events. Figure 3.10 shows that this occurs when winds are onshore (from directions south, clockwise through north). When there is high flow and winds are offshore, there is no significant increase in turbidity as shown in Figure 3.11. This contradicts Operator Observation 2. It is possible that an increase in turbidity at the intake during an offshore wind combined with high flow, could be due to flow from the outfalls. Further analysis would be required to determine if this is the case.

Operator Observation 3 suggests that during high onshore winds, turbidity increase is likely due to wave induced suspended sediment. The material is gritty sand, likely from the lakebed. Figure 3.12 provides an example of this response.

During the autumn of 2003 and the winter of 2004, the Operator reported that complicated turbidity conditions existed on a daily basis, making treatment difficult. This can be seen in Figure 3.13. Turbidity levels frequently exceeded 40 NTU as a result of high flow and high wind speed events.

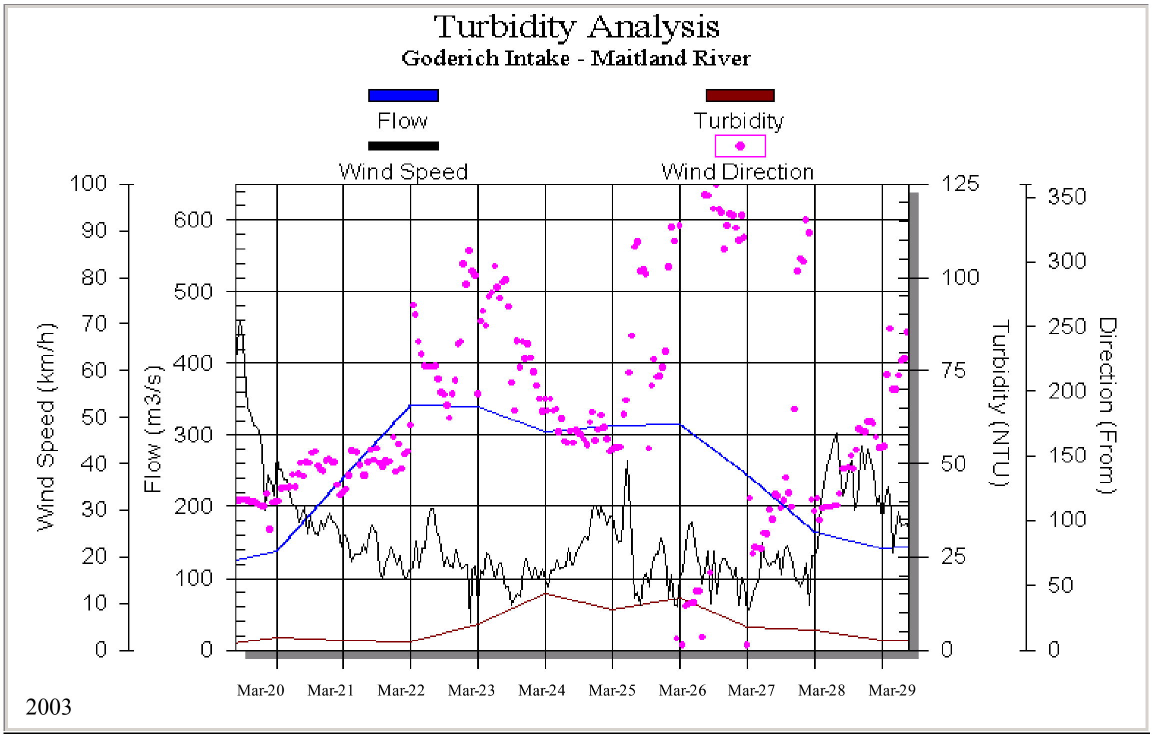


**Figure 3.9 Example of High Flow and Low Wind Showing Low Turbidity Levels**

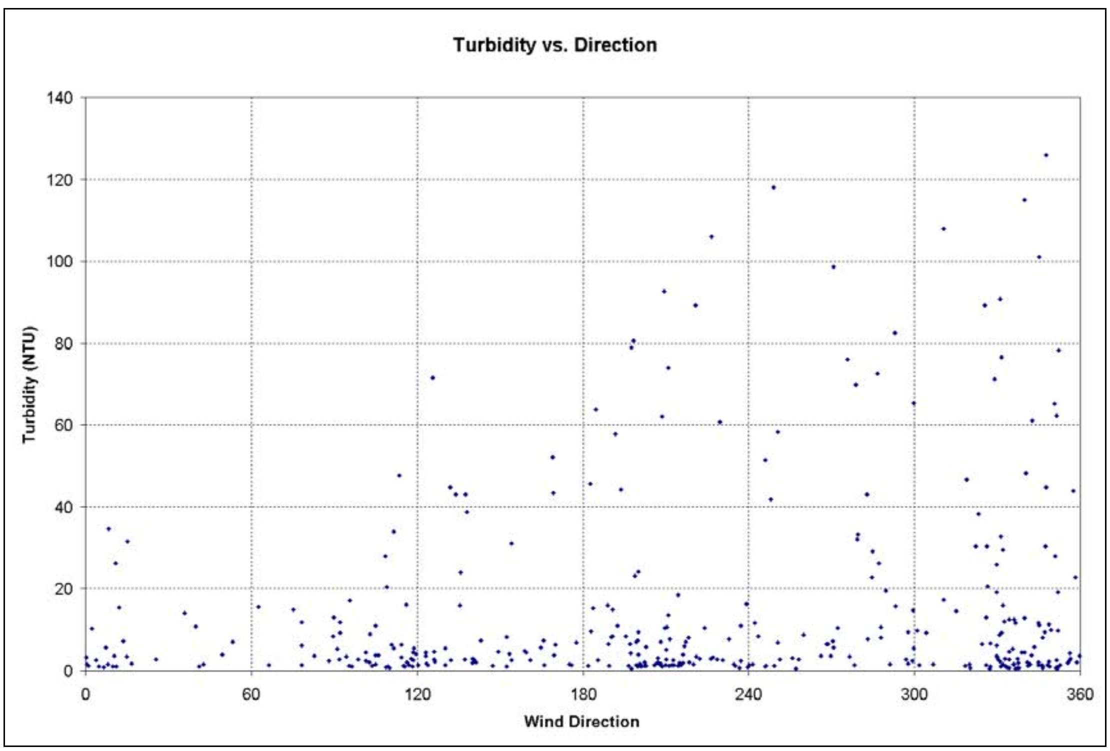


**Figure 3.10 Turbidity vs. Wind Direction showing High Turbidity with Onshore Winds**

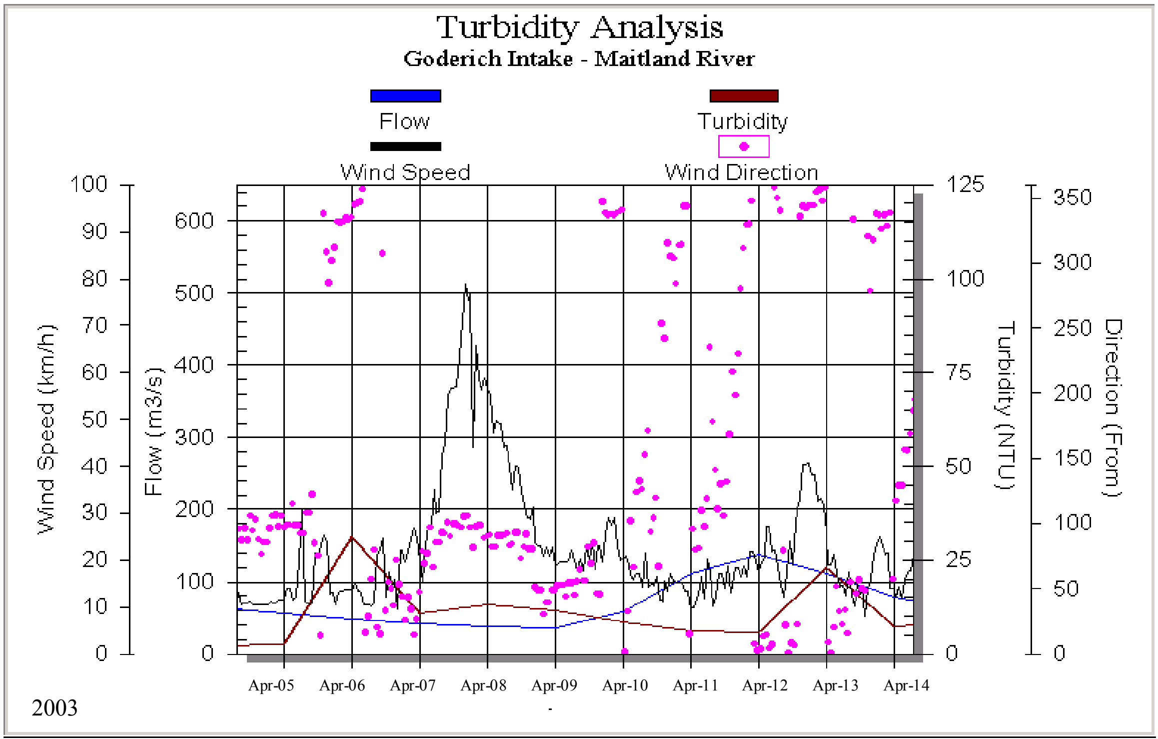


**Figure 3.11 Example of Low Turbidity Associated with High Offshore Wind Speed and High Flow**

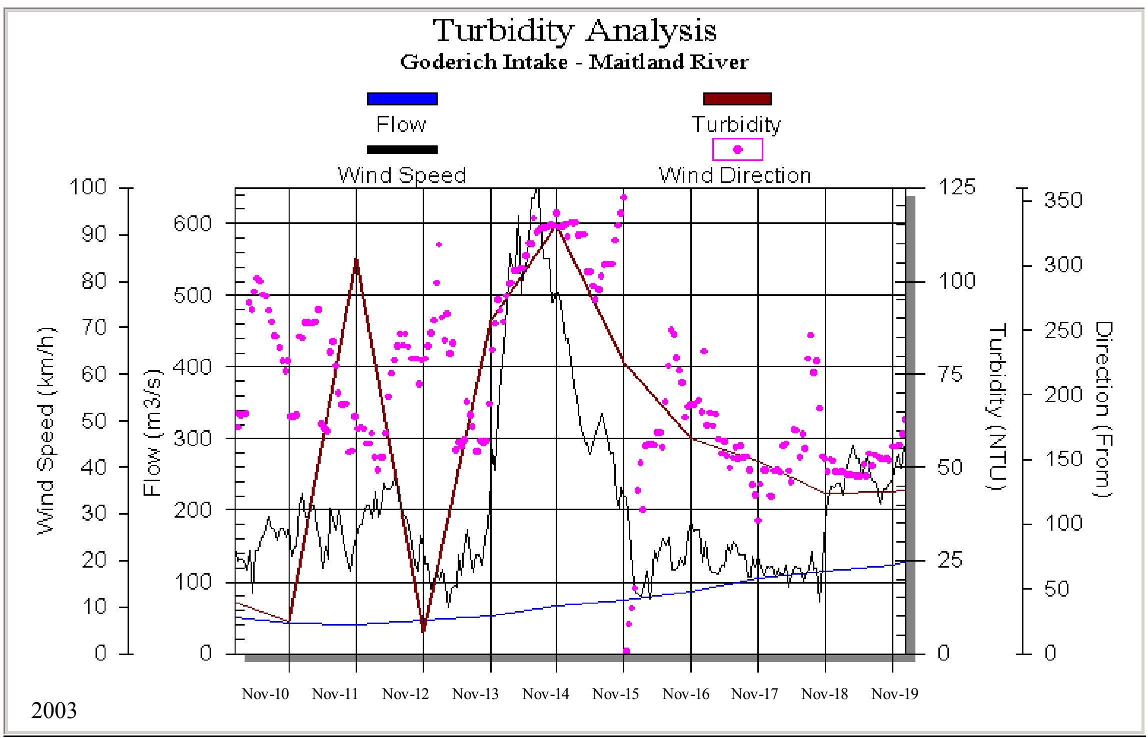


**Figure 3.12 Example of High Turbidity Event Associated with High Onshore Wind and Moderate Flow**

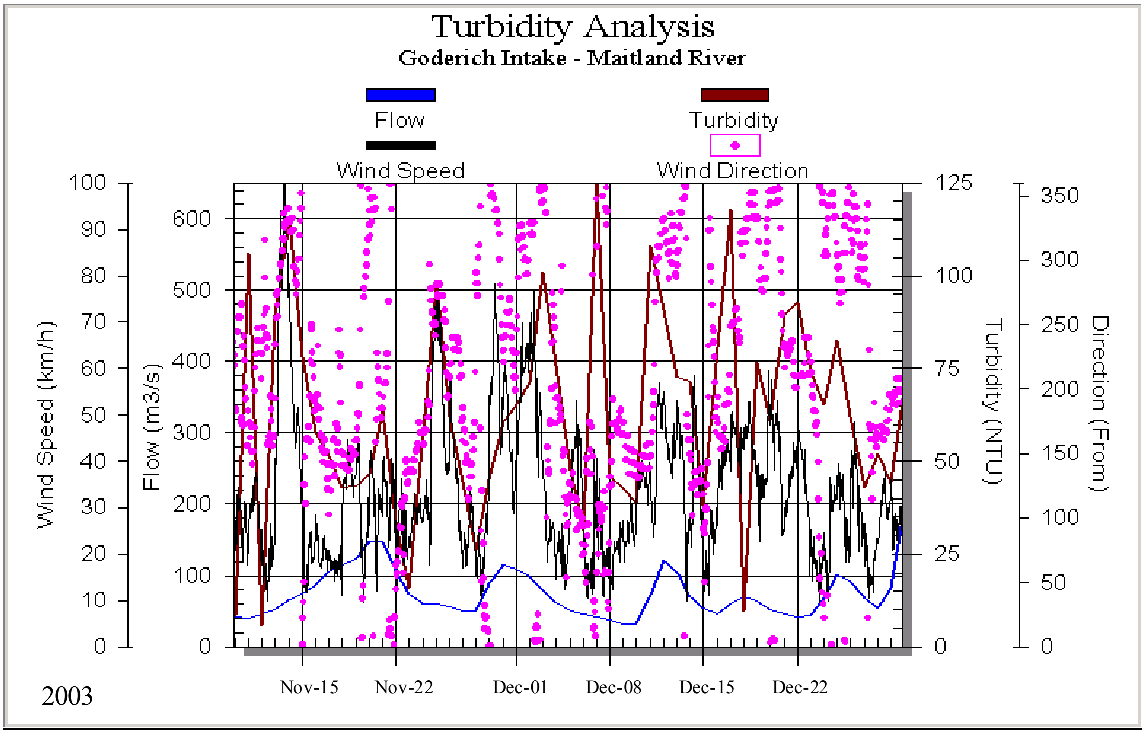


**Figure 3.13 Frequent High Turbidity in November-December 2003**

### 3.6.4 Analysis of Influence from Storm Sewers

**a) Based on Raw Water Alkalinity**

Storm sewer discharges only occur during and immediately following rainfall events. The purpose of this analysis was to determine if there is a relationship between daily rainfall and alkalinity at the Goderich Water Treatment Plant. A significant change in alkalinity, corresponding with a rainfall event, might indicate that the Goderich storm drainage outlets influence raw water quality at the WTP inlet.

Goderich Water Pollution Control Plant (WPCP) rainfall data was available for 2003 to 2006. Rainfall data for Benmiller, close in proximity to Goderich, was available for 2003 to November 2006. Figure 3.14 provides a sample graph used in this analysis.

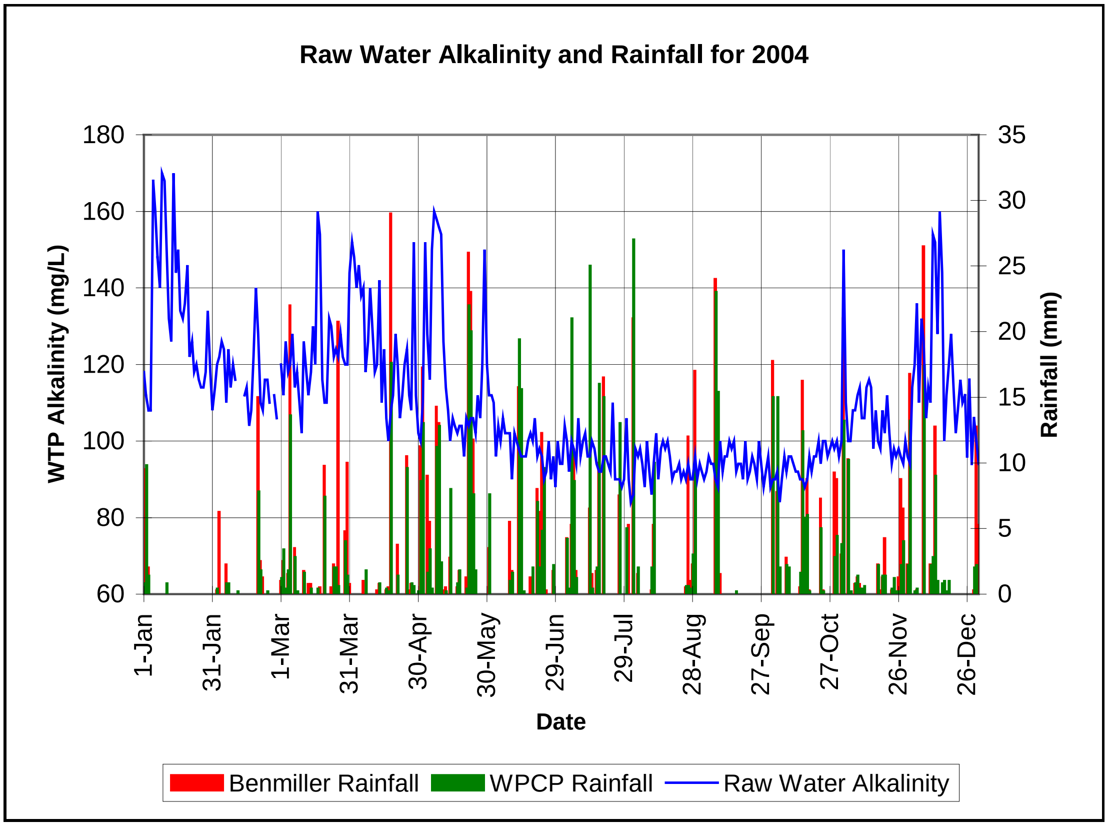


**Figure 3.14 Rainfall and Raw Water Alkalinity for 2004**

As discussed in Section 3.6.3, events where alkalinity in the raw water at the Treatment Plant increased by more than 30% in a single day were identified. Rainfall during the days leading up to these events was compared to the alkalinity events. Table 3.5 provides examples of two specific events used in the comparison.

**Table 3.5**
**Example of Alkalinity Events and Rainfall**

| Day | Alkalinity (mg/L) | Rainfall (mm) | % Change in Alkalinity | Comments |
|---|---|---|---|---|
| 6-Feb-03 | 90 | | -6.25 | No rainfall to relate alkalinity event to. |
| 7-Feb-03 | 90 | | 0.00 | |
| 8-Feb-03 | 90 | | 0.00 | |
| 9-Feb-03 | 120 | | 33.33 | |
| 19-Nov-03 | | 6.25 | | Alkalinity increase may be linked to rainfall 3 days earlier. |
| 20-Nov-03 | 166 | | | |
| 21-Nov-03 | 134 | | -19.28 | |
| 22-Nov-03 | 194 | | 44.78 | |

- Denotes a raw water alkalinity increase of at least 30% in a one day period

An analysis of the days leading up to each alkalinity event indicated that there is a very weak relationship between rainfall and increased WTP alkalinity. Approximately half of the alkalinity events followed a rainfall event.

An examination of changes in alkalinity, following a significant rainfall (> 20 mm), indicated that there is not a noticeable relationship. Almost 75% of the rainfall events were followed by no change or a slight decrease in alkalinity.

For days in which rainfall exceeded 20 mm, percent change in raw water alkalinity was plotted against rainfall for Benmiller and the WPCP (Figures 3.15 and 3.16, respectively). Linear regressions were obtained for these graphs. $R^2$ values of 0.1582 and 0.2142 for the regressions using Benmiller and WPCP rainfall data, respectively, were also obtained. These values do not indicate a linear relationship between raw water alkalinity and rainfall.

In conclusion, the typical lag of 2 or more days between a rainfall event and an increase in alkalinity requires further investigation. A rainfall event would also tend to increase river flows and a 2 to 5 day delay between increased river flow and an alkalinity event was previously identified. Therefore, the weak relationship with rainfall identified may also be linked to river discharges.

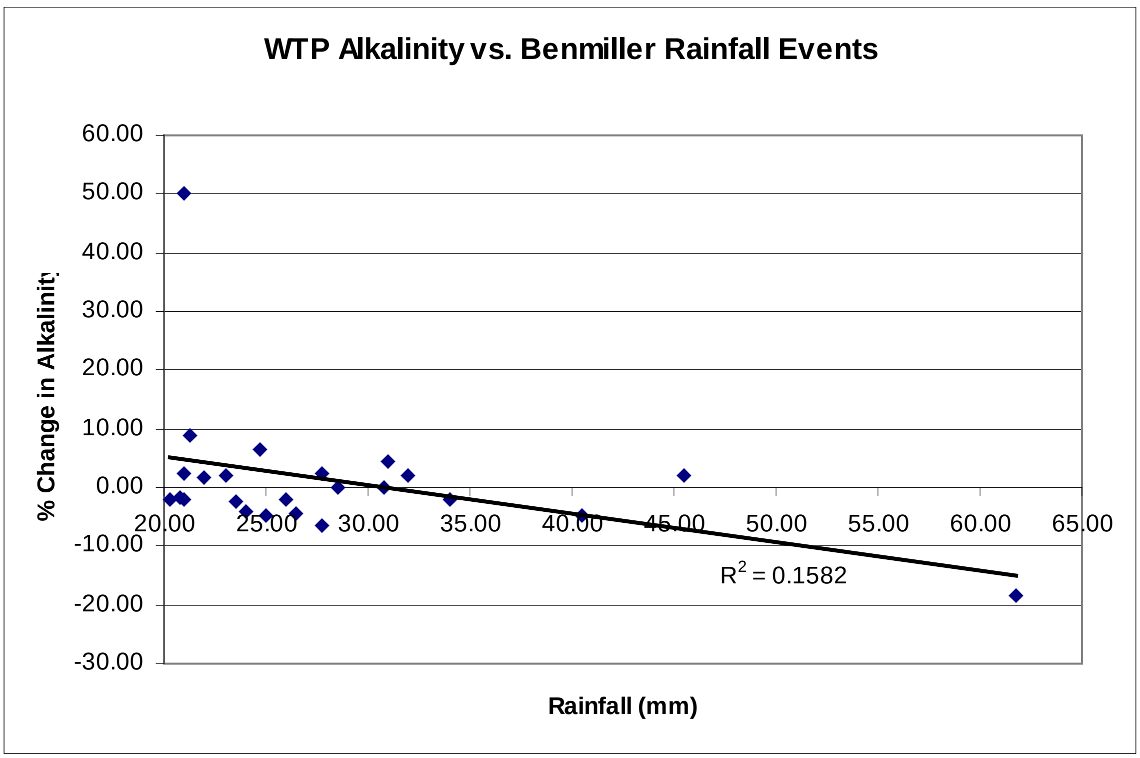


**Figure 3.15 WTP Alkalinity vs. Benmiller Rainfall Events**

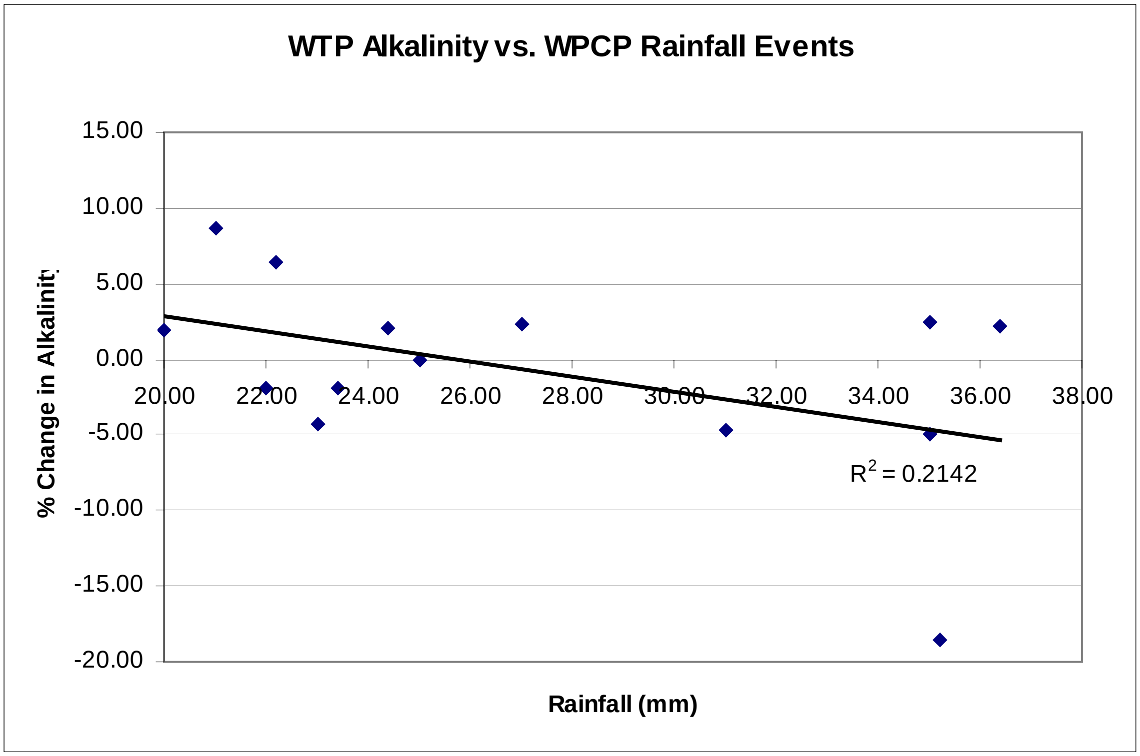


**Figure 3.16 WTP Alkalinity vs. WPCP Rainfall Events**

### b) Based on Raw Water Turbidity

In order to examine the potential effects of storm sewer discharges on water quality at the Goderich Water Treatment Plant intake, rainfall data obtained from the Goderich WPCP was compared to turbidity in raw water. A large change in turbidity was defined as the increase in turbidity levels between consecutive days that was exceeded 10% of the time. Figure 3.17 displays the frequency curve for daily turbidity level increases. A significant rainfall day was defined as a day with total rainfall greater than 20 mm. A large increase in the turbidity level in raw water, following a significant rainfall event, may indicate that water quality at the intake is influenced by storm sewer discharges.

From a frequency analysis of daily turbidity changes, an increase of 25.7 NTU was determined to be exceeded 10% of the time. A total of 26 significant rainfall days were identified at the Goderich Water Pollution Control Plant. Turbidity levels in raw water were reviewed for the two day period following significant rainfall events. It was found that only 10% of significant rainfall events are followed by large turbidity increases. The result of this analysis did not indicate a strong relationship between storm sewer discharge and water quality at the intake, however current speed and direction were not considered.

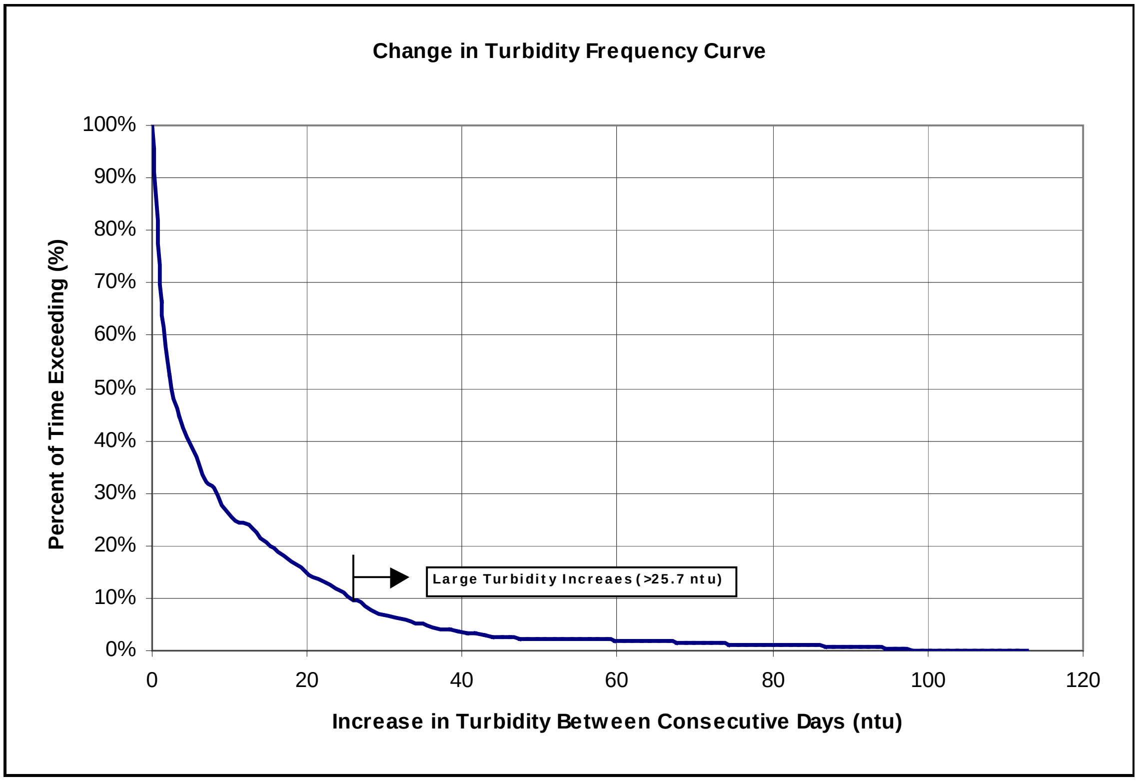


**Figure 3.17 Change in Turbidity Frequency Curve**

### *3.6.5 Conclusions*

The results of the raw water quality analysis revealed the following:

1. Concentrations of metals and pesticides in raw water at the Treatment Plant are too low, and sampling too infrequent, to identify any trend in water quality. For the years 1990 to 2005, average annual chloride, nitrate, phosphorus, and sodium concentrations in the raw water at the intake have not displayed any sustained increase or decrease, though sampling frequency is too low to statistically identify any trends.
2. From 2003 to 2006, alkalinity and turbidity levels in the raw water at the Treatment Plant remained more consistent from May to September than in other months. There was no apparent relationship between time of year and E. Coli in the raw water. Additionally, no definite relationship between alkalinity and turbidity, alkalinity and E. Coli, or turbidity and E. Coli was observed.
3. For the years 2003 to 2005, average alkalinity in the Maitland River was 216 mg/L, approximately 115 mg/L greater than the average alkalinity in raw water at the Treatment Plant. No definite relationship between the river alkalinity and raw water quality could be established with the limited river data available.
4. Based on alkalinity and flow data for the years 2003 to 2006, a weak connection between increasing river flow and increasing WTP alkalinity was identified. The lag between river flow increases and raw water alkalinity events ranged between 1-6 days, with a typical value of 2 to 3 days. Raw water alkalinity events only occurred during the winter, late fall, and early spring. When wind data was considered, incidents of alkalinity increase following high flow events were identified, particularly when winds were from the north. The lag time between high flow events and increases in alkalinity at the intake is well beyond the 2-hour response time identified by the WTP Operator for delineation for the IPZ-2. A more detailed analysis would be required to better understand the processes.

5. Analysis of turbidity, wind and flow data for the years 2003 to 2006, showed that only 19% of high turbidity and high flow events occurred on the same day, and the majority of high turbidity events occurred during the months prior to the majority of high flow events. High flow events that were not accompanied by significant winds did not result in increased turbidity at the intake. The analysis showed that turbidity increased above 100 NTU when high flow events coincide with high wind events. This occured when winds are onshore (from directions south, clockwise through north). Onshore winds alone also caused an increase in turbidity, likely due to wave action and higher suspended sediment loads. When high flow combined with offshore winds, there was no significant increase in turbidity. The latter contradicts the observation of the operator. It is possible that an increase in turbidity at the intake during an offshore wind combined with high flow, could be due to flow from the outfalls. Further analysis would be required to determine if this is the case.
6. Based on data for the years 2003 to 2006, there was not sufficient information to suggest a definite relationship between storm sewer discharge and raw water quality at the intake. The data indicated that alkalinity can increase following a high flow event, particularly when winds were from the north, however a more detailed analysis would be required to better understand the processes. No linear relationship between rainfall events greater than 20 mm and raw water alkalinity could be determined. Only 10% of all turbidity events followed a significant rainfall event. Approximately one half of all alkalinity increases of more than 30% in one day followed rainfall events. Furthermore, the typical lag between rainfall events and alkalinity increases was two days. As rainfall events would also cause an increase in river discharge, it was not possible to differentiate between increases in alkalinity caused by river flow and those caused by storm sewer discharge.

# 4.0 MODELING IN SUPPORT OF INTAKE PROTECTION ZONE DELINEATION

## 4.1 Application of Numerical Models for IPZ Delineation

Numerical modeling was undertaken in support of IPZ delineation for the Goderich intake. Delineation of the IPZ-2 is based on two factors: the time required to shut down the water treatment facility in the event of a spill; and the distance that the contaminant could be transported during that time. An understanding of the current velocities within the IPZ is required to define the distances and directions that the contaminant may be transported.

Hydrodynamic processes on the Great Lakes are in most cases three-dimensional with currents at the lakebed (where the intake is located) often flowing in the opposite direction from currents at the surface. The currents also vary temporally and are highly dependent on wind conditions. Field data, where it exists, defines the current patterns for the duration of the data set only, at the specific instrument location. It is useful in providing current information for a specific time and location, but it does not define the current patterns throughout the IPZ for the full range of conditions. Therefore, numerical modeling calibrated against field measurements is the only scientifically defensible and practical approach to define the IPZ2s. It allows us to evaluate and understand the flow patterns around the intake under a range of conditions.

This section describes model selection, model approach and setup, and the results of the numerical modeling undertaken in support of the preliminary delineation of the IPZs. As outlined in Section 4.5, additional follow-up work is recommended including calibration of the models.

## 4.2 Model Selection

All models have strengths and weaknesses and it is important to select a model that meets the needs of the project considering the technical requirements of the model, user support and possible licensing fees. There is always a trade-off between selecting a well-supported commercial model (with a license fee) versus some public domain models that may be less user-friendly, less widely used and ultimately, not well supported. The technical requirements of this project and the advantages and disadvantages of the alternative models are discussed in this section.

### *4.2.1 Required Modeling Capabilities*

*Technical Requirements*

Based on a review of the ADCP data collected by MOE (discussed in Section 2) it is clear that a three-dimensional hydrodynamic model is required to adequately simulate the processes at Goderich. The current patterns are 3-dimensional with current speed and direction varying significantly from the surface to the lakebed. Upwelling and downwelling events that result in current revearsals at the lakebed were observed. The interaction of these currents with the river flow from the Maitland River requires a three-dimensional model to evaluate the processes.

Since the shoreline in the study area is complex and breakwaters are present between the mouth of Maitland River and the intake, a model with a flexible grid (finite element or curvilinear) is recommended (a finite difference grid (or rectangle grid) may cause large numerical errors near the intake or require a very fine mesh size to adequately represent the shoreline irregularities).

The capabilities to simulate wind driven currents and turbulence are essential for the selected model. Wind is the major forcing function in the lake and the model must be able to handle temporally and spatially varying input wind data. Turbulence modeling capabilities must be included in order to simulate the detailed turbulent mixing where the river flow enters the lake.

When selecting a model, it is important to also consider the model's capabilities with respect to processes that are not necessarily considered in this phase of the modeling, but might be recommended for consideration in a future phase. Some examples include wave induced currents, sediment processes (contaminants or metals may adhere to sediment and be transported to the intake over a period of time), temperature, thermocline (temperature stratification), and water quality.

### *User Support*

In general, commercial models are well supported and user friendly. In contrast, public domain models often do not have user friendly interface and technical support. These models are often developed by universities and/or government agencies and maintenance of the model may or may not be ongoing.

### *Previous Model Applications in the Region*

The Princeton Ocean Model (POM) developed by Blumberg and Mellor (1987) at Princeton University, is a public domain model. The three-dimensional model with Sigma-grid in the vertical axis has been applied by numerous scientists and agencies worldwide and is currently applied by NOAA for the Great Lakes Operational Forecast System (GLOFS) to forecast water levels, currents and temperatures on the Great Lakes on an hourly basis. The model of Lake Huron, Lake Huron Operational Forecast System (LHOFS) is run with a 5 km grid in the horizontal axis. Although the model has been validated and the output is useful for defining the larger current patterns in the lake, the present grid setup is too coarse for defining the IPZ, does not extend into the nearshore and excludes the Maitland River. In addition, the POM model does not include advection/dispersion or water quality, and there is limited technical support. The model output does however provide excellent data describing the large-scale meteorological and hydrodynamic processes in the lake and this data will be used to define the boundary conditions for a more detailed model of the IPZs.

A license for the Delft 3D model was purchased by the Ontario Ministry of the Environment (MOE) in 2002. DELFT 3D is a three-dimensional hydrodynamic model that has been validated and applied on projects throught the world. The modeling suite has modules to inlcude waves, sediment transport, morphology, water quality, particle tracking and ecology. MOE has applied the 2D version of the model on Lake Huron and Georgian Bay. They have recently begun to apply the 3D model at some sites. MOE has also deployed a number of Acoustic Dopler Current Profilers (ADCPs) in the study area for calibrating the Delft 3D model. Baird met with Dr. Todd Howell (MOE) and his modeling group on August 30, 2006 to discuss possible cooperation and data sharing for the Goderich project. Dr. Howell agreed to share the MOE data with the project team. Future cooperation with MOE on this MOE funded project was a consideration in model selection for this project. The Delft 3D model has also been used by Baird to define the in-lake IPZs for ten intakes on Lake Huron and Georgian Bay, For Saugeen Valley Conservation Authoirty.

### *Licensing Fees*

In general, there is a licensing fee and often a maintenance fee for commercial models. Examples of commercial models include the Danish Hydraulics Institute's MIKE suite of models, and Delft Hydraulics' Delft3D. There is no fee for public domain models, however there is often little or no user support, ongoing updates and testing, and the models may not be user-friendly. In addition, the models may not have undergone rigorous testing or validation.

The licensing fee structure varies with the model developer and there are generally different licensing options, to suit the user's requirements. For example, a general use license may be obtained for unlimited use of the model over set a period of time. This type of license would be suitable for a consulting firm that intends to use the model on multiple projects, for various clients. Project specific licensing can be obtained for a reduced rate and the model may only be used on a specific project, for one client. A third licensing option including discounts is often available to government agencies. The government license may be tied to a specific project or water body.

### 4.2.2 Model Evaluation

Five models were considered and evaluated for application on this project. The results are summarized in Table 4.1. On the basis of the comparison, the Delft3D model was recommended for this application. Delft3D is a three dimensional hydrodynamic model with wave, sediment and water quality modules. It uses curvilinear grids, which are suitable for the complicated shoreline boundary conditions. The numerical performance (or computational efficiency) is better than the DHI MIKE3 FD/FM model. MOE is currently applying the Delft3D model in Lake Huron (using the 2D feature) and consideration was also given to the mutual benefits of sharing data and modeling results with the funding agency. In addition, the model is being used by Baird at other sites on Lake Huron and Georgian Bay for Saugeen Valley Conservation Authority. Output from the LHOFS model was used to define the boundary conditions for the Delft3D model.

Purchase of a license by the client was not a requirement of this project. Should the client wish to do so, a license could be purchased in the future. Baird's trial license for Delft3D was therefore used on the project.

**Table 4.1**
**Numerical Model Comparison**

| Model | Distributor | Public Domain or Proprietary | Technical Capabilities | | | | | Model Support | User Friendly | Previous Applications at Project Site | Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Dimensions | Formulation/ Grid | Wave Capability | Sediment Capability | Water Quality Capability | | | | |
| **Delft 3D** | Delft Hydraulics | Proprietary | 2D/3D | Curvilinear Grids | Yes | Yes | Yes | Excellent | Excellent | MOE | $10,500 |
| **MIKE3** | Danish Hydraulic Institute | Proprietary | 3D | FD / FM | Yes | Yes | Yes | Good | Excellent | No | $30,000 |
| **POM** | Princeton Ocean Model | Public Domain | 3D | FD | No | No | No | Fair | None | GLOFS | No charge |
| **MISED** | Baird In-House Model | Proprietary | 3D | Finite Element | No | Yes | No | Good | Fair | No | Negotiable |
| **GEMSS** | ERM Foundation | Proprietary | 2D/3D | Curvilinear Grids | No | No | Yes | Fair | Fair | Nottawasaga | Unavailable |

## 4.3 Modeling Approach and Setup

As described in Section 4.2.2, output from the Lake Huron Operational Forecast System (LHOFS) was used to define the boundary conditions for the nearshore Delft3D model. To optimize model efficiency and run time, the nested grid approach was used with a coarser grid in the offshore and a finer grid in the nearshore. A Delft3D model covering the east part of Lake Huron was developed. A finer grid was developed to model detailed current patterns around the intake and in the lower sections of the river.

### *4.3.1 LHOFS Model*

The LHOFS provides real-time lake wide hydrodynamic nowcasting/forecasting of currents, water temperature, and wind driven surge on an hourly basis for Lake Huron. The model cannot be used directly to delineate the IPZ for this project because the grid setup is too coarse for defining the IPZ, does not extend into the nearshore and therefore does not include inflow from the Maitland River. Sample output from LHOFS, for a specific moment in time is shown in Figure 4.1.

Nevertheless, LHOFS does provide some useful information including spatially varying meteorological data and lakewide circulation. The spatially varying meteorological data developed for LHOFS were interpolated on the basis of wind data from numerous meteorological stations around the lake and buoy data. This wind data and the lakewide circulation data can be used to define the boundary conditions for the nearshore models.

It is important to use a lakewide model to control the open boundary conditions of nearshore models in lakes. The alternative approach, if a lakewide model is not available and it is not possible to model the entire lake due to the duration of the model runs, is to use lake level data to define the open boundary conditions. Figure 4.2 shows the very different flow patterns produced by the two different approaches to defining the open boundary conditions. The flow vectors in red are the model results when LHOFS currents are used to define the open boundary conditions for the ELHM. The vectors in yellow are the model results when the lakewide averaged lake levels in Lake Huron are used to define the open boundary conditions.

A comparison of the modeled current speed near the Goderich intake, for the two different boundary conditions is shown in Figure 4.3. It indicates that the current speeds modeled using LHOFS to define the boundary conditions are significantly smaller than the currents modeled when the lakewide averaged lake levels are used to define the boundary conditions.

This is due to the characteristics of the wind driven currents in the lake and surge effects, which are not accounted for when lakewide averaged water levels are used to define the boundary conditions in the model. The surge induces reverse flow along the lakebed. For a model that only includes a portion of the lake (such as the ELHM), it is important to include surge effects at the open boundary and this can only be done by using a lake wide model, as was done for this project.

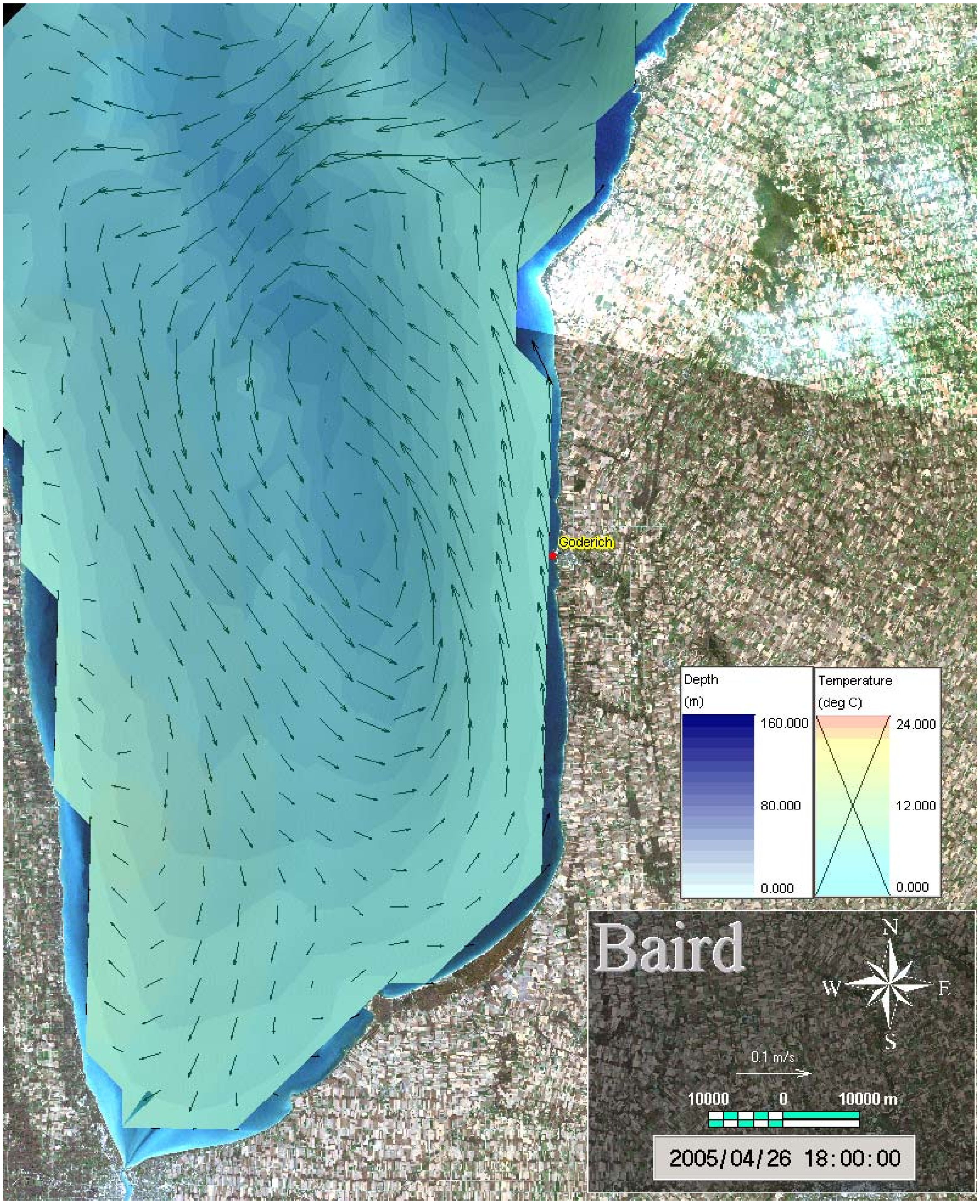


**Figure 4.1 Example of Model Output from LHOFS Showing Surface Currents and Temperatures on Lake Huron**

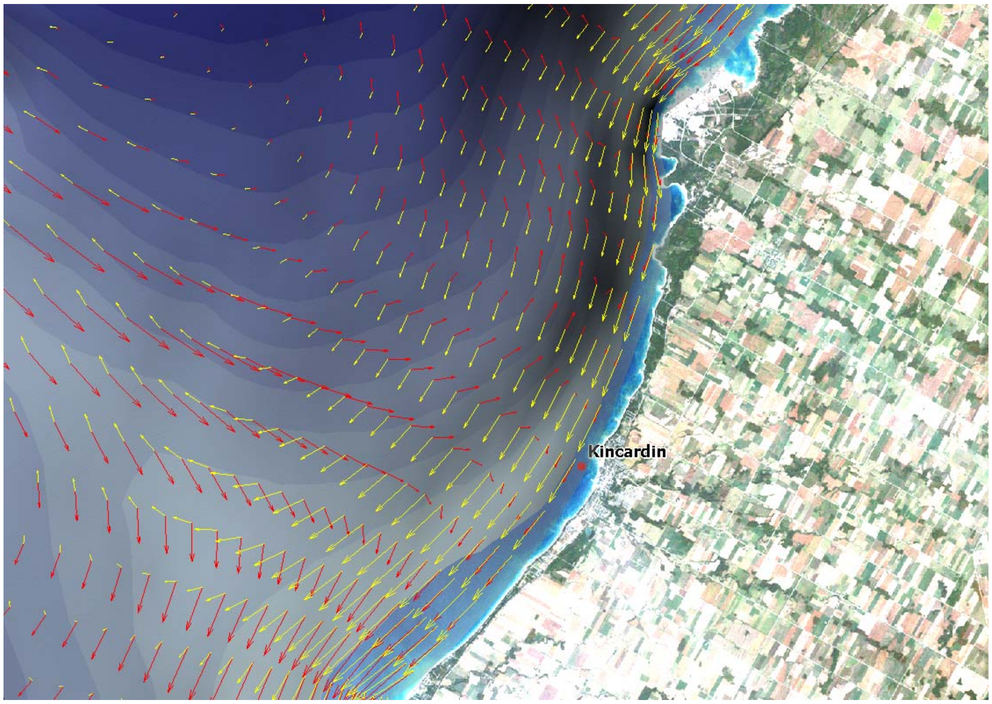


**Figure 4.2 Comparison of Flow Patterns for Two Different Methods of Defining Open Boundary Conditions**

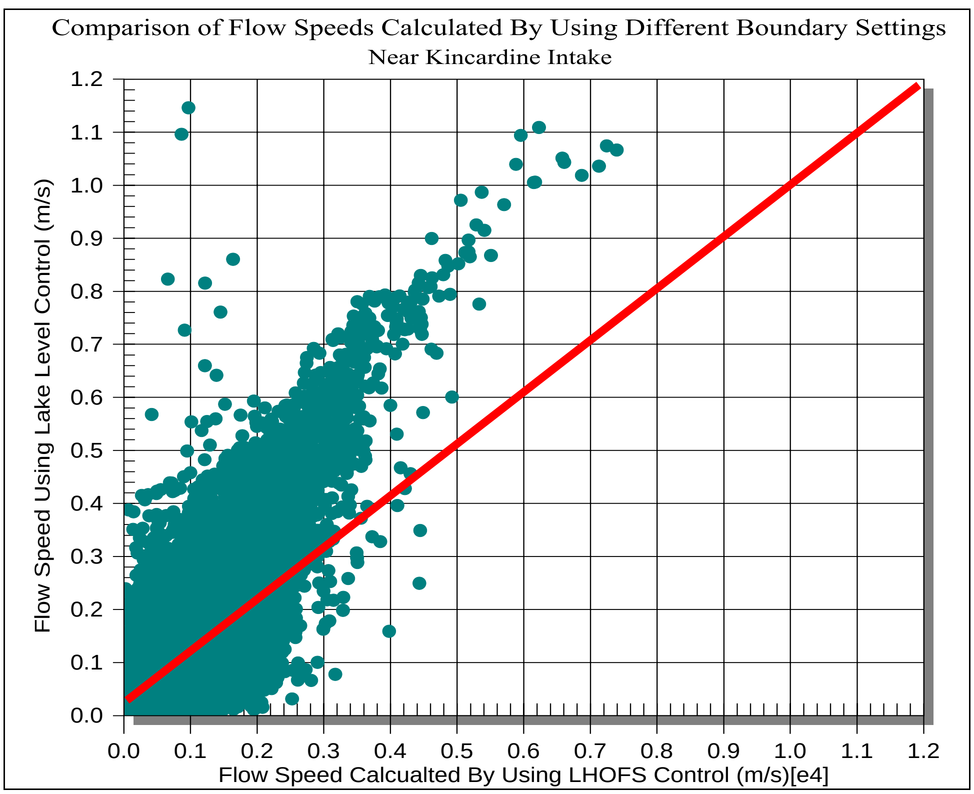


**Figure 4.3 Comparison of Current Speeds for Two Different Methods of Defining Open Boundary Conditions**

### 4.3.2 East Lake Huron Model

Delft 3D was used to develop the East Lake Huron Model (ELHM). The model domain is shown in Figure 4.4. The open boundary conditions for the model were defined with the currents and water levels extracted from LHOFS. The spatially varying hourly wind from LHOFS were also interpolated and used to define the winds at the grid points in the two models.

The grid size of the ELHM varies from 500 m to 2 km with the finer mesh size utilized closer to the shoreline. Bathymetry data as described in Section 2.1 was used to develop the grids. The bathymetry was interpolated for the model grids by using field sheets (see Figure 4.5). There are total of 52X33 = 1716 nodes in the horizontal space and 10 layers in vertical column.

Using the Baird in-house software, Spatial Data Analyzer (SDA) hourly wind data was extracted from the LHOFS to define wind conditions at the grid nodes in the ELHM for the period from 2003 to 2005. Figure 4.6 shows the wind vectors for a sample time step.

The model was run for 2003 to simulate the currents for an entire year. Figures 4.7 to 4.10 demonstrate the seasonal differences in the current patterns. The figures also show the splatter plots of the flow vectors in the 30 days centered on the time of the snapshot. During the winter months the currents typically follow the shoreline and flow in a northerly direction in response to strong alongshore winds (see Figures 4.7 and 4.8). The currents are also stronger than in other seasons, frequently exceeding 0.75 m/s at the surface. In the spring (Figure 4.9), southerly currents dominate and the maximum southerly currents are about 0.75m/s while the maximum northerly currents are about 0.3 m/s. Figure 4.10 shows typical summer currents. There is a roughly equal distribution between north flowing and south flowing currents and the current speeds are notably less than in other seasons (<0.3 m/s).

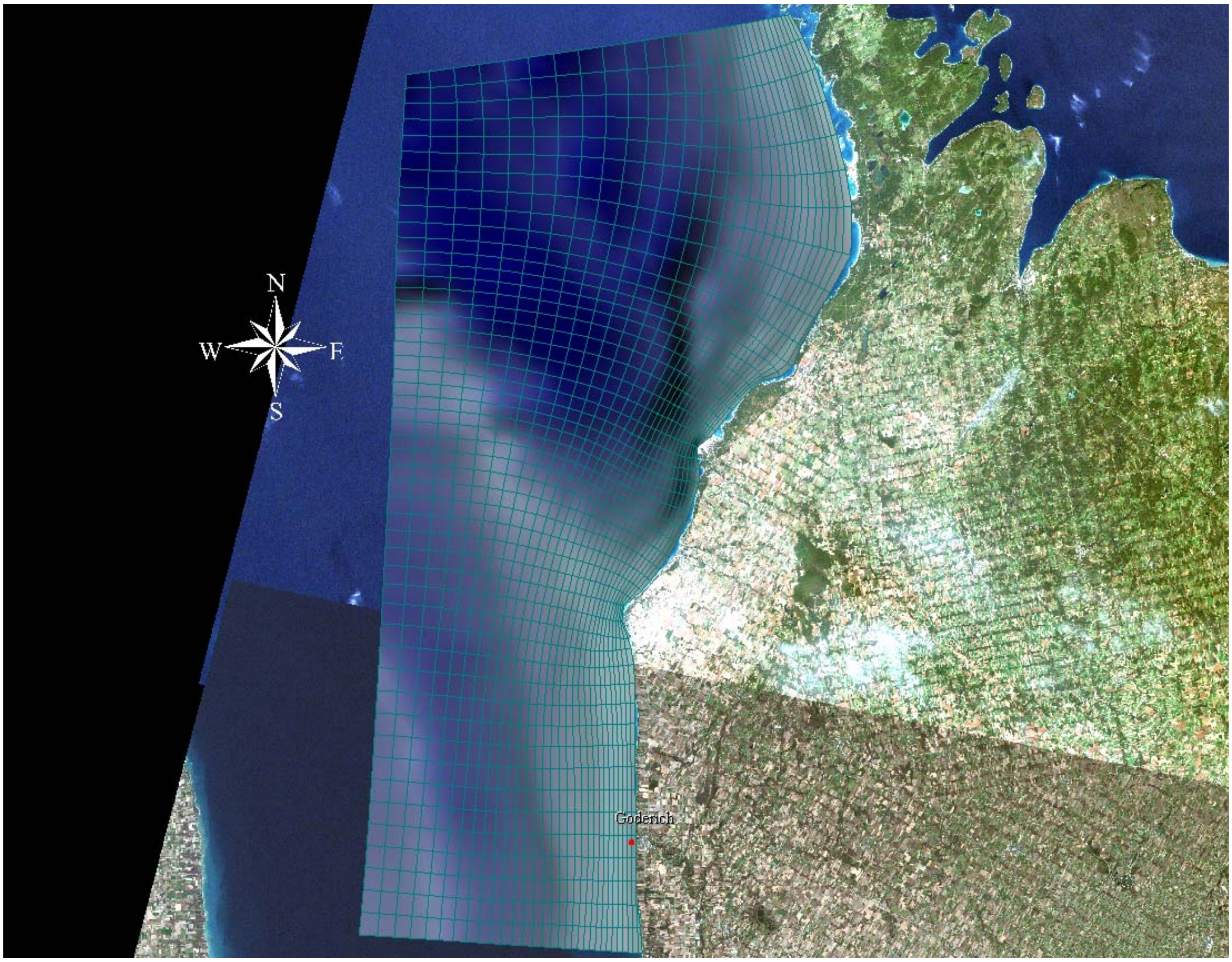


**Figure 4.4 Model Domains for East Lake Huron Model (ELHM)**

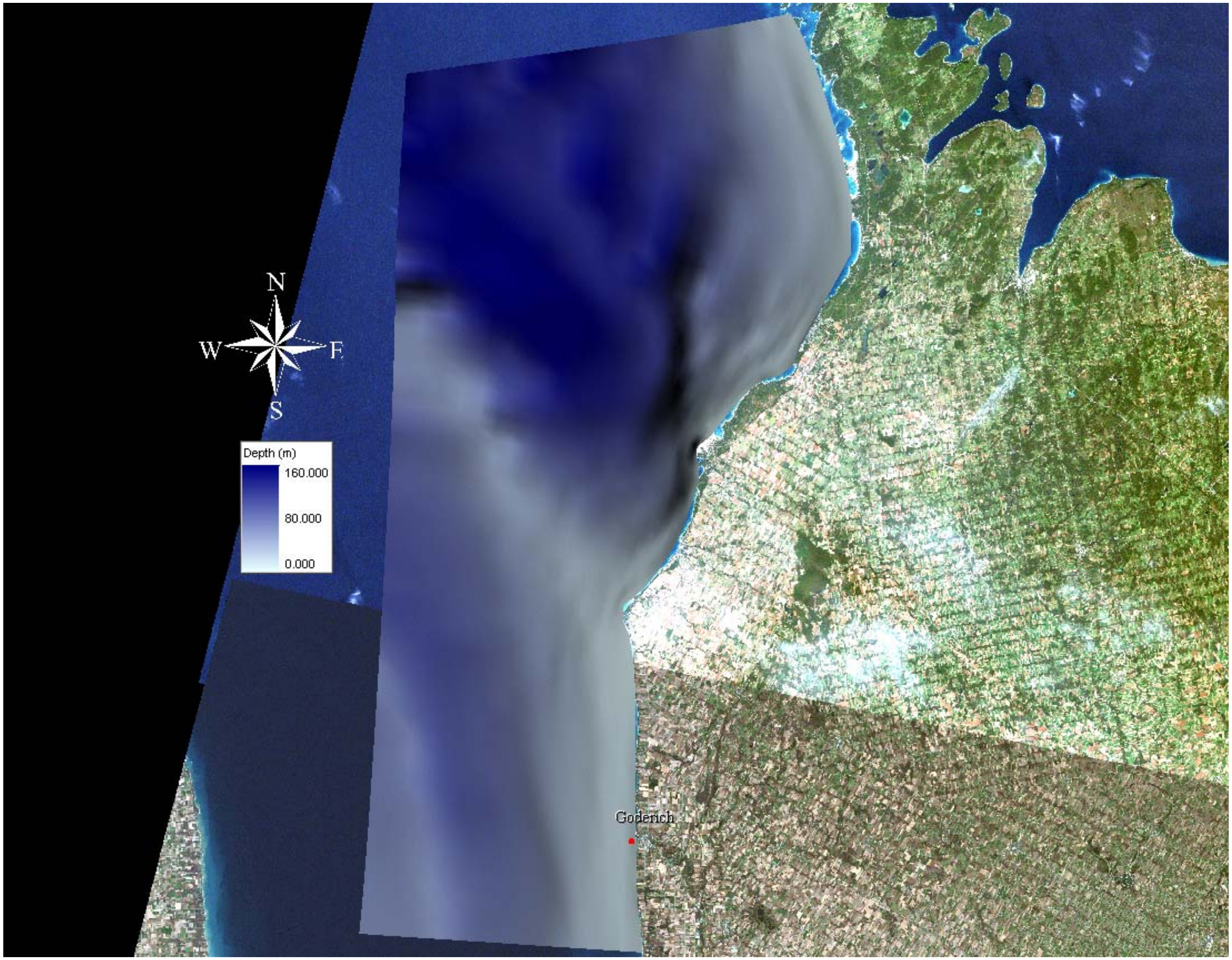


**Figure 4.5 Bathymetry for East Lake Huron Model (ELHM)**

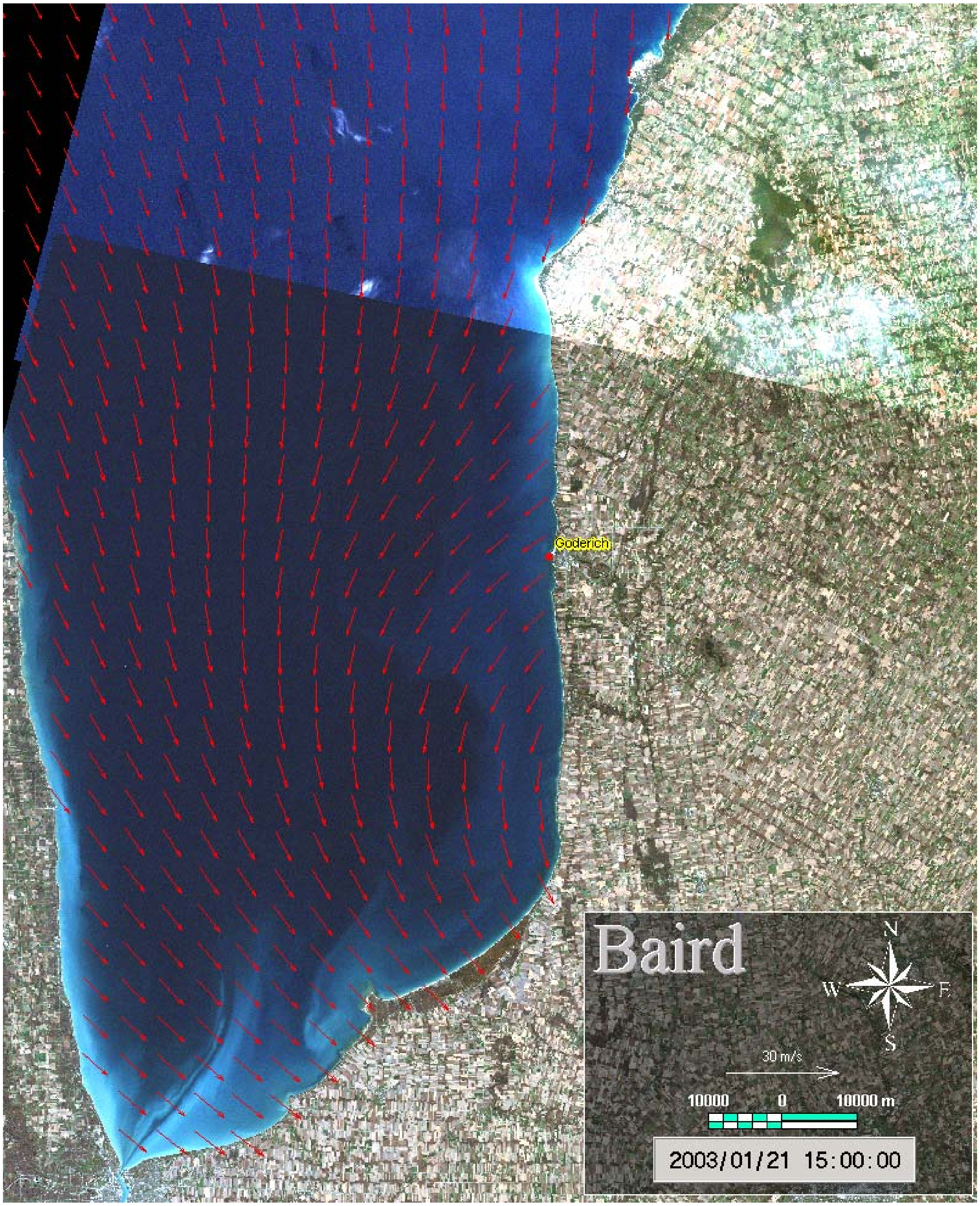


**Figure 4.6 Wind Vectors Showing Speed and Direction Interpolated from LHOFS**

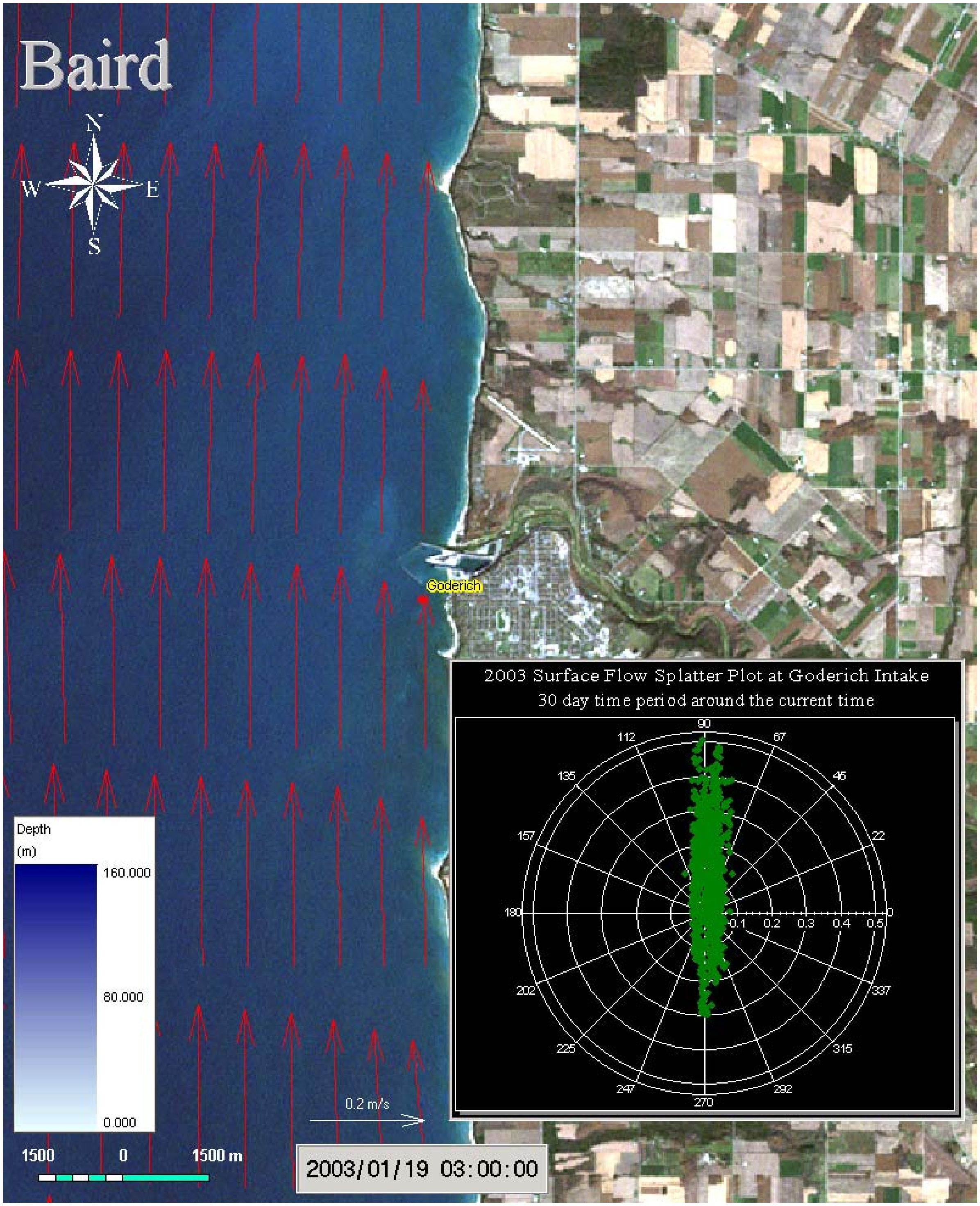


**Figure 4.7 ELHM Showing Typical Winter Currents (January 2003)**

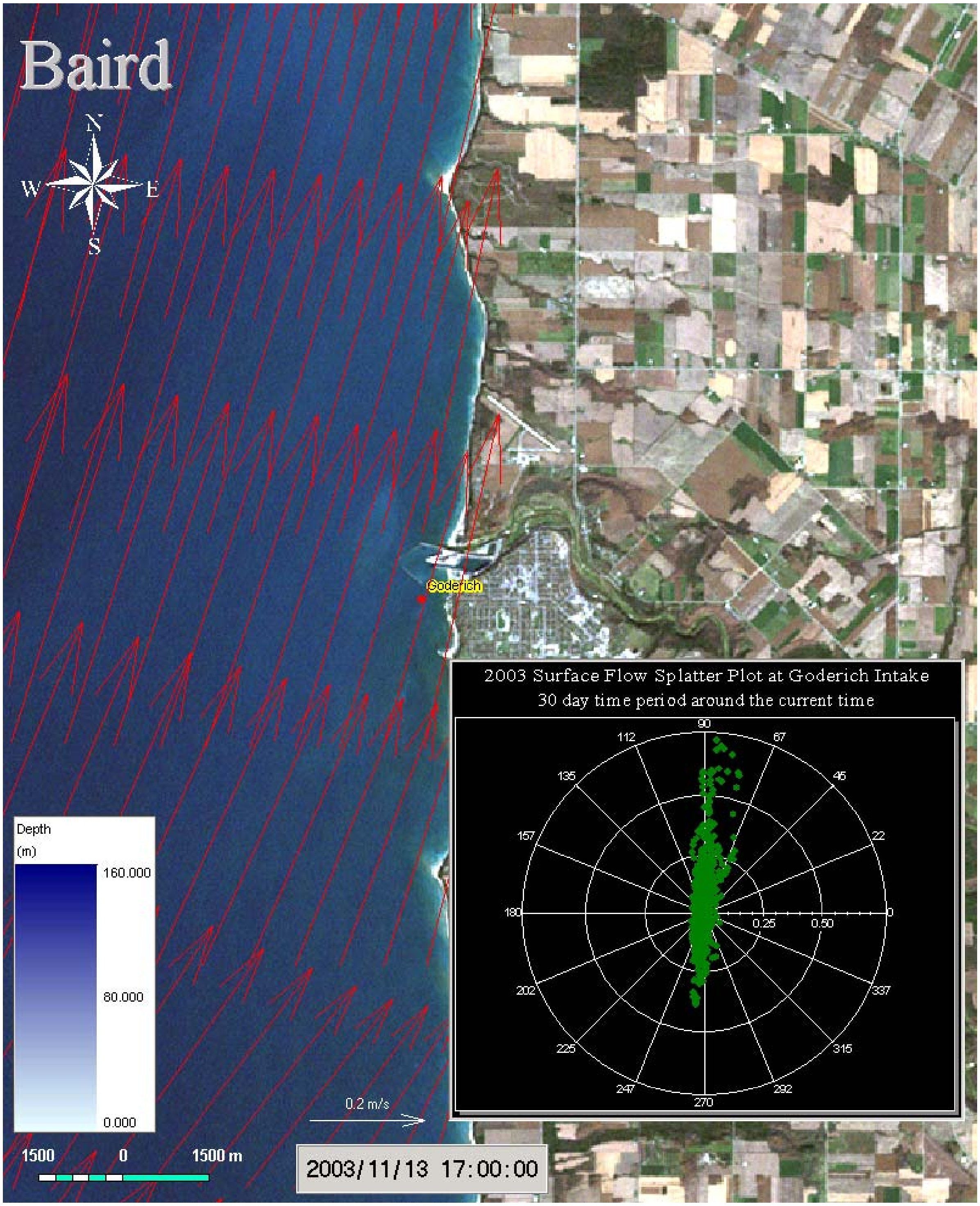


**Figure 4.8 ELHM Showing Typical Fall-Winter Currents (November 2003)**

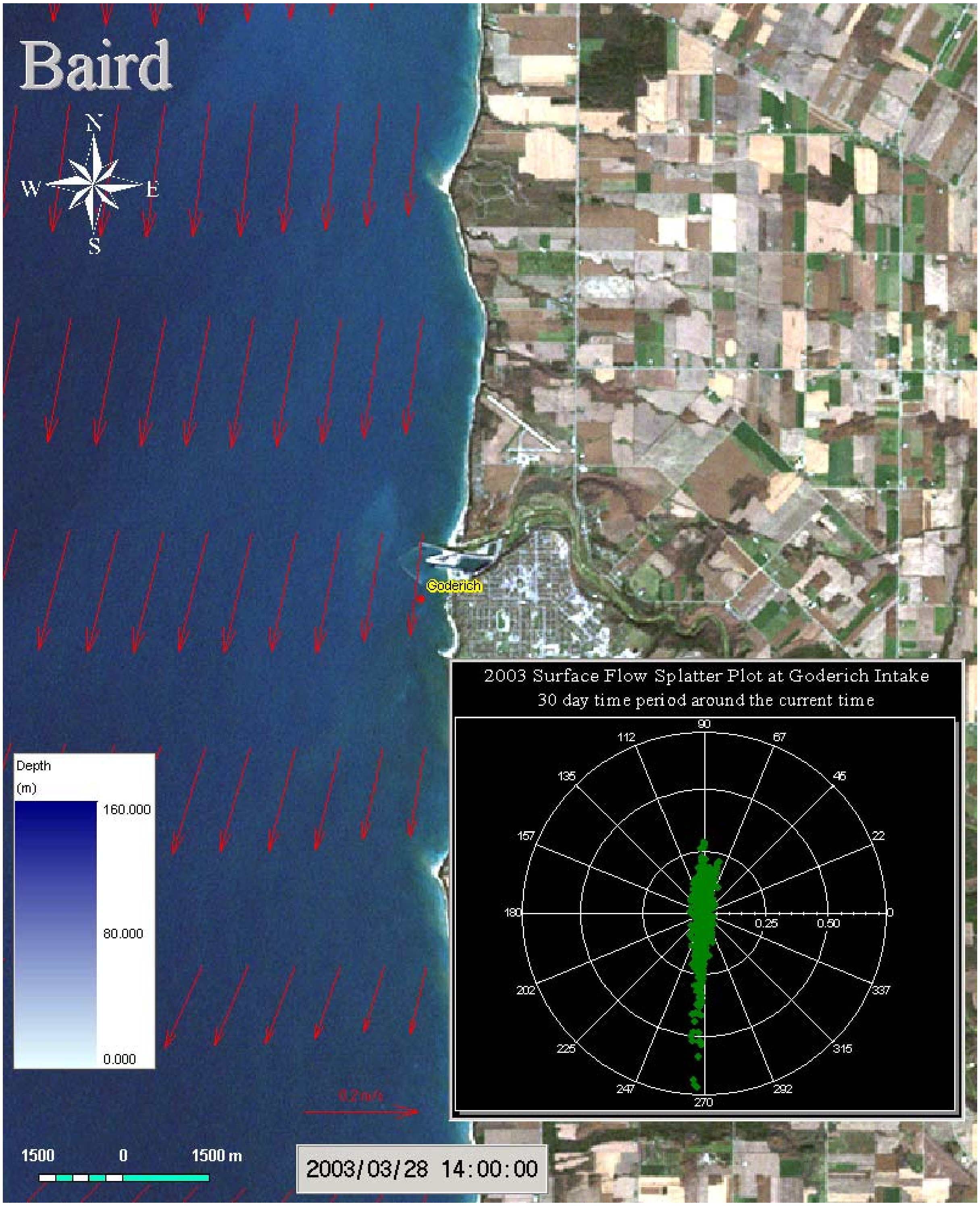


**Figure 4.9 ELHM Showing Typical Spring Currents (March 2003)**

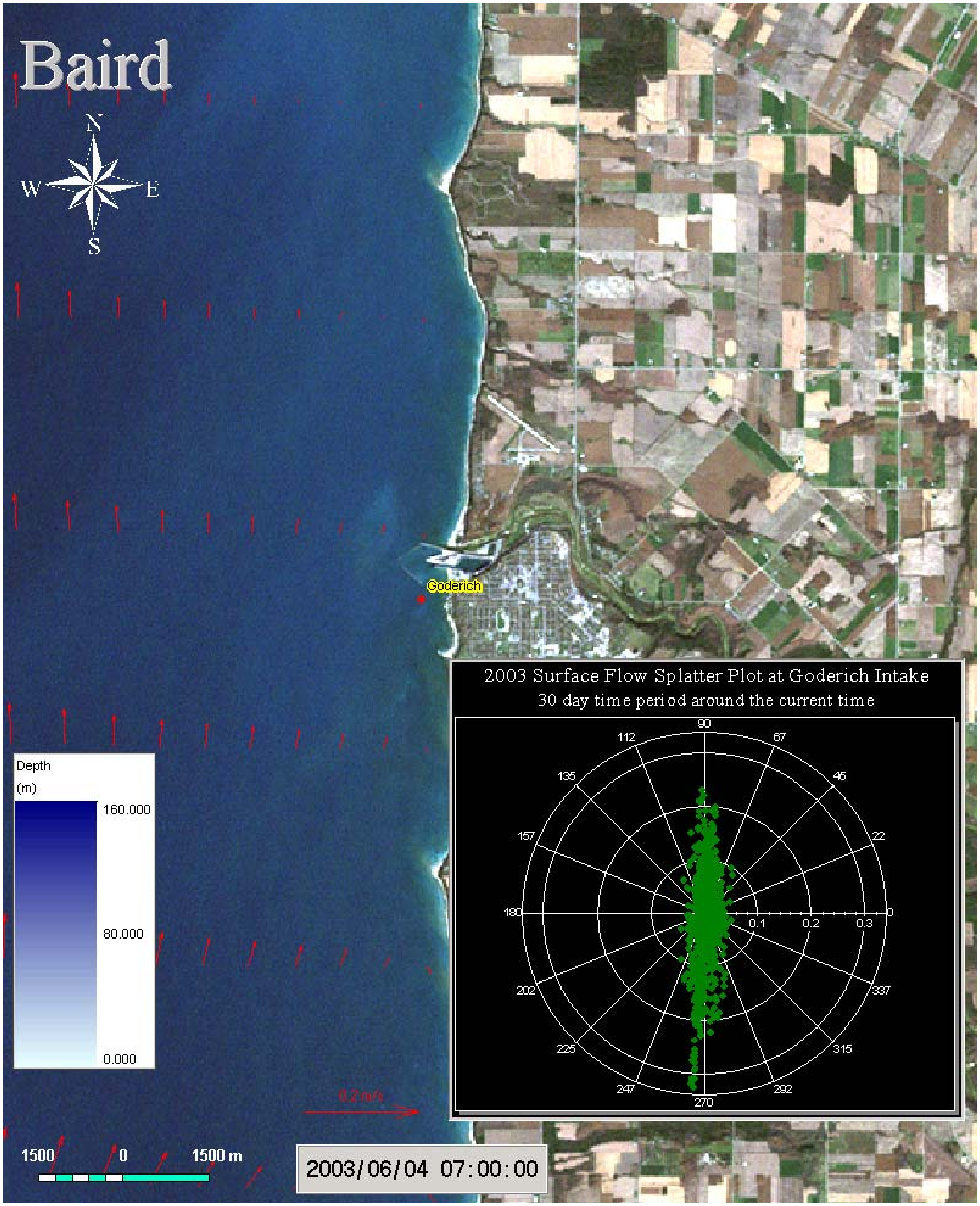


**Figure 4.10 ELHM Showing Typical Summer Currents (June 2003)**

### 4.3.3 Goderich Nested Model

The nested model with the fine grid in the vicinity of Goderich was developed to simulate the interaction of nearshore lake circulation and the river inflow from the Maitland River. The grid size ranges from 4 m in the river and the harbour to 250 m offshore. The model domain extends to 7 km offshore from the river mouth and to 2.5 km upstream in the river. The Goderich nested grid is shown in Figure 4.11. The bathymetry for the nested model was interpolated from the high-resolution field sheets near the mouth or the river, and the coarser-scale depth values available further offshore (see Figure 4.12 for the interpolated bathymetry). Since the bathymetry in the upper part of the river is not available, cross-section information at the mouth was used to generate a uniform cross-section that was applied upstream as well (allowing for approximately a 1:1000 longitudinal slope in the river).

Two open boundaries in the model domain were controlled using the model results of the ELHM and the river inflow. The hydrodynamic conditions (water levels and currents) at the offshore open boundary were extracted from the ELHM. The flow condition at the river open boundary was set as 534 $m^3/s$, corresponding to the two-year return period flow. The wind conditions for the simulation were extracted from the spatially-varying, hourly wind data of the LHOFS.

Due to the limitations of computational time and storage for model output, the simulation for the detailed grid was not run for the entire 2003 calendar year. Instead, two 3-week periods including the largest storm events observed in 2003, i.e. January 30, 2003 to February 20, 2003 and November 10, 2003 to December 5, 2003, were simulated. Based on the output from the ELHM model, these two storm events produced the largest currents in 2003. These two events therefore represent the most extreme hydrodynamic conditions and were used to define the IPZ-2. No statistical analysis was undertaken to determine how these events might compare to the storm events in other years. In addition, no analysis has been undertaken to define how extreme these events might be, i.e. the return period is undefined at present.

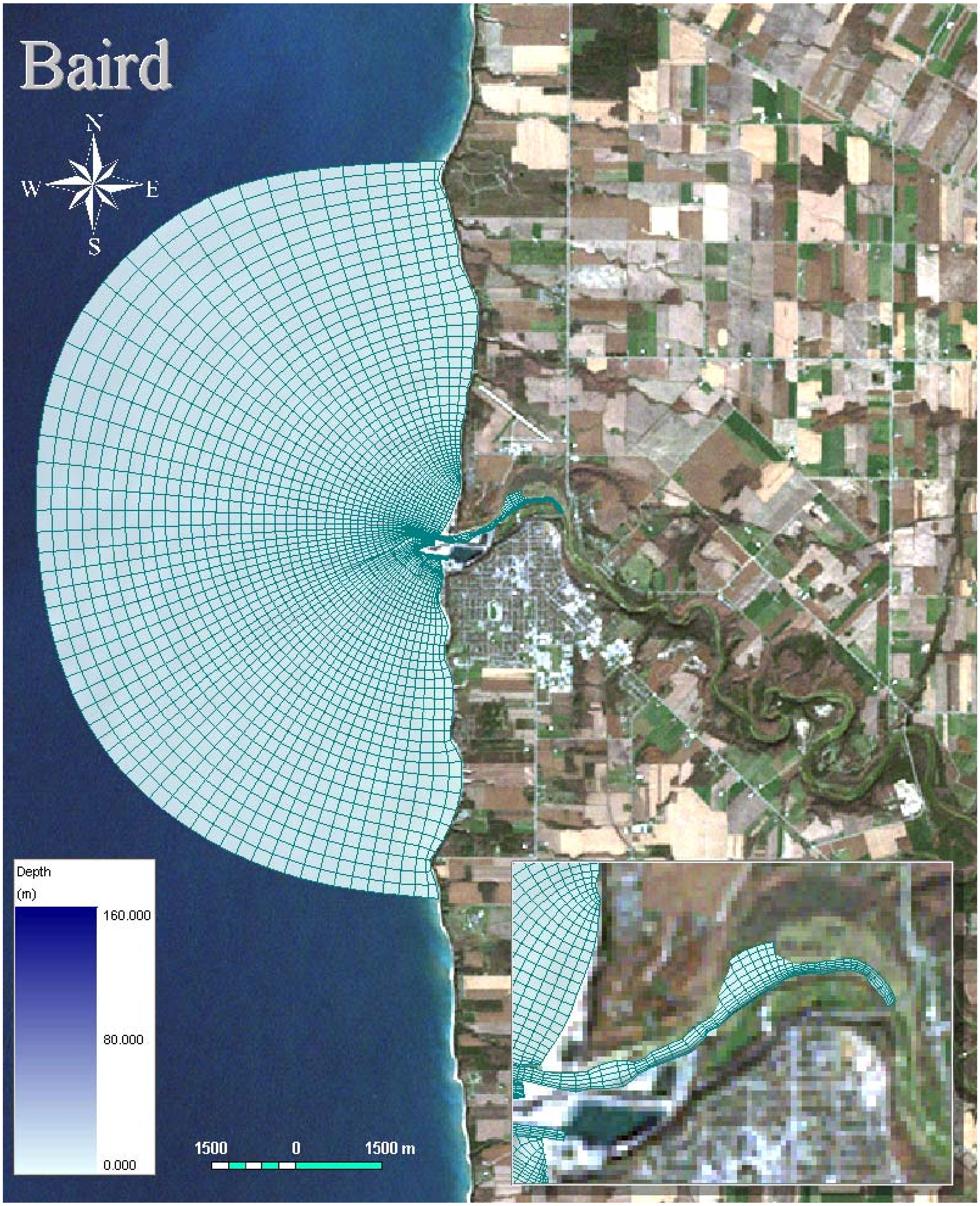


**Figure 4.11 Detailed Grid for Goderich Model**

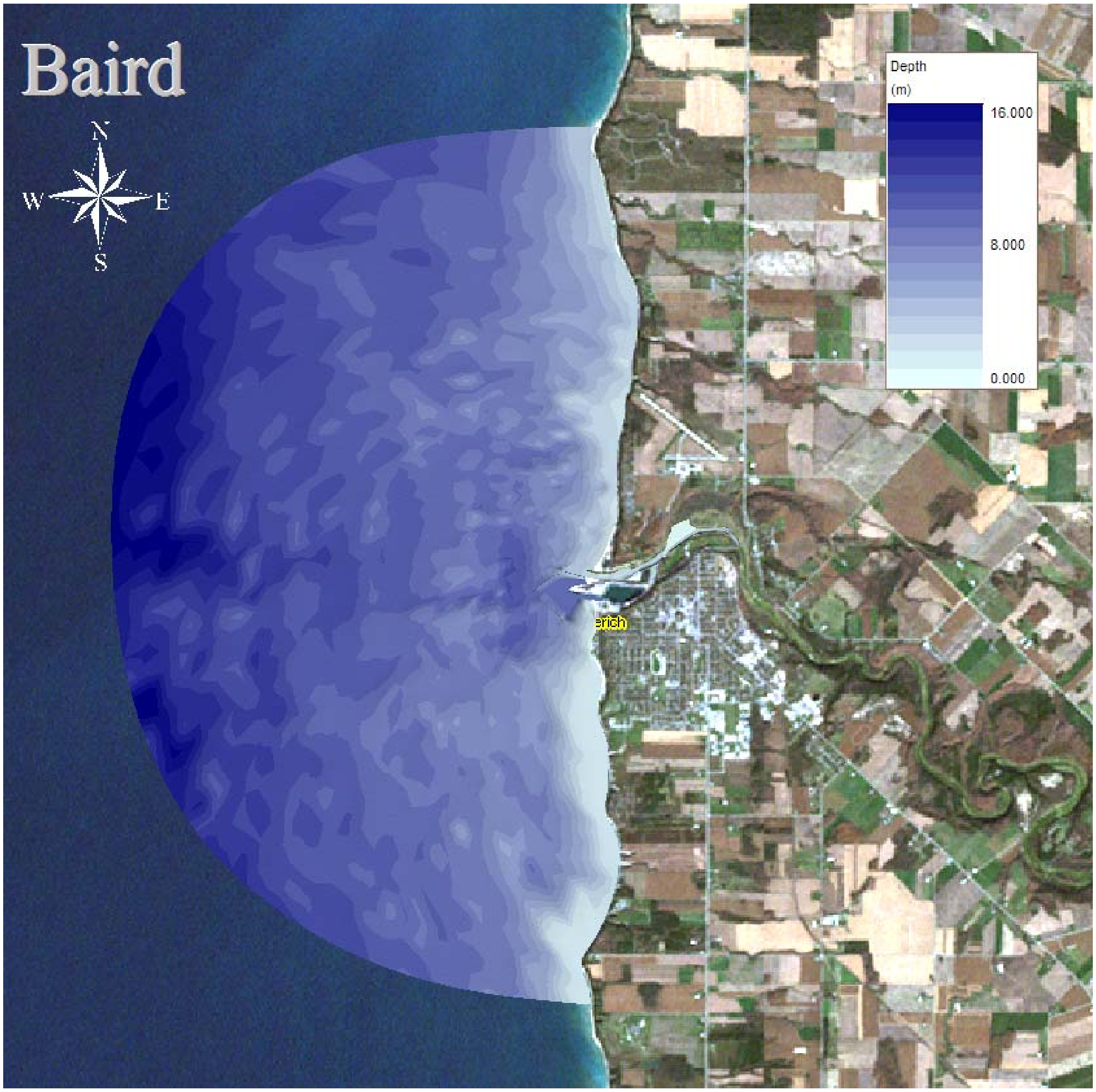


**Figure 4.12 Interpolated Bathymetry for Goderich Model**

## 4.4 Model Results

### *4.4.1 Current Patterns*

Output from the model is shown in Figures 4.13 through 4.16. The interaction of the nearshore currents and the river inflow produces complicated flow patterns at the river mouth and in the vicinity of the harbour. When there is a northward nearshore current, a large eddy is present on the north side of the jetties as shown in Figure 4.13. Under these conditions, there is no mechanism for flow from the river to reach the intake. Figure 4.14 shows the current patterns when there is a southward nearshore current in the lake. A large eddy develops on the south side of the breakwater and in the vicinity of the intake, which lengthens the traveling time from the river to the intake. Figure 4.15 shows the current patterns when the lake currents are weak, i.e. when there is little wind. During high river flow/low wind events, there is no mechanism for the flow from the river to reach the intake. This is consistent with the turbidity analysis (described in Section 3.6.3), which did not show increased turbidity levels at the intake during high flow/low wind speed events. Under these conditions, the river flows directly offshore from the river mouth.

The presence of the jetties at the river mouth and the offshore breakwaters in the harbour, partially obstruct currents generated by the river from reaching the intake. This may reduce the threat of contaminants from the river.

The 2-year return period river flow results in velocities in the river between 1.5 and 3.0 m/s (see Figure 4.16). Caution is advised when using the model results in the river, as the bathymetry in the river is not sufficiently well defined. A constant cross-section was assumed based on the measured cross-section near the river mouth.

Current velocities in the vicinity of the intake are often in the range of 0.5 m/s and currents to the north are dominant (see Figure 4.17). This is because, when there is a wind from the south, currents at the intake are toward the north as shown in figure 4.13. When the wind is from the north, a circulation pattern develops south of the harbour and currents at the intake are again to the north as shown in Figure 4.14. Therefore, currents at the intake are predominantly to the north, irrespective of wind direction. This is a localized phenomenon and currents observed elsewhere, such as north of the harbour do not exhibit the same patterns.

Currents at the intake are largely dependant upon wind conditions rather than river discharges because the breakwaters and the harbour direct the river flow away from the intake. It is therefore the wind driven currents that dominate at the intake.

### *4.4.2 Backward Particle Tracking for Preliminary IPZ Delineation*

Backward (or reverse) particle tracking was used to delineate the preliminary in-lake IPZ-2 for the Goderich intake. The model was run for the two 3-week periods including the most severe storms in 2003. The wind data for 2003 at Goderich is shown in Figure 4.18 with the two extreme events used in the modeling identified. Neutrally buoyant particles were introduced at the intake. The model was run in reverse mode with the particles tracking the paths by which the currents would have transported neutrally buoyant particles to the intake over a 2 hour travel time (see Figures 4.19 a, b and c). The pathways are indicated by the yellow particles (Event A - November/December storm) and the green particles (Event B - January/February storm).

The limits of the 2-hour travel time extend approximately 1.5 km north, 4 km south, 1.0 km offshore of the intake, and about 1 km up the river. The in-lake IPZ-2 extends further to the south than to the north, as a result of the dominant northerly currents at the intake, as described in Section 4.4.1. Although the most frequent wind is from the north-northwest (see Figure 2.3), the currents at the intake are predominantly to the north (as shown in Figure 4.17), due to the large circulation patterns in the lake (which mean that the current direction is not always the same as the wind direction) and localized eddie patterns in the vicinity of the intake. As explained in Section 4.4.1, this is a localized effect, created by the harbour and breakwaters. If the intake were located further offshore, beyond the influence of the breakwaters, the IPZ would look quite different.

Based on the runs undertaken, the probability of contaminants from the river reaching the intake within the 2-hour travel time is relatively small, as indicated by the small number of particles that terminate in the river. The presence of the jetties and the offshore breakwaters limits the distance the IPZ-2 extends inshore, up the river. However, clearly any contaminants in the river would reach the intake if the 2-hour travel time were extended.

Figure 4.20 shows the travel time contours delineated using the more conservative of the two backward particle-tracking runs. The Waste Water Treatment Plant outfall is located approximately 1.5 hours from the intake. This is discussed further in Section 5.

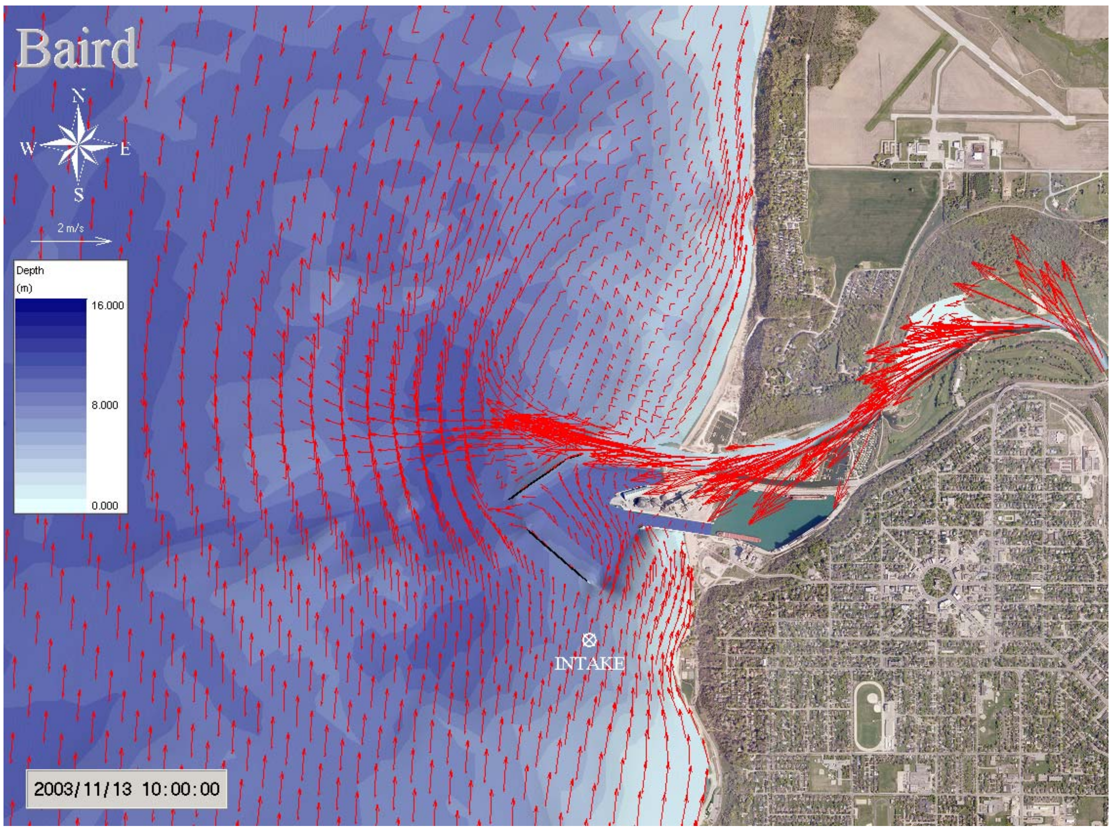


**Figure 4.13 Current Patterns in Vicinity of Harbour at Goderich with Northerly Lake Currents**

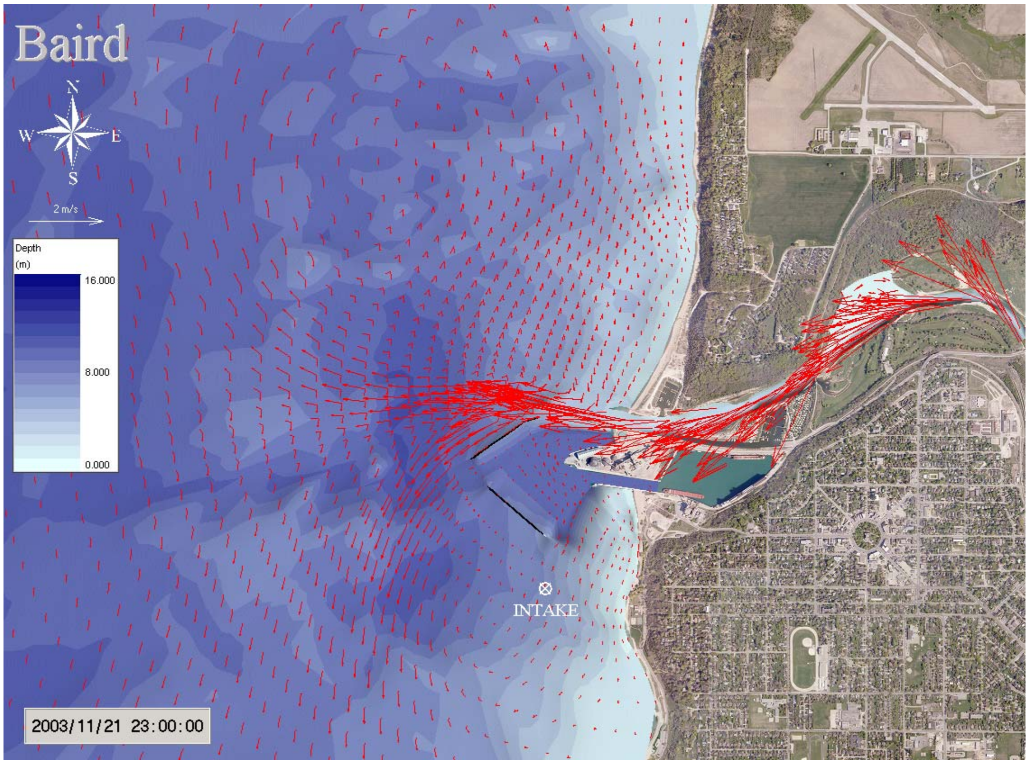


**Figure 4.14 Current Patterns in Vicinity of Harbour at Goderich with Southerly Lake Currents**

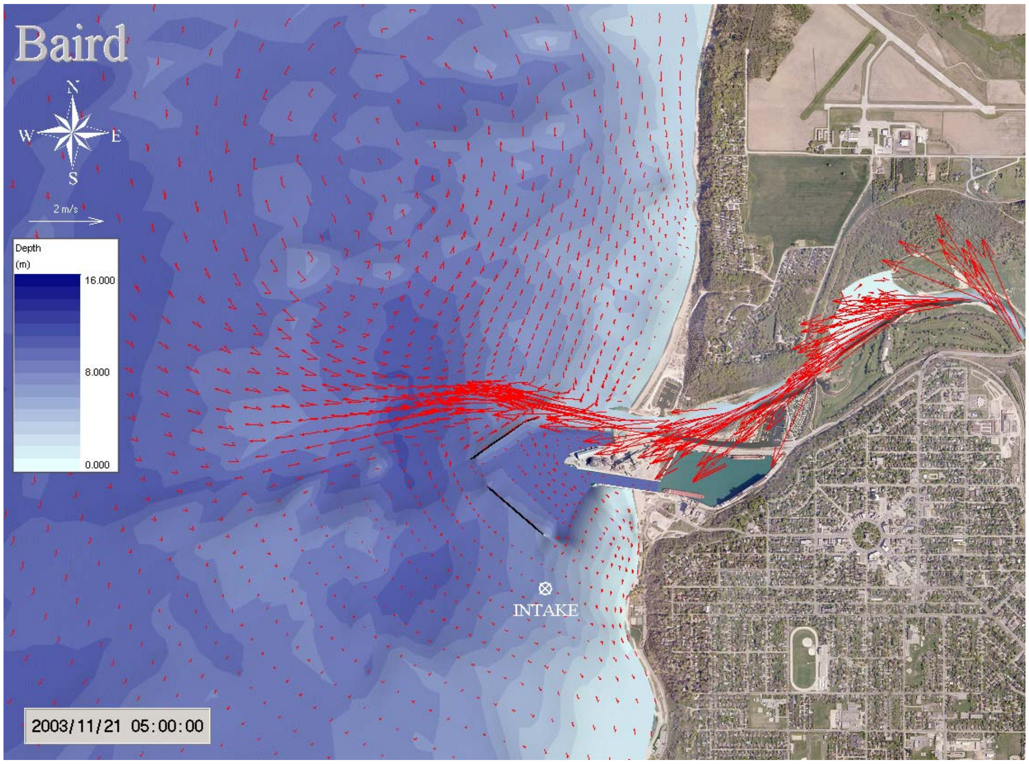


**Figure 4.15 Current Patterns in Vicinity of Harbour at Goderich with Weak Lake Currents**

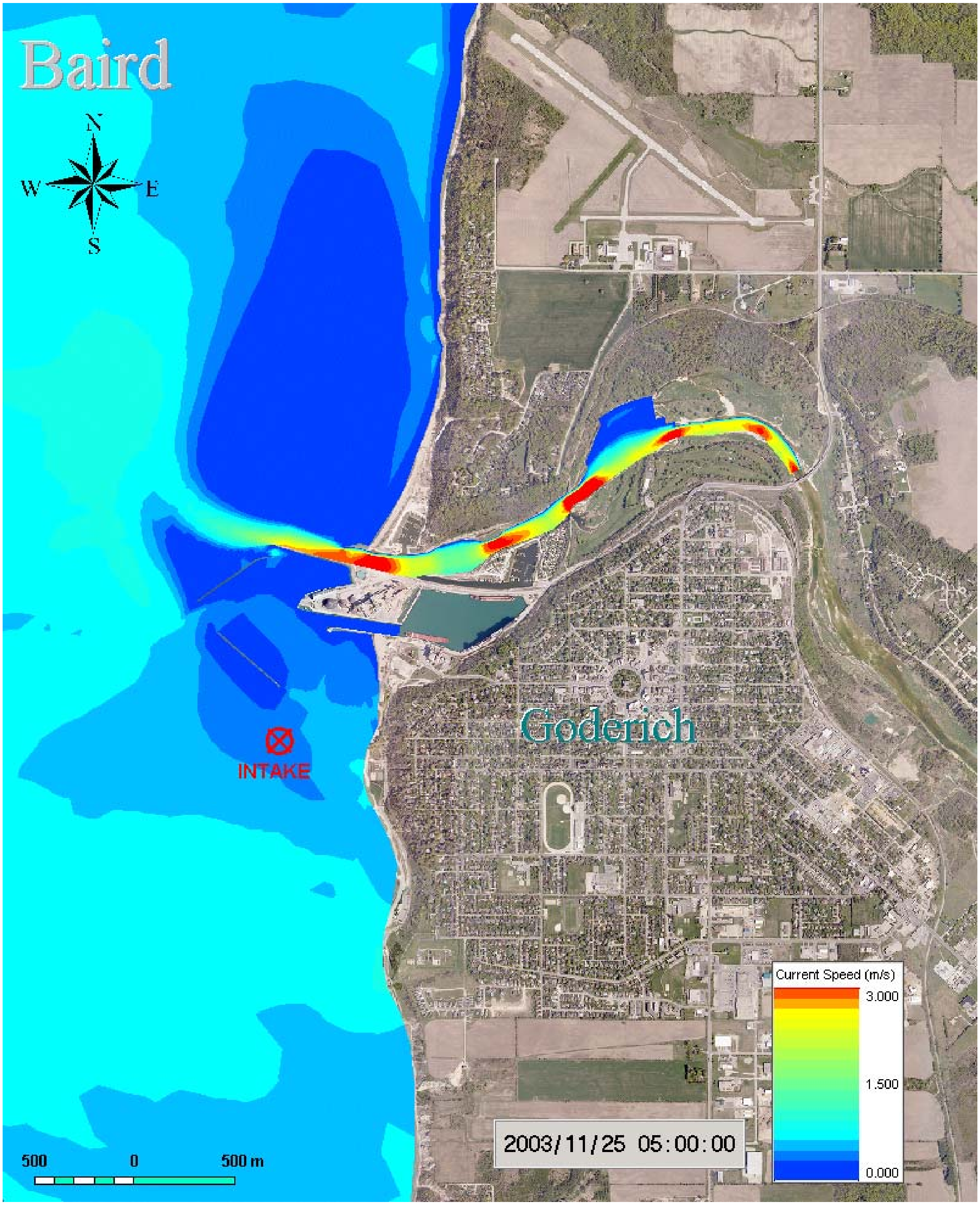


**Figure 4.16 Surface Flow Speed in the Maitland River**

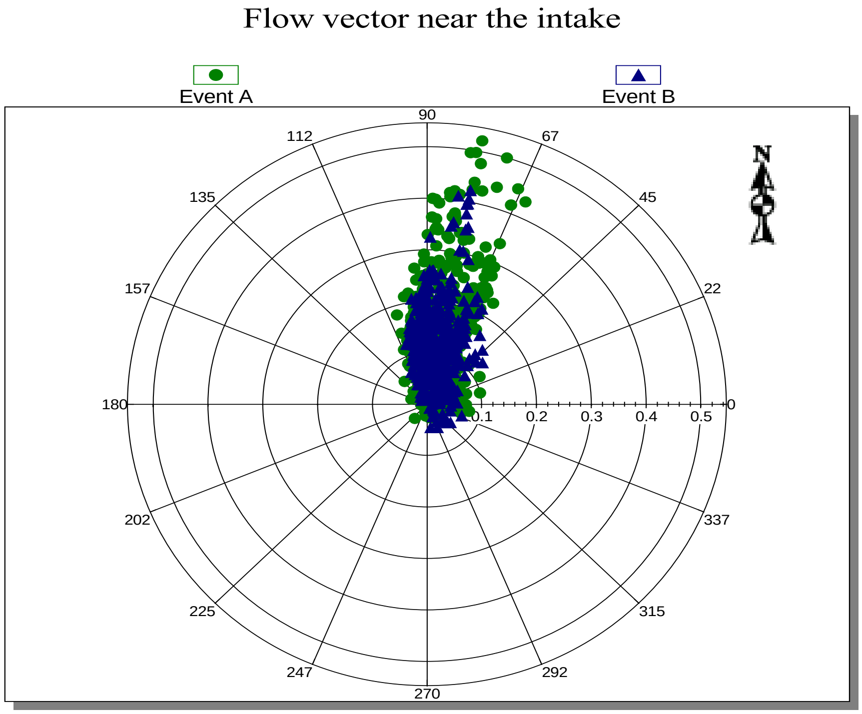


**Figure 4.17 The Flow Vectors Extracted at the Goderich Intake (direction flow is to)**

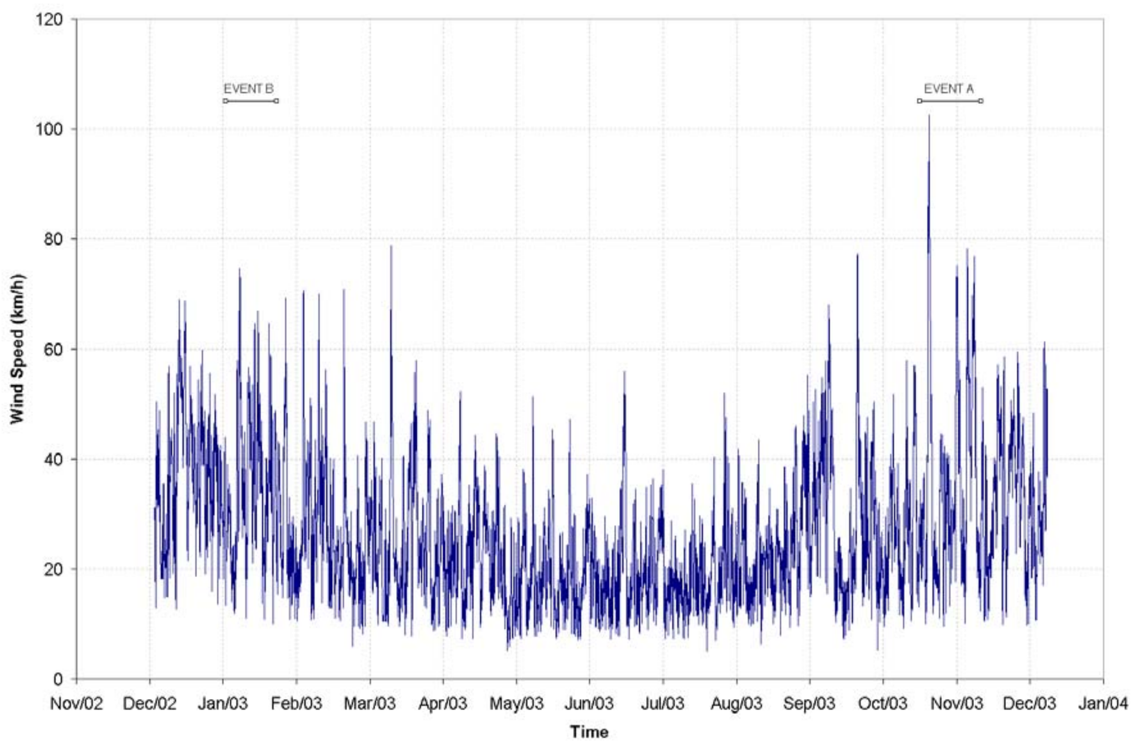


**Figure 4.18 Wind Speeds at Goderich for 2003 Showing Extreme Events Used in Backward Particle Tracking**


**Figure 4.19a Reverse Particle Tracking for Event A (November-December storm)**

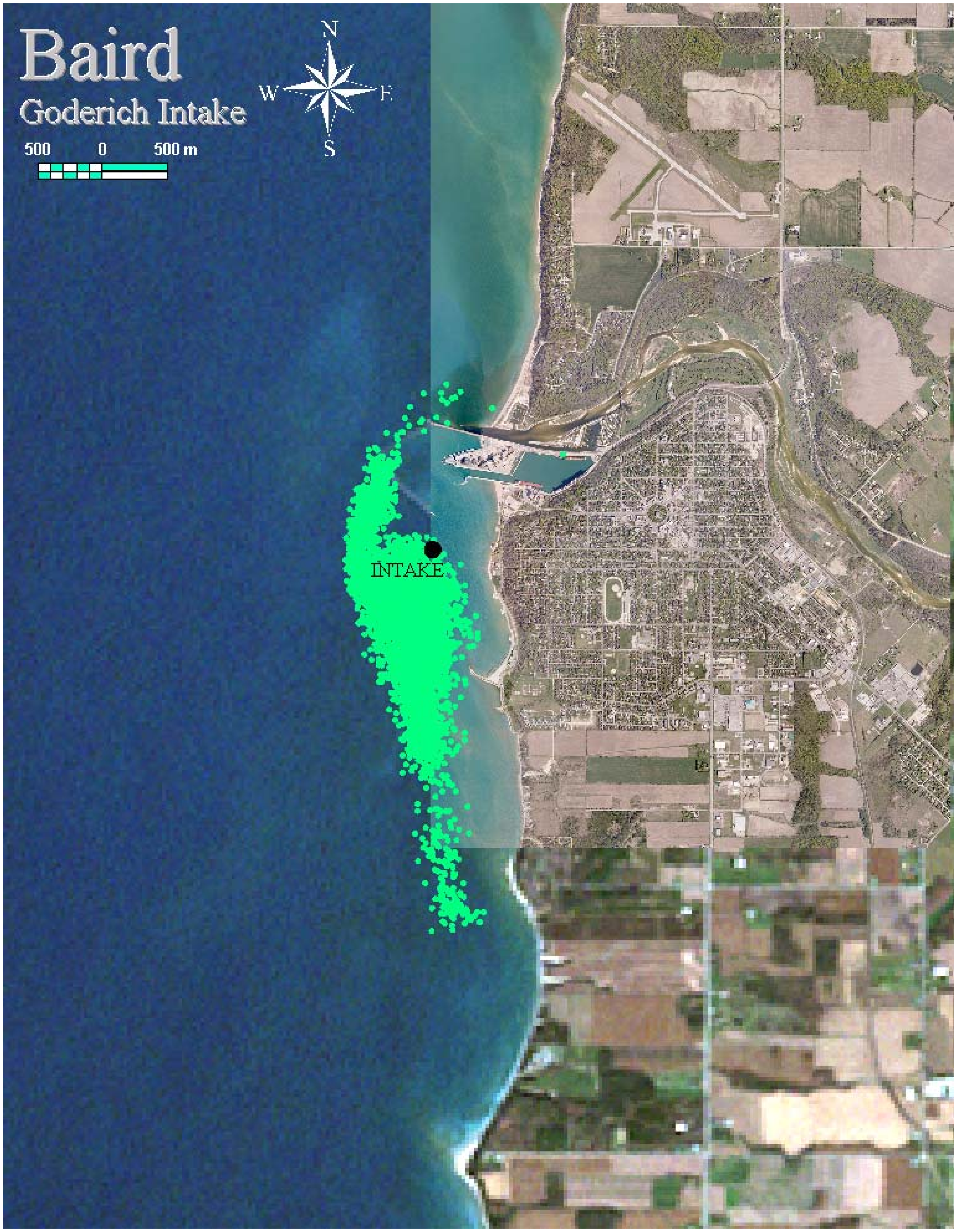


**Figure 4.19b Reverse Particle Tracking for Event B (January-February storm)**

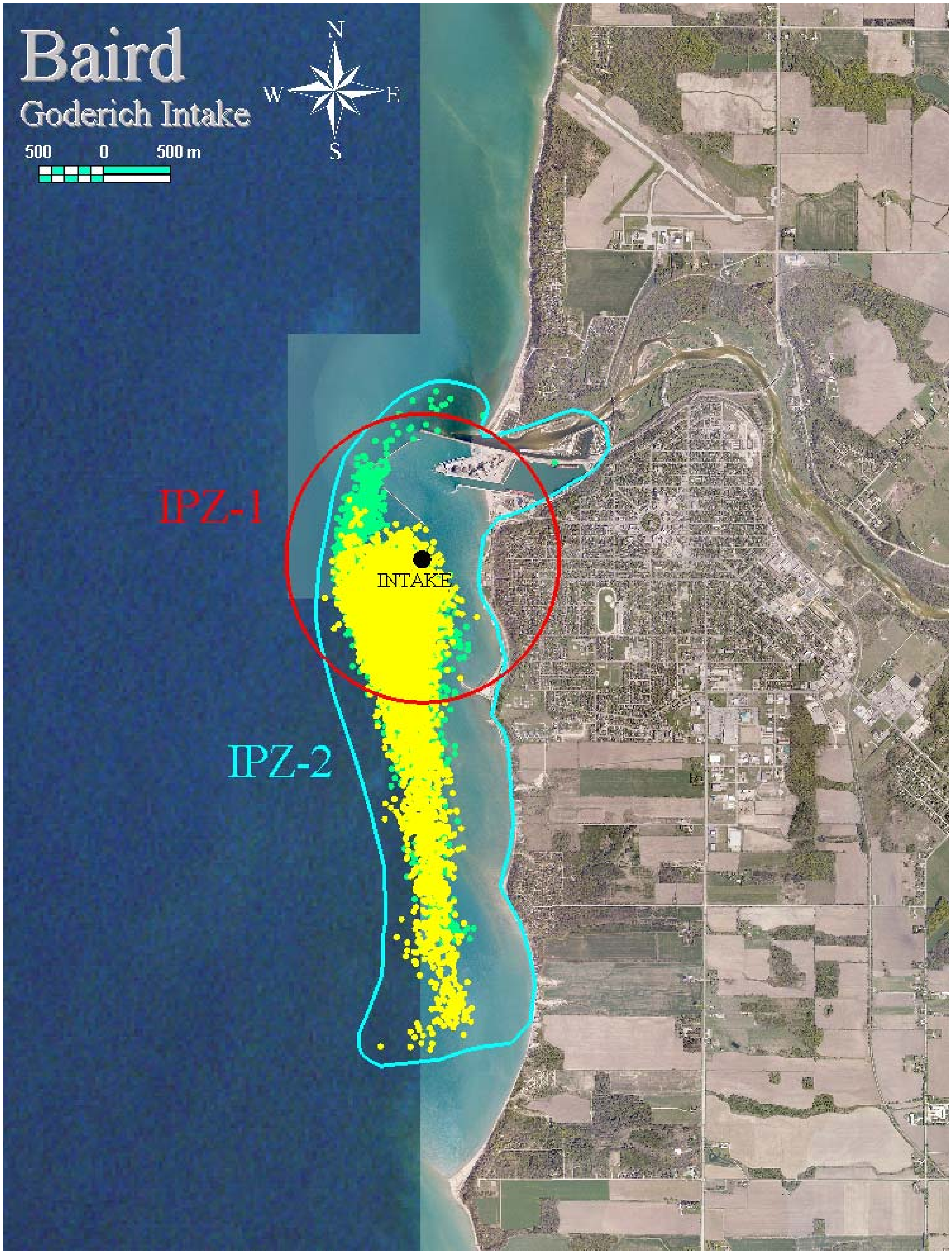


**Figure 4.19c In-lake IPZ Delineation Based on Reverse Particle Tracking**

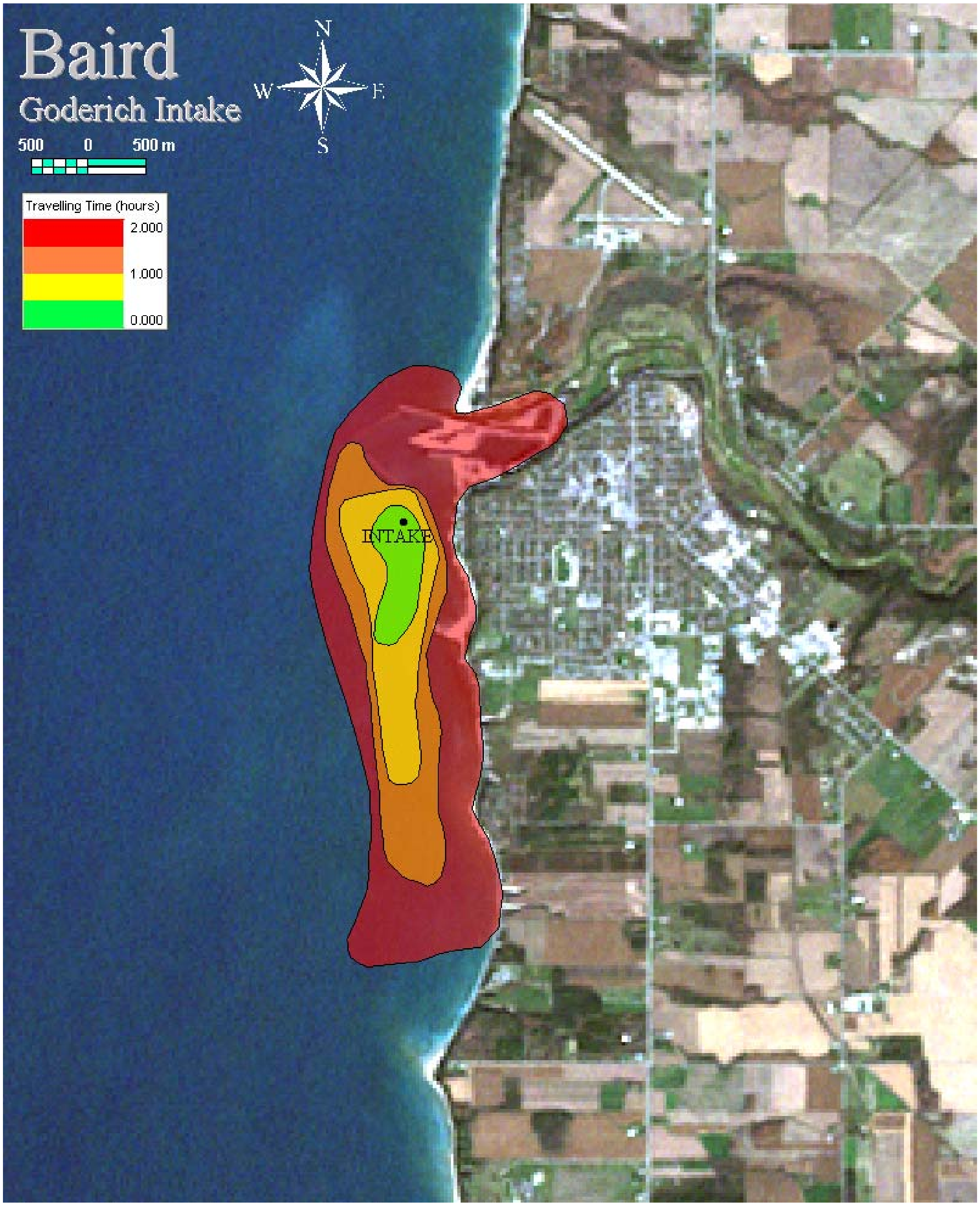


**Figure 4.20 Contours Showing Travel Times Within the IPZ-2 at Goderich**

## 4.5 Model Limitations

As stated in our proposal, numerical modeling undertaken in support of IPZ delineation during this phase of the project provides preliminary delineation of the IPZ-2. It is recommended that additional work be undertaken in Phase 2 to complete the modeling. The key limitations of the modeling are as follows:

1. The model used in this phase of the work is uncalibrated. Until some level of calibration/validation of the model is undertaken, the level of uncertainty must be classified as “high”. ADCP data was collected by MOE in 2003 (see Section 2.3). Although an extensive calibration of the model is beyond the scope of this project, comparison with the measured data is recommended, to determine how well the model is predicting the current velocities.
2. The model has been run for two events in 2003 (including the largest storm), for 3-week periods including these events. There are two limitations with this approach; a) we do not know how these events compare to extreme events in other years and what impact this might have on the IPZ-2; and b) no statistical analysis was undertaken to define the severity of these events, i.e. 2 year return period, 6 month return period, 50 year return period? To be defensible, they must be associated with a statistically defined event. In the next phase of the work, it is recommended that a statistical analysis be undertaken to define return period events for a range of directions and that additional runs be undertaken to delineate the in-lake IPZ-2.
3. Cross-section data for the Maitland River were taken from the bathymetry field sheet for the lake. The data provides an approximation of the river cross-section only. In addition, due to lack of any additional upstream data, it has been assumed that the upstream river cross-sections are the same as the river mouth. This is also an approximation and actual river cross-section data should be collected in Phase 2 to better define the velocities in the river and the IPZ-2 limits.
4. Because the LHOFS model has been used to define the boundary conditions for the more detailed Delft3D model, the Delft3D model can only be run for periods for which the LHOFS model has been run and model output has been archived. This limits the runs that can be undertaken.

# 5.0 PRELIMINARY IPZ DELINEATION

The Goderich intake is classified as a Great Lakes intake as defined in Guidance Module 4. Module 4 also states that the purpose of delineating zones around the Great Lakes intakes is to protect them from immediate contaminants of concern that might enter from nearby areas or known sources. Drinking water intakes on the Great Lakes may be influenced by several environmental factors including: winds, waves and currents. The modeling described in Section 4 and used to delineate the IPZs, includes the effects of wind driven currents and currents generated by tributaries flowing into the lake.

For Great Lakes intakes, two zones are to be delineated: IPZ-1 is a fixed radius around the intake crib; and IPZ-2 takes into account areas outside the IPZ-1 that have the potential to directly impact the intake such as streams, rivers or shoreline features. Preliminary delineation of the IPZs is described below and shown on Figure 5.1. It is intended that the IPZ-2 will be refined during Phase 2 of the project, following further analysis.

## 5.1 Delineation of IPZ-1

The IPZ-1 was delineated as per Assessment Report: Draft Guidance Module 4 (MOE, 2005). The IPZ-1 is the area immediately around the intake crib. Due to its close proximity to the intake, this area is considered the most vulnerable to any contaminant of concern that may be released in this zone. Any contaminants released in this zone will have the highest potential to impact water quality.

The IPZ-1 shown in Figure 5.1 includes a number of recognized threats (discussed in Section 7) including:

- Storm water outfalls;
- Waste Water Treatment Plant outfall;
- Goderich Harbour;
- Maitland River; and
- Sifto Salt storage and loading facilities

The IPZ-1 was extended northward beyond the 1 km radius to include the entire mouth of the Maitland River, which is a potential source of contaminants and would otherwise only have been partially included in the IPZ-1. The boundary was also extended southward to include the Wastewater Treatment Plant outfall (which is located approximately 300 m beyond the 1 km radius).

## 5.2 Delineation of IPZ-2

The IPZ-2 acts as a secondary protective zone around the IPZ-1. In the event of a spill or acute situation, the treatment facility will have minimal time to respond. Contaminants released in this zone through spills have a high chance of reaching the intake quickly and will not have sufficient time to be diluted or filtered prior to reaching the intake (MOE, 2005).

The IPZ-2 is defined based on the minimum response time required for the plant operator to respond to adverse conditions or a spill and the travel time in the lake and/or tributaries. A 2-hour minimum response time is specified in the Guidance Module and has been used on this project based on the operator survey described in Section 3.2 (the operator indicated that the WTP can be shut-down immediately upon notification).

The IPZ-2 includes all land area and stream mixing zones that could potentially influence the intake within the 2-hour response time. There are three components to the IPZ-2: in lake, upstream and inland. Delineation of the IPZ-2 considering these three components is described below.

### *5.2.1 In-lake IPZ-2*

There is no specific guidance in the Assessment Report: Draft Guidance Modules (MOE, 2005) regarding the return periods to be used to determine the current velocities used to define the in-lake IPZ-2. For Great Lakes intakes, the Guidance Modules recommend using the average longshore current velocity during high wind and current period. This is not a specific event with a defined return period. The approach used in this report is based on the numerical modelling described in Section 4. The reverse particle tracking model was run for two extreme events in 2003 including the most severe storm. Output showing the reverse particle tracking results and the resulting IPZ-2 delineation is shown in Figure 4.19. The in-lake travel time contours are shown in Figure 5.1 in 0.5-hour travel time intervals. The limits of the 2-hour travel time extend approximately 1.5 km north, 4 km south, 1.0 km offshore of the intake, and to the shoreline. It is important to recognize the limitations of the modeling as described in Section 4.5.

### *5.2.2 Upstream Limit of IPZ-2*

The main tributary in the vicinity of the intake is the Maitland River. The Maitland River was included in the Delft 3D model described in Section 4. The backward particle tracking showed that the limits of the 2-hour travel time extend approximately 1 km up the river (see Figure 5.1). Based on the runs undertaken, the probability of contaminants from the river reaching the intake within the 2-hour travel time is relatively small, as indicated by the small number of particles in Figure 4.19, that terminate in the river. The presence of the jetties and the offshore breakwaters limits the distance the IPZ-2 extends inshore, up the river. However, clearly any contaminants in the river would reach the intake if the 2-hour travel time were extended.

Where smaller tributaries flowing into the lake lie within the IPZ-2, the IPZ-2 will extend up the tributaries a distance calculated as (shut down time minus travel time from the intake to shore) multiplied by the stream velocity. The stream velocity may be estimated based on flow and tributary cross-section. These are data gaps at present. The tributaries are identified in Figure 5.1, however the upstream limit of the IPZ-2 has not been calculated for this study, due to data limitations. This analysis should be undertaken in Phase 2 when sufficient data is available.

It is important to recognize that the delineation of the IPZ-2 is based on a 2-hour travel time to the intake. There are a number of tributaries that lie beyond the 2-hour travel time that may potentially impact water quality at the intake if longer time periods are considered.

### *5.2.3 Inland Extent of IPZ-2*

The IPZ-2 extends inland to the limit of the Regulated Areas or 120 m – whichever is greater. The Regulated Areas are delineated with respect to the Provincial Policy Statement and the CA Act Regulation 97/04. They include flood plains, streams, valleys, wetlands and shorelines. These areas are of significant risk for loss of life, property damage, infrastructure damage and social disruption. Flood and erosion lines are determined based on regional extreme events and local conditions. The Conservation Authority has delineated the Regulated Areas under the Conservation Authority Act, Subsection 28(1).

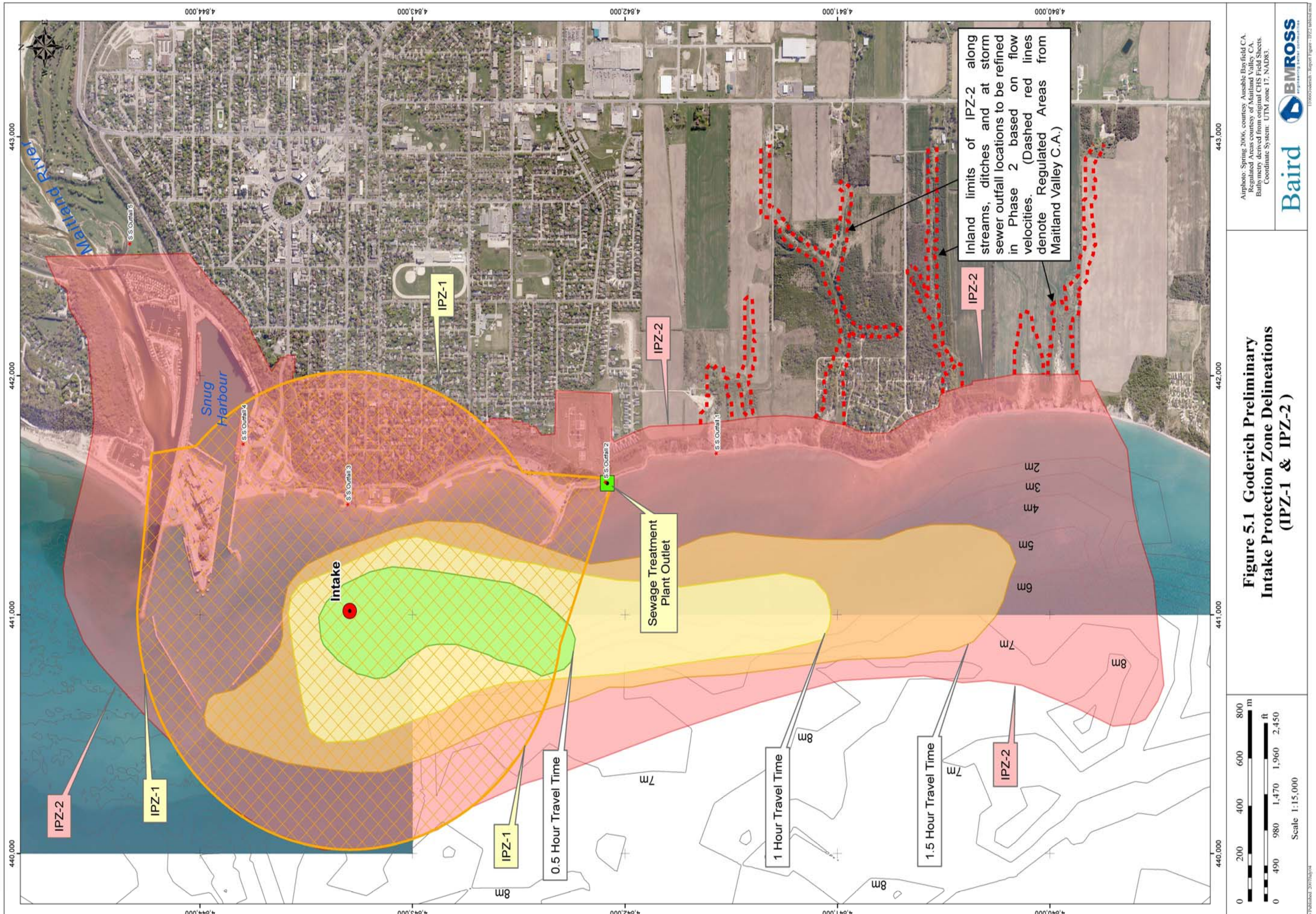


Figure 5.1 Goderich Preliminary Intake Protection Zone Delineations (IPZ-1 & IPZ-2)

# 6.0 VULNERABILITY SCORES AND LEVEL OF UNCERTAINTY

## 6.1 Vulnerability Scores

The vulnerability score quantifies the vulnerability of the intake to contaminants. This score is applied to the intake protection zones (IPZ-1 and IPZ-2). The vulnerability score (V) is defined in Module 4 (MOE, 2005) as:

$$V = Vf_z \times Vf_s$$

where V = vulnerability score

$Vf_z$ = zone vulnerability factor; and

$Vf_s$ = source vulnerability modifying factor

A vulnerability score of less than 5 is defined as low, between 5 and 6 as medium, and a score of greater than 6 is defined as high.

### *6.1.1 Zone Vulnerability Factor*

For IPZ-1s, the $Vf_z$ is set at 10 due to its close proximity to the intake. This value is fixed and cannot be altered (MOE, 2005).

For IPZ-2s, the $Vf_z$ is between 7 and 9, reflecting the moderately high vulnerability of this zone resulting from its proximity to the intake (MOE, 2005). A value of 9 is recommended for IPZ-2s that include numerous direct discharges (e.g. storm sewers etc.) and high potential for surface runoff. Due to the numerous direct discharges in the Goderich IPZ-2 (including storm sewers and tributaries), a value of 9 is recommended.

### *6.1.2 Source Vulnerability Modifying Factor*

The source vulnerability modifying factor applies to the location of the intake on a particular water body. The vulnerability factor for intakes on the Great Lakes are lower than on connecting channels or inland lakes or streams, which are considered more vulnerable. For intakes on the Great Lakes, a value of 0.5 to 0.7 is specified. A lower value within this range is appropriate for intakes located in deeper water, further from shore, and/or where historical water records indicate few or no incidences where raw water quality conditions exceeded the capabilities of the plant. The Goderich intake is located approximately 500 m from shore in an estimated depth of 7 m. It has the potential to be impacted by the Maitland River, as well as numerous discharges from storm sewer outfalls and the Waste Water Treatment Plant outfall. However, the operator reports that there have been no conditions within the past 5-6 years that have required the plant to be shut down and that although at times, conditions make raw water challenging to treat, water quality conditions at the intake have never exceeded the capabilities of the facility. A mid range value of 0.6 is therefore recommended.

### 6.1.3 Vulnerability Score

The vulnerability factors and scores for IPZ-1 and IPZ-2 are summarized in Table 6.1. Vulnerability scores of 6 (IPZ-1) and 5.4 (IPZ-2) classify this intake as medium to high risk. This is appropriate considering the proximity of the Maitland River and the number of outfalls in the IPZs. This may be modified during future phases of the studies.

**Table 6.1**
**Summary of Vulnerability Scores for Goderich**

| IPZ | $Vf_z$ | $Vf_s$ | $V = Vf_z \times Vf_s$ |
|---|---|---|---|
| IPZ-1 | 10 | 0.6 | 6 |
| IPZ-2 | 9 | 0.6 | 5.4 |

## 6.2 Level of Uncertainty

The level of uncertainty associated with the intake protection zone delineation and assessment is a requirement of Module 4 (MOE, 2005). The level of uncertainty accounts for management decisions related to natural systems and the infinite number of data required to achieve complete certainty about a system. The possible sources of uncertainty may be related to the completeness of information, model application and site-specific knowledge related to natural variation (MOE, 2005). The final uncertainty score is based on a combination of the delineation and vulnerability score. A qualitative uncertainty analysis was used to determine the combined uncertainty.

### 6.2.1 Uncertainty for Delineation of Intake Protection Zones

During this first planning cycle, sufficient data was not available to quantify the level of uncertainty for delineation of the IPZs using a formal analysis such as defining specific levels of confidence. A qualitative uncertainty analysis has therefore been provided, consistent with the requirements of the Assessment Report: Draft Guidance Modules (MOE, 2005).

The IPZ-1 was delineated based on defined distances from the intake (IPZ-1) and recognized threats. The level of uncertainty for the IPZ-1 is low.

A 3-dimensional hydrodynamic model was used to evaluate the current patterns, to delineate the in-lake IPZ-2. The level of uncertainty for the delineation of the IPZ-2 is high based on the model limitations listed in Section 4.5. The model used in this phase of the work was uncalibrated. It is recommended that the ADCP data collected by MOE at Goderich be used to validate the model. In addition, no statistical analysis was undertaken to define the severity of the events used to delineate the IPZ-2 and the model was not run for a matrix of extreme conditions with known return periods.

The extent to which the IPZ-2 extends inland was based on Regulated Areas defined by the Conservation Authority. There is a with this aspect of the delineation.

The extent to which the IPZ-2 extends up the Maitland River is based on the modeling described in Section 4. Until the limitations of the modeling described above are addressed, the level of uncertainty for the IPZ-2 delineation up the Maitland River is high. The extent of the IPZ-2 up the smaller tributaries has not been determined due to data limitations as described in Section 5. The level of uncertainty with this aspect of the delineation is therefore high.

### *6.2.2 Uncertainty for Vulnerability Scoring*

The level of uncertainty for the vulnerability scoring for both IPZ-1 and IPZ-2 is high. Although significant water quality data was available, limited water quality data was available for the storm sewer system. In addition, limited sediment sampling data exists. Local knowledge and the inclusion of local studies and investigations improve the level of confidence. Additional data however is required to fill data gaps in Phase 2.

### *6.2.3 Overall Uncertainty Rating*

At this time, a high overall uncertainty rating is recommended. This is due to the high level of uncertainty associated with the delineation of the IPZ-2 as discussed above and the data gaps.

# 7.0 THREATS INVENTORY AND ISSUES EVALUATION

## 7.1 Threats Inventory

Several primary sources of information were reviewed to determine potential contaminant sources located within the preliminary Intake Protection Zone (IPZ). These include the following:

- A review of historic BMROSS files;
- Interviews with Harbour Master & Water Treatment Plant Operator;
- Regional Contaminant Inventory;
- Local knowledge of the Town of Goderich, including a field review of the town and surrounding area to locate potential contaminant sources; and
- Consultation with municipal staff/employees.

### *7.1.1 BMROSS Historic Files*

Several useful documents were reviewed from the BMROSS files pertaining to dredging operations within the harbour, infrastructure projects within the Town of Goderich, and other harbour improvements that have occurred in the past decade. Several of these reports are summarized in Section 2.6. They provided relevant soil, water and sediment sampling data for the harbour area. This information was included in a contaminant inventory prepared for the town, which will be utilized in conjunction with the model to determine the source of potential threats.

In 2003, BMROSS prepared a report for the Town of Goderich pertaining to improvements to the Pollution Control Plant, which is located at the south end of the Goderich urban area, adjacent to Lake Huron. Portions of the Town's sanitary and storm water system were "combined", leading to occasional raw sewage discharges to Lake Huron during high flow events. The report examined the existing storm sewer system, identified individual catchments, and located potential cross contaminations within the system (sources of combined sewage flows).

Mapping prepared in conjunction with this report was utilized with digital aerial photography as a base for the contaminant inventory. In this way, potential contaminant sources could be identified within individual storm sewer catchments.

### *7.1.2 Harbour Activities*

An interview was conducted with the Harbour Master on October 23, 2006. A copy of the entire interview is included in Appendix D. The following key information was obtained during the interview:

- To his knowledge, there have been no significant spills which have occurred within the Goderich Harbour;
- A majority of shipping activity within the harbour is related to agricultural commodities (associated with the Mill) or with the salt mine. None of the activity would present a significant concern to the water intake facility, in his opinion;
- Should a spill occur, an Emergency Spill Action Plan has been prepared to deal with the event in conjunction with the local fire department and coast guard detachment;

- The only storage facility in the harbour of any concern is hydrogen sulfide storage adjacent to the Sifto facility (new storage facility recently constructed within past 5 years);
- No significant fuel storage tanks – large ships are fueled by tanker trucks, which come to the area and pump fuel directly onto ships.

### *7.1.3 Regional Contaminant Inventory*

The most recent provincial contaminant inventory was reviewed for potential sources of threats. The inventory contained limited information for the Town of Goderich, which were subsequently verified in the field. Due to the limited detail provided within the provincial data base, it was determined that a majority of the potential threats would be identified through interviews with municipal staff/employees and a physical inventory of the community and surrounding countryside.

### *7.1.4 Field Inventory*

Using the local knowledge of BMROSS staff (BMROSS has been located within the Town of Goderich since 1951, and has acted as municipal engineer on several municipal infrastructure projects), local contaminant sources were located by utilizing a hand held geographic positioning system (GPS) unit. A description of the potential contaminant was also collected along with street address, digital photo, legal description, business name and closest sanitary storm sewer connection. Table 7.1 summarizes the potential threats located within the preliminary IPZ. These are further illustrated in Figure 7.1.

### *7.1.5 Local Knowledge*

The Town of Goderich staff was provided with the list of potential contaminant sources located within the preliminary intake protection zone, their relative location and source (i.e. business address and description) for verification. Additional contaminant sources, which were identified within the Threats Inventory Module, were also supplied to the Town for identification of additional potential contaminant sources.

## 7.2 Inventory of Constructed Pathways

The Town of Goderich is serviced by full municipal sewage and water facilities. The review of potential constructed pathways focused on man-made and natural drainage systems, which provide a direct pathway for contaminants to reach the surface water intake.

As discussed in Section 7.1.1, a storm sewer system services much of the community, consisting of eleven separate discharge locations to Lake Huron and the Maitland River. The storm sewer system has been divided into individual drainage catchments, which conduct surface and sub-surface flows to the various outlets. Travel times within the various catchments will vary dramatically based on flow rates, proximity to an inlet and size of the individual catchment area. These variables have been identified as significant data gaps and will be addressed in phase two of the study through a detailed modeling exercise to be conducted on the storm sewer system.

Several surface and subsurface drainage systems, which discharge to the Maitland River, are identified in Figure 7.1. These present potential pathways for contaminants to reach the river and ultimately the Goderich Water Treatment Plant. Both agricultural and private drainage outlets were identified along the river reach stretching from the harbour to the settlement of Saltford. Potential threats located adjacent to these pathways have been inventoried and will be assessed in conjunction with the detailed modeling of the system.

## 7.3 Issues Evaluation

An issue, as defined by the draft MOE Guidance Modules, "is a substantiated condition relating to the quality of water that interferes, or that can be reasonably predicted to interfere with the use of a drinking water source in the near term if rising trends continue. Issues are typically associated with a specific land use activity (threat), past of present, but can also reflect a natural occurrence."

Based on the analysis to date, including consultations with the Water Treatment Plant Operator and the study team, it has been determined that there are few substantiated issues effecting the Goderich Water Treatment Plant.

Conditions at the intake have occasionally presented a challenge for treatment. This has generally been related to high turbidity or alkalinity levels. The facility has never been required to shut down due to these conditions. The operator indicated that adverse treatment situations are often related to natural occurrences within the lake or river (wave action/high volume run off events) and are not known to be directly related to a potential contaminant-based threat.

The operator did indicate that a significant number of threats were present within the immediate vicinity of the intake that, in his opinion, presents significant potential risks to the facility. These include discharges from the Goderich STP, activities within the Goderich Harbour (including the Sifto Salt Mine), agricultural activities adjacent to the Maitland River, and storm sewer discharges adjacent to the Water Treatment Plant. These activities have been assessed in conjunction with this study.

# Table 7.1
## Contaminant Inventory

| UNIQUE ID | OWNER | BUSINESS NAME | STREET ADDRESS | SITE REVIEW DATE | UTM EASTING | UTM NORTHING | LOCATIONAL ACCURACY | SITE DESCRIPTION | POSSIBLE CONTAMINANTS | CONTAMINANTS RELATIVE TO PROPERTY LIMITS (m) | CLOSEST STORM SEWER INLET | PHOTO ID |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Goderich Elevators | 230 Harbour St | 4-Dec-06 | 441753 | 4843679 | 04 | Grain Elevators | Chemical, Fuel | 15 | On site/ Road (10m) | Dec4-06-1 |
| | Town of Goderich | Beach Sewage Pump Station | | 4-Dec-06 | 441602 | 4843778 | 02 | Sewage Pump Station | Fecal Matter | 4 | Road (10m) | Dec4-06-2 |
| | Town of Goderich | | Cove Road | 4-Dec-06 | 441553 | 4843305 | 03 | Storm Sewer Catch Basin-3 | Chemical, Pathogen | | | Dec4-06-3 |
| | Town of Goderich | | Cove Road | 4-Dec-06 | 441460 | 4843305 | 03 | Storm Sewer Outlet-3 | Chemical, Pathogen | | | Dec4-06-4 |
| | Town of Goderich | Water Treatment Plant | Cove Road | 4-Dec-06 | 441495 | 4843160 | 03 | Water Plant | Chemical | 20 | On site/ Road (10m) | Dec4-06-5 |
| | Town of Goderich | Wastewater Treatment Plant | | 4-Dec-06 | 441578 | 4842099 | 03 | WWTP Outlet-2 | Fecal Matter, Chemical, Pathogens | | | Dec4-06-6 |
| | Town of Goderich | | | 4-Dec-06 | 441622 | 4841930 | 05 | Storm Sewer Outlet-1 | Chemical, Pathogen | | | |
| | | Goderich Elevators | | 4-Dec-06 | 441694 | 4842675 | 05 | Trucking Probe | Chemical | | On site/ Road (10m0 | Dec4-06-7 |
| | | Gords Car Wash | Kingston | 4-Dec-06 | 442877 | 4843469 | 04 | Car Wash | Chemical | 10 | Road (10m) | Dec4-06-8 |
| 95781-96131 | | Kechnie Chevrolet Oldsmobile | 74 Kingston | 4-Dec-06 | 442918 | 4843380 | 03 | Auto Repair-Dealership | Chemical, Fuel | 10 | On site/ Road (10m0 | Dec4-06-9 |
| 95423 | | Petro-Canada | 63 Victoria St S | 4-Dec-06 | 443042 | 4843345 | 03 | Gas Station-Fuel Storage | Fuel | 15 | Road (20m) | Dec4-06-10 |
| 96136 | | Sunoco | 87 Victoria St S | 4-Dec-06 | 443034 | 4843223 | 03 | Gas Station-Fuel Storage | Fuel | 15 | Road (20m) | Dec4-06-11 |
| 93540 | | Esso | 274 Bayfield Rd | 4-Dec-06 | 443132 | 4842589 | 03 | Gas Station-Fuel Storage, Car Wash | Fuel, Chemical | 15 | On Site/ Road (20m) | Dec4-06-12 |
| | | Heubner-Ridder Veterinary Hospital | 376 Bayfield Rd | 4-Dec-06 | 443316 | 4842125 | 03 | Veterinary Hospital | Drugs, Chemical | 20 | On Site/ Road (20m) | Dec4-06-13 |
| | | Home Hardware | 370 Bayfield Rd | 4-Dec-06 | 443107 | 4842155 | 03 | Household Supplies | Chemical | 20 | On Site/ Road (20m) | Dec4-06-14 |
| | | Speedy Glass | 356 Bayfield Rd | 4-Dec-06 | 443119 | 4842197 | 04 | Auto Glass Repair | Chemical | 10 | On Site/ Road (20m) | Dec4-06-15 |
| | | Solo | Bayfield Rd | 4-Dec-06 | 443184 | 4842061 | 03 | Gas Station- Fuel Storage | Fuel | 10 | On Site/ Road (20m) | Dec4-06-16 |
| | | South End Body | 440 Bayfield Rd | 4-Dec-06 | 443138 | 4841932 | 03 | Auto Repair | Chemical, Fuel | 20 | On Site/ Road (20m) | Dec4-06-17 |
| | | TSC | Bayfield Rd | 4-Dec-06 | 443048 | 4841989 | 03 | Farm and Household Supplies | Chemical | 30 | On Site/ Road (20m) | Dec4-06-18 |
| | | Zellers | Bayfield Rd | 4-Dec-06 | 443277 | 4841997 | 03 | General Merchandise | Chemical | 50 | On Site/ Road (75m) | Dec4-06-19 |
| | | Maitland Recreational Centre | 190 Suncoast Dr E | 4-Dec-06 | 443495 | 4842139 | 03 | Indoor Pool-Arena | Chemical | 50 | On Site/ Road (100m) | Dec4-06-20 |
| | | McGee Pontiac Buick Cadillac | 180 Suncoast Dr E | 4-Dec-06 | 443328 | 4842256 | 03 | Auto Repair-Dealership | Chemical, Fuel | 50 | On Site/ Road (20m) | Dec4-06-21 |
| | | Art's Landscaping | 166 Bennett St E | 4-Dec-06 | 443368 | 4842324 | 04 | Landscaping, Paving | Chemical, Fuel Storage | 50 | On Site/ Road (20m) | Dec4-06-22 |
| | | Suncoast Car Wash | 153 Suncoast Dr E | 4-Dec-06 | 443343 | 4842340 | 03 | Car Wash | Chemical | 10 | Road (30m) | Dec4-06-23 |
| 93668 | | Timbre Mart | 295 Bayfield Rd | 4-Dec-06 | 443177 | 4842466 | 03 | Construction Supplies, Private Fuel Outlet | Chemical, Fuel Storage | 10 | On Site/ Road (30m) | Dec4-06-24 |
| | | True-Centre Napa AutoPro | 101 Bennett St E | 4-Dec-06 | 443093 | 4842547 | 03 | Auto Repair | Chemical, Fuel | 10 | On Site/ Road (10m) | Dec4-06-25 |
| | | Goderich Honda | 268 Bayfield Rd | 4-Dec-06 | 443112 | 4842606 | 03 | Auto Repair | Chemical Fuel | 10 | On Site/ Road (20m) | Dec4-06-26 |
| | | Goderich Dental Centre | 169 Bayfield Rd | 4-Dec-06 | 443186 | 4842931 | 03 | Dentist | Chemical, Drugs | 10 | Road (10m) | Dec4-06-27 |
| | | Argyle Marine | 88 Britannia St E | 4-Dec-06 | 443060 | 4843128 | 04 | Boat Repair | Chemical, Fuel | 10 | Road (50m) | Dec4-06-28 |
| | | Shell | 137 Victoria St N | 4-Dec-06 | 443000 | 4844094 | 03 | Gas Station-Fuel Storage | Fuel | 10 | Road (15m) | Dec4-06-29 |
| 95936 | | Esso | 79 Victoria St N | 4-Dec-06 | 442995 | 4843891 | 04 | Gas Station-Fuel Storage, Auto Repair | Fuel, Chemical | 10 | Road (15m) | Dec4-06-30 |
| | | Rona-Cashway | 155 Anglesea St | 5-Dec-06 | 443317 | 4844136 | 04 | Construction Supplies | Chemical | 20 | Road (20m) | Dec5-06-1 |
| 92917 | | Edward Fuels | 202 Anglesea St | 5-Dec-06 | 443485 | 4844030 | 04 | Bulk Fuel Plant | Fuel, Chemical | 20 | Road (20m) | Dec5-06-2 |
| | | Volvo Plant | Maitland Rd | 5-Dec-06 | 443755 | 4843356 | 03 | Grader Plant | Chemical | 30 | On site/ Road (30m) | Dec5-06-3 |
| 7013 | | Sifto Evaporator Plant | 245 Regent St | 5-Dec-06 | 443948 | 4853199 | 04 | Brine Field | 11250-22500L of brine Sol'n to ground | 10 | Road (10m) | Dec5-06-4 |
| | | Sifto Evaporator Plant | 245 Regent St | 5-Dec-06 | 443948 | 4853199 | 04 | Salt Plant | Salt, Other Chemicals | 10 | Road (10m) | Dec5-06-4 |
| 10483AH01 | | Sifto Evaporator Plant | 245 Regent St | 5-Dec-06 | 443870 | 4843021 | 04 | Salt Plant | PCB | 10 | Road (10m) | Dec5-06-4 |
| 93425 | | Laidlaw Bus Line | 257 Cambridge St | 5-Dec-06 | 443833 | 4843016 | 03 | Bus Line-Private Fuel Outlet | Fuel | 10 | Road (10m) | Dec5-06-5 |
| 93201 | | Laidlaw Bus Line | 233 Cambridge St | 5-Dec-06 | 443833 | 4843016 | 03 | Bus Line-Private Fuel Outlet | Fuel | 10 | Road (10m) | Dec5-06-5 |
| 94170 | Town of Goderich | Public Works Shed | 361 Cambridge St | 5-Dec-06 | 444088 | 4842647 | 03 | Truck Repair, Storage, Private Fuel Outlet | Fuel, Chemical | 10 | Road (10m) | Dec5-06-6 |
| | | Gardiner's | 393 Cambridge St | 5-Dec-06 | 444191 | 4842549 | 03 | Truck Repair and Wash | Chemical, Fuel | 10 | Road (10m) | Dec5-06-7 |
| | Falconer Funeral Homes Ltd | Bluewater Funeral Chapel | 201 Suncoast Dr E | 5-Dec-06 | 443507 | 4842340 | 03 | Funeral Home | Chemical | 20 | On Site/ Road (30m) | Dec5-06-8 |
| | | Da-Lee Dust Control | MacEwen St | 5-Dec-06 | 443674 | 4841847 | 04 | Dust Suppressant | Chemical | 40 | Road (50m) | Dec5-06-9 |
| | | Goderich Signal Star | 120 Huckins St | 5-Dec-06 | 443229 | 4841719 | 03 | Newspaper | Chemical | 50 | Road (60m) | Dec5-06-10 |
| | | TTK Transport Services | 551 Mooney St | 5-Dec-06 | 443388 | 4841544 | 03 | Truck Repair & wash | Chemical, Fuel | 10 | Road (60m) | Dec5-06-11 |
| | | Automotive Machine Shop (Ideal Supply) | 208 Suncoast Dr E | 5-Dec-06 | 443645 | 4842251 | 03 | Car Repair | Chemical | 10 | Road (20m) | Dec5-06-12 |
| | Town of Goderich | Parsons Leachate Holding Tank | Parsons Court | 5-Dec-06 | 444080 | 4842041 | 03 | Leachate Holding Tank | Chemical, Pathogens | 10 | Road (15m) | Dec5-06-13 |
| | | Eastside Auto Repairs | 411 Parsons Court | 5-Dec-06 | 444103 | 4842065 | 05 | Auto Repair | Chemical | 15 | Road (50m) | Dec5-06-14 |
| | | Huron Transmission | 371 Parsons Court | 5-Dec-06 | 444062 | 4842122 | 03 | Auto Repair | Chemical | 20 | Road (50m) | Dec5-06-15 |
| | | Huronia Welding & Industrial Supply | 282 Suncoast Rd E | 5-Dec-06 | 443963 | 4842275 | 03 | Welding, Propane Storage | Chemical | 30 | Road (30m) | Dec5-06-16 |
| | | Windsor-The Canadian Salt Company | 436 Huron Rd | 5-Dec-06 | 444205 | 4842361 | 03 | Salt Storage Warehouse | Salt | 10 | Road (50m) | Dec5-06-17 |
| | | Goderich Print Shop | 413 Huron Rd | 5-Dec-06 | 444238 | 4842399 | 04 | Printers | Chemical | 10 | Road (20m) | Dec5-06-18 |
| | | Car Wash | Britannia St | 5-Dec-06 | 443548 | 4843319 | 03 | Car Wash | Chemical | 5 | Road (20m) | Dec5-06-19 |
| | | Alexandra Marine & General Hospital | 120 Napier St | 5-Dec-06 | 443203 | 4844335 | 05 | Hospital | Chemical, Pathogens | 20 | Road (20m) | Dec5-06-20 |
| | Town of Goderich | | South Harbour Wall | 6-Dec-06 | 441713 | 4843810 | 01 | Storm Sewer Outlet-4 | Chemical, Pathogens | | | Dec5-06-1 |
| | Town of Goderich | | Maitland Golf Course-Hole 8 | 6-Dec-06 | 442545 | 4844350 | 01 | Storm Sewer Outlet-5 | Chemical, Pathogens | | | Dec5-06-2 |
| | Town of Goderich | | Maitland Golf Course-Parking Lot SW corner | 6-Dec-06 | 442837 | 4844453 | 04 | Storm Sewer Outlet-6 | Chemical, Pathogens | | | |
| | Town of Goderich | | North Bridge on Hwy 21 at SE corner | 6-Dec-06 | 443564 | 4844385 | 01 | Storm Sewer Outlet-7 | Chemical, Pathogens | | | Dec5-06-3 |
| | Town of Goderich | | East End of Anglesea St | 6-Dec-06 | 443589 | 4844097 | 03 | Storm Sewer Outlet-8 | Chemical, Pathogens | | | Dec5-06-4 |
| | | Sifto Lagoons | Maitland Rd | 6-Dec-06 | 444080 | 4843288 | 05 | Evaporator Steam Waste | Chemical, Pathogens | 10 | 50m to River | Dec5-06-5 |
| | Town of Goderich | | Maitland Rd | 6-Dec-06 | 444000 | 4843189 | 05 | Storm Sewer Outlet-10 | Chemical, Pathogens | | | |
| | Town of Goderich | | Maitland Rd | 6-Dec-06 | 443721 | 4843560 | 03 | Storm Sewer Outlet-9 | Chemical, Pathogens | | | Dec5-06-6 |
| | Town of Goderich | | Mill Rd | 6-Dec-06 | 444466 | 4842506 | 03 | Storm Sewer Outlet-11 | Chemical, Pathogens | | | Dec5-06-7 |
| | | Maitland Golf Course | North Harbour Rd | 14-Dec-06 | 442817 | 4844325 | 01 | Golf Course & Curling Club | Chemical | 5 | Directly into River | |
| | | Maitland Valley Marina & Trailer Park | 100 North Harbour Rd | 14-Dec-06 | 442324 | 4844085 | 03 | Marina & Trailer Park | Chemical, Fuel, Pathogens | 5 | Directly into River | |
| | | Da-Lee Dust Control | 310 North Harbour Rd | 14-Dec-06 | 441443 | 4844158 | 03 | Storage Tank | Liquid Calcium, Fuel | 1 | Directly into River/ Lak | Dec14-06-1 |


Figure 7.1 Contaminant Inventory

## 8.0 DATA GAPS ANALYSIS

A data gaps analysis was conducted following the preliminary data collection component of the study, to identify data that does not exist and that would be required to complete the analysis.

1. It was determined that there is a sufficient database for water quality and quantity within the Maitland River and the harbour area adjacent to the intake (raw water quality data).
2. However, a significant data gap was identified relating to water quality conditions within the storm sewer system. Though individual storm water catchments had been identified through a previous BMROSS study, no modeling of the system had been completed which would provide time of travel estimates for potential threats.
3. An additional data gap exists for water quality within the storm sewer system. Though the assessment completed in Section 3.6.4 could not establish a direct relationship between storm sewer discharges and elevated alkalinity levels at the treatment facility, no chemical or other hazard-based sampling of the storm sewer system has been undertaken to assess potential threats presented by various land uses located within the Goderich urban area.
4. Previous sampling of the system has focused on bacterial levels (E.coli), to determine potential sources of combined sewer overflows (CSO's) and did not assess other potential contaminant sources.
5. Limited sediment sampling data exists. Additional data would be beneficial.
6. ADCP data was collected in the study area by MOE from May to November 2003. Calibration of the model with this data is strongly recommended to improve the level of confidence in the modeling results and IPZ-2 delineation.
7. Additional model limitations are described in Section 4.5.
8. Cross-section data for the Maitland River were taken from the bathymetry field sheet for the lake. The data provides an approximation of the river cross-section only. In addition, due to lack of any additional upstream data, it was assumed that the upstream river cross-sections are the same as the river mouth. This is also an approximation and actual river cross-section data should be collected in Phase 2 to better define the velocities in the river and the IPZ-2 limits.
9. Cross-section data for the small tributaries flowing into the IPZ-2 is required to calculate flow velocities to delineate the upstream limit of the IPZ-2 at the tributaries. The flow in the tributaries can be estimated using empirical methods.
10. The data sources provide inconsistent information on the depth of the intake. This should be confirmed by a survey, possibly undertaken during the next scheduled inspection of the intake.
11. Field studies such as dye tracers could be used to differentiate the potential for flow from the outfalls south of the intake vs. flow from the Maitland River impacting water quality at the intake. High river flow and high flow at the outfalls can occur as a result of high rainfall, and it is difficult to otherwise differentiate potential impacts on water quality.

## 9.0 IPZ DATA SETS

Spatial datasets are included on the attached CD (Appendix E). The datasets include Surface Water Intake, Surface Water Intake Protection Zone 1 (IPZ-1) and Surface Water Intake Protection Zone 2 (IPZ-2). These have been prepared in accordance with the document "Assessment Report Outputs: Data Specifications Version 3.0, October 24, 2006

# 10.0 SUMMARY AND CONCLUSIONS

- Data collection and review have been undertaken in support of intake protection zone delineation consistent with the methodologies outlined in Assessment Report: Draft Guidance Module 4 (MOE, 2005). The data reviewed includes bathymetry, wind, current, and flow data for the Maitland River, water quality samples from the WTP, the lake and the Maitland River, as well as sediment samples. Numerous technical reports were also reviewed.
- Intake characterization was completed based on a review of engineering drawings, an interview with the Water Treatment Plant Operator, the water treatment plant chief operator, analysis of water quality and an assessment of the hydrodynamic processes in the area. The intake extends approximately 518 m from the Water Treatment Plant and is located at an estimated 7 m depth. Numerous threats are located within a 1-2 km distance from the intake including the Maitland River; Goderich STP discharge; numerous storm sewer outfalls discharging north and south of WTP and into the Maitland River; marinas in the Maitland River; mining activities and salt storage at the mouth of the Maitland river and adjacent to the harbour; and commercial shipping and recreational boating.
- The Operator reported that the WTP could be shut down immediately upon notification. The 2-hour minimum travel time was therefore used for delineation of the IPZ-2.
- Raw water quality data (alkalinity, turbidity, temperature, and E. Coli) were reviewed in an effort to identify potential relationships and sources of contaminants. Concentrations of metals and pesticides in raw water at the Treatment Plant were found to be too low, and sampling too infrequent, to identify any trend in water quality. For the years 1990 to 2005, average annual chloride, nitrate, phosphorus, and sodium concentrations in the raw water at the intake have not displayed any sustained increase or decrease, though sampling frequency is again too low to statistically identify any trends.
- Analysis of turbidity and flow data for the years 2003 to 2006, showed that only 19% of high turbidity and high flow events occurred on the same day, and the majority of high turbidity events occurred during the months prior to the majority of high flow events. When wind was considered, some correlations were observed: a high flow event that was not accompanied by significant winds did not result in increased turbidity at the intake; turbidity increased above 100 NTU when high flow events coincided with high wind events; and when there was high flow and winds were offshore, there was no significant increase in turbidity. These findings were generally consistent with the observations of the WTP Operator, however the Operator reported high turbidity when offshore winds combine with high flow events. This was not consistent with the data analyzed.
- Based on data for the years 2003 to 2006, there was not sufficient information to suggest a definite relationship between storm sewer discharge and raw water quality at the intake. The data indicated that alkalinity can increase following a high flow event, particularly when winds were from the north; however, a more detailed analysis would be required to better understand the processes. No linear relationship between rainfall events greater than 20 mm and raw water alkalinity could be determined. Only 10% of all turbidity events followed a significant rainfall event. Approximately one half of all alkalinity increases of more than 30% in one day followed rainfall events. Furthermore, the typical lag between rainfall events and alkalinity increases was two days. As rainfall events would also cause an increase in river discharge, it was not possible to differentiate between increases in alkalinity caused by river flow and those caused by storm sewer discharge.
- Numerical modeling was undertaken in support of IPZ-2 delineation using the LHOFs model to define boundary conditions for the Delft3D model. The Delft3D model selected for use on this project is a three dimensional hydrodynamic model with wave, sediment and water quality modules.

It uses curvilinear grids, which are suitable for the complicated shoreline boundary conditions. MOE is currently applying the Delft3D model in Lake Huron (using the 2D feature) and consideration was given to the mutual benefits of sharing data and modeling results with the funding agency.

- Backward particle tracking was used to delineate the preliminary IPZs for the intakes. The model was run for the two, 3-week periods including the most severe storms in 2003. Neutrally buoyant particles were introduced at the intake. The model was run in reverse mode with the particles tracking the paths by which the currents would have transported neutrally buoyant particles to the intake over a 2-hour travel time. The preliminary IPZs are shown in Figure 5.1. The limits of the 2-hour travel time extend approximately 1.5 km north, 4 km south, 1.0 km offshore of the intake, and about 1 km up the river.
- Based on the modeling undertaken, the probability of contaminants from the river reaching the intake within the 2-hour travel time is relatively small. The presence of the jetties and the offshore breakwaters limits the distance the IPZ-2 extends inshore, up the river. Based on the modeling, the Waste Water Treatment Plant outfall is located approximately 1.5 hours from the intake.
- The limitations of the modeling used to delineate the IPZs are as follows: the model is uncalibrated, a limited number of runs have been undertaken and no return period has been associated with the events used in the analysis, and the river cross-section used to calculate travel times up the Maitland River has been estimated. It is recommended that the model be valibrated in Phase 2, that a statistical analysis be undertaken to define extreme events and associated return periods, and that additional runs be completed to delineate the IPZ-2.
- Vulnerability scores have been recommended for the IPZs. Vulnerability scores of 6 (IPZ-1) and 5.4 (IPZ-2) classify this intake as medium to high risk. This is appropriate considering the proximity of the Maitland River and the number of outfalls in the IPZs.
- There is a high level of uncertainty associated with the IPZ-2 delineation and the vulnerability scores at this time, due to the limitations on the modeling, including the use of an uncalibrated model and the data gaps. It is recommended that these issues be addressed in Phase 2.
- A threats inventory and issues evaluation was undertaken. There are a significant number of threats within the IPZs, as shown in Figure 7.1. These include: discharges from the Goderich STP, activities within the Goderich Harbour (including the Sifto Salt Mine), agricultural activities adjacent to the Maitland River and storm sewer discharges adjacent to the Water Treatment Plant and marina activities within the Maitland River.
- A data gaps analysis was conducted following the preliminary data collection component of the study. The data gaps are summarized in Section 8.

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