SCREENING LEVEL HUMAN HEALTH RISK ASSESSMENT
HALIFAX HARBOUR SOLUTIONS PROJECT

PROJECT NO. NSD13960-6029

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REPORT TO

HALIFAX REGIONAL MUNICIPALITY

ON

SCREENING LEVEL HUMAN HEALTH RISK ASSESSMENT
HALIFAX HARBOUR SOLUTIONS PROJECT

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EXECUTIVE SUMMARY

At the request of the Halifax Regional Municipality (HRM), Jacques Whitford Environment Limited (JWEL) has undertaken a Screening Level Risk Assessment (SLRA) to evaluate the potential risks to public health associated with the construction and operation of four proposed municipal sewage treatment plants (STPs) that comprise the proposed Halifax Harbour Solutions Project (HHSP).

The HHSP is a regional treatment system to reduce the amount of raw sewage which is currently being discharged into Halifax Harbour. The HHSP requires a screening level environmental assessment pursuant to the *Canadian Environment Assessment Act* (CEAA). The HHSP will also require technical review and approvals from the Nova Scotia Department of the Environment and Labour (NSDEL, formerly Nova Scotia Department of Environment (NSDOE)) in order to construct and operate the STPs.

The purpose of this study is to qualitatively evaluate the potential risks to human health associated with three specific aspects of STPs, including: potential airborne contaminants from STP operations; waterborne contaminants from sewage effluent entering the harbour; and the treatment of sewage sludge. The human receptors examined included both adult and children neighbouring residents and also recreational water users (*i.e.*, SCUBA divers, swimmers, etc). The risks are compared to the current human exposures associated with the discharge of untreated sewage through over 40 sewage outfalls into Halifax Harbour.

This study concluded the following:

- Large volumes of untreated sewage are currently entering Halifax Harbour resulting in a contribution of inorganic, organic and biological waste. This waste consists of pathogens and chemicals, which have a detrimental impact on water quality, sediment quality, and may be accumulated by aquatic organisms which inhabit Halifax Harbour and are, or could potentially be, harvested for food.

- Airborne contaminants, in the form of VOCs, are currently released from sewage at outfalls. A small amount of these contaminants will be released from the STPs, however the concentrations will be very low and well below guideline limits developed to protect human health.

- Recreational users of the harbour who are directly exposed to harbour water are currently at risk from sewage related pathogens. Health risk from this type of activity will be reduced due to a significant decrease in pathogens and other contaminants related to sewage treatment.

- The construction and operation of STPs are considered to be a positive step toward improving current human exposures and associated health risks from impacts to harbour water, sediment and ambient air, as well as the aquatic organisms which are, or could potentially be a food source for humans. Immediate and significant improvements will be realized as each of the four STPs is phased in over a ten year period.

- Although current concentrations of persistent and bioaccumulative contaminants will remain, the addition of new contaminants will proceed at a significantly reduced rate. The benefit of sewage treatment must therefore be regarded as an overall significant improvement to the current discharges of chemical and biological compounds currently entering Halifax Harbour.

In general, there is expected to be an overall improvement in the water quality, sediment quality, and air quality due to the HHSP resulting in decreased health risk from human exposures through direct contact, inhalation or ingestion of organisms harvested from Halifax Harbour. The proposed sewage treatment project will provide a proven means for HRM to reduce risks associated with existing exposure to untreated sewage.

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1.0 INTRODUCTION

At the request of the Halifax Regional Municipality (HRM), Jacques Whitford Environment Limited (JWEL) has undertaken a Screening Level Risk Assessment (SLRA) to evaluate the potential risks to public health associated with the construction and operation of four proposed municipal sewage treatment plants (STPs) for the Halifax Harbour Solutions Project (HHSP).

The STPs are located at: Halifax North (Cornwallis and Barrington Streets); Dartmouth (Coast Guard Station South of Dartmouth Cove); Halifax South (railyards area); and Herring Cove. Refer to Appendix A for maps indicating the locations of project infrastructure.

The HHSP is a regional sewage treatment system to reduce and treat raw sewage which is currently being discharged to the Harbour. The HHSP requires a screening level environmental assessment pursuant to the *Canadian Environment Assessment Act* (*CEAA*).The HHSP will also require technical review and approvals from Environmental Health Engineers within the Nova Scotia Department of the Environment and Labour (NSDEL, formerly Nova Scotia Department of Environment).

The purpose of this study is to qualitatively compare the potential human health risks to adjacent residents from exposure to contaminant discharges resulting from the ongoing operation of the STPs. This includes an evaluation of the treated sewage effluent, air quality, water quality and sewage sludge management practices. The receptors of concern include both nearby adult and children residents and also adult recreational harbour users (*i.e.*, SCUBA divers, swimmers, etc.). The study was conducted to review the concerns of HRM citizens with respect the location of sewage treatment plants in proximity to existing residential properties.

The SLRA has been undertaken utilizing a "qualitative" risk assessment approach. This includes a qualitative comparison between risks and exposures associated with the project and net increase or decrease in public health risk associated with the current situation (*i.e.*, no sewage treatment).

1.1 Regulatory Framework

1.1.1 Canadian Environmental Assessment Act (CEAA)

The construction and operation of the proposed STPs trigger an environmental assessment (EA) under the *CEAA*. Triggers for a *CEAA* assessment include the transfer of federal land for one site (Dartmouth) and federal regulatory authorization including approvals under the *Fisheries Act* and the *Navigable Waters Protection Act (NWPA).* Federal funding, if provided, would constitute another trigger for a *CEAA* assessment.

A screening level EA is currently being undertaken with Fisheries and Oceans Canada as the federal department responsible for the assessment. A number of Valued Environmental Components (VECs) have been identified upon which to focus the assessment, including human health. An EA under the Nova Scotia *Environment Act* is not required.

1.1.2 Nova Scotia *Environment Act* and Regulations

The *Activity Designation Regulations* under the Nova Scotia *Environment Act* identify certain activities which require a regulatory approval from NSDEL. Section 7(2) of the *Regulations* designates the construction, operation or reclamation of sewage works as an activity, where sewage works includes: sewage collection systems and pumping stations; retention or storage facilities; treatment facilities; and outfalls

In addition, the HHSP is expected to include options for the collection and offsite treatment/composting of stabilized sewage sludge removed from the primary treatment cells of the STPs. Section 26 of the *Regulations* also designates the "construction , operation or reclamation of an industrial composting facility" as an activity, thereby requiring regulatory approval from NSDEL.

1.1.3 Canadian Council of Ministers of the Environment (CCME) Environmental Quality Criteria

NSDEL has not developed specific environmental quality criteria for contaminants in marine water or sediment, however, it does endorse the Canadian Council of Ministers of the Environment (CCME) sediment and surface water quality criteria for use (which is also approved by federal regulators). Criteria have been derived for both marine and freshwater sediment and surface water as well as for soil and biota tissue. The CCME (1999) criteria defines acceptable concentrations of specific contaminants in these media below which no adverse effects to ecological receptors are expected. In addition to these guidelines, the CCME also outlines acceptable health and safety and aesthetic parameters for recreational water use. A copy of the Recreational Water Use Guidelines is presented in Appendix B.

1.1.4 Composting Guidelines

The HHSP Concept Plan involves construction and operation of a central sludge composting facility to process stabilized sewage sludge for beneficial end use (e.g., compost or land spreading). CCME has developed *Guidelines for Compost Quality* (1996) for composted material intended for sale or to be given away. These Guidelines are based on four criteria involving product safety and quality: foreign matter; maturity; pathogens; and trace elements. The Guidelines apply to all compost produced from municipal solid waste or other feedstock as determined by regulatory agencies. It provides guidelines for maximum concentrations of metals, carbon and nitrogen, and pathogens acceptable in compost material.

NSDEL's *Composting Facility Guidelines* (NSDOE 1998) establishes approval requirements for composting facilities in Nova Scotia, including general siting, operating procedures and acceptable concentrations of certain trace elements in compost, groundwater, leachate and surface water.

1.1.5 NSDEL Air Quality Regulations

The Nova Scotia *Air Quality Regulations* establish limits on certain air contaminants. Schedule "A" of the *Air Quality Regulations* outlines the maximum permissible ground level concentrations for carbon monoxide, hydrogen sulphide, nitrogen dioxide, ozone, sulphur dioxide and total suspended particulates (TSP).

1.1.6 Ontario Ministry of the Environment Summary of Point of Impingement Standards, Air Quality Criteria (AAQCs), and Approval Screening Levels (ASLs)

With the exception of those substances listed in the NSDEL *Air Quality Regulations*, Nova Scotia has no other ambient air quality objectives for other contaminants such as Volatile Organic Compounds (VOCs). The Ontario Ministry of the Environment (MOE) has, however, established air quality criteria and approval screening levels for acceptable contaminant concentrations in air (MOE, 1992). The criteria are twofold. They contain point of impingement standards including half hour point of impingement limit (health based) and point of impingement limiting effect (*i.e.*, odour, health reasons, etc.). They also contain ambient air quality criteria for annual, 24 hour, one hour, and ten minute exposures. These criteria have been endorsed for use in Nova Scotia by NSDEL.

1.1.7 Regulatory Acceptance of Risk Assessment Process

Human Health Risk Assessment is being used by governments, industry and public interest groups to analyze the impacts of proposed activities on public health. In Nova Scotia, the Risk Based Corrective Action (RBCA) process has been endorsed for use at petroleum contaminated sites. Nationally the Canadian Council of Ministers of the Environment (CCME) has embarked on the development of a number of Canada Wide Standards utilizing Risk Assessment as the basis for developing scientifically defendable environmental quality standards. Toxicity data used in risk assessments are generally taken from the fields of epidemiology, toxicology and ecology. The Risk Assessment process is intended to integrate this information into an evaluation of potential consequences of human exposures to some identified potential hazard.

2.0 BACKGROUND

Halifax Harbour currently receives more than 150 million litres of untreated sewage effluent per day from the metropolitan area through approximately 40 sewer outfalls. The discharge of raw sewage and surface runoff into Halifax Harbour has elevated the concentration of pathogenic microorganisms and chemical compounds in harbour waters. Public health is a concern due to exposures to pathogens through direct contact (recreational use of the harbour), inhalation of vapours from sewage effluent, and through ingestion of marine organisms, such as shellfish and crustaceans, which may be harvested in the harbour.

In order to limit the volume of untreated sewage entering the harbour, HRM has proposed the construction of up to four STPs in the Halifax-Dartmouth area.

2.1 Previous Human Health Risk Assessment (1992)

In 1992, Halifax Harbour Cleanup Inc. (HHCI) was commissioned to develop a regional sewage treatment strategy. HHCI proposed to construct one STP on an artificial island at the north end of McNab's Island, in Halifax Harbour. As part of the joint federal/provincial environmental assessment conducted for the HHCI project, a human health risk assessment was conducted to assess potential risks to human receptors.

The focus of the previous risk assessment, conducted by Bio-Response Systems Ltd. and JWEL, (1992), was on potential human health effects from microbiological pathogenic organisms, trace elements, and organic chemical compounds, for three primary harbour usages:

- recreational use in which people are in direct contact with water;
- consumption of shellfish; and
- consumption of lobster.

Excerpts related to the toxicity of pathogens are presented in Appendix B.

Potential impacts were evaluated in relation to the existing and acceptable risks as established in health guidelines and other risk assessment studies. Risks were ranked according the following criteria:

- A significant impact: defined as one that increases the risks to human health beyond acceptable levels;

- An insignificant risk: defined as one that increases risk to human health beyond existing risks but not beyond acceptable risks; and

- A positive effect: defined as one that has the potential to reduce existing risk to human health.

The study concluded that the proposed primary sewage treatment, coupled with source control and monitoring, would provide an effective method for managing potential risks to humans from contaminants and pathogens entering Halifax Harbour from the current sewer discharges.

2.2 Current Study

On May 30, 2000, a Request for Proposals (RFP) was issued by HRM for a public-private partnership for the HHSP including the design, construction and commissioning of sewage collection and treatment facilities as well as sludge handling and management systems. Conceptual plans of the sewage collection and treatment system and other related drawings included in the RFP are provided in Appendix A.

2.2.1 Outfall and STP Siting Criteria

The location of the proposed sewage treatment facilities is in part dependent on the location of selected outfalls. Finding acceptable locations for these outfalls was considered critical to minimizing potential environmental impacts to Halifax Harbour and maximizing the effectiveness of the proposed system. Significant outfall placement considerations included the following:

- Incorporation of the principle of "containment" of potential environmental effects to the area of the Inner Harbour already affected by current discharges.
- No outfall in Bedford Basin due to concerns with assimilative capacity of these receiving waters (must be south of the MacDonald Bridge).
- No outfall in the area of the Northwest Arm due to the significant recreational use in the area.
- Optimize conditions to include sufficient depth (>20 m) and strong currents to promote mixing and dispersion, as well as the provision for an engineered diffusion system to maximize effluent dispersion.
- The proposed outfall locations should be sited to reduce conflicts with anchorages and recreational beaches.

2.2.2 Proposed Collector Sewers

A system of new collector sewers is proposed to be built to intercept sewage flows currently discharging untreated into Halifax Harbour. These flows will be conveyed to up to four proposed STP locations. The collection system will be approximately 14 km in length and will include approximately nine major pumping stations.

2.2.3 Proposed Sewage Treatment Plants

The proposed STPs will include advanced primary level of treatment as a minimum, and will also include ultraviolet (UV) disinfection of the effluent prior to final discharge. NSDEL has established treatment criteria for effluent quality from the STPs. These criteria include: fecal coliforms of less than 5000/100 mL; Biological Oxygen Demand (BOD) of 50 mg/L; and suspended solids (SS) of 40 mg/L. The STPs must also be designed to provide for possible future expansion and possible upgrades to secondary treatment. Each of the STPs must be totally enclosed, under negative pressure, to provide noise and odour control. The odour control system will be designed and operated to ensure that no odours are detectable at the STP property boundary.

2.2.4 Proposed Sludge Management Operations

All STPs must be designed to include enclosed onsite sludge dewatering. Dewatered sludge is intended to be collected and transported by trucks to a central facility for stabilization, treatment and possible composting in preparation for environmentally beneficial end use. The specific nature and location of this facility will be determined when a successful proponent is chosen by HRM. The specific design details will not be known until this time.

2.2.5 Impact on Existing Treatment Facilities

The two existing STPs on Halifax Harbour (Mill Cove and Eastern Passage) are not expected to be affected by the scope of the project. The existing piping systems will be joined to a new collection infrastructure. There will be no decommissioning of existing collection systems. Some existing outfalls may continue to be used as combined sewer overflows after they are upgraded to include screening.

2.3 Community Concerns/Summary of Key Issues

As part of the most recent discussions on sewage treatment in Halifax Harbour, public information sessions were held at a number of locations in Halifax and Dartmouth. During these sessions a number of concerns were raised by local residents regarding the potential health effects of the proposed STPs adjacent to residential properties.

These concerns were summarized in a variety of correspondence and briefing materials to government officials from local residents groups. In general, the comments of the residents, can be categorized into three main concerns:

- exposures and health impacts from airborne emissions from the STPs;
- exposures and health impacts from waterborne and sediment contaminants through recreational water contact and through consumption of lobster harvested from Halifax Harbour; and

C potential exposures and health effects from the offsite management of sewage sludge.

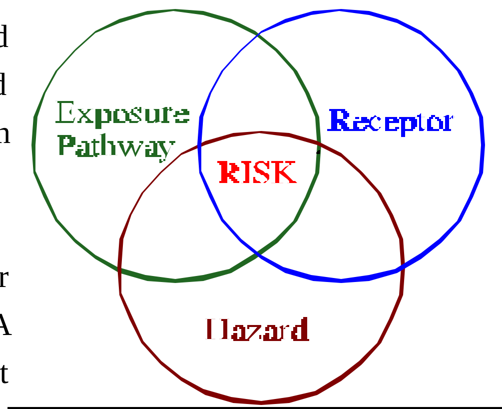
This SLRA is intended to evaluate these concerns by utilizing a qualitative risk assessment approach to identify potential risks to human receptors from air emissions, exposure to harbour water and sediments (indirectly through ingestion of shellfish and crustaceans), and sewage sludges. The context of this review is to evaluate generic public health concerns that would be common to all proposed sites, and not strictly with regard to any particular site.

3.0 RISK ASSESSMENT METHODOLOGY

The risk assessment approach has become an accepted tool to evaluate potential impacts of proposed activities on identified human receptors.

The risk assessment process typically contains four main components: hazard identification; receptor identification; exposure assessment; and risk characterization. The SLRA approach utilized in this report follows the following methodology:

Elements of Risk



- Hazard Identification - Identification of the environmental or biological hazards that may pose a health risk (*e.g.* chemicals or biological pathogens). The chemical hazards to be reviewed are generally based on the results of field testing programs and an understanding of the toxicology of the chemicals of concern (COC).

- Receptor Identification - Identification of the human and other organisms that may be exposed to the above hazard(s). A receptor survey is generally carried out to identify the most sensitive receptors for the hazards identified at the site.

- Exposure Assessment - This involves a qualitative or quantitative evaluation of the likelihood or degree to which the receptors will be exposed to the hazard. For the exposure assessment, all potential exposure pathways are identified for each hazard-receptor combination. From this list, a qualitative assessment of the likelihood of exposure can be made for each receptor- pathway combination. Those pathways with the highest likelihood of exposure (and thus with the highest likelihood to contribute a health risk) are recommended for either further assessment or risk management.

- Risk Characterization - Qualitative assessment of the actual health risk of each hazard to each receptor, based on the anticipated degree of exposure.

Uncertainty assessment is then performed to qualitatively assess the uncertainty associated with the risk estimation. All assumptions utilized and all uncertainties encountered in the study are described with an assessment of their acceptability. Details of the SLRA methodology developed by JWEL and used in this evaluation is presented in Appendix C .

3.1 Hazard Identification

3.1.1 Biological Hazards and Chemicals of Concern

With the exception of potential exposure to volatile organic compounds (VOCs), the potential pathogens and other chemicals of concern in domestic sewage and the associated hazards of exposure to these have been well defined in previous reports (Land and Sea, 1991; Bio-Response Systems Ltd. and JWEL, 1992; SNC Lavalin, 1999; Coastal Ocean Associates Inc., 1999). A summary of these hazards as follows:

- **Bacteria**: *Campylobacter* spp., enteropathogenic *Escherichia coli*, *Proteus* spp., *Pseudomonas aeruginosa*, *Salmonella* spp., *Shigella* spp., *Staphylococcus* spp., *Vibrio cholerae*, and *Yersinia enterocolitica;*

- **Viruses**: Adenoviruses, coxcackieviruses, echoviruses, hepatitis A virus, non-A, non-B hepatitis virus, Norwalk virus, poliovirusis, reoviruses, and rotaviruses;

- **Protozoa**: *Entamoeba hystolytica* and *Giardia lamblia*;

- **Metals**: includes those expected to be identified dissolved in sewage, such as cadmium, nickel, copper, lead and zinc. Additional metals which may be present include: aluminum, arsenic, barium, boron, chromium, iron, manganese, mercury, molybdenum, selenium, silver, strontium;

- **Volatile Organic Compounds (VOCs)**: studies of STPs in other jurisdictions have identified the following VOCs which may result from STP operations: acetone, benzene, chloroform, dichloromethane or Methylene Chloride (MC), tetrachloroethylene (Perc), toluene, trichloroethylene (TCE) 1,1,1, Trichloroethane (TCA); and

- **Other contaminants**: polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), petroleum hydrocarbons (TPH).

The assumed discharges and distribution of these chemicals and biological contaminants varies widely throughout the harbour. Analytical data collected from previous characterization studies are presented in Appendix D and the concentrations of selected hazards have been predicted using oceanographic modeling (Coastal Ocean Associates Inc., 1999). In order to account for potential VOCs present in the untreated sewage influent, specific VOC concentrations have been assumed based on other studies of municipal wastewater characteristics in other jurisdictions (Zhu *et al.*, 1999).

Toxicity summaries of each of the chemical and biological hazards are presented in Appendix E.

3.1.2 Properties and Toxicity of Identified Contaminants of Concern

Depending on their physical and chemical properties, the contaminants and pathogens of concern may be present in one or more media (air, water, sediment or organism tissues). Appendix E identifies the expected media where each identified substance could potentially be present, the likely exposure route, and the potential toxic effects for human receptors.

3.2 Receptor Identification

The potential human "receptors", or people which may be most affected by the potential hazards identified in the study included the following:

- adult and child residents in the vicinity of the STPs;
- harbour related recreational users (*i.e.* divers, swimmers, boaters, etc.); and
- adults and children consuming shellfish and crustaceans harvested from Halifax Harbour.

For the purpose of this SLRA, the potential receptors are characterized as an adult or child with no extreme sensitivities.

Adult employees at the STPs were not specifically assessed as part of this study. It is assumed that the health and safety of workers will be addressed by operational procedures established for the facility and managed according to relevant occupational health and safety legislation and guidelines.

3.3 Exposure Assessment

The exposure assessment evaluates the likelihood that the potential receptors can come into contact with the identified hazards. The likelihood of exposure is determined through consideration of the properties of individual contaminants which control chemical mobility, and the various pathways through which the hazard could move to contact the receptor, or through which the receptor could move to contact with the hazard. The exposure analysis also considers the possible contact mechanisms through which a hazard can be introduced to a human receptor (*i.e.*, ingestion, dermal contact, inhalation).

3.3.1 Potential Transport Pathways

The principal pathways through which the identified environmental hazards can typically contact one or more of the potential receptors include the following:

- direct contact (with sediment or water);
- transport in marine surface water;
- airborne transport (as dust or a vapour) and

- uptake into biological tissue (shellfish and crustaceans).

3.3.2 Potential Exposure Mechanisms

The mechanisms by which receptors typically become exposed to these potential hazards include:

- inhalation of vapours and particulates;
- direct ingestion of impacted sediment or water;
- indirect ingestion by ingestion of contaminated biota (*i.e.*, shellfish and crustaceans); and
- dermal contact.

Consideration of potential transport pathways and exposure mechanisms for the HHSP have been considered in the development of potential exposure scenarios for human receptors (Table 3.1). Based on the likelihood of exposure, justification is provided in Table 3.1 for the selection of the following three risk pathways for further evaluation in this SLRA:

- dermal contact with harbour water;
- ingestion of shell fish/crustaceans; and
- inhalation of VOCs (outdoor air).

Table 3.1 Potential Exposure Scenarios - Human Receptors

Exposure Pathway Description	Likelihood of Exposure	Carried Forward for Further Analysis?	Justification
Ingestion/dermal contact with contaminated sediments	Unlikely	No	The only identified receptor which may be in direct contact with harbour sediment is the recreational adult diver/swimmer. Given the depth of the harbour, the limited amount of sediment at shallow depths, the average temperature of the harbour water (necessitating the use of a 'wet-suit' or 'dry-suit' with protective hand covering), long-term exposure to the sediments is not expected to be a significant pathway and has not been further assessed.
Ingestion of harbour water	Unlikely	No	The only identified receptor which may be in direct contact with harbour water is the recreational adult diver/swimmer. Significant ingestion of marine water is not expected to be a significant pathway and has not ben further assessed.
Dermal contact with harbour water	Possible	Yes	Recreational use of the harbour may result in exposure by human receptors to harbour water (diving, sailing, swimming, etc.)

Exposure Pathway Description	Likelihood of Exposure	Carried Forward for Further Analysis?	Justification
Ingestion of shellfish/crustaceans	Possible	Yes	Harvesting of shellfish and crustaceans occurs in various areas of Halifax Harbour. Human receptors may ingest potentially contaminated shellfish and/or crustaceans.
Inhalation of VOCs (outdoor air)	Possible	Yes	Sewage related VOCs may be emitted from the STP and may migrate to adjacent properties. On-site and off-site human receptors may inhale vapours in outdoor air.
Inhalation of VOCs (indoor air)	Very Unlikely	No	Sewage related VOCs may be emitted from the STP and may migrate to outdoor air at adjacent properties. However, significant infiltration is not expected between outdoor and indoor air. Outdoor air would be considered a more significant exposure pathway
Direct contact with sludge as a result of a traffic accident	Unlikely	No	Area would be blocked from public access while cleanup is ongoing. Proper cleanup after the incident would eliminate any unacceptable exposure.
VOC emissions from sludge treatment facility (outdoor air)	Possible	No	VOC exposures from plant emissions considered a more significant pathway (already considered).
Inhalation of pathogens through outdoor air	Unlikely	No	No incidents of pathogen related illness has been reported from the operation of existing facilities within HRM.
Direct contact with chemicals/pathogens from composted sludge used on residential properties	Unlikely	No	Compost quality guidelines have been established for acceptable levels of chemical and biological compounds in treated compost.

3.4 Risk Characterization

Using site-specific information, the qualitative risk analysis was performed for the contaminants and pathogens of concern as identified in Section 3.1 of this report based on the exposure scenarios involving airborne VOCs, waterborne contaminants and pathogens and sewage sludge. No unacceptable exposures are expected from the proposed sludge management options due to regulatory approval requirements and compost quality restrictions (refer to Section 6.0).

The exposure scenarios which were considered most relevant for this study were the following:

- Off-site adult and child residents in contact with vapours in the outdoor air resulting from STP operations. Adults and children may inhale the vapours.

- Off-site adult recreational users swim/sail/dive in Halifax Harbour. Adult recreational users are exposed to potential contaminants and pathogens through dermal contact of marine water containing sewage effluent.

- Off-site adults and children ingest shellfish and/or crustaceans that were harvested in Halifax Harbour. Adults and children may ingest potential contaminants which have accumulated in these organisms from exposure to contaminated sediment and surface water.

4.0 AIRBORNE CONTAMINANTS AND PATHOGENS

4.1 Current Exposures

JWEL has identified the potential for VOCs to be present in wastewater effluent. Currently, over 40 outfalls discharge untreated sewage to Halifax Harbour. These outfalls are located in close proximity to residential and recreational areas along the Halifax and Dartmouth waterfronts. Consequently a broad cross section of the population is exposed to untreated VOC emissions from many of these outfalls.

4.2 Identification of Potential Air Contaminants from STPs

Municipal wastewater treatment plants in general emit low levels of VOCs that may be found in the influent. Due to the potential for influents to occasionally contain small quantities of chemicals from commercial and industrial sources and the identified concerns of local residents, the air pathway requires some level of quantitative evaluation in this SLRA.

Studies have indicated that any hazardous air pollutants emitted from STPs are likely to be in the form of VOCs. However, VOCs were not included in the testing parameters of the wastewater characterization study which was undertaken for the Harbour Solutions Project in 1999 (SNC, 1999). In order to account for and evaluate the potential air quality impacts from VOC emissions, a number of technical papers were reviewed which identified a variety of VOC compounds commonly found in municipal wastewater influents. The list of compounds evaluated in this study include the following:

- Acetone
- Toluene
- Dichloromethane (Methylene Chloride, MC)
- Tetrachloroethylene (Perc)
- Benzene
- 1,1,1, Trichloroethane (TCA)
- Trichloroethylene (TCE)
- Chloroform

The list of VOCs identified above has been compiled from published information collected from other studies of sewage treatment plants and are generally representative of municipal treatment plant influents. Other specific chemicals have not been considered due to lack of data or their low frequency of occurrence.

4.2.1 Modelled Scenarios

Based on the qualitative exposure evaluation completed in Section 3.3, it is expected that the most likely hazard for residents from a proposed treatment plant would be in the form of exposure to VOCs via inhalation of outdoor air. In order to evaluate these potential exposures, JWEL has undertaken air dispersion modelling to determine the relationship between the potential releases from an STP to the exposure of residents in the adjacent neighbourhoods. This relationship is then used to evaluate the safety of forecast emissions, and, if required, to provide suggested operating guidance to ensure that safe levels of emissions are maintained.

It is acknowledged that in many cases VOCs can partition or become attached to solid particles in wastewater and be carried with the solids to sludge treatment facilities. It is also acknowledged that VOCs have been reported from sludge treatment facilities. However, VOCs are generally destroyed during the composting process, and because any proposed sludge treatment facility would also have to meet the separation distances established by NSDEL, it is very unlikely that VOC generation from such facilities would result in airborne concentrations greater than those generated from the sewage treatment plant site. This VOC exposure scenario at sludge treatment facilities has thus not been selected for further evaluation.

4.2.2 Air Quality Standards

Nova Scotia has not developed air quality standards for the VOCs under consideration, therefore JWEL has selected the regulated limits of the Province of Ontario (MOE, 1992). These are in the form of one-half hour Point of Impingement Standards. The standards used in this assessment are primarily health-based; that is, the limits are deemed to represent levels that are protective of the general population.

4.2.3 Modelling Tools

JWEL has undertaken quantitative air dispersion modelling using the ISC3 model (Industrial Source Complex - Version 3). This model is recommended by the United States Environmental Protection Agency (USEPA) and has ben endorsed for use in modeling air emissions by numerous regulatory authorities in Canada including the NSDEL. The model is used to predict the dispersion of pollutants from sources in the atmosphere using local weather information and the well-accepted "Gaussian" formulation for dispersion models.

VOCs are discharged from a point source and travel with wind speed, dispersing both laterally and vertically. The turbulence of the atmosphere is reflected in the parameters of the normal distribution that the VOC concentrations follow in the horizontal and vertical dimensions.

The model simulates the dispersion for each hour of weather data provided. For this study, five years of data were evaluated, therefore the model simulated over 40,000 concentrations at various points. In each of the 40,000 cases the concentration were predicted at 400 data points in the vicinity of a hypothetical sewage treatment plant. Meteorological data inputs to the model include wind speed, direction, temperature, atmospheric stability, and mixing height. The model was used together with the assumed VOC emissions rates to complete the analysis.

4.2.4 Methodology and Model Input Data

Because the STP design has not yet been finalized, JWEL has made a number of assumptions regarding the specific exposures and pathway scenarios for the emission of VOCs from an operating facility. In this case, conservative assumptions can be made about the likely configuration and dimensions of the proposed plant as well as the transport mechanisms to assist in the evaluation. These assumptions are presented in Table 4.1.

For this evaluation, JWEL has used the results of the ISC3 model to determine the contaminant emission rates from the plant that would cause an exceedence of the air quality objectives at the plant boundaries. These maximum allowable emissions were then compared to unmitigated emission rates prorated from influent concentrations measured at other facilities (Zhu *et al.*,1999).

Atmospheric data input for the model has been selected from representative data collected at the Halifax International Airport by Environment Canada. Although the Shearwater weather station is physically closer to the Project sites, this weather station has operated intermittently over the past several years, resulting in data gaps. The high quality data set for Halifax Airport is sufficiently representative for this analysis.

Table 4.1 Evaluation of Assumptions used for Air Dispersion Model

Risk Analysis Study Factor/ Assumption	Justification	Analysis Likely to Over/Under Estimate Risk	Acceptable Assumption?
Facility Length= 50 metres Facility Width = 50 metres Facility Height = 10 metres	These assumptions represent the minimum physical dimensions required to house the facility based on maximum anticipated flow rates.	Neutral	Yes
Stack Height = 5 metres above the top of the building	A nominal stack height was used for the purposes of this analysis as the specific plant construction details were not available. This scenario represents the worst case for low stack heights (<2x height of STP building) as it is anticipated that air emissions will be emitted by vent at roof level, rather than stack.	Over-estimate	Yes
Surface area of primary treatment vessel = 1440 m^2	Estimated surface area based on existing facilities with similar flow rates.	Neutral	Yes
Surface Area of Disinfection unit 5 m^2	Estimated surface area based on other existing facilities with similar flow rates.	Neutral	Yes
Influent Flow Rate = 5.0 m^3/s	Based on average daily influent flow rates for the year 2000.	Over-Estimate	Yes
VOC removal efficiency of air scrubber	Details of the scrubber system were not available at the time of this analysis. Efficiencies may vary with scrubber media, design and operating conditions. This assumption represents the worst case scenario.	Over-Estimate	Yes
Evaluation of Exposure to modified 24 hr Point of Impingement criteria from MOE	This is the standard number used to site facilities in Ontairo and has been endorsed by NSDEL	N/A	Yes

4.2.5 Modeling Results

The results of the quantitative modeling indicate the following:

- The ISC 3 Model has been used to predict "allowable" emission rates for selected VOCs from a point source (one of the proposed STPs) such that the Ontario air quality standards would not be exceeded in the surrounding community.

- Emission rates were predicted for VOCs to be generated above primary treatment tanks at typical sewage treatment plants. These emission rates were calculated by prorating measured flow and emission rates from existing treatment plants to predicted inflow rates for the Halifax STPs.

- The calculated "maximum allowable" emission rates were then compared to the predicted emission rates from an STP as proposed. This analysis indicates that the predicted VOC emission rates from the Halifax STPs are significantly lower than the maximum allowable emission rates calculated by the model (see Table 4.2).

- The ISC 3 model predicted VOC concentrations would decrease rapidly with distance from the proposed STPs.

- The highest levels predicted were within 150 metres from the facility.

- This analysis indicates that the highest exposure concentrations at the property boundary would not exceed MOE criteria for the specified VOCs of concern.

- The predicted emission rates and maximum allowable emission rates for selected VOCs are provided in Table 4.2. for comparison.

Table 4.2 Maximum Allowable VOC Emission Rates At Source Compared to Acceptable Point of Exposure Concentrations

Parameter	Assumed Influent Concentration (mg/m³)*	Assumed Unmitigated Emission (g/s)	Maximum Allowable Emission Rate (g/s)	24 Hour Ambient Air Quality Criteria (µg/m³)	Acceptable? Concentration Does Not Exceed MOE Criteria	Multiplication Factor to Exceed MOE Criteria
Acetone	24.08	0.120	347.8	48,000	Yes	2,898
Benzene	3.08	0.015	Pending	Pending	Yes	n/a
Chloroform	2.52	0.013	3.6	500	Yes	277
Dichloromethane (MC)	3.71	0.019	12.8	1,765	Yes	674
Tetrachlorethylene (Perc)	4.66	0.023	29.0	4,000	Yes	1,260
Toluene	7.14	0.036	14.5	2,000	Yes	403
Trichloroethylene (TCE)	1.62	0.008	202.9	28,000	Yes	25,363
Trichloroethane (TCA)	0.44	0.002	833.3	115,000	Yes	416,650

* Prorated from concentrations and flowrates from measure concentrations above dissolved air flotation (DAF) treatment units at other treatment municipal waste treatment plants with industrial discharges (Zhu *et al*., 1999).

4.3 Conclusions and Risk Characterization from Airborne VOCs

VOCs measured from other sewage treatment plants are released to the atmosphere primarily through the agitation/aeration systems used to flocculate suspended particles and/or to provide a mechanism for oxidation of organics contaminants in the waste water. In this case, the STPs proposed for the HHSP utilize advanced primary treatment which includes solids removal and gravity separation. The dissolved air flotation and other forced aeration systems are not expected to be present, and thus the emission rates from the proposed STPs are expected to be significantly lower than emission rates developed for this analysis.

VOC emission rates have been calculated using the ISC3 model to identify allowable emission rates. These have then been compared to anticipated emission rates from the proposed STPs. The analysis has indicated that expected emissions would have to be 277 times greater to exceed the chloroform criteria, and as much as 417,000 times greater to exceed the air quality objective for TCA. This result indicates that the proposed treatment plants will adequately attain the Ontario Standards.

It is anticipated that the design of the facility will be enclosed under negative air pressure, and will incorporate a wet air scrubbing system to control odours and remove VOCs from the air stream. Scrubber systems can achieve up to 99 percent reduction of VOC emissions, thereby providing an additional margin of safety for the surrounding community.

5.0 WATERBORNE CONTAMINANTS AND PATHOGENS

5.1 Identification of Potential Human Exposures to Waterborne Contaminants

Previous risk assessments (Bio-Response Systems Ltd. and JWEL, 1992) have identified that waterborne contaminants and pathogens from untreated sewage being discharged into Halifax Harbour are a significant public health hazard. The previous assessment focused on a review of recreational exposures and indirect contact with contaminants via ingestion of contaminated shellfish and crustaceans.

The exposure assessment component of this report has also identified human exposures to waterborne contaminants and pathogens as significant. The significant potential pathways identified for waterborne contaminants include the following:

C dermal contact with harbour water through recreational contacts (*i.e.*, swimming, sailing, SCUBA diving, etc.); and

C ingestion of shellfish and crustaceans harvested from Halifax Harbour.

5.2 Predictive Modeling of Pathogen Distributions in Halifax Harbour

Modeling and prediction of faecal coliform concentrations in harbour water has been undertaken by Coastal Ocean Associates for the environmental assessment. A comparison between untreated 1991 conditions and those predicted for the year 2041 (untreated) shows an increase in the aereal extent and concentration of bacterial loading in the harbour as the predicted volume of discharge increases over this time period (Figure 5.1).

Figure 5.2 compares the predicted 2041 conditions with and without the proposed treatment program. These modeling results predict a significant decrease in feacal coliform concentrations with the proposed use of advanced primary treatment and UV disinfection.

5.3 Risk Characterization from Waterborne Contaminants and Pathogens

The following section provides a discussion about the significance of existing and potential future exposures to waterborne contaminants and pathogens.

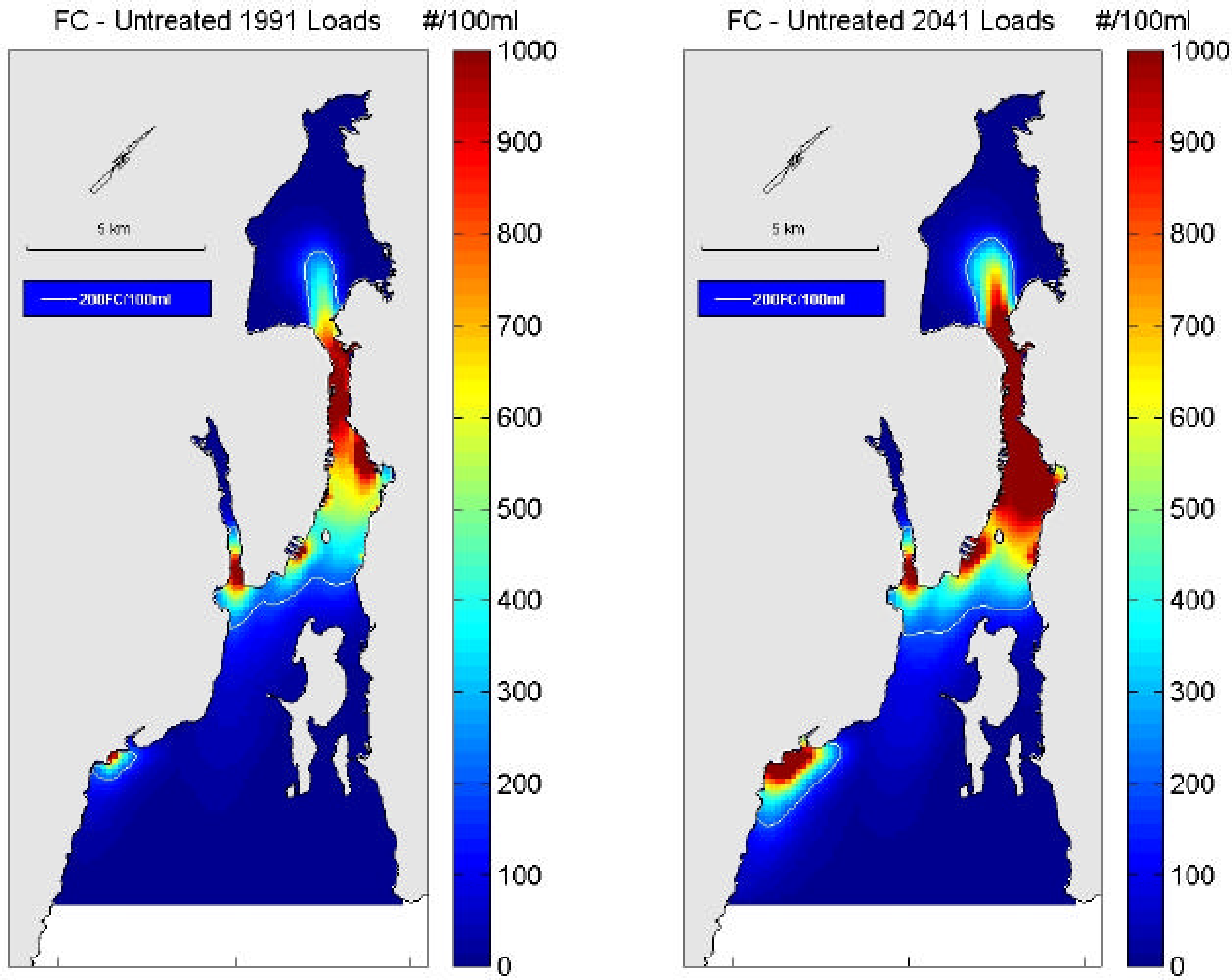


Figure 5.1 Modelled Faecal Coliform Loading for Untreated Sewage Discharges, 1991 and 2041

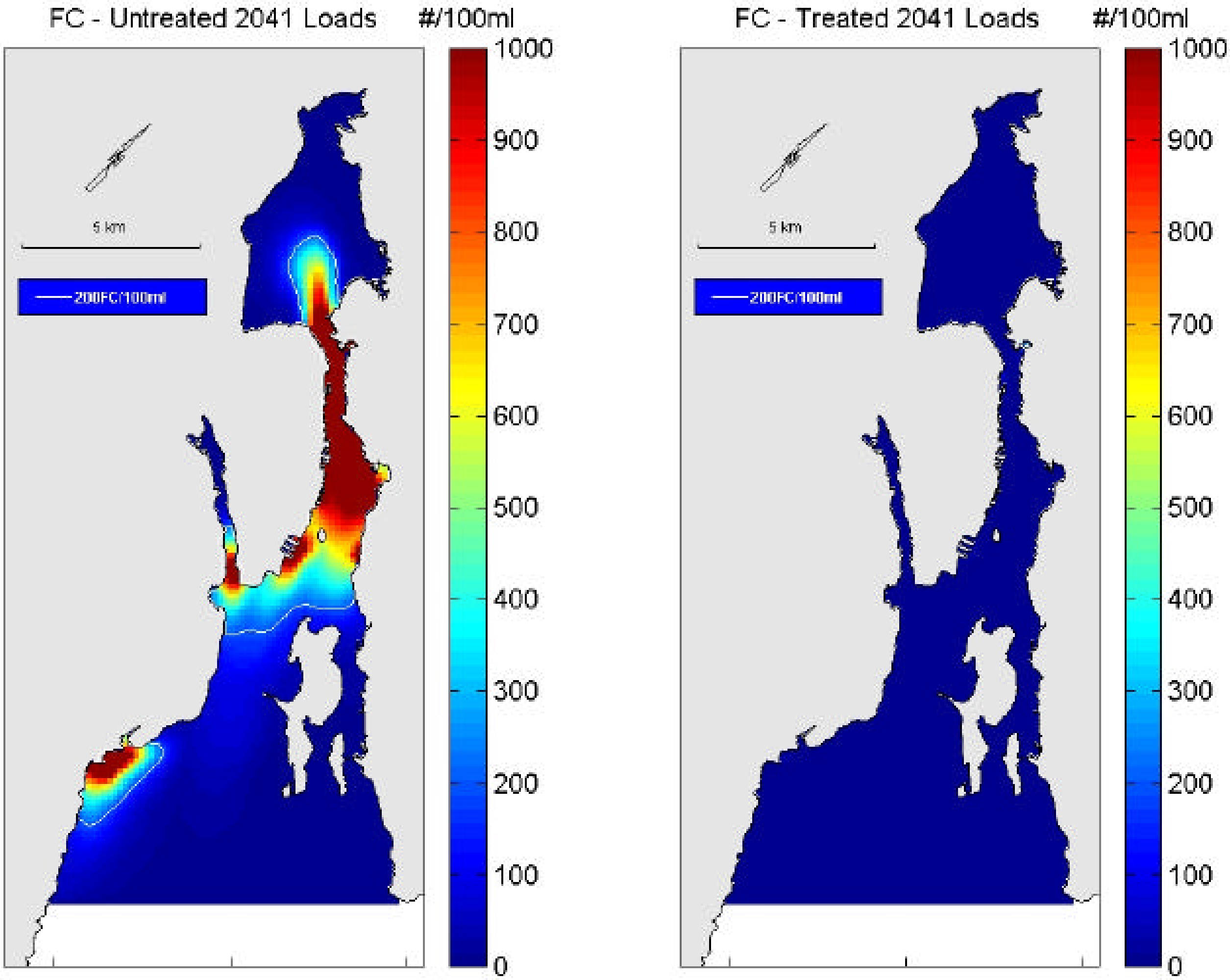


Figure 5.2 Modelled Faecal Coliform Loading for Untreated and Treated Sewage Discharges 2041

5.3.1 Recreational Users

Faecal coliform is commonly used an indicator for regulatory purposes as a measure of sewage contamination in water as well as the risk to humans through typical direct contact exposures such as swimming, diving or sailing activities. High levels of coliform indicators have been detected in 88% of the waterborne disease outbreaks in North America (Moore *et al.*, 1994).

The recreational limit for faecal coliform bacteria for contact recreation is 200 coliform bacteria /100 mL. Modelling has shown that these limits are consistently exceeded in the Inner Harbour, the Northwest Arm and near Herring Cove (Figure 5.1). It is predicted that the HHSP, which includes advanced primary treatment and UV disinfection, will dramatically reduce the concentration of faecal coliform and associated pathogens in the harbour. It is anticipated that post-treatment bacteria levels will be acceptable for contact recreation in most areas of the harbour. Figure 5.2 indicates that without the Project, bacteria levels will continue to rise with increased future flows.

Where chlorine has been used for disinfection, the reduction of coliform numbers to target limits provides sufficient reduction to pathogens and viruses to prevent the transmission of communicable disease. UV disinfection has been shown to achieve better virus inactivation than the comparable chlorine dose (Yip and Konasewick, 1972).

5.3.2 Consumption of Shellfish

5.3.2.1 Mollusks

The harbour is closed to harvesting of mollusks, therefore theoretically, there is no risk to humans under present conditions. However, there have been cases of illness associated with the consumption of mollusks from Halifax Harbour. At present there is no indicator of pathogenic contamination of mollusks. Therefore, there is a risk to those that choose to ignore harvesting prohibition and to those that purchase (wholesale or retail) mollusks from unknown suppliers.

As discussed above, modeling shows a reduction in faecal coliform bacteria concentration throughout the harbour to levels well below the shellfish limit of 14 counts/100 mL with the proposed treatment system (COA, 2000) (Figure 5.1). However, faecal coliforms cannot be used to quantify the risk of illness from consumption of mollusks. Only a monitoring program using adequate indicators will evaluate the potential for harvesting and aquaculture in some areas of the harbour.

5.3.2.2 Lobster

The Human Health Risk Assessment Component Study Report (Bio-Response Systems Ltd. and JWEL, 1992) evaluates in detail the dose-response for the consumption of lobster taken from Halifax Harbour. The results of that risk assessment concluded that consuming lobster hepatopancreas (commonly called tomalley) presents a higher risk for both PCBs and PAHs than consuming only lobster meat. The highest estimated contaminants levels for both meat and hepatopancreas from the consumption of lobsters are from those lobsters taken from Dartmouth Cove and Bedford Basin.

Consumption of only lobster meat does not exceed the acceptable levels of risk in any scenario considered in the previous risk assessment (Bio-Response Systems Ltd. and JWEL, 1992). The consumption of whole lobster (meat and tomalley) taken from Dartmouth Cove, Bedford Basin and the Harbour mouth exceeds the range of acceptable risk with respect to PCB levels. The consumption of whole lobster taken from Dartmouth Cove and Bedford Basin exceeds the range of acceptable risk with respect to carcinogenic PAH (CPAH) levels. This analysis is based on a "Most Exposed Individual" who consumes lobster from Halifax Harbour as a significant portion of his/her diet. The consumption of tomalley exceeds an acceptable level of risk range for PCB and CPAH if it is made exclusively from Dartmouth Cove lobsters; if made from Bedford Basin lobsters, the range for CPAH is exceeded. The data and analysis suggests that anyone with a personal concern of exposure to the compounds analyzed in the study can significantly reduce risk by avoiding consumption of lobster hepatopancreas (tomally).

The model predictions show a 25 percent reduction in metals discharge due to primary treatment. However, no analysis was undertaken for PCBs or PAHs. These organic contaminants will be largely adsorbed onto organic and particulate matter rather than in a dissolved state. The removal efficiency of total suspended solids is predicted to be approximately 75 percent. Therefore, a significant reduction of PCB and PAH loadings to the harbour is anticipated. Over the long term, contaminant uptake by lobsters is likely to reduce in areas outside the zones of influence of settleable solids from the four outfalls. There is expected to be an overall long term reduction in contaminant uptake by harbour lobster and a consequent reduction in risk to humans who consume them.

6.0 SEWAGE SLUDGE MANAGEMENT

Residents have expressed concern about health effects from potential exposure to unstabilized sewage sludge, including transportation of that sludge to a management facility and exposures from treated sludges.

6.1 Current Sewage Sludge Composting Activities in Nova Scotia

Composting of municipal sewage sludge is currently undertaken at several facilities in Nova Scotia, including Colchester, Pictou and Lunenburg Counties. In addition, there are several other composting facilities which collect and compost animal manure (NSDEL, 2000). It is understood that these existing compost facilities would not be used to process the sewage sludge which would be collected from the proposed STPs. A new sludge management facility is expected to be constructed in the HRM area which would be constructed and operated in accordance with all applicable provincial and federal guidelines.

6.2 Composting Guidelines

The CCME have developed *Guidelines for Compost Quality* (1996). Compost must meet all criteria as established for foreign matter, maturity, pathogens and trace elements. Testing of compost is required for every 1000 tonnes of compost produced or every three months. The guidelines have also established minimum testing procedures.

According to the *Solid Waste Resource Management Regulations* and Section 26 of the *Activity Designation Regulations* made under the Nova Scotia *Environment Act*, a regulatory approval is required in order to construct, expand or modify an industrial composting facility or a facility which can process more than sixty cubic metres annually of finished compost. All zoning requirements and municipal bylaws must be satisfied prior to construction or modification of such a facility. NSDEL has also developed operating guidelines for composting facilities in Nova Scotia. The *Composting Facility Guidelines* (NSDOE, 1998) outline the requirements for construction and operation of a compost facility in Nova Scotia as well as incorporate the *CCME* compost quality criteria.

According to these *Composting Facility Guidelines*, all composting facilities are required to include the following components and specifications.

C Impermeable pads for receiving and tipping areas including enclosed structures.

C Containment systems for the actual composting and curing areas must including drainage control and leachate collection and treatment.

- Specific leachate management systems must be designed to collect, monitor, control and treat leachate.

- Discharge standards for liquid effluents from composting facilities must meet background water quality in the receiving water body and the *Canadian Water Quality Guidelines*. Effluents must not be lethal to fish as required by the Section 34 of the *Fisheries Act*.

- Facilities are required to develop and submit surface water management plans including a comprehensive monitoring program.

- Groundwater monitoring plans are required to be implemented and must remain in force throughout the life-cycle of the facility. Groundwater monitoring must include background and down gradient groundwater sampling in close proximity to operating areas to ensure early detection of contaminant migration laterally or vertically.

- Odours must be controlled as a condition of approval of all composting facilities. Handling areas must be enclosed and operate under negative atmospheric pressure in order to avoid the escape of odours. Ventilation systems must incorporate treatment systems.

- Separation distances are imposed on composting facilities. Separation distances required by the operating approvals are as follows:

Residential or Institutional Buildings	500 metres
Commercial or industrial buildings	250 metres
Property Boundaries	100 metres
Property Boundaries (engineered facilities)*	30 metres
Watercourses (fresh water or marine)	30 metres

*Note: Any modification of separation distances will only be permitted with the written consent of all adjacent property owners.

Feedstocks are also restricted by the approval. All facilities are required to prepare and implement emergency response plans to deal with reasonably foreseeable emergencies including fires, explosions, leachate leaks or spills.

6.3 Risk Characterization for Exposures from Sludge Management Activities

Sewage sludge from other existing HRM facilities, as well as from domestic sources is routinely transported in and around urban areas of HRM without incident to the sludge lagoon at Aerotech Park for treatment and disposal.

No unacceptable risks to human receptors are expected from the exposure to sewage sludge management activities due to the following:

- The composting facility where the sludge will be disposed of must meet the required Conditions of Approval in terms of siting, containment, odour management, leachate testing, distance to off-site human receptors, etc. as defined by CCME and NSDEL.

- Workers who are in direct contact with the sludge will be required to wear personal protective equipment to minimize exposure. Details of required equipment are expected to be described in a health and safety plan for each STP.

- Prior to removal for offsite applications, the sludge is required to be analysed for various disposal parameters (including metals and pathogens), and any sludge in excess of these concentrations will not be accepted.

- Transportation of the sewage sludge from the STP is to be undertaken with appropriate equipment and containment of the material to prevent leakage. Using sealed containers will act to minimize odour migration during sludge transfer from the STP to the collection truck. If a spill were to occur, an Emergency Response Plan would be activated. In an extreme case, residents would be evacuated. The residue would likely be removed by using high-pressure wash water systems and effluents would be collected or directed back to the STP. Unacceptable risks are therefore not expected as a result of sewage sludge handling. Sewage sludge is currently transported in and around urban areas of HRM from existing STPs and domestic sources to the sludge management facility at Aerotech Park.

7.0 SCREENING LEVEL RISK ASSESSMENT RESULTS

The results of the screening level risk assessment are summarized in Table 7.1.

Table 7.1 Screening Level Risk Assessment Results

Exposure Scenario	Current Effects	Effects - Post Treatment	Overall Impact to Human Health
Airborne Contaminants (via outdoor air)	Airborne contaminants partition to air from sewage effluent at the current 40+ outfalls, many of which are located near residential and recreational areas	Anticipated levels of contaminants emitted from STPs are very low and below Guideline limits.	Net improvement due to reduction in airborne emissions compared with current situations. Emissions from STPs will not exceed health related criteria. Scrubbers will provide added level of contaminant removal.
Waterborne contaminants/pathogens (via direct contact with harbour water)	Recreational harbour users (diving, swimming, sailing, etc) may be exposed through dermal contact with contaminants and pathogens	Sewage treatment will decrease the overall contaminant and pathogen concentrations in the harbour water.	Net improvement due to lower contaminant/ pathogen concentrations which may decrease the potential for illness associated with exposure.
Ingestion of tainted shellfish and crustaceans from pathogens in water and sediment in Halifax Harbour	No significant effect on current consumers of shellfish as the harbour is closed to shellfish harvesting due to high faecal coliform concentrations. Pathogens in crustaceans are killed by proper cooking methods.	Lower pathogenic discharges and potential uptake by food species.	Net improvement due to fewer pathogens, better water quality, improved quality of shellfish and crustaceans.
Ingestion of tainted shellfish and crustaceans from chemical contamination in Halifax Harbour water and sediment	Many of the contaminants in the sediment may concentrate in organisms which are in direct contact with the contaminated media. People ingesting the 'fatty' tissue or detoxifying organs (*i.e.*, lobster tomalley) of these organisms may ingest any contaminants which have accumulated in these organisms.	Given that many of the contaminants are persistent and bioaccumulative, there may be little or no short-term improvement in contaminant concentrations in shellfish or crustaceans. In the long-term, a decrease in contaminant loading into the harbour will decrease overall water and sediment contaminant concentrations available for uptake, and lower contaminant concentrations will be expected in future generations of these organisms.	Net long-term improvement due to reduction in persistent contaminants taken up by food species.

Table 7.1 Screening Level Risk Assessment Results

Exposure Scenario	Current Effects	Effects - Post Treatment	Overall Impact to Human Health
Exposure to sewage sludge	Untreated sewage is currently discharged directly into Halifax Harbour including floatables and other solids	Sewage sludge will be generated through the removal of solids in the treatment process. Sludge stabilization at the STP will kill most pathogens. Sludge will be further processed at a composting facility that is operated according to provincial regulations and will be tested to ensure that the quality of the composed sludge is acceptable for intended end use including potential use at residential properties.	Net improvement compared with current situation whereby sludge will be managed to ensure there are no unacceptable exposures/risks to potential receptors.

In general, there is expected to be an overall improvement in the water quality, sediment quality, and air quality due to the HHSP resulting in decreased health risk from human exposures through direct contact, inhalation or ingestion of organisms harvested from Halifax Harbour. The proposed sewage treatment project will provide a proven means for HRM to reduce risks associated with existing exposure to untreated sewage.

8.0 UNCERTAINTY ANALYSIS

Risk estimates normally include an element of uncertainty, and generally these uncertainties are addressed by incorporating overly conservative assumptions in the analysis. As a result, risk assessments tend to overstate the actual risk. Although many factors are considered in preparation of a risk analysis, analysis results are generally only sensitive to very few of these factors. The uncertainty analysis is included to demonstrate that assumptions used are conservative, or that the analysis result is not sensitive to this assumption.

A risk assessment containing a high degree of confidence will be based on:

- conditions where the problem is defined with a high level of certainty based on data and physical observations;

- an acceptable and reasonable level of conservatism in assumptions which will ensure that risks are overstated; or

- an appreciation of the bounds and limitations of the final solution.

The exposure assessment performed as part of this study was based on:

- available data to describe proposed sewage treatment strategy;
- sound conservative assumptions for certain parameters, as required; and
- well-understood and generally accepted methods for risk prediction.

Table 8.1 contains a summary of the assumptions used in this risk analysis, provides an evaluation for each assumption and an opinion as to whether the assumption is acceptable.

Table 8.1 Evaluation of Assumptions in the Risk Analysis

Risk Analysis Study Factor/Assumption	Justification	Analysis Likely to Over/Under Estimate Risk ?	Acceptable Assumption?
No data regarding VOC contaminant concentrations in sewage based on Halifax Harbour or Atlantic Canada data	Study used VOCs measured above dissolved air flotation systems in STPs from other jurisdictions to assess likely contaminant concentrations resulting from the HRM STPs. This data has been prorated according to the projected STP flows.	Neutral	Yes
Receptor/exposure characteristics are applicable	Receptors selected for study were considered to be the most significant from an exposure perspective. All other potential receptors were assumed to only be in potential contact with sewage for very limited periods of time.	Over-estimate	Yes
Assumed that all sewage treatment operations and disposal would be conducted according to standard practices, guidelines and regulations	Since this project is federally and provincially regulated, all applicable guidelines and regulations must be adhered to in the design and operation of all aspects of the STP and sludge management.	Likely Over-estimate	Yes
No information regarding the actual design of the STP	Where possible, the SLRA assumed the building would be constructed similar to other STPs, with conservative assumptions regarding stack height and facility dimensions.	Likely Over-Estimate	Yes
Ultraviolet disinfection is assumed to remove a large majority of pathogens	Most bacteria and viruses require relatively low UV doses for inactivation. UV dose requirement for inactivation of pathogens, including viruses, is less than a factor of 5 greater than that required for FC (Sakamoto 1999).	Over Estimate	Yes
No sludge management facility design or location	Facility must be built and operated in accordance with established standard. Compost must meet national quality criteria prior to off-site use.	n/a	Yes

9.0 CONCLUSIONS

Large volumes of untreated sewage are currently entering Halifax Harbour resulting in a contribution of inorganic, organic and biological waste. This waste consists of pathogens and chemicals, which have a detrimental impact on water quality, sediment quality, and may be accumulated by aquatic organisms which inhabit Halifax Harbour and are, or could potentially be, harvested for food.

Airborne contaminants, in the form of VOCs, are currently released from sewage at outfalls. A small amount of these contaminants will be released from the STPs, however the concentrations will be very low and well below guideline limits developed to protect human health.

Recreational users of the harbour who are directly exposed to harbour water are currently at risk from sewage related pathogens. Health risk from this type of activity will be reduced due to a significant decrease in pathogens and other contaminants related to sewage treatment.

The construction and operation of STPs are considered to be a positive step toward improving current human exposures and associated health risks from impacts to harbour water, sediment and ambient air, as well as the aquatic organisms which are, or could potentially be a food source for humans. Immediate and significant improvements will be realized as each of the four STPs is phased in over a ten year period.

Although current concentrations of persistent and bioaccumulative contaminants will remain, the addition of new contaminants will proceed at a significantly reduced rate. The benefit of sewage treatment must therefore be regarded as a overall significant improvement to the current discharges of chemical and biological compounds currently entering Halifax Harbour.

In general, there is expected to be an overall improvement in the water quality, sediment quality, and air quality due to the HHSP resulting in decreased health risk from human exposures through direct contact, inhalation or ingestion of organisms harvested from Halifax Harbour. The proposed sewage treatment project will provide a proven means for HRM to reduce risks associated with existing exposure to untreated sewage.

10.0 RECOMMENDATIONS

The following recommendations should be implemented by HRM to verify the predictions of this report and ensure that the proposed sewage collection treatment systems will operate in such as way to realize an overall reduction in risk of exposure from sewage discharges to Halifax Harbour.

- Characterize sewage effluent for the presence and concentrations of VOCs to determine if these are consistent with those assumed in this report.

- Review proposed building design and performance criteria for the proposed STPs to ensure they are consistent with the assumptions of this assessment.

- Continue implementation of HRM source control programs to reduce potential discharges of VOC and other chemical contaminants to Halifax Harbour.

11.0 CLOSURE

The locations of potential contaminant sources are based on available information for the proposed systems. The data and interpretations presented in this report are based solely on the reports prepared for the previous and current Halifax Harbour sewage treatment studies.

The results of this study are based on our current understanding of environmental and/or human health effects of the hazards in question and the mechanisms of their exposure. This document evaluates only the risks posed by identified environmental hazards.

This work is specific to the sewage treatment strategy proposed by the Halifax Harbour Solutions Project, and is not intended to be applied generically to other sites or locations that have not been specifically outlined in this report.

The information presented in this report is based upon work undertaken according to sound engineering and scientific practices by trained professional and technical staff. Should future investigations provide information which supplements or differs from the information presented in this report, we request to be notified and permitted to reassess the results and interpretations provided herein.

This report was prepared by John Henderson, P.Eng., John Walker, Ph.D., Susan Belford, M.Sc. and Allison Denning M.E.S. Review was provided by Robert Federico, M.P.A.

Yours truly,

JACQUES, WHITFORD ENVIRONMENT LIMITED

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Environmental Engineer

Robert Federico, M.P.A.
Project Manager

12.0 LITERATURE CITED

Air Quality Regulations, NS Reg. 55/95 (April 11, 1995), Nova Scotia.

Bio-Response Systems Ltd. and Jacques Whitford Environment Limited (JWEL). 1992. Human Health Risk Assessment, Component Study, Halifax Harbour Cleanup Inc., Sewage Treatment Project. May.

Cabelli, V.J. 1983. Health Effects Criteria for Marine Recreational Waters. U.S. Environmental Protection Agency.

Canadian Council of Ministers of the Environment (CCME). 1999. Canadian Environmental Quality Guidelines, Canadian Water Quality Guidelines for the Protection of Aquatic Life; Canadian Sediment Quality Guidelines for the Protection of Aquatic Life; Canadian Tissue Residue Guidelines for the Protection of Wildlife Consumers of Aquatic Biota; and Recreational Water Quality Guidelines and Aesthetics.

CCME. 1996. Guidelines for Compost Quality. Prepared by the Composting Subcommittee Solid Waste Management Task Group. March.

Canadian Environmental Assessment Act (S.C. 1992, c-37).

Coastal Ocean Associates Inc. 2000. Oceanographic Modelling and Assimilative Capacity Study. Prepared for Halifax Harbour Solutions Project. March.

Environment Act (S.N.S., 1994-95, c.1), Nova Scotia.

Fisheries Act (R.S.C. 1985, c. F-14).

Land and Sea Environmental Consultants Limited. 1991. Component Study on Marine Water and Sediment Quality. Prepared for the Halifax Harbour Cleanup Inc. December.

Moore, A.C. et at. 1994. Waterborro Disease in the United States, 1991-1992. Journal of the American Water Works Associates. 86(2): 87-89.

Navigable Waters Protection Act. (R.S., C.N-19, s.l)

Nova Scotia Department of Environment (NSDOE). 1998. Nova Scotia Department of the Environment Composting Facility Guidelines. March, 1998.

Nova Scotia Department of the Environment and Labour (NSDEL). 2000. Organic Composting Facilities in Nova Scotia. Http://www.gov.ns.ca/envi/wasteman/compsite.htm.

Ontario Ministry of the Environment (MOE). 1992. Summary of Point of Impingement Standards, Ambient Air Quality Criteria (AAQCs), and Approvals Screening Levels (ASLs). Air Resources Branch. August.

Sakamoto, G. 1999. Overview of Wastewater Disinfection. Trojan Technologies Inc. London, ON.

SNC Lavalin. 1999. Halifax Harbour Solutions Project Wastewater Characterization Study. Report Submitted to the Halifax Regional Municipality. August.

Toxicology Data Network (TOXNET). 2000. Maintained by the National Library of Medicine. http://toxnet.nlm.nih.gov/cgi-bin/sis/search

Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG). 1997a. Selection of representative TPH fractions based on fate and transport considerations. Vol. III in a Series, Final Draft - July 97, Amherst Scientific Publishers, 102 pp.

TPHCWG. 1997b. Development of fraction specific reference doses (RFDs) and reference concentrations (RFCs) for total petroleum hydrocarbons (TPH). Vol IV. Amherst Scientific Publishers. 197 pp.

Yip, R.W. and E. Konasewick. 1972. Ultraviolet Sterilization of Water - Its Potential and Limitations. Water and Pollution Control (Can.) No. 6. pp. 14-18.

Zhu, H. *et al.* 1999. Temporal and Longitudinal Characteristics of Volatile Organic Compound Emissions from Aeration Units of Publicly Owned Treatment Works. Journal of the Air and Waste Management Association, April.

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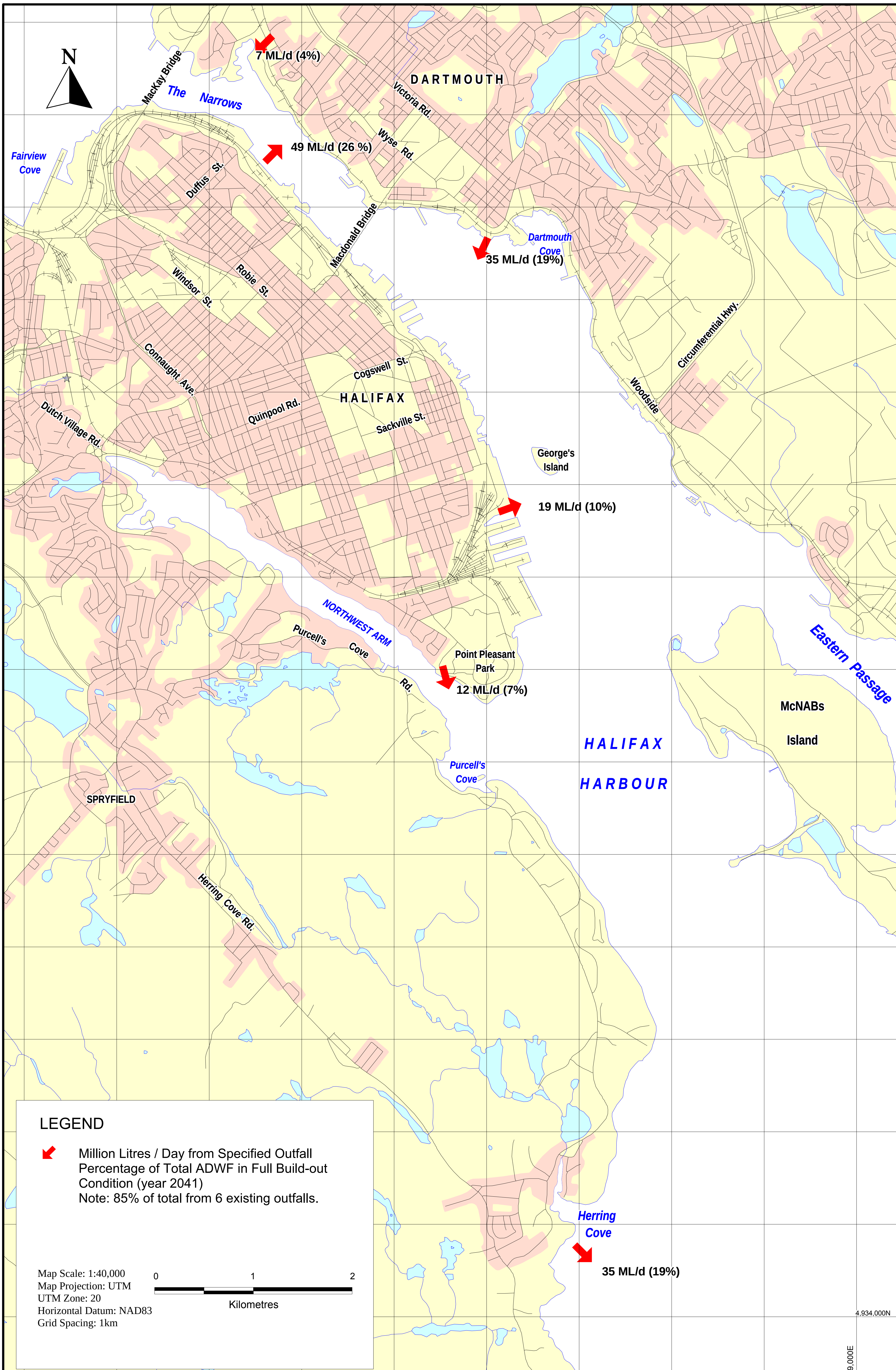
APPENDIX A

SEWAGE TREATMENT CONCEPT PLAN FIGURES



HALIFAX REGIONAL MUNICIPALITY

Halifax Harbour Solutions Project

Figure 2.1
Major Sewage Outfall Flows

Jacques Whitford Environment Limited

December 2000
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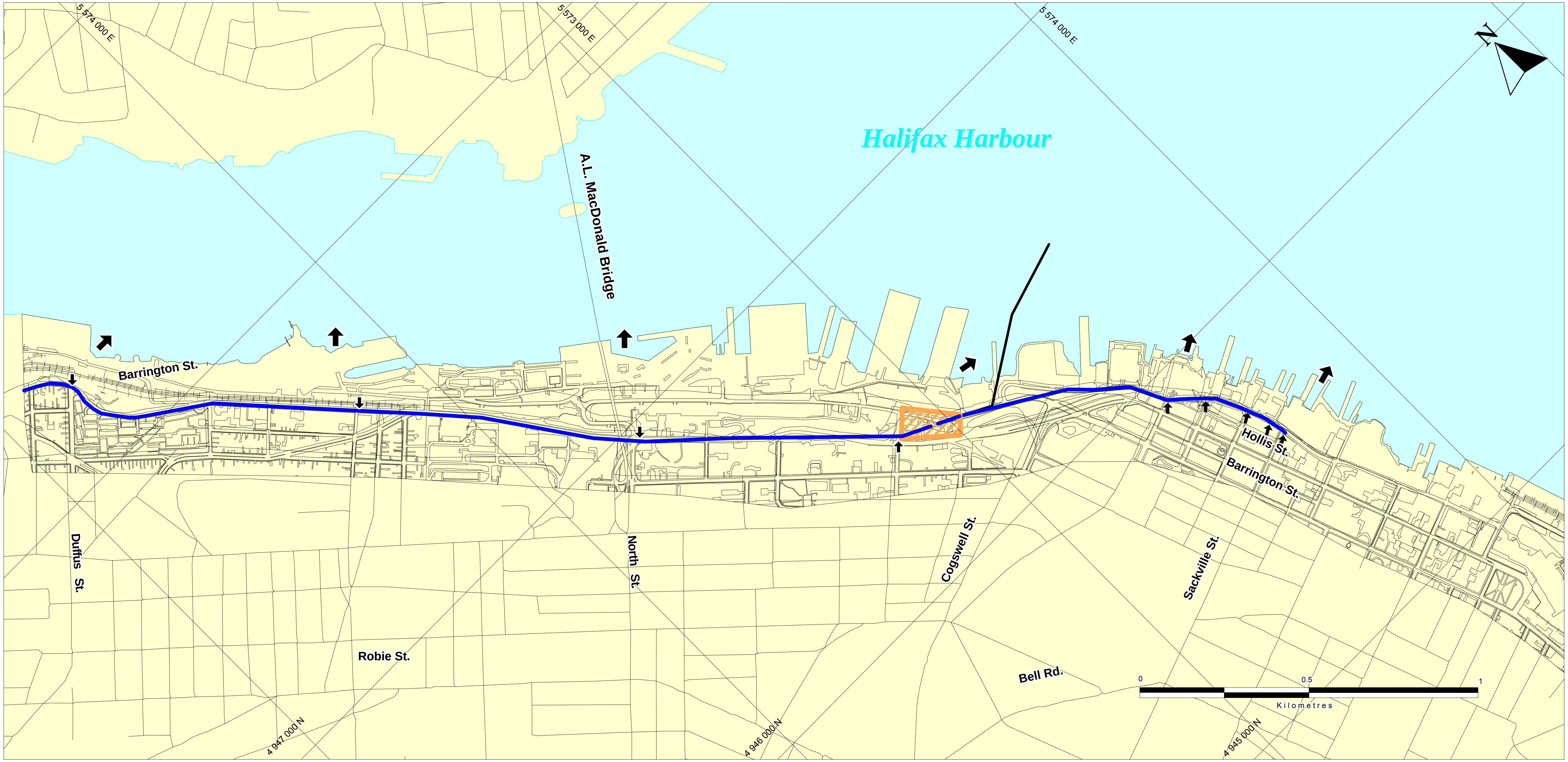

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Halifax Harbour Solutions Project;
Basemap Provided by HRM.

Figure 2.2
Halifax North STP Collection System

Halifax Harbour Solutions Project

HALIFAX REGIONAL MUNICIPALITY

Jacques Whitford Environment Limited

LEGEND

Sewage Treatment Plant	Interception Location
Forcemain	Combined Sewer Overflow
Collector Sewer	Pumping Station
Tunnel	Outfall/Diffuser

January 2001
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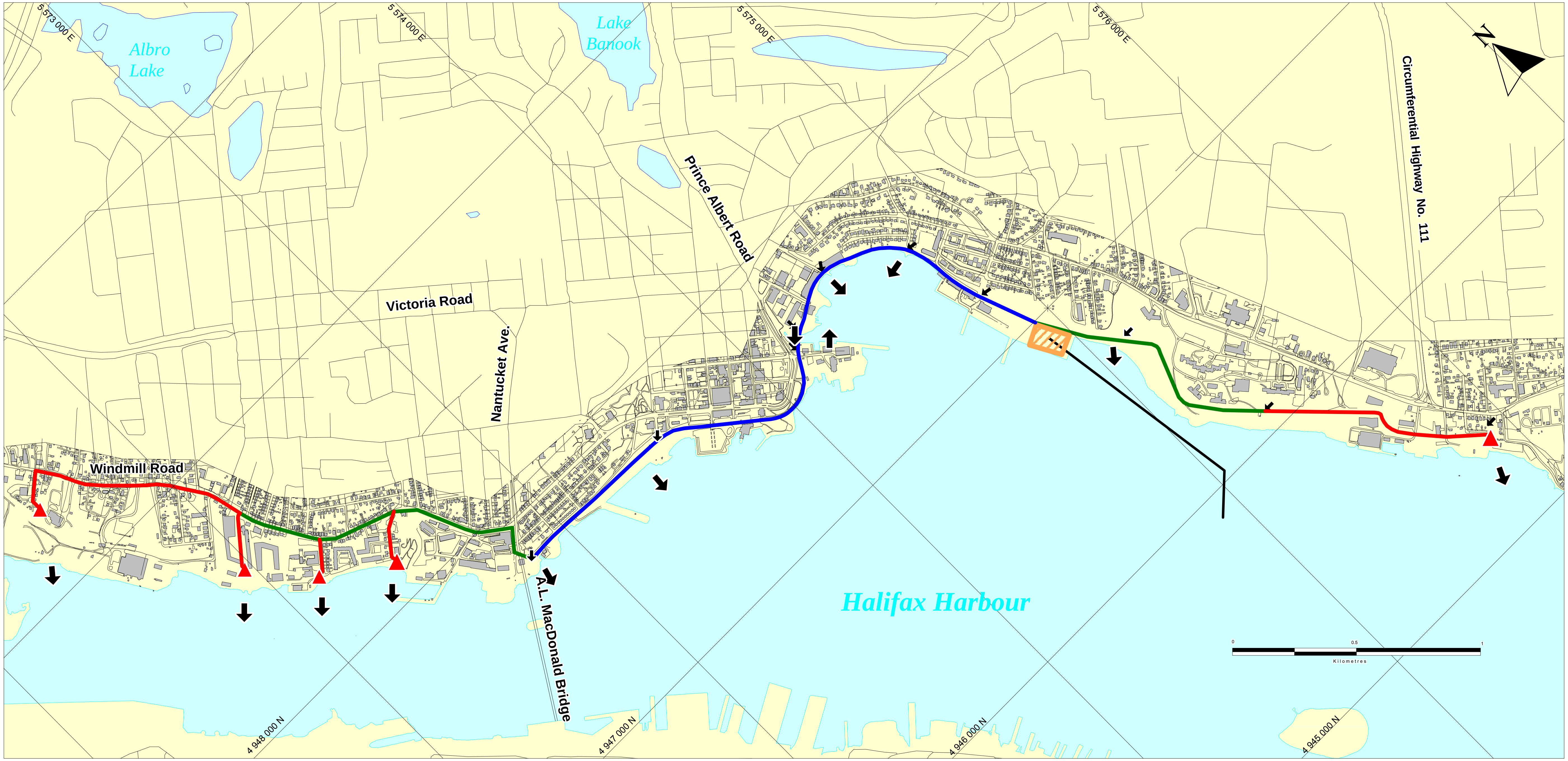

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Basemap Provided by HRM.

Figure 2.3
Dartmouth STP Collection System

Halifax Harbour Solutions Project

HALIFAX
REGIONAL MUNICIPALITY

Jacques Whitford Environment Limited

LEGEND

- Sewage Treatment Plant
- Forcemain
- Collector Sewer
- Tunnel
- Interception Location
- Combined Sewer Overflow
- Pumping Station
- Outfall/Diffuser

January 2001
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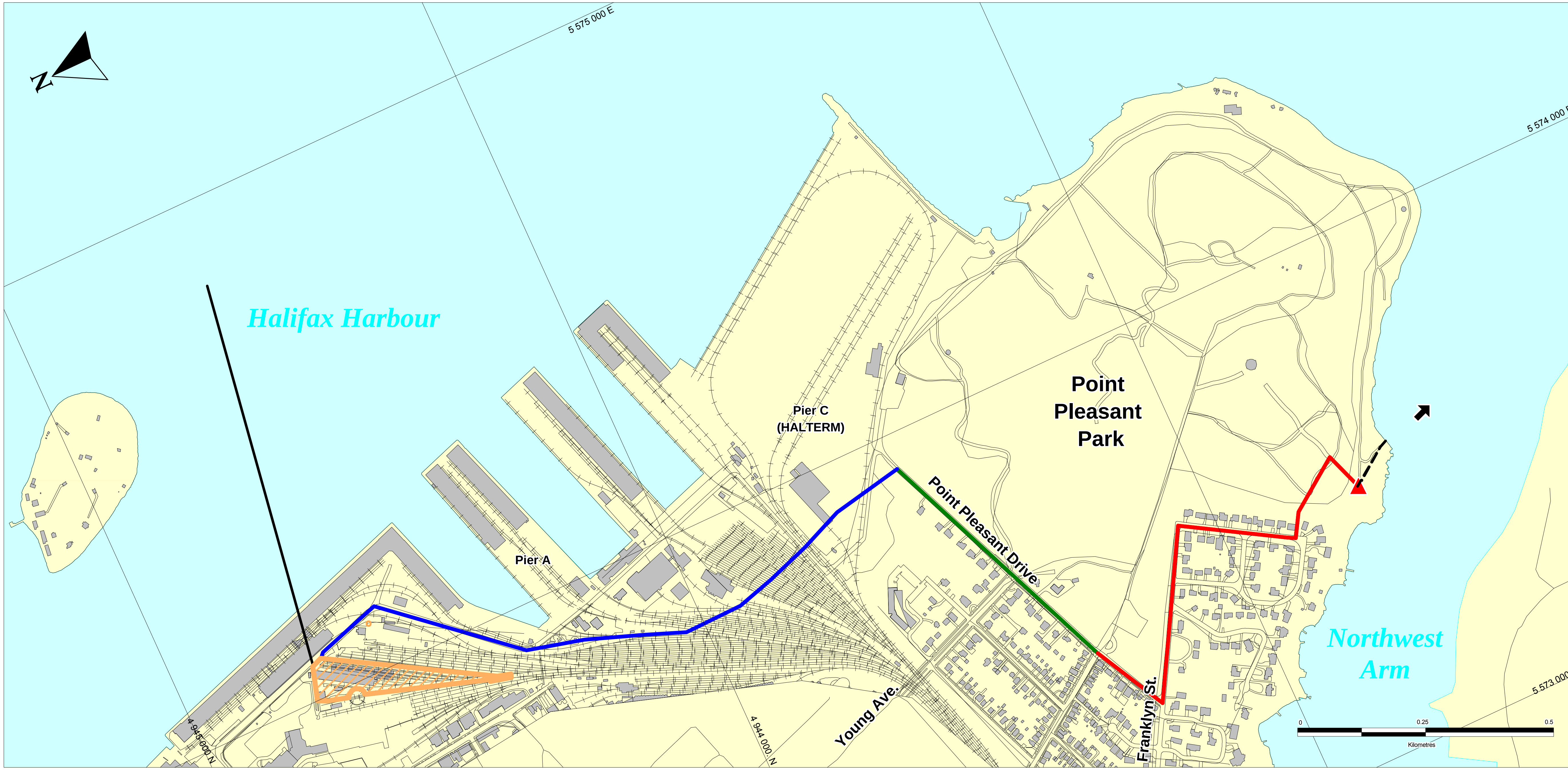

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Basemap Provided by HRM.

Figure 2.4
Halifax South STP Collection System (Alternative A)

Halifax Harbour Solutions Project

LEGEND

- Sewage Treatment Plant
- Forcemain
- Collector Sewer
- Tunnel
- Interception Location
- Combined Sewer Overflow
- Pumping Station
- Outfall/Diffuser

HALIFAX
REGIONAL MUNICIPALITY

Jacques Whitford
Environment Limited

january 2001
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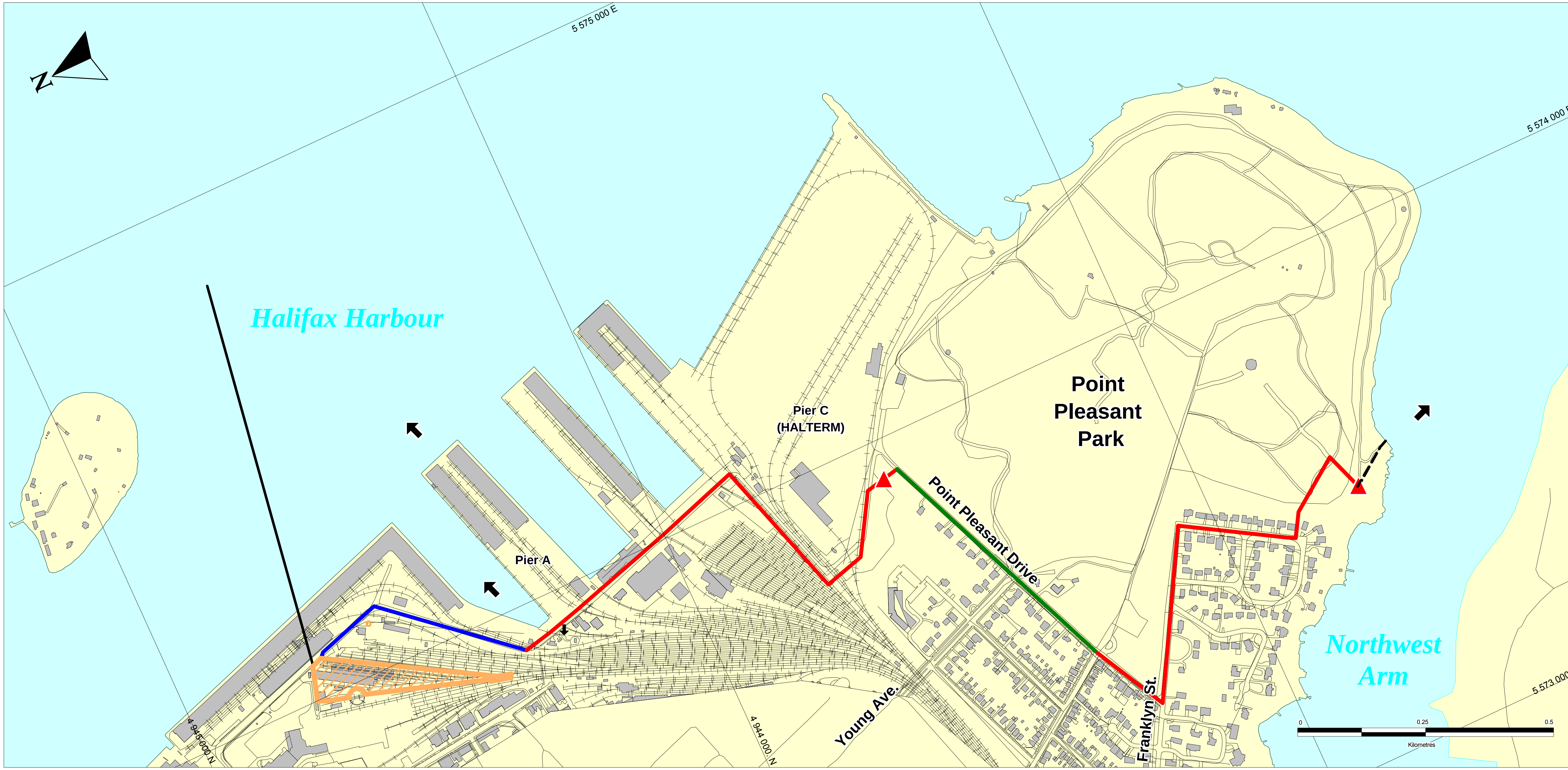

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Data Source:
Halifax Harbour Solutions Project;
Basemap Provided by HRM.

Figure 2.5
Halifax South STP Collection System (Alternative B)

Halifax Harbour Solutions Project

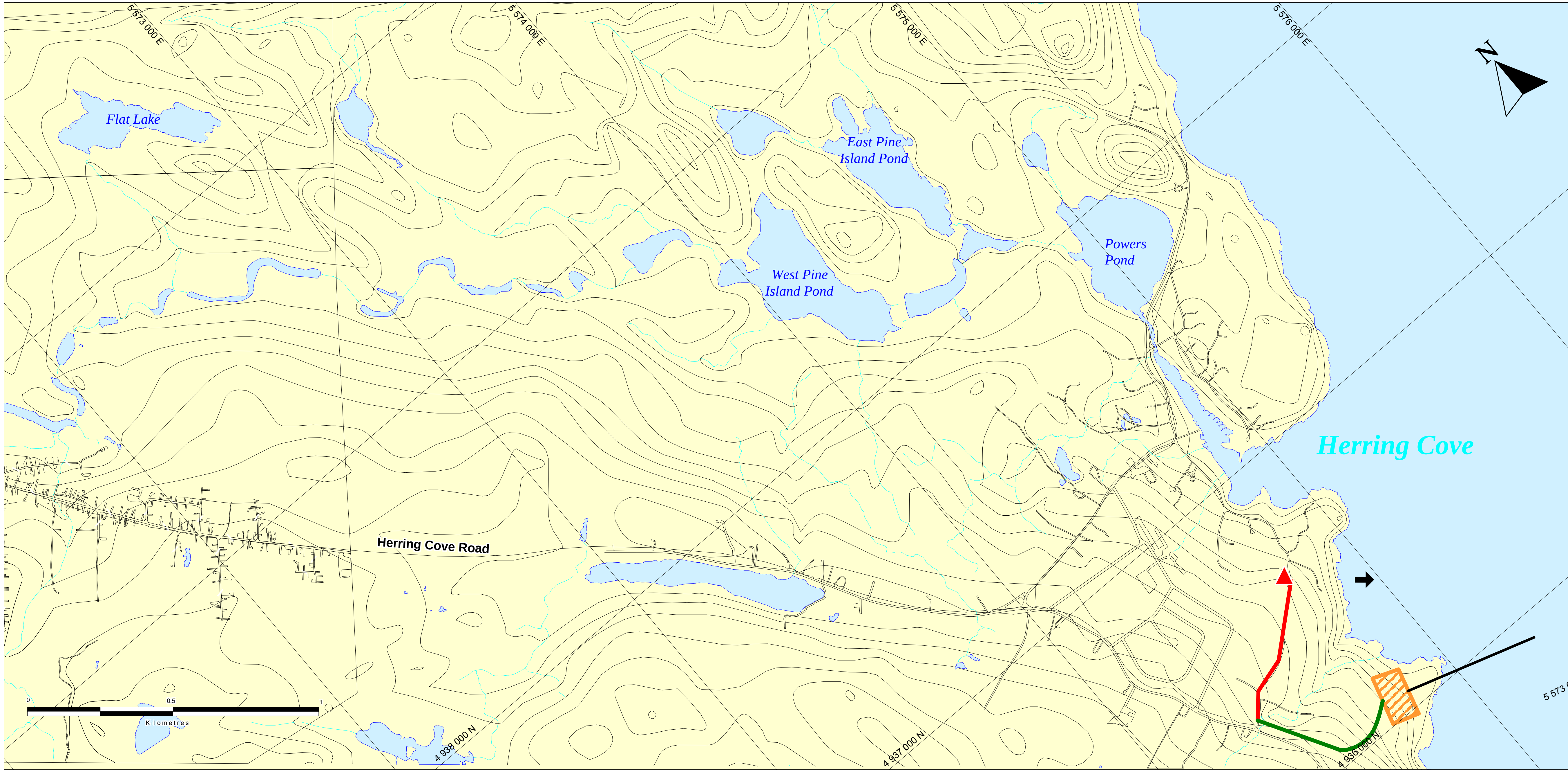
HALIFAX REGIONAL MUNICIPALITY

Jacques Whitford Environment Limited

LEGEND

Sewage Treatment Plant	Interception Location
Forcemain	Combined Sewer Overflow
Collector Sewer	Pumping Station
Tunnel	Outfall/Diffuser

January 2001
P:\envsci\13xxx\13960\6027\maps\figure4Br1.wor



Map Parameters:
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Zone : 5
Datum: ATS77
Scale: 1 : 15 000
Grid Spacing: 1 km
Data Source:
Halifax Harbour Solutions Project;
Basemap Provided by HRM.

Figure 2.6
Herring Cove STP Collection System

Halifax Harbour Solutions Project

HALIFAX
REGIONAL MUNICIPALITY

Jacques Whitford
Environment Limited

LEGEND

Sewage Treatment Plant	Combined Sewer Overflow
Forcemain	Pumping Station
Collector Sewer	Outfall/Diffuser

January 2001
Proj. #: 13960
P:\envsci\13960\6027\maps\figure3r1.wor

APPENDIX B

RECREATIONAL WATER QUALITY GUIDELINES AND AESTHETICS, TOXICITY OF PATHOGENS (BIO-RESPONSE SYSTEMS AND JWEL 1992)

Recreational Water Quality Guidelines and Aesthetics

Recreational water refers to surface waters that are used primarily for activities in which the user comes into frequent direct contact with the water, either as part of the activity or incidental to the activity. Examples include swimming, windsurfing, waterskiing, white water sports, scuba diving, and dinghy sailing. Secondary recreational uses include boating, canoeing, and fishing, which generally have less frequent body contact with water.

General Requirements

Health and Safety

Water used for primary recreational purposes should be sufficiently free from microbiological, chemical, and physical hazards, e.g., poor visibility, to ensure that there is negligible risk to the health and safety of the user. Recreational water quality guidelines, summarized in Table 1, were prepared by the Federal–Provincial Advisory Committee on Environmental and Occupational Health and published by Health and Welfare Canada (1992).

These guidelines deal mainly with potential health hazards related to primary recreational water use, but also relate to water quality aesthetics and nuisance conditions. Health hazards associated with direct recreational contact with water include infections transmitted by pathogenic microorganisms and injuries resulting from impaired visibility in turbid waters. The determination of the risk of infection is based on a number of factors, including results of environmental health assessments, results of epidemiological studies, levels of indicator organisms, and the presence of pathogens. Sampling and enumeration of microbiological indicators and pathogens in recreational waters are also discussed. New guidelines for safe recreational water environments are currently being prepared by the World Health Organization with the assistance of Health Canada.

Aesthetics

The local setting of recreational water bodies is also important, as the surrounding countryside has a strong visual effect on the enjoyment of lakes and rivers, whether the activity is physically active or passive, such as gazing on the scenery.

In northern waters, swimming is not a major recreational activity, and factors other than microbiological are major components when determining the suitability of lakes and rivers and their environments as recreational areas. Visual impact of the whole area is as important as the quality of the water.

Impacts on a water source come from many activities. These include logging, mining, drainage of wetlands, dredging, dam construction, agricultural runoff, industrial and municipal wastes, land erosion, road construction, and land development. These factors all have to be considered in areas of natural beauty that are used for the many recreational activities engaged in by Canadians and visitors to Canada.

References

Health and Welfare Canada. 1992. Guidelines for Canadian recreational water quality. Cat. No. H49-70/1991E. Minister of Supply and Services Canada, Ottawa.

Moody, R.P., and I. Chu. 1995. Dermal exposure to environmental contaminants in the Great Lakes. Environ. Health Perspect. 103(Suppl. 9):103–114.

Summary — Guidelines for Canadian recreational water quality.

Parameter	Guideline
Microbiological	
Escherichia coli (fecal coliforms)	The geometric mean of at least five samples taken during a period not to exceed 30 d should not exceed 2000 *E. coli* per litre. Resampling should be performed when any sample exceeds 4000 *E. coli* per litre. See Health and Welfare Canada (1992) for additional information on application of guideline.
Enterococci	The geometric mean of at least five samples taken during a period not to exceed 30 d should not exceed 350 enterococci per litre. Resampling should be performed when any sample exceeds 700 enterococci per litre. See Health and Welfare Canada (1992) for additional information on application of guideline.
Coliphages	Limits on coliphages can not be specified at this time. See Health and Welfare Canada (1992) for additional information.
Waterborne pathogens	The pathogens most frequently responsible for diseases associated with recreational water use are described in Health and Welfare Canada (1992), i.e., *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Salmonella*, *Shigella*, *Aeromonas*, *Campylobacter jejuni*, *Legionella*, human enteric viruses, *Giardia lamblia*, and *Cryptosporidium*.
Cyanobacteria (blue-green algae)	Limits have not been specified. Health Canada is in the process of developing a numerical guideline for microcystin, a cyanobacterial toxin. Water with blue-green surface scum should be avoided because of reduced clarity and possible presence of toxins.
Chemical characteristics	Limits for chemicals have not been specified because of lack of data. Decisions for use should be based on an environmental health assessment and the aesthetic quality. Dermal exposures to environmental contaminants has recently been reviewed by Moody and Chu (1995).
Temperature	The thermal characteristics of water should not cause an appreciable increase or decrease in the deep body temperature of bathers and swimmers.
Clarity	The water should be sufficiently clear that a Secchi disc is visible at a minimum of 1.2 m.
pH	When the buffering capacity of the water is very low, 6.5 to 8.5; range of 5.0 to 9.0 is acceptable.
Turbidity	The turbidity of water should not be increased more than 5.0 NTU over natural turbidity when turbidity is low (<50 NTU).
Oil and grease	Oil or petrochemicals should not be present in concentrations that • can be detected as a visible film, sheen, or discoloration on the surface; • can be detected by odour; or • can form deposits on shorelines and bottom deposits that are detectable by sight and odour.
Aquatic plants	Bathers should avoid areas with rooted or floating plants; very dense growths could affect other activities such as boating and fishing.
Aesthetics	All water should be free from • materials that will settle to form objectionable deposits; • floating debris, oil, scum, and other matter; • substances producing objectionable colour, odour, taste, or turbidity; and • substances and conditions or combinations thereof in concentrations that produce undesirable aquatic life.
Nuisance organisms	Bathing areas should be as free as possible from nuisance organisms that • endanger the health and physical comfort of users or • render the area unusable. Common examples include biting and nonbiting insects and poisonous organisms, for example jelly-fish.

Reference listing:

Canadian Council of Ministers of the Environment. 1999. Recreational water quality guidelines and aesthetics. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

For further scientific information, contact:

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Shigella spp.

(1) *Sh. sonnei*
Clinical symptoms are generally mild, with diarrhoea usually subsiding by the second day, although stools may be loose and rather frequent for another 3–4 days. Abdominal pain is not usually prominent but there may be severe pain resembling appendicitis. Populations of greatest concern are infants, who may easily develop symptoms of dehydration, and the elderly. Convulsions may occur in younger children and infants.

(2) *Sh. flexneri* and *Sh. dysenteriae*
Symptoms may sometimes be no more severe than dysentery caused by *Sh. sonnei*; in most cases, however, the illness is more acute. Abdominal pain and tenderness, fever, headache, generalized pain, chills, and malaise are often present. Diarrhoea is most severe on the first two days, but often persists for more than a week.

Campylobacter spp.
The clinical manifestations of infection with *Campylobacter* include diarrhoea preceded by fever and malaise. Diarrhoea is usually severe and watery, sometimes with blood in the stool. Diarrhoea generally lasts for 2–3 days, but stools may be loose for much longer. Abdominal pain may be quite severe and persist for several days. A retrospective study among patients admitted to a hospital with Guillain-Barré syndrome provided evidence for a relationship between *Campylobacter* infection and incidence of this syndrome.

Pseudomonas spp.
Otitis externa is the most common form of *Pseudomonas* infection involving the ear and is characterized by chronic serosanguineous and purulent drainage from the external auditory canal. Corneal ulceration is the most severe form of ocular *Pseudomonas* infection, which usually follows a traumatic abrasion.

Enteropathogenic *Escherichia coli*
Enteropathogenic *E. coli* causes a gastroenteritis, which is generally found in infants less than two years old and rarely seen in adults. The severity of the gastroenteritis varies from mild cases, which consist of diarrhoea that quickly returns to normal, to severe cases with vomiting and diarrhoea that increases until stools are passed almost hourly and consist only of clear watery fluid. Severe cases may be fatal unless fluids and electrolytes are promptly replaced.

Salmonella typhi and *S. paratyphi*
Presenting symptoms of typhoid fever are generally malaise, chills, and a nagging headache. In the majority of patients, the fever is prolonged and the patient's condition deteriorates

steadily. Many patients develop frank psychosis, delirium, or mania. Intestinal complaints develop rapidly and include abdominal pain, constipation, anorexia, and nausea.

Paratyphoid fever is usually milder, shorter in duration, and with fewer complications. Symptoms are very frequently those of acute gastroenteritis rather than of an invasive fever.

Staphylococcus spp.

The onset of symptoms is usually abrupt with severe nausea, vomiting, cramping abdominal pain, and diarrhoea. The disease is brief and requires no treatment. Rare fatalities have occurred in the elderly.

Proteus spp.

There are four pathogenic species of *Proteus*. They have been implicated as a cause of epidemic diarrhoea in infants, but the evidence is inconclusive. *Proteus* organisms are rarely primary invaders, but produce disease in locations previously infected by other organisms. These locations include the skin, ears and mastoid sinuses, eyes, peritoneal cavity, urinary tract, meninges, lung, and bloodstream.

Yersinia enterocolitica

The most common symptoms of *Y. enterocolitica* infection are diarrhoea, fever, and abdominal pain, which can be severe.

Vibrio cholerae

Most people with symptoms of *V. cholerae* infection have a mild illness. In the mild case, there is a looseness of stools lasting five to seven days. In severe cases, there are copious fluid stools, vomiting, and dehydration. The patient may go into shock from loss of fluid within a few hours; severe cholera can rapidly lead to death.

Coxsackieviruses and Echoviruses

The coxsackie- and echoviruses produce a similar variety of illnesses (ranging from mild to severe or life-threatening) and therefore will be discussed together.

Gastroenteritis

Infections are often mild with diarrhoea as the main symptom.

Bornholm disease (epidemic myalgia)

This illness is marked by a severe, disabling pain in the lower part of the chest or the upper abdomen, with headache and a rise in temperature during the spasms. The infection generally lasts two to four days but may persist for two to three weeks. The only frequent complication is orchitis.

Lymphocytic meningitis

Aseptic meningitis is one of the more common manifestations of enteroviral infections. The onset is usually abrupt, with headache, vomiting, pain, and rigidity of the neck frequently observed. Fever is almost always present. Lymphadenitis and conjunctivitis are present in many patients. Transient paralyses (usually mild but at times severe) have been common in some outbreaks of enteroviral infections. Lymphocytic meningitis is a self-limiting disease and not a fatal condition. Patients usually recover in two weeks.

Acute febrile illness

This illness presents with mild symptoms of malaise and headache with a rise in temperature.

Rashes

Echovirus and coxsackievirus infections have been associated with a variety of rashes that may accompany the febrile illness. The type and presentation of the rash depends on the viral type causing the infections. Symptoms are generally mild and often not diagnosed as a viral disease.

Hand, foot, and mouth disease

This illness is characterized by ulcers in the mouth and on the hands and feet. The disease is self-limiting, with ulcers resolving in seven to ten days, and no complications.

Herpangina

This disease is generally seen in children and is characterized by ulcerative lesions at the back of the throat, fever, vomiting, and headache. Young infants with high temperatures may have convulsions. Symptoms usually last for about four days.

Acute haemorrhagic conjunctivitis

This is a self-limiting disease with acute conjunctivitis lasting six to ten days. The main concern is with neurological complications, which generally occur approximately 18 days after infection. Flaccid paralysis occurs, often referred to as poliomyelitis-like illness, with the incidence highly variable and apparently dependent on the area and/or outbreak.

Pericarditis and myocarditis

Fever, tachycardia, and dyspnoea are the common symptoms. There may be precordial pain and sometimes a pericardial effusion. The symptoms of myocarditis are those of heart failure. The tendency in older children and adults is towards recovery; however, it may take several weeks or months for electrocardiographic changes to return to normal.

Orchitis

Orchitis, an inflammation of the testicles, is not common and usually occurs as a complication of one of the more severe illnesses, especially Bornholm disease or lymphocytic meningitis, but may also occur alone. Coxsackie B viruses are the only enteroviruses concerned.

Hepatitis A and non-A, non-B Hepatitis Viruses

The clinical manifestations of hepatitis vary widely in severity, from trivial to severe enough to cause death. Most cases of hepatitis are mild. The three diseases (A, B, and non-A, non-B) cannot be distinguished clinically. Hepatitis may be anicteric or icteric.

Anicteric hepatitis

Patients feel mildly unwell and may have abdominal discomfort and no appetite for a few days. Anicteric infections may result in post-necrotic cirrhosis.

Icteric hepatitis

In the pre-icteric stage, the most common symptom is malaise, often with a pronounced abdominal or gastrointestinal element. This is accompanied by headache and generalized aches and pains. These symptoms usually last one week, occasionally two to three. The icteric stage is marked by jaundice and itching. In the milder cases, the patient's symptoms abate quickly (two days). After a week to 10 days, nearly all patients feel well.

The disease, however, may take several different courses including acute hepatitis with cholestatis, fulminant hepatitis, subacute fatal hepatitis, chronic persistent hepatitis, and chronic active hepatitis. In acute hepatitis with cholestasis, jaundice may become deeper and may persist for two to three months before gradually clearing. Nearly all patients make a complete recovery. Fulminant hepatitis occurs rarely, but generally leads to death. In subacute fatal hepatitis, there are signs of liver failure as well as central nervous system involvement and death may occur within two to three months of onset. In some cases, chronic persistent hepatitis may occur, which rarely progresses to chronic active hepatitis or cirrhosis. Chronic active hepatitis results in considerable hepatocellular damage, with bouts of fever and mild attacks of jaundice. There is enlargement of the liver and spleen. The course is one of deterioration and possible cirrhosis.

Norwalk Virus

The Norwalk virus produces symptoms of gastroenteritis, generally vomiting and diarrhoea.

Rotaviruses

Rotaviruses cause acute gastroenteritis with vomiting and diarrhoea that cannot be clinically distinguished from the gastroenteritis of *E. coli*. The infection is usually mild, even in infants, but can be severe and the diarrhoea choleraic in type. The disease is generally not severe, although fatal cases have occurred.

Adenoviruses

Infections restricted to the gastrointestinal tract cause only mild symptoms of gastroenteritis, or none at all (WHO 1979).

Reoviruses

The clinical illness associated with reovirus infections has not been well defined.

Poliovirus

Most infections with poliovirus cause no symptoms, and the symptoms it does cause may differ greatly from the classical picture of paralysis. Minor illness consists of non-specific symptoms of malaise, fever, mild sore throat, upper respiratory catarrh, or mild headache. In a minority of patients, paralysis occurs varying from mild to severe cases.

Giardia lamblia

The most prominent symptom of *Giardia* infections is protracted diarrhoea. It can be mild or intene and debilitating. Untreated, diarrhoea may last for weeks or months, although it may vary in intensity, with exacerbations and remissions. The average length of illness is 44 days, but symptoms have been reported in some cases for as long as three to four years.

Entamoeba histolytica

Entamoeba histolytica is the causative agent of amoebic dysentery. Less frequently, it also causes extraintestinal infections. The majority of infected individuals are free of symptoms; however, those who are symptomatic experience a wide range of manifestations. The most common is nonspecific diarrhoea lasting more than the usual few days. Ulcerative colitis represents the next stage of severity and can be either localized and cause few or no symptoms, or extensive, resulting in dysentery. Untreated infections may result in more severe complications.

APPENDIX C

SCREENING LEVEL RISK ASSESSMENT METHODOLOGY

1.0 SCREENING LEVEL RISK ASSESSMENT METHODOLOGY

The following sections describe the methodology used in the qualitative assessment of risk in the Screening Level Risk Assessment (SLRA). The SLRA qualitatively evaluates the risk which known or potential hazards may present to known or potential receptors. This methodology, developed by Jacques Whitford Environment Limited (JWEL) is consistent with the Canadian Council of Ministers of the Environment (CCME) tiered approach to risk assessment (CCME, 1996a). The SLRA is intended to provide a record of the assumptions employed in performing the qualitative estimation of risk and to identify the limitations of the data used in this risk estimation process. The results of the SLRA can then be used to make risk management decisions or used as inputs to the next stages of quantitative risk assessment, if required.

The SLRA is performed in three steps:

1) Hazard Characterization and Assessment;
2) Exposure Assessment;
3) Qualitative Risk Estimation.

1.1 Hazard Characterization and Assessment

Chemical Screening

The chemicals carried forward for analysis in the SLRA include the following:

- Chemicals with on-site concentrations that exceed established regulatory guidelines
- Chemicals that may cause adverse health effects with prolonged or repeated exposure
- Chemicals with concentrations that substantially exceed the natural background levels

Each chemical carried forward in this way is considered a *Contaminant of Potential Concern*, or a *Potential Hazard*.

Qualitative Assessment

Each potential hazard is considered and evaluated in terms of its relative severity based on the following series of definitions.

Severity	Receptor	Definition
Minimal	Human	No effects expected.
Minor	Human	Small and temporary (reversible effects expected)
Moderate	Human	Short-term disability or potential chronic effects possible.
Severe	Human	Long-term disability, acute effects, or death likely

The potential hazards identified in the study are qualitatively ranked in severity according to the severity of their toxicological effects. This assessment is independent of the concentration of the chemical or the degree of exposure to any receptors. Chemicals with a high potential for bioaccumulation or biomagnification (such as PCBs) are considered severe hazards.

1.2 Exposure Assessment

The exposure assessment involves two steps:

a) Exposure Pathway Characterization
b) Receptor Identification

1.2.1 Exposure Pathway Characterization

The potential exposure pathways are characterized by identifying the possible mechanisms by which a potential hazard can travel from the known or potential source areas and affect a potential receptor. Each exposure pathway is considered and evaluated. The likelihood of exposure is then defined for each pathway based on the understanding of exposure mechanism and the fate and transport characteristics of the hazard, according to the following definitions:

C *Very Unlikely* - Level of exposure that could result in adverse effects is not expected
C *Unlikely* - Level of exposure that could result in adverse effects would probably not occur
C *Possible* - Level of exposure that could result in adverse effects might be expected
C *Likely* - Level of exposure that could result in adverse effects is expected. Exceedence of this exposure level might be expected.

1.3 Qualitative Risk Estimation

The potential risks associated with each potential hazard-exposure-receptor scenario are estimated by comparing the severity of the hazard with the likelihood of exposure as per the following chart:

		Exposure Assessment			
		Very Unlikely	***Unlikely***	***Possible***	***Likely***
Hazard Assessment	***Minimal***	Low	Low	Low	Low
	Minor	Low	Low	Medium	Medium
	Moderate	Low	Medium	Medium	High
	Severe	Low	Medium	High	High

In addition to estimating the risk according to the hazard severity and likelihood of exposure, the SLRA also provides an assessment of the data quality which was used to estimate the risks and an evaluation of the work required to confirm this assessment.

1.3.1 Data Assessment

The quality of the data used to make the qualitative assessment of the severity of the hazard and the likelihood of exposure is evaluated for each exposure pathway. The general definitions identified below are used:

Assessment	Definition
High	Additional data will not change the risk estimate
Medium	More data will not likely change the risk estimate - but is necessary to accurately quantify risk
Poor	Additional data could change the risk estimate
None	Risk estimate based on assumptions

APPENDIX D

ANALYTICAL DATA FROM “WASTEWATER CHARACTERIZATION STUDY - 1999" (SNC LAVALIN 1999)

Table 5-2: Analytical Results - Roaches Pond

Parameter	EQL	Units	Sample ID Date Period	Roaches Pond-01 June 14 - June 15 11:40am - 11:40am	Roaches Pond-02 June 15 - June 16 11:40am - 11:40am	Roaches Pond-03 June 16 - June 17 11:40am - 11:40am
pH	0.1	Units		6.8	7.1	7
Carbonaceous BOD	2	mg/L		110	99	96
Total Suspended Solids	0.5	mg/L		77	101	75
Volatile Suspended Solids	0.3	mg/L		71	91	68
Total Oil & Grease	5	mg/L		-	23.4	-
Aluminum	10	ug/L		-	490	-
Antimony	2	ug/L		-	nd	-
Arsenic	2	ug/L		-	nd	-
Barium	5	ug/L		-	28	-
Beryllium	5	ug/L		-	nd	-
Boron	5	ug/L		-	51	-
Cadmium	0.3	ug/L		-	0.2	-
Chromium	2	ug/L		-	nd	-
Cobalt	1	ug/L		-	nd	-
Copper	2	ug/L		-	35	-
Iron	20	ug/L		-	610	-
Lead	0.5	ug/L		-	2	-
Manganese	2	ug/L		-	130	-
Molybdenum	2	ug/L		-	nd	-
Nickel	2	ug/L		-	2	-
Selenium	2	ug/L		-	nd (2)	-
Silver	0.5	ug/L		-	nd	-
Strontium	5	ug/L		-	56	-
Thallium	0.1	ug/L		-	nd	-
Tin	2	ug/L		-	nd	-
Uranium	0.1	ug/L		-	0.2	-
Vanadium	2	ug/L		-	nd	-
Zinc	2	ug/L		-	54	-
Mercury	0.05	ug/L		-	nd	-

EQL = Estimated Quantitation Limit for Routine Analysis
nd = not detected above standard EQL
nd () = not detected at the elevated EQL specified due to matirx interference or sample pre-dilution
- = Parameter not requested in sample

Table 5-4: Analytical Results - Point Pleasant Park

Parameter	EQL	Units	Point Pleasant-01	Point Pleasant-02	Point Pleasant-03
		Sample ID	Point Pleasant-01	Point Pleasant-02	Point Pleasant-03
		Date Period	June 7 - June 8 11:10am - 11:10am	June 8 - June 9 11:10am - 11:10am	June 9 - June 10 11:10am - 11:10am
pH	0.1	Units	6.9	6.7	6.8
Carbonaceous BOD	2	mg/L	110	54	87
Total Suspended Solids	0.5	mg/L	60	51	80
Volatile Suspended Solids	0.3	mg/L	53	44	67
Total Oil & Grease	5	mg/L	-	-	14.3
Aluminum	10	ug/L	-	-	730
Antimony	2	ug/L	-	-	nd
Arsenic	2	ug/L	-	-	2
Barium	5	ug/L	-	-	26
Beryllium	5	ug/L	-	-	nd
Boron	5	ug/L	-	-	300
Cadmium	0.3	ug/L	-	-	0.2
Chromium	2	ug/L	-	-	nd
Cobalt	1	ug/L	-	-	2
Copper	2	ug/L	-	-	31
Iron	20	ug/L	-	-	930
Lead	0.5	ug/L	-	-	4.1
Manganese	2	ug/L	-	-	190
Molybdenum	2	ug/L	-	-	nd
Nickel	2	ug/L	-	-	6
Selenium	2	ug/L	-	-	nd (10)
Silver	0.5	ug/L	-	-	nd
Strontium	5	ug/L	-	-	390
Thallium	0.1	ug/L	-	-	nd
Tin	2	ug/L	-	-	nd
Uranium	0.1	ug/L	-	-	0.1
Vanadium	2	ug/L	-	-	nd
Zinc	2	ug/L	-	-	60
Mercury	0.05	ug/L	-	-	0.18

EQL = Estimated Quantitation Limit for Routine Analysis
nd = not detected above standard EQL
nd () = not detected at the elevated EQL specified due to matirx interference or sample pre-dilution
- = Parameter not requested in sample

Table 5-8: Analytical Results - Bell Road

Parameter	EQL	Units	Bell Rd-01	Bell Rd-02	Bell Road-03
Sample ID			Bell Rd-01	Bell Rd-02	Bell Road-03
Date Period			June 21 - June 22 7:00pm - 7:00pm	June 22 - June 23 7:00pm - 7:00pm	June 23 - June 24 7:00pm - 7:00pm
pH	0.1	Units	6.9	6.7	6.7
Carbonaceous BOD	2	mg/L	130	91	100
Total Suspended Solids	0.5	mg/L	109	78	71
Volatile Suspended Solids	0.3	mg/L	94	71	63
Total Oil & Grease	5	mg/L	18.8	-	-
Aluminum	10	ug/L	550	-	-
Antimony	2	ug/L	nd	-	-
Arsenic	2	ug/L	5	-	-
Barium	5	ug/L	46	-	-
Beryllium	5	ug/L	nd	-	-
Boron	5	ug/L	90	-	-
Cadmium	0.3	ug/L	0.2	-	-
Chromium	2	ug/L	13	-	-
Cobalt	1	ug/L	nd	-	-
Copper	2	ug/L	37	-	-
Iron	20	ug/L	2500	-	-
Lead	0.5	ug/L	7.7	-	-
Manganese	2	ug/L	120	-	-
Molybdenum	2	ug/L	7	-	-
Nickel	2	ug/L	5	-	-
Selenium	2	ug/L	nd (2)	-	-
Silver	0.5	ug/L	2.8	-	-
Strontium	5	ug/L	71	-	-
Thallium	0.1	ug/L	nd	-	-
Tin	2	ug/L	nd	-	-
Uranium	0.1	ug/L	nd	-	-
Vanadium	2	ug/L	nd	-	-
Zinc	2	ug/L	79	-	-
Mercury	0.05	ug/L	0.1	-	-

EQL = Estimated Quantitation Limit for Routine Analysis
nd = not detected above standard EQL
nd () = not detected at the elevated EQL specified due to matirx interference or sample pre-dilution
\- = Parameter not requested in sample

Table 5-10: Analytical Results - Tufts Cove

Parameter	EQL	Units	Tufts Cove-01	Tufts Cove-02	Tufts Cove-03
Sample ID			Tufts Cove-01	Tufts Cove-02	Tufts Cove-03
Date Period			June 28 - June 29 9:05am - 9:05am	June 29 - June 30 9:05am - 9:05am	June 30 - July 01 9:05am - 9:05am
pH	0.1	Units	6.5	6.7	6.5
Carbonaceous BOD	2	mg/L	160	180	150
Total Suspended Solids	0.5	mg/L	113	114	93
Volatile Suspended Solids	0.3	mg/L	91	100	80
Total Oil & Grease	5	mg/L	-	-	29.6
Aluminum	10	ug/L	-	-	450
Antimony	2	ug/L	-	-	nd (20)
Arsenic	2	ug/L	-	-	nd (20)
Barium	5	ug/L	-	-	110
Beryllium	5	ug/L	-	-	nd (50)
Boron	5	ug/L	-	-	87
Cadmium	0.3	ug/L	-	-	nd (1)
Chromium	2	ug/L	-	-	nd (20)
Cobalt	1	ug/L	-	-	nd (10)
Copper	2	ug/L	-	-	120
Iron	20	ug/L	-	-	1700
Lead	0.5	ug/L	-	-	14
Manganese	2	ug/L	-	-	170
Molybdenum	2	ug/L	-	-	nd (20)
Nickel	2	ug/L	-	-	nd (20)
Selenium	2	ug/L	-	-	nd (10)
Silver	0.5	ug/L	-	-	150
Strontium	5	ug/L	-	-	50
Thallium	0.1	ug/L	-	-	nd (1)
Tin	2	ug/L	-	-	nd (20)
Uranium	0.1	ug/L	-	-	nd (1)
Vanadium	2	ug/L	-	-	nd (20)
Zinc	2	ug/L	-	-	150
Mercury	0.05	ug/L	-	-	0.12

EQL = Estimated Quantitation Limit for Routine Analysis

nd = not detected above standard EQL

nd () = not detected at the elevated EQL specified due to matirx interference or sample pre-dilution

\- = Parameter not requested in sample

Table 5-12: Analytical Results - Jamieson Street

Parameter	EQL	Units	Jamieson St-01	Jamieson St-02	Jamieson St-03
Sample ID			Jamieson St-01	Jamieson St-02	Jamieson St-03
Date Period			June 21 - June 22 11:00am - 11:00am	June 22 - June 23 11:00am - 11:00am	June 23 - June 24 11:00am - 11:00am
pH	0.1	Units	6.7	6.9	6.8
Carbonaceous BOD	2	mg/L	74	130	40
Total Suspended Solids	0.5	mg/L	61	87	67
Volatile Suspended Solids	0.3	mg/L	55	81	60
Total Oil & Grease	5	mg/L	9.6	-	-
Aluminum	10	ug/L	460	-	-
Antimony	2	ug/L	nd	-	-
Arsenic	2	ug/L	2	-	-
Barium	5	ug/L	22	-	-
Beryllium	5	ug/L	nd	-	-
Boron	5	ug/L	52	-	-
Cadmium	0.3	ug/L	0.4	-	-
Chromium	2	ug/L	nd	-	-
Cobalt	1	ug/L	nd	-	-
Copper	2	ug/L	41	-	-
Iron	20	ug/L	550	-	-
Lead	0.5	ug/L	2.2	-	-
Manganese	2	ug/L	220	-	-
Molybdenum	2	ug/L	nd	-	-
Nickel	2	ug/L	4	-	-
Selenium	2	ug/L	nd (2)	-	-
Silver	0.5	ug/L	nd	-	-
Strontium	5	ug/L	50	-	-
Thallium	0.1	ug/L	nd	-	-
Tin	2	ug/L	nd	-	-
Uranium	0.1	ug/L	nd	-	-
Vanadium	2	ug/L	nd	-	-
Zinc	2	ug/L	56	-	-
Mercury	0.05	ug/L	0.06	-	-

EQL = Estimated Quantitation Limit for Routine Analysis
nd = not detected above standard EQL
nd () = not detected at the elevated EQL specified due to matirx interference or sample pre-dilution
\- = Parameter not requested in sample

Table 5-14: Analytical Results - Chamber#1

Parameter	EQL	Units	Chamber1-01	Chamber 1-02	Chamber 1-03
		Sample ID	Chamber1-01	Chamber 1-02	Chamber 1-03
		Date Period	June 14 - June 15 12:00pm - 12:00pm	June 15 - June 16 12:00pm 12:00pm	June 16 - June 17 12:00pm - 12:00pm
pH	0.1	Units	6.9	7	6.9
Carbonaceous BOD	2	mg/L	160	150	140
Total Suspended Solids	0.5	mg/L	133	104	117
Volatile Suspended Solids	0.3	mg/L	121	94	104
Total Oil & Grease	5	mg/L	-	12.3	-
Aluminum	10	ug/L	-	510	-
Antimony	2	ug/L	-	nd	-
Arsenic	2	ug/L	-	nd	-
Barium	5	ug/L	-	20	-
Beryllium	5	ug/L	-	nd	-
Boron	5	ug/L	-	49	-
Cadmium	0.3	ug/L	-	0.4	-
Chromium	2	ug/L	-	3	-
Cobalt	1	ug/L	-	nd	-
Copper	2	ug/L	-	42	-
Iron	20	ug/L	-	600	-
Lead	0.5	ug/L	-	2.5	-
Manganese	2	ug/L	-	95	-
Molybdenum	2	ug/L	-	nd	-
Nickel	2	ug/L	-	3	-
Selenium	2	ug/L	-	nd (2)	-
Silver	0.5	ug/L	-	7.5	-
Strontium	5	ug/L	-	44	-
Thallium	0.1	ug/L	-	nd	-
Tin	2	ug/L	-	nd	-
Uranium	0.1	ug/L	-	0.1	-
Vanadium	2	ug/L	-	nd	-
Zinc	2	ug/L	-	67	-
Mercury	0.05	ug/L	-	0.08	-

EQL = Estimated Quantitation Limit for Routine Analysis
nd = not detected above standard EQL
nd () = not detected at the elevated EQL specified due to matirx interference or sample pre-dilution
- = Parameter not requested in sample

Table 5-16: Analytical Results - Dartmouth Cove

Parameter	EQL	Units	Dart. Cove-01	Dart. Cove-02	Dart. Cove-03
Sample ID / Date Period			June 28 - June 29 9:30am - 9:30am	June 29 - June 30 9:30am - 9:30am	June 30 - July 01 9:30am - 9:30am
pH	0.1	Units	6.7	6.8	6.7
Carbonaceous BOD	2	mg/L	110	130	130
Total Suspended Solids	0.5	mg/L	114	135	95
Volatile Suspended Solids	0.3	mg/L	95	117	78
Total Oil & Grease	5	mg/L	-	-	16.9
Aluminum	10	ug/L	-	-	870
Antimony	2	ug/L	-	-	nd (20)
Arsenic	2	ug/L	-	-	nd (20)
Barium	5	ug/L	-	-	nd (50)
Beryllium	5	ug/L	-	-	nd (50)
Boron	5	ug/L	-	-	71
Cadmium	0.3	ug/L	-	-	nd (1)
Chromium	2	ug/L	-	-	nd (20)
Cobalt	1	ug/L	-	-	nd (10)
Copper	2	ug/L	-	-	53
Iron	20	ug/L	-	-	1100
Lead	0.5	ug/L	-	-	5
Manganese	2	ug/L	-	-	260
Molybdenum	2	ug/L	-	-	nd (20)
Nickel	2	ug/L	-	-	nd (20)
Selenium	2	ug/L	-	-	nd (10)
Silver	0.5	ug/L	-	-	nd (5)
Strontium	5	ug/L	-	-	66
Thallium	0.1	ug/L	-	-	nd (1)
Tin	2	ug/L	-	-	nd (20)
Uranium	0.1	ug/L	-	-	nd (1)
Vanadium	2	ug/L	-	-	nd (20)
Zinc	2	ug/L	-	-	100
Mercury	0.05	ug/L	-	-	0.19

EQL = Estimated Quantitation Limit for Routine Analysis
nd = not detected above standard EQL
nd () = not detected at the elevated EQL specified due to matirx interference or sample pre-dilution
- = Parameter not requested in sample

APPENDIX E

SUMMARY OF TOXICITY EFFECTS FROM SELECTED BIOLOGICAL AND CHEMICAL HAZARDS

Summary of Toxicity Effects from Selected Biological and Chemical Hazards

The following table summarizes potential health effects from exposure to selected contaminants identified in the wastewater characterization study completed for the project. Actual effects will vary based on individuals and exposure conditions. Excerpts from occupational exposure data, epidemiological studies and other observed effects have been summarized here for information on hazard identification data on the basis of a variety of exposure scenarios.

Note: The effects listed here are not to be construed as likely or probable effects expected from exposure to treated or untreated harbour sewage. The risk from expected exposure is analyzed in the main body of the report and summarized in Section 7.

Table E.1 Summary of Toxicity Effects from Selected Biological and Chemical Hazards

Potential Hazards	Media Where Expected to be Identified	Expected Exposure Route	Toxic Effects
Biological			
Microbial Pathogens (bacteria, viruses, and protozoa)[1]	Surface water	Dermal contact/ingestion of surface water	Symptoms range from gastrointestinal effects (*i.e.* diarrhea), fever, chills, headache, nausea, vomiting, cramping, rashes. See Appendix B for specific details on effects from each pathogen.
Metals			
Aluminum	Dissolved in water (limited) Sorbed to sediment Uptake by shellfish/ crustaceans	Dermal contact/ingestion of surface water (limited) Dermal contact with sediment (limited) Ingestion of contaminated shellfish/ crustaceans	Ingestion can result in gastrointestinal irritation or corrosion, with nausea, vomiting, abdominal pain and diarrhea
Arsenic			Ingestion of water high in inorganic arsenic can result in multiple internal organ cancers (liver, kidney, lung, and bladder) and skin cancer
Barium			Ingestion exposure may result in increased incidences of hypertension. No-observed effect level (NOEL) of 0.21 mg/kg-day
Boron			Chronic ingestion may cause anorexia, weight loss, vomiting, mild diarrhea, skin rash, alopecia, convulsions and anaemia
Cadmium			Ingestion can result in severe nausea, vomiting, diarrhea, muscular cramps, vertigo, exhaustion, shock (rare)
Chromium			The US Food and Nutrition Board has recommended a safe and adequate dietary intake of 50-200 ug chromium/day
Copper			Ingestion can result in gastrointestinal disturbance, nausea, vomiting

Table E.1 Summary of Toxicity Effects from Selected Biological and Chemical Hazards

Potential Hazards	Media Where Expected to be Identified	Expected Exposure Route	Toxic Effects
Iron			Iron is an essential element. Exposure to elevated concentrations of iron can cause heart disease, liver disease
Lead			Ingestion can result in hematological, gastrointestinal, and neurological dysfunction
Manganese			Essential element, severe exposure may result in apathy, anorexia, euphoria, impulsiveness, insomnia, headache, cramps
Mercury			Ingestion can result in immediate burning pain, sense of constriction, and ashen discoloration of the mucous membrane in mouth and pharynx, followed by intense epigastric and abdominal pain, severe vomiting, and in severe cases, death
Molybdenum			Ingestion can result in increased blood uric levels and cause gout-like symptoms
Nickel			Dermal contact may cause dermatitis. Ingestion can result in emetic effects, capillary damage (esp. in brain and adrenals), renal injury, and central nervous system depression
Selenium			Ingestion can result in gastrointestinal disturbances, icteroid discolouration of skin, decayed teeth, jaundice, dermatitis
Silver			Ingestion may cause generalized argyria
Strontium			Ingestion may cause gastrointestinal disorders, painful contractions in limbs
Zinc			Essential element, severe exposure may result in gastritis with vomiting, diarrhea
TPH	Dissolved in water	Dermal contact/ingestion of surface water	Symptoms of exposure to elevated concentrations of TPH include hepatoxicity, nephrotoxicity, decreased body weight, hepatic and hematological changes (TPHCWG, 1997a and 1997b)
PCBs	Sorbed to sediment Uptake by shellfish/ crustaceans	Dermal contact with sediment Ingestion of contaminated shellfish/ crustaceans	PCBs may be carcinogenic to humans; they are liver toxins and can cause chloroacne, and possible peripheral neuropathy, one study indicated increased brown pigmentation of nails and skin, follicular accentuation, acneform eruptions, increased eye discharge, increased sweating at the palms, feeling of weakness

Table E.1 Summary of Toxicity Effects from Selected Biological and Chemical Hazards

Potential Hazards	Media Where Expected to be Identified	Expected Exposure Route	Toxic Effects
PAHs	Sorbed to sediment Uptake by shellfish/ crustaceans	Dermal contact with sediment Ingestion of contaminated shellfish/crustaceans	Heavier end PAHs tend to be lipophilic, hydrophobic, bioaccumulative and are likely human carcinogens, may produce multiple organ cancer with sufficient doses (including skin, colon, lung)
Volatile Organic Compounds (VOCs)			
Acetone	Outdoor air	Inhalation of outdoor air	Acetone is rapidly cleared from the body by metabolism and excretion through exhalation (major route of elimination for acetone and its terminal metabolite CO2); the fraction of administered acetone that is exhaled as unchanged acetone is dose-related. Inhalation can cause central nervous system depression, cardiorespiratory failure and death at high doses; acute exposure to atmospheric concentrations have produced no gross toxic effects or minor transient effects, such as eye irritation; more severe transient effects (vomiting, fainting) were reported for workers exposed to acetone vapour concentrations for four hours.
Dichloromethane (methylene chloride)	Outdoor air	Inhalation of outdoor air	Dichloromethane is rapidly absorbed through the lung alveoli into the systemic circulation. Methylene chloride is quite rapidly excreted, mostly via the lungs in the exhaled air. It can cross the blood-brain barrier. The majority of DCM is metabolized to carbon monoxide, carbon dioxide, and inorganic chloride. Inhalation can cause headache, giddiness, stupor, irritability, numbness and tingling in the limbs. Potential human carcinogen- carcinogenic in several rat and mouse studies

Table E.1 Summary of Toxicity Effects from Selected Biological and Chemical Hazards

Potential Hazards	Media Where Expected to be Identified	Expected Exposure Route	Toxic Effects
Chloroform	Outdoor air	Inhalation of outdoor air	At high concentrations, exposure to chloroform can result in anaesthesia, central nervous system depression (14,000 ppm), renal damage and liver damage. At lower concentrations, exposure can result in inebriation, excitation, central nervous system depression, vomiting and gastrointestinal upsets (1000 ppm). Acute exposure to chloroform at 4096 ppm has been associated with fainting and vomiting, dizziness and salivation after a few minutes exposed to 1475 ppm and fatigue and headache after exposure to 1024 ppm for several hours. Signs of chloroform poisoning in humans include a characteristic sweetish odor on the breath, dilated pupils, cold and clammy skin, initial excitation alternating with apathy, loss of sensation, abolition of motor functions, prostration, unconsciousness and eventual death. Concentrations of chloroform up to 400 ppm can be endured for 30 minutes without complaint.
Toluene	Outdoor air	Inhalation of outdoor air	Inhalation exposure caused noticeable irritation to human eyes at 300-400 ppm in air; exposure produced reversible effects upon liver, renal, and nervous systems; lower level exposure produced dizziness, exhilaration and confusion; high level toluene exposures produced in-coordination, ataxia, unconsciousness and eventually death.
1,1,1 Trichloroethane (TCA)	Outdoor air	Inhalation of outdoor air	1,1,1-TCE is a central nervous system depressant that produces changes ranging from headache, lightheadedness, impaired coordination, disequilibrium, drowsiness, and convulsion to gait disturbances, stupor, coma, and death presumably from respiratory depression. Death has occurred both with industrial use in small, poorly ventilated spaces and with recreational abuse of decongestant aerosols. Concentrations greater than 5000 ppm in air have been associated with potentially life-threatening central nervous system depression, and from 500-350 ppm have been associated with an obvious TCE odour and slight changes in and individual's perception, with 100 ppm considered the odour threshold.
Tetrachloroethylene (Perc)	Outdoor air	Inhalation of outdoor air	Suspected human carcinogen; in high doses inhalation can act is a central nervous system depressant, with symptoms of exposure including unconsciousness, dizziness, headache, vertigo.

Table E.1 Summary of Toxicity Effects from Selected Biological and Chemical Hazards

Potential Hazards	Media Where Expected to be Identified	Expected Exposure Route	Toxic Effects
Trichloroethylene (TCE)	Outdoor air	Inhalation of outdoor air	Suspected human carcinogen; inhalation exposure was associated with headaches, dizziness and sleepiness, severe exposure may result in liver and kidney lesions, reversible trigeminal (or other nerve) degeneration, and psychic disturbances prolonged exposure may be associated impairment of the nervous system, persistent neuritis. disturbances; prolonged exposure may be associated impairment of the nervous system, persistent neuritis.
Source: Toxicology Data Network (TOXNET), 2000 (except where otherwise referenced)			