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HALIFAX REGIONAL MUNICIPALITY FUTURE SERVICED COMMUNITIES – SANDY LAKE WATERSHED STUDY AND STORMWATER MANAGEMENT PLAN

Final Report

December 12, 2024

Prepared for:
Halifax Regional Municipality

Prepared by:
Stantec Consulting Ltd.

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160410459

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0	Draft Watershed Study and SWM Plan	MS/DB	2024-10-21	AP	2024-10-24	SRW	2024-11-01
1	Final Watershed Study and SWM Plan	DB	2024-11-19	AP	2024-11-22	SRW	2024-11-25
2	Final Watershed Study and SWM Plan	DB	2024-11-19	MS	2024-11-28	AP	2024-12-10

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1 Introduction

The 2006 Halifax Municipal Planning Strategy (Regional Plan) provides guiding principles on the development of future settlement in the Halifax Regional Municipality (HRM) until 2031. Land development within a watershed has the potential to negatively impact the biophysical environment, therefore the Regional Plan requires that prior to undertaking secondary municipal planning or considering amendments to existing secondary plans, HRM must complete watershed studies to aid in municipal planning. The assessment of study areas and watershed studies are intended to provide solutions and recommendations to existing issues or potential impacts due to future development.

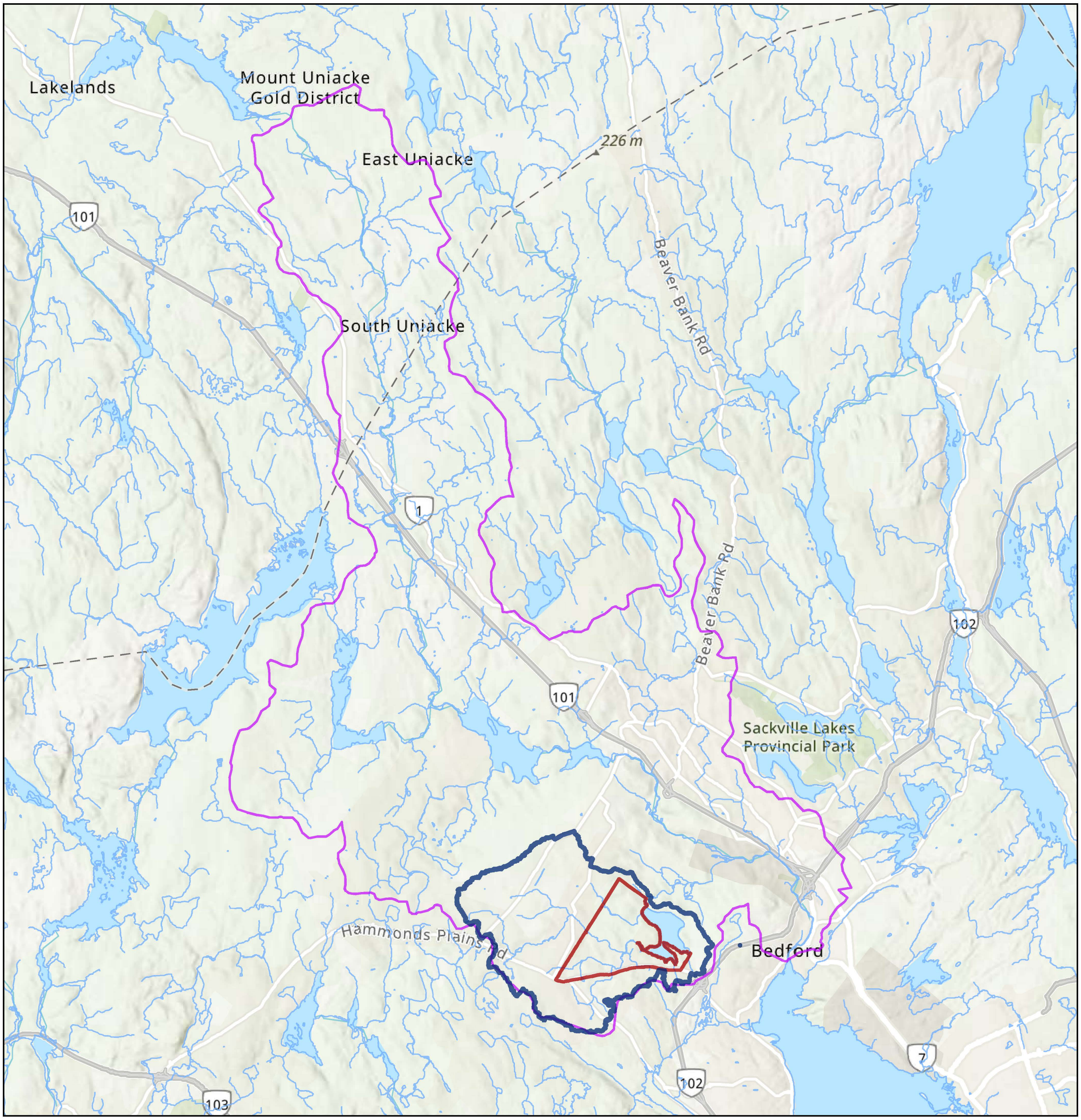
The areas being studied as part of this project are the remaining Future Serviced Communities identified for development by the Regional Municipal Planning Strategy (Regional Plan) and the Road to Economic Prosperity for African Nova Scotian Communities. Sandy Lake, Highway 102 West Corridor and Morris Lake had not yet undergone the comprehensive neighbourhood planning process outlined by the Regional Plan and a fourth area, Westphal was added for consideration of future serviced development through the African Nova Scotian Road to Economic Prosperity Action Plan.

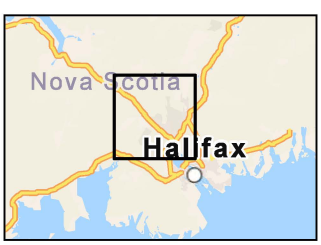
This study was prepared in conjunction with the Land Suitability Analysis (Stantec 2024) of the Sandy Lake Study Area. More information regarding existing conditions of the site with respect to topography, wildlife, wetlands, watercourses, forest habitat, species at risk, contaminated sites, and archeology can be found within the Land Suitability Report. Additionally, further background conditions on the site can be found within the suite of studies prepared for the Sandy Lake Future Serviced Community, which include:

- Development Scenarios Report – Sandy Lake (Stantec 2023)
- Sandy Lake Interim Report (Stantec 2023)
- Sandy Lake Transportation Study (Stantec 2024)
- Sandy Lake Water Servicing Plan Report (Stantec 2024)

1.1 Background

The Sandy Lake watershed is located within the highly urbanized Sackville River Secondary Watershed (1EJ-4) in the Halifax Regional Municipality (HRM), in Bedford, Nova Scotia (NS) (**Figure 1-1**), with prominent commercial and residential land use in the surrounding areas (Sackville River Association 2011). The Sandy Lake watershed has a drainage area of approximately 17.69 km^2 (1,769 ha). Runoff within the watershed flows from the west and southwest into Sandy Lake which then discharges into Peverills Brook, Marsh Lake, and eventually into the Sackville River, which discharges into the Bedford Basin in Halifax Harbour. Sandy Lake is a prominent headwater lake and has a surface area of 78.5 ha. Bathymetry of the lake was conducted by Conrad et. al. in 2001 and observed the mean depth to be 8.2 m. The lake volume is approximately 6.08 Mm^3 (Conrad et al. 2002) and the mean time that water remains in the lake (retention time) is estimated to be 0.34 years (White et. al. 1984).





Legend

- Sandy Lake Study Area
- Watershed Boundary
- Sackville River Secondary Watershed (1EJ-4)
- Watercourse
- Waterbody

0 1 2 3 4 5 km

(At original document size of 8.5x11)
1:150,000

N

Notes
1. Coordinate System: NAD 1983 CSRS UTM Zone 20N
2. Data Sources: Stantec; Halifax Regional Municipality, Government of Nova Scotia
3. Background: Esri

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Project Location
Halifax Regional Municipality, Nova Scotia

Prepared by AC on 2024-04-10

Client/Project
Halifax Regional Municipality
Future Serviced Communities

160410459

Figure No.
1-1

Title
Sandy Lake Watershed Location

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1.2 Report Objectives for Surface Water Quality

The objective of this watershed study is to determine water quality impacts to sensitive or natural receptors within or downstream of the Sandy Lake study area. The focus of this study is on sourcing and quantifying contaminant loadings of phosphorus (P), fecal coliforms and sediment due to impacts of land-use change to the Sandy Lake Study Area (SLSA) and its contributing watershed area from proposed development scenarios. These specific contaminants were selected based on observed adverse effects to the recreational use of waterbodies around HRM from these contaminants, and historic Sandy Lake municipal beach closures due to fecal bacteria.

In this study, contaminant loading models for three land development scenarios (developer-requested, low-density, and high-density) were evaluated to understand the potential water quality effects resulting from each scenario, a fourth scenario incorporates the same housed population as the developer-requested scenario, however this scenario covers 20% less land area compared to the developer-requested scenario. This scenario was evaluated to assess impacts of development on the watershed when forested area is conserved within the watershed. The outcome of the study is to provide a number of recommendations for the planning, design, and implementation of new developments that will help to maintain existing water quality.

1.3 Surface Water Quality Data Collection

Surface water data collection was completed by Stantec Consulting Ltd. (Stantec) monthly between April and November 2023 and was used in conjunction with the historical water quality collected intermittently since 1980 to characterize water quality in the SLSA. Data collected prior to 1980 was not included in this study in the detailed analysis due to the sparsity of measurements and their potential limitations in representing temporal trends accurately. Data prior to an including 1980 are generally limited to one measurement per year, which makes the data less reliable for detecting nuanced patterns or changes over time. It is also important to note that the primary objective of this study was to model changes in water quality under specific development scenarios rather than to evaluate historical water quality or long-term trends. As such, data with sufficient temporal resolution was prioritized to support modeling and scenario-based analysis. Field monitoring of water quality was conducted at select locations across the SLSA including in-lake, deep zone, watercourses, lake inlet, and lake outlets (Stantec 2024a). The data was used as a comparison tool for contaminant models as well as a measure of lake water quality.

Table 1-1 is a summary of the surface water quality data sources collected within the SLSA. A description of local water quality and summary of the 2023 Stantec water quality results can be found in the Sandy Lake Land Suitability Analysis (Stantec 2024a) and results of the water quality monitoring can be found in **Appendix A**.

Contaminant models were developed to assess key parameters that are particularly sensitive to changes in land use within a watershed, such as when forested land is developed to residential or commercial use. Probable causes of water quality impacts may be identified by examining changes to these key parameter concentrations. Total phosphorus (TP), fecal coliform (represented by *E.coli*), and sediment (represented as total suspended sediments (TSS) were identified as key parameters that will be used to assess changes in trophic level/nutrients, water clarity, and anthropogenic inputs, respectively. A description of existing conditions of parameters that may affect the internal loading of the lake including pH, dissolved oxygen (DO), temperature, and conductivity is provided in **Section 1.3.4**.

Table 1-1 Historical Water Quality Data Sources

Data Source	Sampling Location	Period of Record	Number of Samples	Month of Sampling Events	Parameters Sampled
Department of Fisheries and Oceans (DFO)	Sandy Lake	1980, 1991, 2000	5	January	Inorganics, Metals, Chlorophyll *a,* Total phosphorus
Nova Scotia Environment	Sandy Lake, Sandy Lake Outlet	1998	3	September	Inorganics, General chemistry, Total aluminum, Total copper, Total zinc, Total phosphorus
Dalhousie University	Sandy Lake, Sandy Lake Inlet, Sandy Lake Outlet	2001	4	November	General chemistry
HRM	Sandy Lake	2006 to 2011	14	May, August, September, and October	Nutrients, General chemistry, Total coliforms, *E. coli*, Ammonia, Metals, Chlorophyll *a*
HRM – Lake Watchers	Sandy Lake and Sandy Lake Outlet	2022-2023	4	May and August	Total phosphorus, Chloride, Chlorophyll *a*, Metals and *E. coli*
HRM	Sandy Lake Outlet	2007 to 2011	11	May, August, September, October	Bacteria
DFO	Sandy Lake	2011	2	April	Nutrients, General Chemistry, Chlorophyl *a*, Metals
AECOM	Sandy Lake Outlet and Peverills Brook (Marsh Lake Outlet)	August and November 2013; April 2014	3	August, April, and November	Nutrients, Bacteria, Metals, Chlorophyll *a*
Dalhousie University (Doucet, C)	Sandy Lake	2021	2	March	Nutrients, General Chemistry, Chlorophyll *a*, Metals
Stantec Consulting Ltd	Sandy Lake, Sandy Lake Deep Zone, Peverills Brook, Johnson Brook, Unnamed outlet, Unnamed Inlet	2023	8 per site for a total of 72 samples	Monthly from April to November	Total phosphorus, Dissolved chloride, Turbidity, Colour, Total suspended solids, and *E.coli* (counts).

1.3.1 TOTAL PHOSPHORUS

Phosphorus (P) is a common water quality parameter associated with the growth and proliferation of algae and aquatic vegetation in freshwater bodies. It is typically considered a limiting nutrient in natural freshwater systems, indicating it is not as readily available in comparison with other nutrients required for plant growth. The level of biological productivity within a lake is defined by the trophic level of the lake (**Table 1-2**). Lakes can naturally transition to a higher trophic level by accumulating nutrients (such as P) over thousands of years (Anderson 2002). In urbanized watersheds, however, the influence of human activities can cause an increase in P loading to waterbodies, contributing to an overabundance of vegetation and algae growth in a process called cultural eutrophication (Anderson 2002).

Table 1-2 Total Phosphorus Trigger Ranges for Canadian Lakes and Rivers (CCME 2004)

Trophic Status	Total Phosphorus (mg/L)
Ultra-oligotrophic	<0.004
Oligotrophic	0.004 to 0.010
Mesotrophic	0.010 to 0.020
Meso-eutrophic	0.020 to 0.035
Eutrophic	0.035 to 0.100
Hyper-eutrophic	>0.100

Source: Brylinsky 2004

Levels of TP in Sandy Lake are presented in **Figure 1-2**. TP for Sandy Lake ranged from 0.001 to 0.043 mg/L with an average value of 0.013 mg/L using the 1980 to 2023 dataset. The majority of the samples were taken during the spring and fall seasons. The median P concentration was found to be 0.009 mg/L, which is classified as oligotrophic (0.004 to 0.010 mg/L). The AECOM (2014) watershed study of Sandy Lake assessed data from 2006 to 2014 and found the trophic status of the lake to be on the low end of mesotrophic range (0.010 to 0.020 mg/L), with a median concentration of 0.012 mg/L.

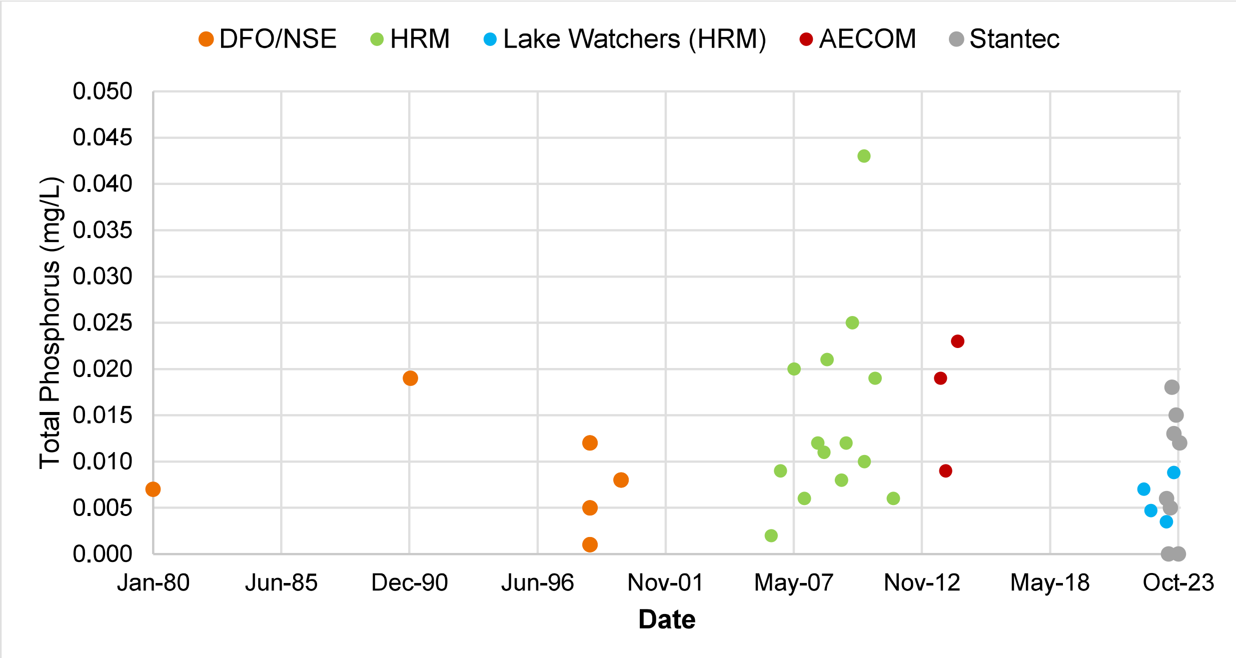

Figure 1-2 Sandy Lake Total Phosphorus Concentration (mg/L)

1.3.1.1 Internal Loading

Internal P loading is the process by which P trapped in the sediment of a lake becomes resuspended in the water column (Sondergaard 2003). During periods of increased external loading of a lake system, organic and inorganic P can become bound in the sediment. The increased loading of P within the lake during the internal loading process often leads to eutrophication and deterioration of the ecosystem health such as an increase in cyanobacterial blooms, dissolved oxygen depletion, turbid water, and poor aquatic habitat. Factors that can influence P solubility and release back into the water column include redox reactions (P sorbed onto iron (III) compounds is released as iron (III) is reduced to iron (II)), resuspension of sediment, temperature, pH, chemical diffusion, microbial processes, and mineralization (Sondergaard 2003).

Anthropogenic watershed runoff is the primary source of external P loading into a lake (James 2016). Without the implementation of low-impact development (LID) or mitigation measures, runoff from the surrounding watershed can result in the deposition of P-rich sediment in lake basins.

1.3.2 FECAL COLIFORM

E.coli is a species of coliform bacteria of fecal origin, referred to as a fecal coliform bacteria. It is commonly used as an indicator of fecal bacteria in water, denoting the potential presence of fecal matter and pathogens associated with risk to human health. Although there are other species of bacteria within the fecal coliform family, *E.coli* and fecal coliform are considered analogous in this report for the purposes of modelling. In urbanized watersheds, presence of *E.coli* in recreational waters may come from wild or domestic animals in proximity to a waterbody, stormwater runoff and domestic wastewater discharge represent additional human-related sources of *E.coli.* Potential sources of fecal coliform within the Sandy Lake watershed include runoff from the nearby dairy milk processing operation, human fecal sources from nearby land use (e.g., recreation), wildlife and avian. As such, fecal coliforms are included as a key parameter for watershed load modelling.

The supervised beach on Sandy Lake is sampled for *E.coli* and fecal coliforms on a weekly basis from July 1 to August 31 each year. In 2023, Sandy Lake Beach closed for four days between July 13 and July 17 due to high bacteria, when samples returned concentrations >500 Colony forming units (CFU)/100mL. A wastewater pumping station failure during summer 2023 resulted in a second closure of Sandy Lake Beach from July 21 due to high water levels and remained closed until August 2 due to the potential exposure to fecal matter from the overflow. Two samples taken by Stantec had bacteria concentrations above 25 MPN/100 mL; however, all samples were below the Health Canada Guideline for Canadian Recreational Water Quality for *E.coli* of 235 CFU/100 mL (Health Canada 2024).

Summary statistics for coliform levels in Sandy Lake are presented in **Table 1-3** with water quality results presented in **Appendix A**. Fecal coliforms and *E. coli* have been measured in Sandy Lake since 2006. The mean value of total coliform was 419 CFU/100 mL while *E.coli* levels were lower with a mean value of 16 CFU/100 mL. The maximum total coliform concentration was observed at the Sandy Lake Outlet during the November 9th, 2010 sampling event. The maximum *E.coli* concentration was observed at the Sandy Lake Outlet during the same monitoring event as the maximum total coliform concentration, on November 9th, 2010.

Table 1-3 Coliform Water Quality Statistics for Sandy Lake

Parameter	N	Mean	Median	Max	Min
Total Coliforms (CFU/100 mL)	27	419	111	2420	20
E. coli (CFU/100 mL)	28	16	10	41	<2

1.3.3 TOTAL SUSPENDED SOLIDS

Sediment carried in water has a variety of effects on water quality and is commonly measured as Total Suspended Solids (TSS) (mg/L) (Environment Canada n.d.). Sediment is associated with clarity of water and can decrease the penetration of light which has the potential to impact the health and survival of fish and other aquatic life. Additionally, sediment plays a role in the transport and fate of pollutants in water as contaminants can attach to sediment particles and be transported and deposited in other areas.

Construction and land development projects accelerate the transport of sediment by exposing large areas of soil to rain and runoff within a watershed. Without implementation of erosion and sediment control measures, there is a risk of the degradation or destruction of fish habitat and impact to users of the lake or waterbody for recreational use.

Summary statistics for TSS concentrations in Sandy Lake are presented in **Table 1-4** and **Appendix A**. TSS concentrations are low in Sandy Lake with a median value of 2 mg/L and a maximum value of 5 mg/L. The low TSS concentrations suggest that Sandy Lake is not substantially affected by urban runoff or erosion within the watershed. The CCME Canadian Water Quality Guideline for the Protection of Freshwater Aquatic Life (CCME CWQG-FAL) for TSS is a maximum average increase of 25 mg/L from background levels for short term exposures, and a maximum average increase of 5 mg/L from background levels for longer term exposures (e.g., lasting between 24 h and 30 days) (CCME 1999).

Table 1-4 Total Suspended Solids Water Quality Statistics for Sandy Lake

Parameter	N	Mean	Median	Max	Min
Total Suspended Solids (mg/L)	31	1.0	1.0	39	<1

1.3.4 BASELINE WATER QUALITY

Water quality in Sandy Lake and the SLSA has been collected and monitored since 1980 on an intermittent basis for various water quality parameters. As the temporal frequency of the historical data is sparse, the data was used only to infer trends in water quality with changes to the watershed at the time. Parameters collected include TP, fecal coliform and TSS, as previously discussed as well as chloride, dissolved oxygen, pH, temperature, and conductivity.

Chloride in freshwater environments is an anthropogenic environmental stressor (Szklarek et. al 2022) and can negatively impact freshwater aquatic life when concentrations are in excess of 120 mg/L (CCME CWQG-FAL). By decade, the chloride values in Sandy Lake have had an increasing trend (**Appendix A**), starting with a value of 13.7 mg/L in 1980, average chloride values for the 1990's was 29.5 mg/L, 35.5 mg/L in the 2000's, and 45.3 mg/L in 2010 to present. Although these baseline chloride values do not exceed CCME CWQG-FAL, land use planning mitigation strategies can be applied when planning development in the area to reduce further increases in chloride concentrations. As development increases within a watershed, it is expected to see increased chloride values due to developments and road salt accumulation entering watercourses (Bermarija et al 2023).

Water quality profiles of Sandy Lake for parameters that may affect the nutrient loading of the lake, including pH, dissolved oxygen (DO), temperature, and conductivity were collected by Stantec between April and October 2023. The results from the 2023 monitoring and historical water quality monitoring are presented in **Appendix A**, and a description of water quality for the SLSA is presented in the Land Suitability Analysis (Stantec 2024).

As described in section 1.3.1.1, the internal loading of phosphorus in a lake system has the potential to deplete dissolved oxygen levels, resulting in the decrease in water quality of a lake environment. There was only one measurement of historical dissolved oxygen levels prior to 2000, in September 1998 with a value of 3 mg/L, which is below the CCME Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (CWQG-FAL) of 6.0 mg/L for early life stage aquatic life and 5.50 mg/L for other life stages. Dissolved oxygen values from 2000-2010 have an average value of 10.61 mg/L which indicate a more oxygenated environment. Dissolved oxygen profiles of Sandy Lake were measured throughout the 2023 monitoring period. DO and Temperature readings are presented in **Figure 1-3** for the period of April to October 2023; it should be noted that while temperature readings were taken in October, the DO probe malfunctioned, and DO readings were not collected during that monitoring event. The DO values for Sandy Lake reached a minimum of 2.2 mg/L during the September monitoring event at a depth of 8 m below surface. The September and July sampling events had the lowest average DO concentrations with values of 5.35 and 5.88 mg/L, respectively. The lake would be considered to be hypoxic during these months, especially at depths below 4 m. This increases the potential for internal loading of P within the water column as anoxic conditions can induce the release of sediment-bound P (Deeds et. al. 2021).

The pH of Sandy Lake range between 6.28 to 7.45, with an average value of 6.52 throughout the 2023 monitoring period. A value of 7.00 represents neutral pH, and the mean pH value is within the CCME CWQG-FAL guidelines (6.5 to 9.0). Conductivity in Sandy Lake ranges between 0.108 to 0.203 mS/cm. Maximum conductivity value of 0.203 was observed in July which is expected due to increased temperature.

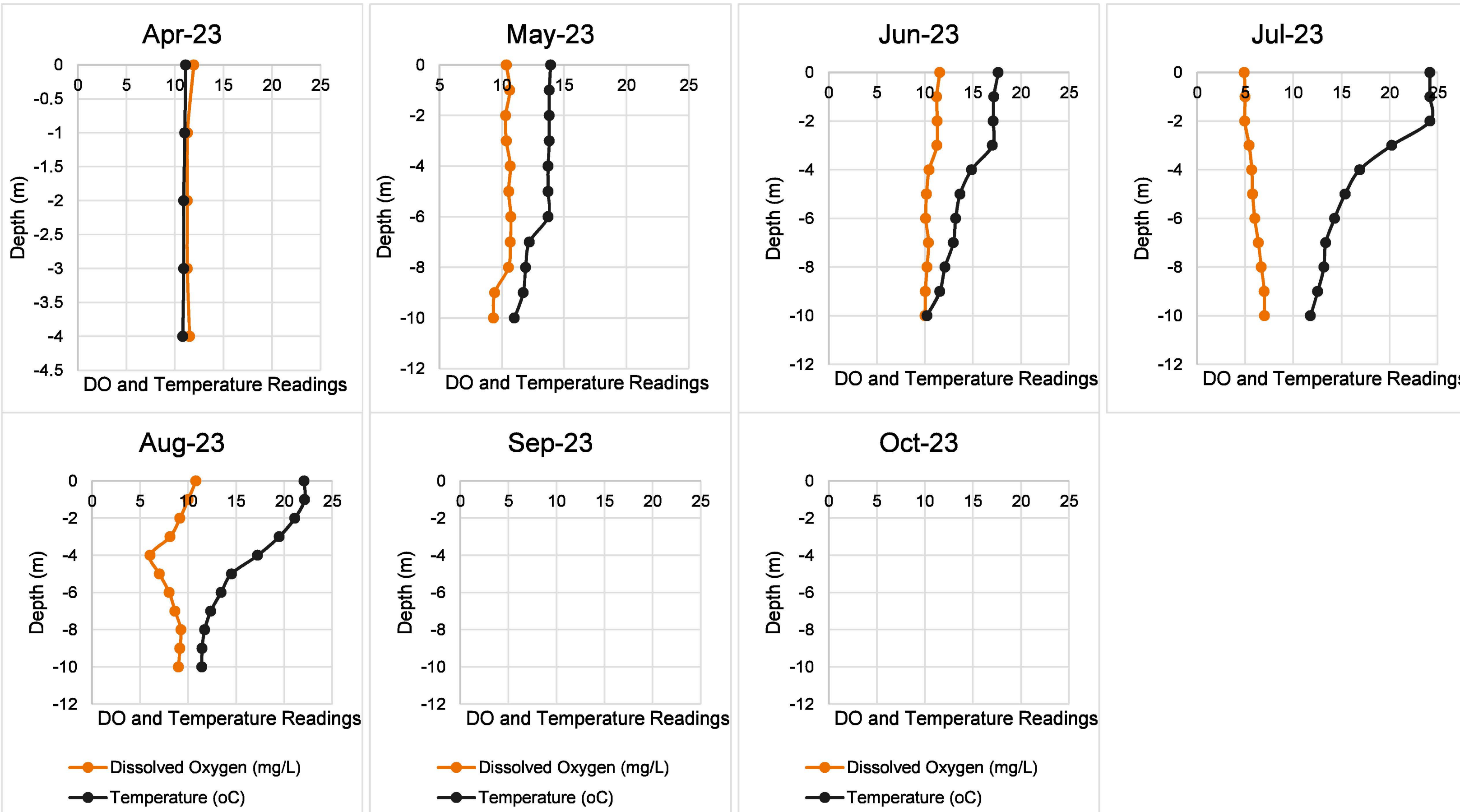

Figure 1-3 Dissolved Oxygen and Temperature Profiles of Sandy Lake

2 Water Quality Methodology

2.1 Watershed Delineation

Watershed delineation was completed using provincial LiDAR data (Halifax) to delineate the sub-watershed area contributing to Sandy Lake and outfall points of interest. Watercourse and waterbody GIS data was provided through the Nova Scotia Topographic Database. Land uses for the watershed were derived from Nova Scotia Department of Natural Resources and Renewables Forestry Layer as well as the zoning boundary layer from HRM. The results of the land use assessment are presented in **Figure 2-1** and **Figure 2-2**.

The dominant land use within the Sandy Lake Watershed is forested (68%) followed by low-density residential (17%), these two land use types makeup more than 75% of the lands within the watershed.

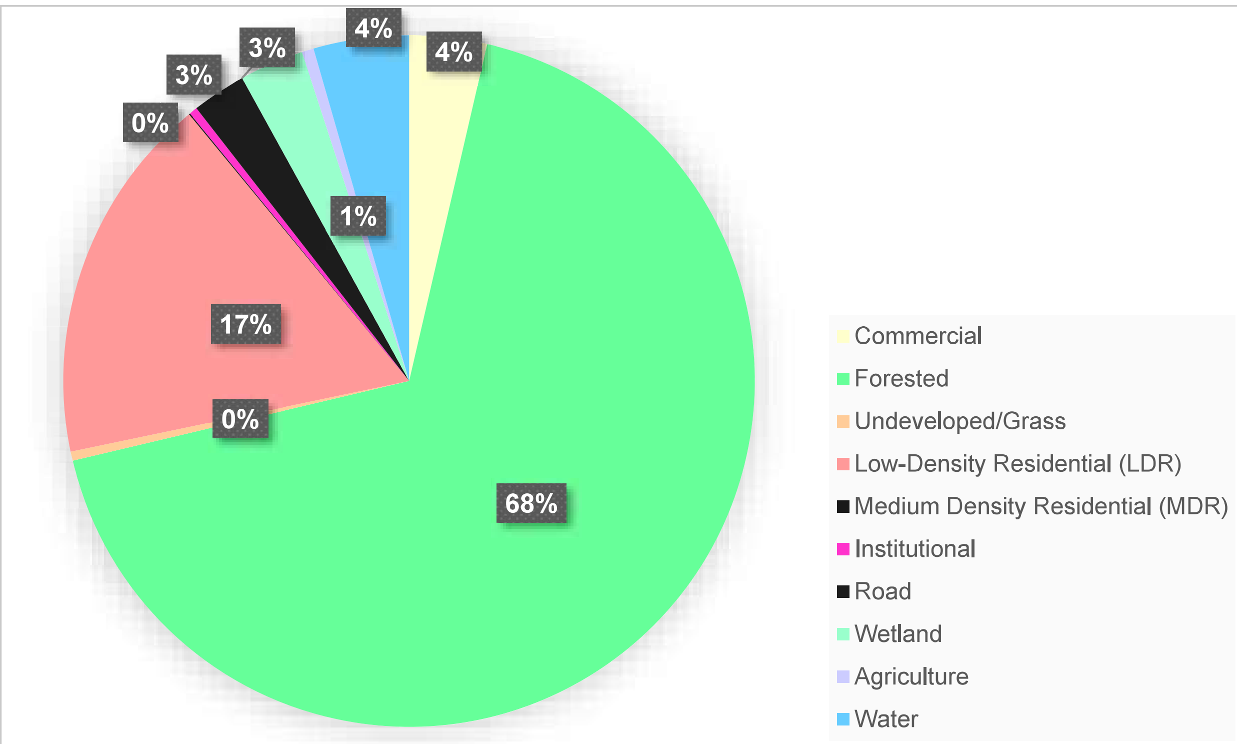

Figure 2-1 Existing Sandy Lake Watershed Land Use Breakdown

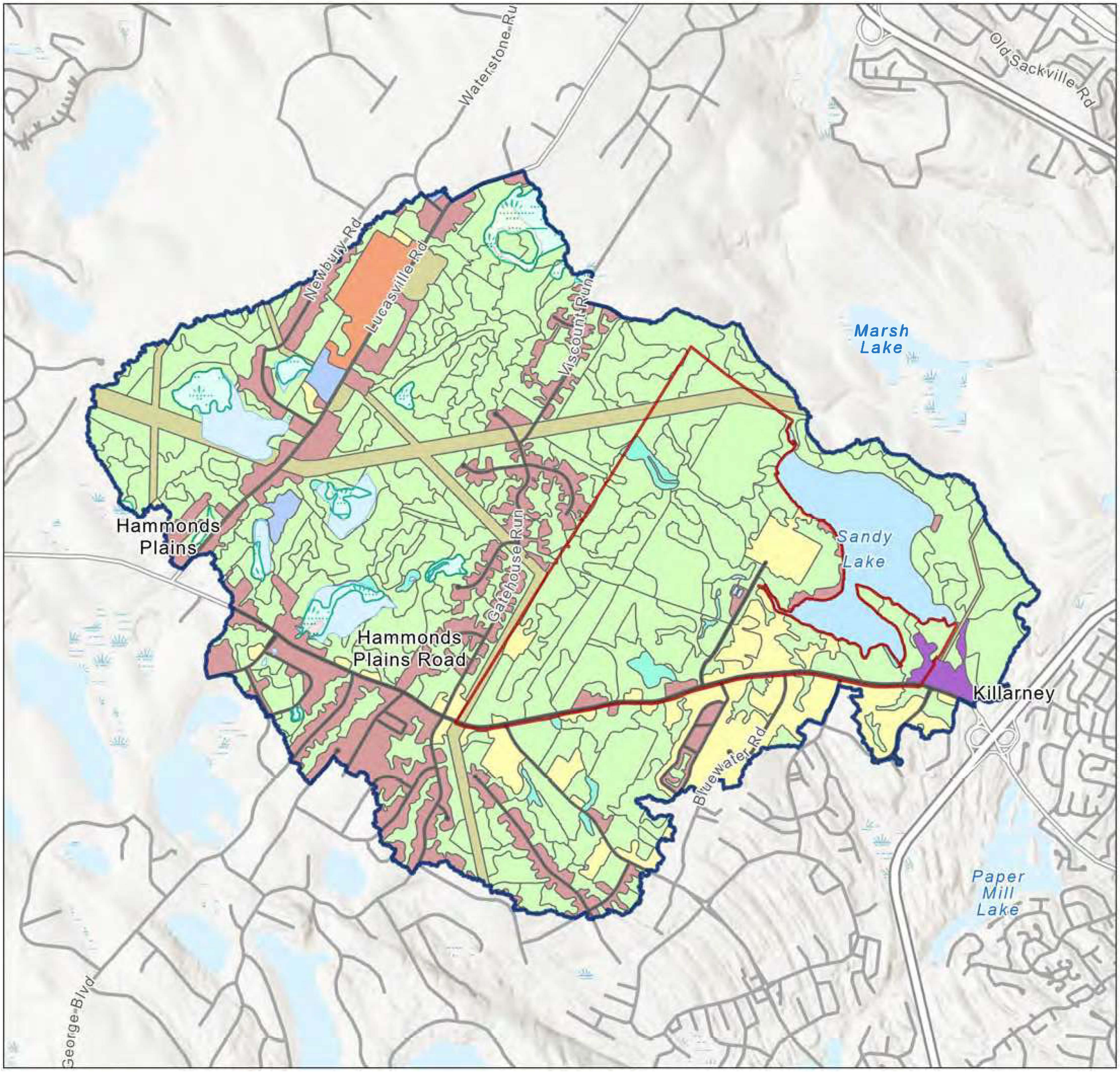

Figure No.
2-2

Title
Nova Scotia Department of Natural Resources Land Use - Sandy Lake Watershed

Client/Project 160410459
Halifax Regional Municipality
Future Serviced Communities

Project Location
Halifax Regional Municipality, Nova Scotia

Prepared by AC on 2024-04-10
Revised by NW on 2024-05-17

N

0 250 500 750 1,000 Metres
(At original document size of 8.5x11)
1:40,000

Legend

- Study Area
- Watershed Boundary

Land Use

- Agriculture/Blueberries
- Commercial
- Forest
- Institutional
- Low Density Residential
- Medium Density Residential
- Roads
- Undeveloped/Grass
- Waterbody
- Wetlands

Notes
1. Coordinate System: NAD 1983 CSRS UTM Zone 20N
2. Data Sources: Stantec; Halifax Regional Municipality, Government of Nova Scotia (DNR)
3. Background: Esri

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2.2 Climate

Climate normal data were used for an estimate of the annual rainfall in the study area. The Environment Canada Halifax Stanfield International Airport Climate Station (Climate ID: 8202249) data from 1981 to 2010 were used. This station is located approximately 20 km from Sandy Lake and is the closest climate station to the study area with complete 30 years of climate normal data. For the thirty-year data period, the annual precipitation is 1,396.2 mm per year.

Table 2-1 Climate Normals Data – Halifax Stanfield International Airport (ID: 8202249)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	83.5	65	86.9	98.2	109.8	96.2	95.5	93.5	102	124.6	139.1	101.8	1,196.1
Precipitation (mm)	134.3	105.8	120.1	114.5	111.9	96.2	95.5	93.5	102	124.9	154.2	143.3	1,396.2
Temperature (°C)	-5.9	-5.2	-1.3	4.4	10	15.1	18.8	18.7	14.6	8.7	3.5	-2.4	6.6

Annual precipitation amounts for 2023 were higher than the climate normal (1,396.2 mm) with a total annual precipitation of 1,575.2 mm. Large precipitation events during the months of June and July caused flooding events within the Sackville River Watershed. As mentioned in **Section 1.3.2**, the flooding caused a wastewater pumping system failure which resulted in the closure of Sandy Lake Beach.

As historical data is the input for calculating climate normals for a particular site, there is limited applicability of climate normals data to assess the future climate conditions. The Climate Atlas of Canada's online tool (Prairie Climate Center 2019) was used to generate projected climate change precipitation and temperature data for the Municipality of Halifax. This online data portal provides downscaled data projections of temperature and precipitation from an ensemble of 24 different climate models. Projected climate changes in temperature and precipitation associated with the Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathway 8.5 (RCP8.5) scenario over a 30-year time horizon were selected. The RCP8.5 scenario was chosen as it represents greenhouse gas emissions continuing to be released at current rates, i.e., a High Carbon climate future. The RCP8.5 scenario reflects an intermediate stabilization scenario for the emission of greenhouse gases, in which radiative forcing is stabilized at approximately 8.5 Watts per metre squared (IPCC 2020). Results of the climate change projections are found in **Table 2-2**.

Quantity and timing of precipitation on a watershed have the capacity to influence runoff volumes within the watershed. As precipitation trends increase, as shown in **Table 2-2**, greater runoff volumes are expected within the watershed; timing of these precipitation events have the potential to cause increased flooding events, changes to lake turnover rates, or sedimentation events within watersheds (Qiu et.al. 2021).

Table 2-2 Climate Change Projections – Halifax (RCP8.5)

		1976-2005	2021-2050			2051-2080		
Parameter	Period	Mean	Low	Mean	High	Low	Mean	High
Precipitation (mm)	annual	1,440	1,280	1,519	1,781	1,324	1,571	1,849
Temperature (°C)	annual	6.8	7.5	8.6	9.9	9.2	10.6	12.1

2.3 Development Scenarios

The SLSA has been zoned for residential, commercial, and industrial development. The focus of future development in Sandy Lake is on lands owned by Clayton Developments Ltd., which has the largest landholding within the Sandy Lake Watershed. Four development scenarios were considered by Stantec (2023) to be assessed for changes in annual contaminant loads in this study. Details on each of the development scenarios being evaluated by HRM are provided in the Development Scenarios – Sandy Lake Study Area (Stantec 2023).

Table 2-3, provides a breakdown of the land use changes to the Sandy Lake watershed for each development scenario based on the scenarios proposed for Sandy Lake (Stantec 2023). **Sections 2.3.1, 2.3.2, 2.3.3** and **2.3.4** provide short descriptions of each development scenario. It should be noted that for the low-density and high-density development scenarios, the primary change is the number of units considered and does not necessarily reflect a difference in affected area. This is evident in **Table 2-3** as the developer requested scenario maintains the greatest forested area compared to existing conditions, while the low density and high-density scenarios maintain second and third-most forested area, respectively.

Table 2-3 Development Scenarios Land Use Changes

Land Use Type	Existing Land Uses (ha)	Low-Density Scenario (ha)	Developer Requested Scenario (ha)	High Density Scenario (ha)	Areal Land-Use Scenario (ha)
A - Commercial	128.23	182.46	182.46	182.46	171.61
B - Low-Density Residential (LDR)	221.53	310.48	228.11	226.47	226.80
C - Medium Density Residential (MDR)	23.61	91.10	37.35	34.73	34.60
D - High Density Residential (HDR)	0.00	0.00	66.53	162.91	53.22
E- Institutional	9.71	9.71	25.53	9.71	22.37
F - Forested	1104.84	878.15	931.92	855.63	963.30
G - Undeveloped/Grass	93.49	93.49	93.49	93.49	93.49
H – Road	45.90	61.92	61.92	61.92	61.92
I - Wetland	53.03	53.03	53.03	53.03	53.03

Land Use Type	Existing Land Uses (ha)	Low-Density Scenario (ha)	Developer Requested Scenario (ha)	High Density Scenario (ha)	Areal Land-Use Scenario (ha)
J - Agriculture	9.79	9.79	9.79	9.79	9.79
K – Water	78.70	78.70	78.70	78.70	78.70
Developed Land	438.77	665.46	611.69	687.98	580.31
Undeveloped Land	1330.06	1103.37	1157.14	1080.85	1188.52
Note: Developed Land is the sum of A,B,C,D,E, H and J; undeveloped land is the sum of F, G, I and K					

2.3.1 DEVELOPER REQUESTED SCENARIO

The developer requested scenario explores the proposed intentions of key developers that own lands within the Study Area, such as Clayton Developments and Arsenal which have also communicated their intentions to develop land to accommodate residential and commercial/office uses. At this time only the conceptual plan of Clayton Developments was available (**Figure 2-3**) and therefore it was used as the developer requested scenario. The developer-requested scenario proposes to have an estimated population of 15,423 with a population density of 34.9 persons per acre (Stantec 2023).

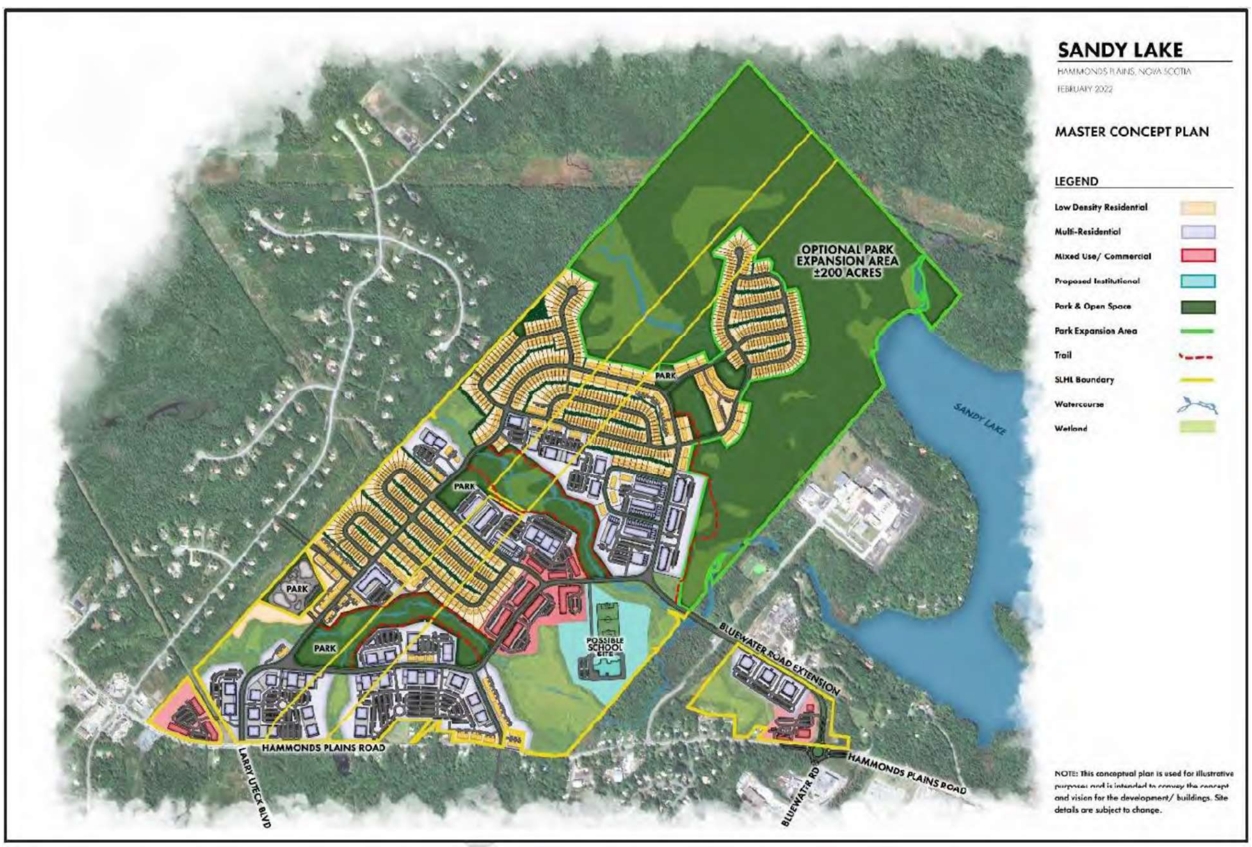


Figure 2-3 Clayton Developments Concept Plan (Stantec 2023)

2.3.2 LOW-DENSITY SCENARIO

A Low-Density scenario will consider a conservative approach to development, reducing the density proposed by developers to understand the contrast between scenarios. This approach will utilize the current low and medium-low density housing typologies, such as single detached dwellings, townhouses, and low-rise apartments. The primary difference between the developer-requested scenario and the low-density scenario is the capacity of the units within the development, i.e., smaller population inhabiting this area. The low-density scenario proposes to have an estimated population of 9,808 with a population density of 25 persons per acre (Stantec 2023).

2.3.3 HIGH-DENSITY SCENARIO

A High-Density scenario attempts to optimize on the opportunity to create a higher density increasing the developer requested densities. This approach accommodates low, medium-low, and medium-high density housing typologies such as single detached, duplex, townhouse, low-rise residential, multi-family medium density buildings, as well as mixed-use buildings adding up to an 80% density increase compared to the Low-Density scenario. The high-density scenario proposes to have an estimated population of 17,654 with a population density of 45 persons per acre (Stantec 2023).

2.3.4 AREAL LAND-USE SCENARIO

The areal land-use scenario incorporates the same housed population as the developer requested scenario, however this scenario covers 20% less residential, commercial and industrial land area compared to the developer requested scenario. This scenario was evaluated to assess impacts of development on the watershed when forested area is conserved within the watershed. The areal land-use scenario proposes to have an estimated population of 15,423.

2.4 Storm-Event Model

Rainfall event-based contaminant load modeling is useful in design of appropriate stormwater treatment system for a Project area. A rainfall event-based contaminant load model uses literature-based contaminant concentration values derived for specific land uses to determine a stormwater contaminant load for a single precipitation event. Event mean concentration (EMC) data is derived from sampling runoff from specific land uses over the duration of a storm event. It is used for the purposes of modeling as it represents an average contaminant concentration generated over the duration of an event.

For the rainfall-event based model, the event-associated contaminant export load is calculated using the following formula:

$$P_{Event} = \sum R\, x A_{LU} x EMC_{LU} x RC_{LU} x 0.001$$

Where:

P_{Event} = total contaminant load on an event basis, kg or CFU

R = rainfall depth associated with selected precipitation event, mm

A_{LU} = area associated with a specific land use, m^2

EMC_{LU} = contaminant event mean concentrations associated with a specific land use, mg/L or CFU/100 mL

RC_{LU} = rainfall runoff coefficient associated with a specific land use, unitless

To determine the volume of runoff discharging from each land use during the rain event, a hydrologic model was developed for the Sandy Lake Stormwater Management Plan (Stantec 2024b) using PCSWMM (Computational Hydraulics Inc. of Guelph, Ontario, CA) to firstly estimate the runoff from the Sandy Lake watershed. The 2-yr 24-hr Chicago design storm was used as it is one of the design storms in the Sandy Lake Stormwater Management Plan (Stantec 2024b). Land use-based curve numbers (CN) were selected for use with the SCS method of rainfall runoff estimation (**Table 2-4**) (Stantec 2024b). Initial abstraction of 1.5 mm accounts for depression storage, interception and infiltration occurring before runoff begins and was estimated for pervious land use areas as per United States Department of Agriculture (USDA) 1986. When the total watershed runoff volume was determined, runoff for each land use was estimated using the formula provided above, with the runoff coefficients (RC) given in **Table 2-4**. The hydrologic model results were then used to validate the runoff volumes from the rain-event based model.

Table 2-4 Summary of Land Use Runoff Parameters

Land Use	Curve Number[1]	Runoff Coefficient[1]
Agriculture	77	0.28
Commercial Development	92	0.85
Institutional	89	0.70
Forest	65	0.14
Undeveloped/Grassed	61	0.20
High-Density Residential	85	0.75
Medium-Density Residential	72	0.75
Low-Density Residential	68	0.65
Roadway	98	0.90
Water	99	0.99
Wetland	99	0.99

[1] McCuen 1998

2.4.1 PARAMETER SELECTION FOR PRECIPITATION EVENT BASED PHOSPHORUS MODEL

EMC TP data were sourced for the land use distribution found within the studied watershed. As there is limited availability of local data, EMC values were taken from commonly referenced literature sources and are given in **Table 2-5**.

Table 2-5 Total Phosphorous Event Mean Concentrations for Select Land Use

Land Use	Total Phosphorous Event Mean Concentration (mg/L)
Agriculture	0.50[3]
Commercial Development/ Institutional	0.30[1]
Forest	0.15[2]
Undeveloped/Grassed	0.56[2]
High-Density Residential	0.22[2]
Medium-Density Residential	0.45[2]
Low-Density Residential	0.36[2]
Roadway	0.62[2]
Wetland	0.10[1]

[1] CH2M HILL 1993; [2] Pitt and MacLean 1986; [3] USEPA 2001

2.4.2 PARAMETER SELECTION FOR PRECIPITATION EVENT BASED FECAL COLIFORM LOADING MODEL

EMC fecal coliform data were sourced for the land use distribution found within the studied watersheds, as presented in **Table 2-6**. Data is given in units of CFU/100 mL, which refers to the number of colony forming units (CFU) of bacteria per 100 mL of sample volume. fecal coliform EMC values were used as there is limited available data for land use associated *E.coli* concentrations. These values are considered comparable to E. coli concentrations for the purpose of this study. Where available, data were taken from a study completed by Theriault and Duchesne (2012) on fecal coliform loading in urban watersheds in Quebec. Commonly referenced literature sources were used for the remaining EMC values. Barnhart et al. (nd) found higher bacteria counts in runoff from residential areas and attributed loadings to wildlife rather than domestic animals with variation in bacterial loadings from specific land uses thought to be due to the transient nature of the wildlife sources. Differences in EMC values between forest and undeveloped/grassed areas may also be attributed to differences in runoff volumes from the specific land uses. A forested site would have substantial wildlife use but minimal runoff volume comparison with a grassed site. As noted in the USEPA Preliminary Data Summary of Urban Stormwater Best Management Practices (1999), literature values for land use-based fecal coliform EMCs vary greatly between studies and show a strong trend of seasonal fluctuation.

Table 2-6 Fecal Coliform Event Mean Concentrations for Select Land Uses

Land Use	Fecal Coliform Event Mean Concentration (CFU/100 mL)
Commercial Development / Institutional	4,500[1]
Agriculture Field within Low-Density Residential	3,100[1]
Forest	500[2]
Undeveloped/Grassed	10,365[3]
High-Density Residential	7,750[1]
Medium-Density Residential	7,750[1]
Low-Density Residential	7,750[1]
Roadway	1,400[2]
Wetland / Water	n/a

[1] Theriault and Duchesne 2012; [2] CH2M HILL1993; [3] Burnhart *et al.* nd

2.4.3 PARAMETER SELECTION FOR PRECIPITATION EVENT BASED SEDIMENT LOADING MODEL

The precipitation event-based sediment loading was calculated using the Modified Universal Soil Loss Equation (MUSLE) (Haan 1982). MUSLE is a storm-based application of the Revised Universal Soil Loss Equation (RUSLE) and uses the volume of storm event runoff (m^3) and peak discharge (Q_p) to calculate the rainfall factor (R_w). Sediment loading (A) is then calculated using the following equation:

$$A = R_w \times K \times LS \times C \times P$$

Where:

A	is the potential, long term average annual erosion loss (tonnes ha^{-1} $year^{-1}$)
R_w	is the MUSLE *rainfall factor* (MJ mm ha^{-1} $hour^{-1}$)
K	is the *soil erodibility factor* (tonnes hour MJ^{-1} mm^{-1})
LS	is the *slope length and steepness factor* (dimensionless)
C	is the *cropping management factor* (dimensionless)
P	is the support practice factor (dimensionless)

Table 2-7 provides the input parameters used to calculate the MUSLE precipitation event sediment load for Sandy Lake watershed.

Table 2-7 MUSLE Input Parameters

Input	Value	Assumptions	MUSLE Source
Rainfall Factor (Rw)	106.057	Calculated using the volume of runoff in m^3 and peak discharge	Haan 1982
Soil Erodibility Factor (K) (tonnes h MJ-1 mm-1)	0.017	Dominant soil type in the area is gravelly sandy loam till (Halifax/Danesville soils); Table K-1	Wall et al. 2002, p56
Slope length and Steepness Factor (LS)			
General Forest Cover	1.62	General Forest cover is average slope across the watershed and average flow length (7% slope, 250 m length)	Wall et al. 2002 Table LS-1
Roads (Paved and Gravel)	2.91	Roads and Transmission lines use the maximum slope and flow length in watershed, (12.8% slope, 125 m length)	Wall et al. 2002 Table LS-2
Urban Areas	0.09	Areas prepared for Residential / commercial development have minimal slope and average flow length of 250 m	Wall et. al. 2002 Table LS-3
Cropping Management Factor (C)			
Undisturbed Forest Land	0.001	Forested land natural condition with duff at least 2 inches deep	Table C-6 Wall et. al 2002
Roads (Paved and Gravel)	0.07		Table C-8 Wall et al 2002
Disturbed forested Land	0.04		Table C-7 Wall et. al 2002
Urban areas	0.17	Urban Land use C-Factor	Ramlal (2007), HECL 2012
Support Management Factor (P)	1	No management practices	Wall et al. 2002

2.5 Annual Loading Model

Annual contaminant loading models use land use-based contaminant loading rates to determine the contaminant load derived from a watershed on an annual basis (Brylinsky 2004). As the annual rainfall amount is inherently integrated into the land use-based contaminant loading rates, the use of local data is most accurate. In the absence of local data, literature values are used. For the annual loading model, the estimated annual contaminant load is calculated using the following formula:

$$Load_{Annual} = \sum LR_{LU} \: x \: A_{LU}$$

Where:

$Load_{Annual}$ = total contaminant load on an annual basis, kg/year or CFU/100mL·year^{-1}

LR_{LU} = areal contaminant loading rate associated with a specific land use, phosphorus (g/m^2·year^{-1}) or *E.coli* (CFU/100mL/m^2·year^{-1})

A_{LU} = area associated with a specific land use, m^2

2.5.1 PARAMETER SELECTION FOR ANNUAL PHOSPHORUS LOADING MODEL

Land use based areal loading P data were sourced for the land use distribution found within the studied watershed. Where possible, parameters were selected from the Nova Scotia-focused study conducted by Brylinsky (2004) and are indicated with an asterisk (*). Selected parameters are presented in **Table 2-8**.

Table 2-8 Area-based Phosphorous Loading Rates for Select Land Uses

Land Use	Phosphorous Loading Rate ($g/m^2 \cdot yr$)
Commercial Development*	0.202[1]
Forest*	0.0024[2]
Undeveloped/Grassed*	0.015[2]
High-Density Residential*	0.035[1]
Medium-Density Residential*	0.030[1]
Low-Density Residential*	0.025[1]
Institutional*	0.042[2]
Roadway	0.35[3]
Agriculture	0.0108[3]
Wetland*	0.0024[2]

[1]Waller and Hart 1986; [2] Reckhow *et al.* 1980; [3] MDEP 2000, * - indicates loading rate from Brylinsky (2004)

2.5.2 LAKE SYSTEM MODEL

In addition to the annual loading model, the lake system model provides an estimate of the P balance within the studied lake system. It considers P lake inputs from atmospheric deposition, surface runoff, and contributing waterbodies and provides an estimate of in-lake P concentration after accounting for P sedimentation and surface outflow. The estimated in-lake P concentration can then be compared to measured P concentration values.

The lake system model is taken from the widely accepted *User's Manual for Prediction of Phosphorus Concentration in Nova Scotia Lakes* (Brylinsky 2004). The model described by Brylinsky (2004) is a mass-balance approach, using the Vollenweider equation, as follows:

$$PV = \frac{M/V}{\left(\frac{Q}{V}\right) + \sigma}$$

Where:

PV = Total mass of phosphorus in lake (g)

P = Lake phosphorus concentration (g/m^3)

V = Lake volume (m^3)

t = time

M = Annual mass of phosphorus input to lake (g/year)

Q = Annual volume of water outflow from lake (m^3/year)

σ = Sedimentation coefficient (/year)

Brylinsky (2004) proposes a series of physical, hydraulic, and water-quality-based parameters to determine the total mass of phosphorous in the studied lake. A full table of model parameters and results is presented in **Appendix B**. A summary of select lake system model parameters are given in **Table 2-9**, below.

Table 2-9 Summary of Select Lake System Model Parameters

Parameter	Abbrev.	Value	Units	Source
Annual Unit Precipitation	Pr	1.396	m/yr	Estimated using climate normals data
Annual Unit Lake Evaporation	Ev	0.52	m/yr	Calculated using Thornthwaite (1948) method
Annual Unit Hydraulic Runoff - Developed	Ruv	1.10	m/yr	Brylinsky (2004)
Annual Unit Atmospheric P Deposition	Da	0.0173	g P m^2/yr	Brylinsky (2004)
Phosphorus Retention Coefficient	V	12.40	n/a	Brylinsky (2004)

2.5.2.1 Lake Evapotranspiration

Potential Evapotranspiration (PET) was calculated using the Thornthwaite Method (Thornthwaite 1948) and the average annual temperature shown in

Table 2-1. For the lake, actual evapotranspiration (ET) is considered equivalent to the sum of monthly PET multiplied by the area of the lake. The annual ET loss is estimated to be 512 mm/year.

2.5.3 PARAMETER SELECTION FOR ANNUAL FECAL COLIFORM LOADING MODEL

As there is limited areal-loading data available for land use associated fecal coliform loading, event mean concentration (EMC) values were used to determine the annual loading of fecal coliform from the studied watershed. Using the climate normal average annual precipitation value of 1396.2 mm (Section 1.3), the event-based loading method was used to calculate the fecal coliform loading associated with the annual depth of rainfall. Input parameters are presented in **Table 2-10** below. Due to limited available data, fecal coliform loading from wetlands and partially cleared forest land uses were assumed to be similar to forest/park land use. Similarly, fecal coliform loading from institutional land use was assumed to be similar to commercial development land use.

Table 2-10 Area-based Fecal Coliform Loading Rates for Select Land Uses

Land Use	Fecal Coliform Loading Rate (CFU/ha·yr)
Commercial Development/Institutional	4.99×10^5
Forest	6.94×10^3
Agriculture/ Undeveloped/Grassed	1.38×10^6
High-Density Residential	3.62×10^5
Medium-Density Residential	1.46×10^7
Low-Density Residential	2.83×10^5
Roadway	1.10×10^6

2.5.4 PARAMETER SELECTION FOR ANNUAL SEDIMENT LOADING MODEL

The sediment loading model was completed using the RUSLE tailored for application in Canada (RUSLEFAC) by Wall et. al. (2002). The RUSLEFAC model is a commonly used empirical equation for estimating soil loss from water erosion for a variety of land uses and the approach used in this study is specifically for use in Canada, including regional specific input parameter value tables. Only the area undergoing change in land use is considered in this model. The annual soil loss in tonnes/ha/year is calculated using the RUSLEFAC equation, presented below:

$$Annual\ Average\ Soil\ Loss\ (A)\ = R \times K \times LS \times C \times P$$

Where:

A is the potential, long term average annual erosion loss (tonnes ha^{-1} year^{-1})
R is the *rainfall factor* (MJ mm ha^{-1} hour^{-1})
K is the *soil erodibility factor* (tonnes hour MJ^{-1} mm^{-1})
LS is the *slope length and steepness factor* (dimensionless)
C is the *cropping management factor* (dimensionless)
P is the support practice factor (dimensionless)

Table 2-11 summarizes the inputs, assumptions, and sources used for the RUSELFAC calculations.

Table 2-11 RUSELFAC Input Parameters

Input	Value	Assumptions	RUSLEFAC Source
Rainfall Factor (R) (MJ mm ha-1 hour-1)	1790	Table R-1 - Erosivity index and monthly distribution (%) for sites in the Prairie Region and Eastern Canada	Wall et al. 2002, p. 44
Soil Erodibility Factor (K) (tonnes h MJ-1 mm-1)	0.017	Dominant soil type in the area is gravelly sandy loam till (Halifax/Danesville soils); Table K-1	Wall et al. 2002, p56

Input	Value	Assumptions	RUSLEFAC Source
Slope length and Steepness Factor (LS)			
General Forest Cover	1.62	General Forest cover is average slope across the watershed and average flow length (7% slope, 250 m length)	Wall et al. 2002 Table LS-1
Roads (Paved and Gravel)	2.91	Roads and Transmission lines use the maximum slope and flow length in watershed, (12.8% slope, 125 m length)	Wall et al. 2002 Table LS-2
Urban Areas	0.09	Areas prepared for Residential / commercial development have minimal slope and average flow length of 250 m	Wall et. al. 2002 Table LS-3
Cropping Management Factor (C)			
Undisturbed Forest Land	0.001	Forested land natural condition with duff at least 2 inches deep	Table C-6 Wall et. al 2002
Roads (Paved and Gravel)	0.07		Table C-8 Wall et al 2002
Disturbed forested Land	0.04		Table C-7 Wall et al 2002
Urban areas	0.17	Urban Land use C-Factor	Ramlal (2007), HECL 2012
Support Management Factor (P)	1	No management practices	Wall et al. 2002

3 Water Quality Results

3.1 Storm-Event Model

3.1.1 PHOSPHOROUS

Precipitation event-based TP loading was completed for a design storm event with a 2-year 24hr precipitation depth occurring over the studied watershed. Resultant TP loading for the existing conditions, low-density, developer requested, high-density, and areal land-use scenarios are predicted with results given in **Table 3-1**. When compared to the annual phosphorous load, the event-based TP loading is approximately 9% of the annual load for each scenario, including existing condition. Compared to the existing conditions TP loading, the development scenarios result in an increase of TP loading of 40%, 20%, 33%, and 23% for the low-, developer-requested, high-density, and areal land-use scenarios, respectively. The low-density and high-density scenarios are predicted to have the greatest increase in TP loading due to the amount of commercial area in addition to the added housing within the watershed; the additional change in land use to commercial (e.g., impervious surfaces for parking lots and building size) increases the TP loading.

Table 3-1 Predicted P Loading to Sandy Lake for Existing Condition during Storm Event

Development Scenario	Land Use	Area (ha)	P Loading (kg)	Land Use Percentage	P Load Percentage
Existing Conditions	Commercial / Industrial	137.93	8.6	7.8%	22.8%
	Forest	1,104.84	3.3	62.5%	8.8%
	Undeveloped / Grass	93.49	1.8	5.3%	4.9%
	Low-Density Residential	221.53	14.7	12.5%	39.1%
	Medium-Density Residential	23.61	1.5	1.3%	3.9%
	Road	45.90	6.4	2.6%	17.0%
	Wetland	53.03	1.3	3.0%	3.5%
	Agriculture	9.79	0.4	0.6%	1.0%
	High Density	0.00	0.0	0.0%	0.0%
	Water	78.70	-	4.4%	
	Total	**1768.8**	**37.619**	**100.0%**	**100.00%**
Low-Density Scenario	Commercial / Industrial	192.16	11.962	10.9%	22.72%
	Forest	878.15	2.634	49.6%	5.00%
	Undeveloped / Grass	93.49	1.832	5.3%	3.48%
	Low-Density Residential	310.48	20.608	17.6%	39.15%
	Medium-Density Residential	91.10	5.658	5.2%	10.75%
	Road	61.92	8.638	3.5%	16.41%
	Wetland	53.03	1.313	3.0%	2.49%
	Agriculture	9.79	0.366	0.6%	0.70%
	High Density	0.00	0.000	0.0%	0.00%
	Water	78.70	-	4.4%	
	Total	**1768.83**	**52.6**	**100.0%**	**100.0%**
Developer Requested Scenario	Commercial / Industrial	207.99	12.95	11.8%	28.8%
	Forest	931.92	2.80	52.7%	6.2%
	Undeveloped / Grass	93.49	1.83	5.3%	4.1%
	Low-Density Residential	228.11	15.14	12.9%	33.7%
	Medium-Density Residential	37.35	2.32	2.1%	5.2%
	Road	61.92	8.64	3.5%	19.2%
	Wetland	53.03	1.31	3.0%	2.9%

Development Scenario	Land Use	Area (ha)	P Loading (kg)	Land Use Percentage	P Load Percentage
	Agriculture	9.79	0.37	0.6%	0.8%
	High Density	66.53	2.52	3.8%	5.6%
	Water	78.70	-	4.4%	
	Total	**1768.83**	**45.0**	**100.0%**	**100.0%**
High-Density Scenario	Commercial / Industrial	192.16	11.96	10.9%	23.9%
	Forest	855.63	2.57	48.4%	5.1%
	Undeveloped / Grass	93.49	1.83	5.3%	3.7%
	Low-Density Residential	226.47	15.03	12.8%	30.0%
	Medium-Density Residential	34.73	2.16	2.0%	4.3%
	Road	61.92	8.64	3.5%	17.3%
	Wetland	53.03	1.31	3.0%	2.6%
	Agriculture	9.79	0.37	0.6%	0.7%
	High Density	162.91	6.18	9.2%	12.4%
	Water	78.70	-	4.4%	
	Total	**1768.83**	**50.0**	**100.0%**	**100.0%**
Areal Land Use Scenario	Commercial Development	193.98	12.08	11.0%	26.1%
	Forest	963.30	2.89	54.5%	6.2%
	Undeveloped / Grass	93.49	1.83	5.3%	4.0%
	Low-Density Residential	226.80	15.05	12.8%	32.5%
	Medium-Density Residential	34.60	2.15	2.0%	4.6%
	Road	61.92	8.64	3.5%	18.6%
	Wetland	53.03	1.31	3.0%	2.8%
	Agriculture	9.79	0.37	0.6%	0.8%
	High Density	53.22	2.02	3.0%	4.4%
	Water	78.70	-	4.4%	-
		1768.83	**46.3**	**100.0%**	**100.0%**

3.1.2 FECAL COLIFORM

Precipitation event-based fecal coliform loading was completed for a design storm event with a 2-year 24hr duration precipitation depth occurring over the studied watershed. Resultant fecal coliform loading for the existing conditions, low-development, developer requested, high-density and areal land-use scenarios are predicted with results given in **Table 3-2**. From existing conditions, this represents an increase in fecal coliform load of 41.6%, 39.4%, 53.7%, and 31.5% for the low-density, developer requested, high-density scenarios, and areal land-use respectively.

Table 3-2 Predicted Fecal Coliform Loading to Sandy Lake during Storm Event

Development Scenario	Existing Condition Land Use	Area (ha)	FC Loading (CFU)	Land Use Percentage	FC Load Percentage
Existing Conditions	Commercial Development	137.93	1.29E+12	8%	42%
	Forest	1157.88	1.16E+11	65%	4%
	Undeveloped/Grassed	93.49	4.36E+11	5%	14%
	High-Density Residential	0.00	0.00E+00	0%	0%
	Medium-Density Residential	23.61	1.33E+11	1%	4%
	Low-Density Residential	221.53	9.44E+11	13%	31%
	Agriculture	9.79	1.67E+10	1%	1%
	Roadway	45.90	1.32E+11	3%	4%
	Water	78.70	-	4%	-
	Total	**1768.83**	**3.07E+12**	**100.00%**	**100.00%**
Low-Density Scenario	Commercial Development	192.16	1.79E+12	11%	41%
	Forest	931.19	9.31E+10	53%	2%
	Undeveloped/Grassed	93.49	4.36E+11	5%	10%
	High-Density Residential	0.00	0.00E+00	0%	0%
	Medium-Density Residential	91.10	5.12E+11	5%	12%
	Low-Density Residential	310.48	1.32E+12	18%	30%
	Agriculture	9.79	1.67E+10	1%	0%
	Roadway	61.92	1.78E+11	4%	4%
	Water	78.70	-	4%	-
	Total	**1768.83**	**4.35E+12**	**100.00%**	**100.00%**
Developer Requested Scenario	Commercial Development	208.0	1.94E+12	12%	45%
	Forest	985.0	9.85E+10	56%	2%
	Undeveloped/Grassed	93.5	4.36E+11	5%	10%
	High-Density Residential	66.5	4.25E+11	4%	10%

Development Scenario	Existing Condition Land Use	Area (ha)	FC Loading (CFU)	Land Use Percentage	FC Load Percentage
	Medium-Density Residential	37.3	2.10E+11	2%	5%
	Low-Density Residential	228.1	9.72E+11	13%	23%
	Agriculture	9.8	1.67E+10	1%	0%
	Roadway	61.9	1.78E+11	4%	4%
	Water	78.7	-	4%	-
	Total	**1768.83**	**4.28E+12**	**100.00%**	**100.00%**
High-Density Scenario	Commercial Development	192.16	1.79E+12	11%	38%
	Forest	908.67	9.09E+10	51%	2%
	Undeveloped/Grassed	93.49	4.36E+11	5%	9%
	High-Density Residential	162.91	1.04E+12	9%	22%
	Medium-Density Residential	34.73	1.95E+11	2%	4%
	Low-Density Residential	226.47	9.65E+11	13%	20%
	Agriculture	9.79	1.67E+10	1%	0%
	Roadway	61.92	1.78E+11	4%	4%
	Water	78.70	-	4%	-
	Total	**1768.83**	**4.72E+12**	**100.00%**	**100.00%**
Areal Land Use Scenario	Commercial Development	193.98	1.81E+12	11%	45%
	Forest	1016.33	1.02E+11	57%	3%
	Undeveloped/Grassed	93.49	4.36E+11	5%	11%
	High-Density Residential	53.22	3.40E+11	3%	8%
	Medium-Density Residential	34.60	1.94E+11	2%	5%
	Low-Density Residential	226.80	9.67E+11	13%	24%
	Agriculture	9.79	1.67E+10	1%	0%
	Roadway	61.92	1.78E+11	4%	4%
	Water	78.70	-	4%	-
	Total	**1768.83**	**4.04E+12**	**100.00%**	**100.00%**

3.1.3 SEDIMENT

The total event-based soil loss load (tonnes) for each development scenario is presented in **Table 3-3** The low-, developer-requested, and high-density scenarios had the largest sediment load increase from existing conditions (5 tonnes). This is likely due to the increase of residential development and loss of forested area in comparison to the areal land-use scenario (33 tonnes of sediment). These values represent no mitigation or management condition, therefore with the implementation of standard erosion and sedimentation controls, these values would be expected to decrease. The development scenarios represent a sediment load increase of 17.2% for the low-, developer-requested, and high-density scenarios, and 13.7% sediment load increase for the areal land-use scenario when compared to existing conditions.

Table 3-3 Event-Based Sediment Loading Results

Development Condition	Land Use	A (tonnes/ha)	Area (ha)	Total Storm Event Load (tonnes)
Existing Condition	Forest General (Non-Disturbed)	0.0029	1104.84	29
	Roads	0.2045	45.90	
	Disturbed Forest Land	0.1168	103.28	
	Urban	0.0114	383.08	
Low-Density Development	Forest General (Non-Disturbed)	0.0029	878.15	34
	Roads	0.2045	61.92	
	Disturbed Forest Land	0.1168	103.28	
	Urban	0.0114	593.75	
Developer Requested Scenario	Forest General (Non-Disturbed)	0.0029	931.92	34
	Roads	0.2045	61.92	
	Disturbed Forest Land	0.1168	103.28	
	Urban	0.0114	539.98	
High-Density Development	Forest General (Non-Disturbed)	0.0029	855.63	34
	Roads	0.2045	61.92	
	Disturbed Forest Land	0.1168	103.28	
	Urban	0.0114	616.27	
Areal Land-Use Scenario	Forest General (Non-Disturbed)	0.0029	963.30	33
	Roads	0.2045	61.92	
	Disturbed Forest Land	0.1168	103.28	
	Urban	0.0114	508.60	

3.2 Annual Watershed Loading Model

Modelling was completed to predict changes in land use associated contaminant loadings for the three proposed development scenarios. Models were completed for TP, FC, and sediment using methods described in Section 2.

3.2.1 PHOSPHORUS

The annual TP loading from the Sandy Lake watershed is approximately 297.6, 409.7, 395.9, 421.6 and 387.4 kg/year from the approximate 1,768 ha watershed for the existing conditions, low-density, developer requested, high density, and areal land-use scenarios respectively (**Table 3-4**). The existing condition annual TP load corresponds to an annual loading rate of 0.0168 gm P/m^2·yr. This loading rate is similar to the P export loading rates measured by Scott et. al. (2000) for a watershed in Halifax as presented in Brylinsky (2004).

Table 3-4 Sandy Lake Predicted Annual P Loading for the Selected Development Scenarios

Development Scenario	Land Use	Area (ha)	Annual P Loading (kg/year)	Land Use Percentage	P Load Percentage
Existing Condition	Commercial	128.2	25.90	7.2%	8.7%
	Forested	1103.5	26.49	62.4%	8.9%
	Undeveloped/ Grassed	93.5	14.02	5.3%	4.7%
	Low-Density Residential	221.5	55.38	12.5%	18.6%
	Medium-Density Residential	23.6	9.93	1.3%	3.3%
	Institutional	9.7	2.91	0.5%	1.0%
	Road	45.9	160.64	2.6%	54.0%
	Wetland	53.0	1.27	3.0%	0.4%
	Agriculture	9.8	1.06	0.6%	0.4%
	High-Density Residential	0.0	0.00	0.0%	0.0%
	Water	78.5	0.00	4.4%	0.0%
	Grand Total	**1768.8**	**297.61**	**100.0%**	**100.0%**
Low-Density Condition	Commercial	182.5	36.86	10.3%	9.0%
	Forested	876.9	21.04	49.6%	5.1%
	Undeveloped/ Grassed	93.5	14.02	5.3%	3.4%
	Low-Density Residential	310.5	77.62	17.6%	18.9%
	Medium-Density Residential	91.1	38.26	5.2%	9.3%
	Institutional	9.7	2.91	0.5%	0.7%
	Road	61.9	216.71	3.5%	52.9%
	Wetland	53.0	1.27	3.0%	0.3%
	Agriculture	9.8	1.06	0.6%	0.3%

Development Scenario	Land Use	Area (ha)	Annual P Loading (kg/year)	Land Use Percentage	P Load Percentage
	High-Density Residential	0.0	0.00	0.0%	0.0%
	Water	78.5	0.00	4.4%	0.0%
	Grand Total	**1768.8**	**409.76**	**100%**	**100.0%**
Developer Requested Scenario	Commercial	182.5	36.86	10.3%	9.3%
	Forested	930.6	22.33	52.6%	5.6%
	Undeveloped/ Grassed	93.5	14.02	5.3%	3.5%
	Low-Density Residential	228.1	57.03	12.9%	14.4%
	Medium-Density Residential	37.3	15.69	2.1%	4.0%
	Institutional	25.5	7.66	1.4%	1.9%
	Road	61.9	216.71	3.5%	54.7%
	Wetland	53.0	1.27	3.0%	0.3%
	Agriculture	9.8	1.06	0.6%	0.3%
	High-Density Residential	66.5	23.29	3.8%	5.9%
	Water	78.5	0.0	4.4%	0.0%
	Grand Total	**1768.8**	**395.92**	**100%**	**100.0%**
High-Density Condition	Commercial	182.5	36.86	10.3%	8.7%
	Forested	854.3	20.50	48.3%	4.9%
	Undeveloped/ Grassed	93.5	14.02	5.3%	3.3%
	Low-Density Residential	226.5	56.62	12.8%	13.4%
	Medium-Density Residential	34.7	14.59	2.0%	3.5%
	Institutional	9.7	2.91	0.5%	0.7%
	Road	61.9	216.71	3.5%	51.4%
	Wetland	53.0	1.27	3.0%	0.3%
	Agriculture	9.8	1.06	0.6%	0.3%
	High-Density Residential	162.9	57.02	9.2%	13.5%
	Water	78.5	0.00	4.4%	0.0%
	Grand Total	**1768.8**	**421.56**	**100%**	**100.00%**
Areal Land Use Scenario	Commercial	171.6	34.67	9.7%	8.9%
	Forested	963.3	23.12	54.5%	6.0%
	Undeveloped/ Grassed	93.5	14.02	5.3%	3.6%
	Low-Density Residential	226.8	56.70	12.8%	14.6%
	Medium-Density Residential	34.6	14.53	2.0%	3.8%
	Institutional	22.4	6.71	1.3%	1.7%
	Road	61.9	216.71	3.5%	55.9%
	Wetland	53.0	1.27	3.0%	0.3%

Development Scenario	Land Use	Area (ha)	Annual P Loading (kg/year)	Land Use Percentage	P Load Percentage
	Agriculture	9.8	1.06	0.6%	0.3%
	High-Density Residential	53.2	18.63	3.0%	4.8%
	Water	78.7	0.00	4.4%	0.0%
	Grand Total	**1768.8**	**387.42**	100%	100.00%

Figure 3-1 present the land use breakdown of TP loading for each development scenario. Roadways and low-density residential areas account for approximately 70% of annual loading within the watershed for the selected development conditions. Of the proposed development scenarios, the areal land-use scenario has the lowest annual TP load (389.9 kg P/yr); this may be attributed to the development scenario with the largest amount of forested area compared to the other three scenarios. Despite the low-density development scenario having no high-density residential units, the low- and high-density annual TP loading rates are similar (410 kg P/yr and 422 kg P/yr, respectively).

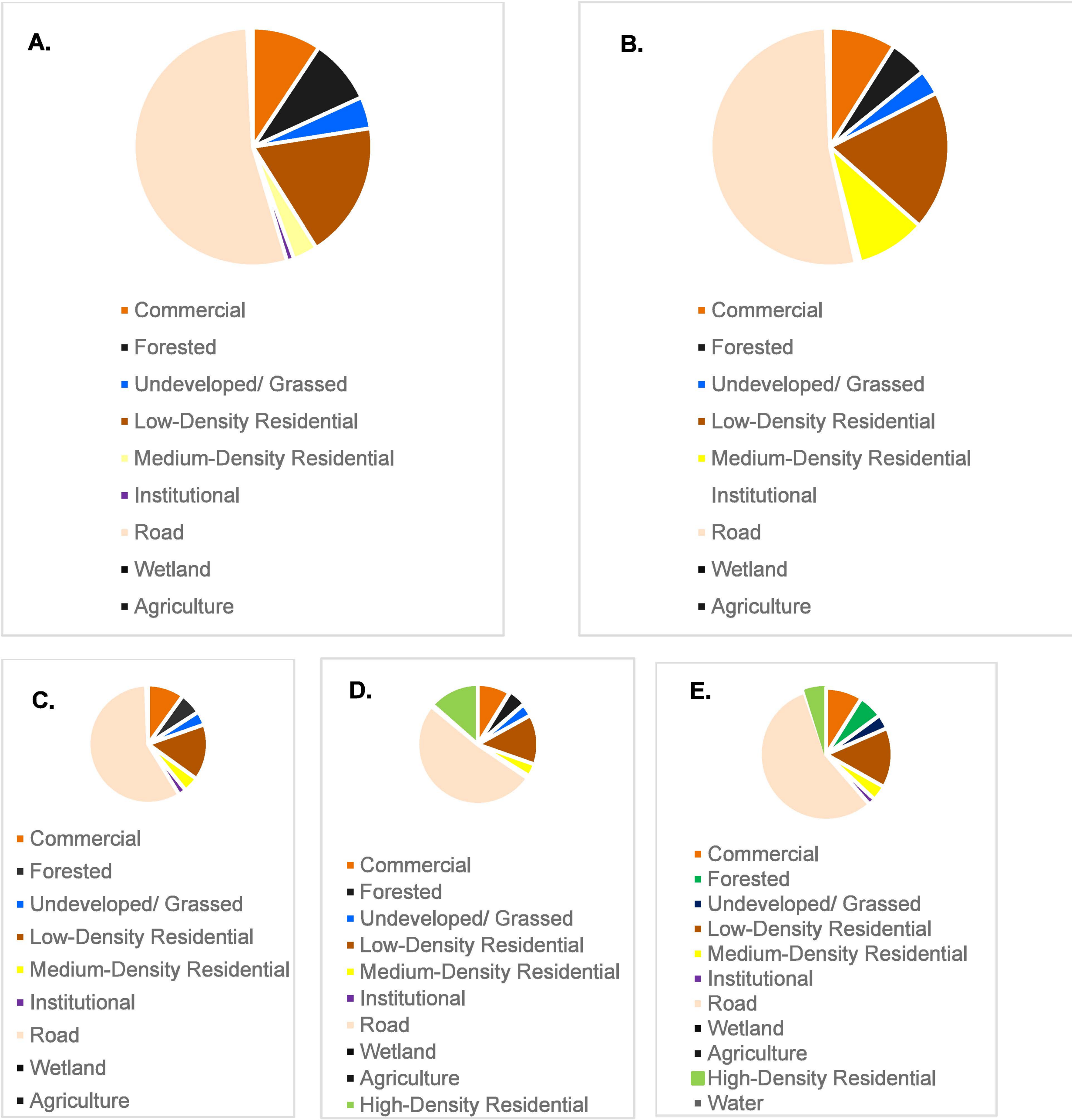


Figure 3-1 TP Loading - Existing Conditions (A) Low-Density (B) Developer Requested (C) High-Density (D), Areal Land Use Scenario (E)

3.2.2 FECAL COLIFORM

The annual fecal coliform loading from Sandy Lake watershed is approximately 2.01E+14, 2.81E+14, 2.72E+14, 3.00E+14, and 2.58E+14 CFU/year from the 1,768 ha watershed for the existing conditions, low-density, developer requested, high-density, and areal land-use scenarios, respectively (**Table 3-5**). An estimated 70% annual loading is generated from commercial and low-density residential land use types within the watershed for the selected development scenarios. Forested areas account for between 51-65% of the land use within the watershed and contribute 2.5-4.4% of the annual fecal coliform loading whereas commercial areas account between 8-11% of the overall area and contribute approximately 40% of the annual load.

Table 3-5 Predicted Annual Fecal Coliform Loading to Sandy Lake the Selected Development Scenarios

Development Scenario	Land Use	Area (ha)	Annual FC Loading (CFU/year)	Land Use Percentage	FC Load Percentage
Existing Condition	Commercial + Institutional	137.93	7.63E+13	7.80%	37.97%
	Forested + Wetlands	1157.88	8.89E+12	65.46%	4.43%
	Undeveloped/ Grassed	93.49	3.52E+13	5.29%	17.52%
	Low-Density Residential	221.53	6.95E+13	12.52%	34.62%
	Medium-Density Residential	23.61	8.18E+12	1.34%	4.07%
	Road	45.90	1.61E+12	2.59%	0.80%
	Agriculture	9.79	1.19E+12	0.55%	0.59%
	High-Density Residential	0.00	0.00E+00	0.00%	0.00%
	Water	78.70		4.45%	0.00%
	Grand Total	**1768.83**	**2.01E+14**	**100.00%**	**100.00%**
Low-Density Condition	Commercial + Institutional	192.16	1.06E+14	10.86%	37.82%
	Forested + Wetlands	931.19	7.15E+12	52.64%	2.55%
	Undeveloped/ Grassed	93.49	3.52E+13	5.29%	12.52%
	Low-Density Residential	310.48	9.74E+13	17.55%	34.68%
	Medium-Density Residential	91.10	3.15E+13	5.15%	11.23%
	Road	61.92	2.18E+12	3.50%	0.78%
	Agriculture	9.79	1.19E+12	0.55%	0.42%
	High-Density Residential	0.00	0.00E+00	0.00%	0.00%
	Water	78.70		4.45%	0.00%
	Grand Total	**1768.83**	**2.81E+14**	**100.00%**	**100.00%**
Developer Requested Condition	Commercial + Institutional	207.99	1.15E+14	11.76%	42.24%
	Forested + Wetlands	984.95	7.56E+12	55.68%	2.78%
	Undeveloped/ Grassed	93.49	3.52E+13	5.29%	12.92%

Development Scenario	Land Use	Area (ha)	Annual FC Loading (CFU/year)	Land Use Percentage	FC Load Percentage
	Low-Density Residential	228.11	7.16E+13	12.90%	26.29%
	Medium-Density Residential	37.35	1.29E+13	2.11%	4.75%
	Road	61.92	2.18E+12	3.50%	0.80%
	Agriculture	9.79	1.19E+12	0.55%	0.44%
	High-Density Residential	66.53	2.66E+13	3.76%	9.78%
	Water	78.70		4.45%	0.00%
	Grand Total	**1768.83**	**2.72E+14**	**100%**	**100.00%**
High-Density Condition	Commercial + Institutional	192.16	1.06E+14	10.86%	35.41%
	Forested + Wetlands	908.67	6.98E+12	51.37%	2.33%
	Undeveloped/ Grassed	93.49	3.52E+13	5.29%	11.72%
	Low-Density Residential	226.47	7.11E+13	12.80%	23.68%
	Medium-Density Residential	34.73	1.20E+13	1.96%	4.01%
	Road	61.92	2.18E+12	3.50%	0.73%
	Agriculture	9.79	1.19E+12	0.55%	0.40%
	High-Density Residential	162.91	6.52E+13	9.21%	21.73%
	Water	78.70		4.45%	0.00%
	Grand Total	**1768.83**	**3.00E+14**	**100.00%**	**100.00%**
Areal Land-Use Scenario	Commercial + Institutional	193.98	1.07E+14	10.97%	41.56%
	Forested + Wetlands	1016.33	7.80E+12	57.46%	3.02%
	Undeveloped/ Grassed	93.49	3.52E+13	5.29%	13.63%
	Low-Density Residential	226.80	7.12E+13	12.82%	27.58%
	Medium-Density Residential	34.60	1.20E+13	1.96%	4.64%
	Road	61.92	2.18E+12	3.50%	0.84%
	Agriculture	9.79	1.19E+12	0.55%	0.46%
	High-Density Residential	53.22	2.13E+13	3.01%	8.26%
	Water	78.70	-	4.45%	0.00%
	Grand Total	**1768.83**	**2.58E+14**	**100.00%**	**100.00%**

3.2.3 SEDIMENT

The estimated total annual sediment loss load (tonnes/year) for each development scenario are presented in **Table 3-6**. For the existing conditions, the total annual loading rate is 490 tonnes/year of sediment leaving the watershed, with no mitigation measures in place. The developer requested scenario, and the areal land-use scenario had the next lowest total annual sediment loading rates (567 and 562 tonnes/year, respectively). The low- and high-density development scenarios resulted in similar sediment loading rates (574 and 578 tonnes/year, respectively).

Table 3-6 Predicted Annual Sediment Loading to Sandy Lake for the Selected Development Scenarios

Development Condition	Land Use	Sediment Loading (tonnes/ha/yr)	Area (ha)	Total Annual Load (tonnes/yr)
Existing Condition	Forest General (Non-Disturbed)	0.04	1104.84	490
	Roads	3.4	45.90	
	Disturbed Forest Land	2.0	103.28	
	Urban	0.2	383.08	
Low-Density Development	Forest General (Non-Disturbed)	0.05	878.15	574
	Roads	3.5	61.92	
	Disturbed Forest Land	2.0	103.28	
	Urban	0.2	593.75	
Developer Requested Scenario	Forest General (Non-Disturbed)	0.05	931.92	567
	Roads	3.4	61.92	
	Disturbed Forest Land	2.0	103.28	
	Urban	0.2	539.98	
High-Density Development	Forest General (Non-Disturbed)	0.05	855.63	578
	Roads	3.4	61.92	
	Disturbed Forest Land	2.0	103.28	
	Urban	0.20	616.27	
Areal Land Use Scenario	Forest General (Non-Disturbed)	0.05	963.30	562
	Roads	3.4	61.92	
	Disturbed Forest Land	2.0	103.28	
	Urban	0.20	508.60	

3.3 Phosphorus Lake Model

A lake system TP loading model was completed for Sandy Lake using a method developed by Brylinsky (2004), as described in Section 2. A summary of results is given in **Table 3-7**.

Table 3-7 Lake System P Model Results Summary for the Selected Development Scenarios

Parameter	Existing Condition	Low-Development	Developer Requested	High-Development	Areal Land-Use
Lake Characteristics					
Lake Flushing Rate (times/year)	0.44	0.53	0.50	0.54	0.49
Lake Turnover Time (yr)	2.28	1.89	1.98	1.85	2.04
Phosphorus Budget (g/yr)					
Upstream inflow	0	0	0	0	0
Atmosphere	13,345	13,345	13,345	13,345	13,345
Land Runoff	297,598	409,765	395,920	421,561	387,424
Development	10,560	10,560	10,560	10,560	10,560
Sedimentation	-131,816	-199,488	-188,921	-204,914	-180,985
Total Outflow	**189,687**	**234,182**	**230,904**	**240,552**	**230,344**

Phosphorous input sources are partitioned into four categories: input from upstream waterbodies (as Sandy Lake is a headwater lake, this is considered to be 0 g/yr), atmospheric deposition, overland runoff, and development. Phosphorous exits the lake system through either in-lake sedimentation or lake outflow. Phosphorous, however, can become re-suspended into the water column through internal loading during periods of anoxic lake conditions. As Sandy Lake is prone to anoxic events, this should be taken into consideration of potential loading within the lake.

For the existing conditions scenario, approximately 40% of P input remains in the lake, with 60% discharged; 45% of P inputs remains in Sandy Lake for the low-development, developer requested, and areal land-use scenarios and 55% is discharged; and approximately 47% of P input remains in the lake, with 53% discharged for the high-development scenario.

Table 3.8 Model Validation of Predicted vs. Measured P Concentrations

Model Validation	P (mg/L)
Predicted P – Lake system model – Existing Condition	0.0136
Measured mean P – 1980 to 2023 (mg/L)	0.013
% Difference	4.5
Predicted P – Lake system model – Low-Density Scenario	0.0204
Predicted P – Lake system model – Developer Requested Scenario	0.0191
Predicted P – Lake system model – High-Density Scenario	0.0214
Predicted P – Lake system model – Areal Land-Use Scenario	0.0185

As a result of lake system nutrient loading modeling, in-lake P concentrations were predicted to have an average value of 0.0136 mg/L within Sandy Lake. This represents a mesotrophic trophic status under the

CCME FAL guidelines. When compared to measured P concentrations within Sandy Lake taken between 1980 to 2023 there is a 4.5% difference.

4 Water Quality Discussion

4.1 Total Phosphorus

Area and concentration-based TP loadings within the Sandy Lake watershed are largely generated by anthropogenic sources, namely low-density residential and roadways. These two land uses contributed approximately 60% of the loading to Sandy Lake for the selected development scenarios. TP loads from residential land use are mitigated in the existing condition and development scenarios by municipal wastewater services and centralized wastewater treatment, which remove these additional loads form the watershed. The existing condition annual TP loading was calculated to be 297 kg/year. For the four proposed development scenarios, the areal land use scenario resulted in the lowest increase in TP loading for both event-based and annual loading calculations, with the developer-requested scenario having the next lowest TP loading. The reduced TP load for the areal land-use scenario is attributable to a larger forested land use area remaining in the watershed, though alternative high-density scenarios could result in an even larger area of forested land maintained. Future development for the SLSA should consider the conservation of natural forested area, rather than the expansion of development within the watershed. A mix of higher density, smaller footprint housing may mitigate the loss of forested area within the watershed. The low- and high-density development scenarios have approximately 30% more TP discharging from the watershed compared to existing conditions. As Sandy Lake has previously identified to be at risk of increased TP loads (AECOM 2014), the implementation of mitigation measures will be required for developments to reduce TP loads to match existing or background conditions.

According to results of the lake systems P model, Sandy Lake currently retains approximately 132 kg of P on an annual basis and is predicted to retain 199, 189, 205, and 182 kg for the low-, developer requested-, high-density, and areal land-use scenarios, respectively.

The predicted in-lake TP concentrations for the future development scenarios range from 0.0189 mg/L to 0.0214 mg/L which represent the high-end of mesotrophic and eutrophic trophic levels, respectively. The increase in TP within the lake predicted by the loading models pose the risk of a decline in lake water quality. The increase in nutrient concentration is directly correlated to the likelihood of harmful algal blooms. Algal blooms are associated with a number of water quality issues, e.g., cyanotoxin production, foams and scums from algae biomass that can interfere with recreational water use.

4.2 Fecal Coliform

According to the EMC-based model results, area and concentration-based fecal coliform loadings within Sandy Lake are largely generated by residential developments and commercial developments for the existing condition and development scenarios. It is noted, however, that model parameters used for fecal coliform have a high degree of variability. Results from rainfall-event modeling in Sandy Lake give a calculated loading of 3.07 x 10^{12} CFU/100 mL during a 2yr-24hr Chicago design storm event. When compared to annual loading calculations within the watershed, at 2.01 x 10^{14} CFU/100 mL, the annual model results appear to overestimate fecal coliform loading from the watershed.

Similarly, the rainfall-event based fecal coliform loading resulted in approximately 1.5% of the annual fecal coliform loads for the four development scenarios. The increase in annual fecal coliform load from baseline conditions for each of the development scenarios was 39.8%, 35.3%, 49.3%, and 28.4% for the low-density, developer requested, high-density, and areal land-use scenarios, respectively.

Based on the event-based and annual fecal coliform loading model results for the development scenarios, mitigation measures will be required to reduce loads to equal existing conditions.

4.3 Sediment

Sediment load modelling using MUSLE and RUSLEFAC calculations for the four development scenarios resulted in sediment loads between 562 to 578 tonnes/year on an annual basis and 29 to 34 tonnes per storm-event. This equates to an increase in annual sediment loading of 17.1%, 15.7%, 17.9% and 14.7% from existing conditions for the low-density, developer-requested, high-density, and areal land-use scenarios, respectively. The storm event loadings represent approximately 6% of total annual sediment load. Baseline sediment loading was estimated to be 490 tonnes per year, with approximately 29 tonnes deposited during a storm event. The addition of roads, and disturbance of soils during construction of the development scenarios have the potential to increase sediment loading in the watershed. Therefore, the implementation and design of mitigation measures will be required to reduce loads to equal existing conditions. These calculations were performed conservatively, without considering any erosion and sedimentation control measures. The implementation of ESC measures would reduce the transport of sediment within the watershed as these methods are highly effective (HESL 2012). Additional recommendations for sediment mitigation are presented in the following section.

5 Recommendations to Mitigate Loading

5.1 Phosphorous Loading Mitigation

5.1.1 LAND USE-BASED MITIGATION

Low-density residential and road land uses are estimated to contribute the highest percentage of TP loading to the lake system on an annual basis for the four land development scenarios. To reduce annual TP load to the watershed, the development scenarios must consider implementation of low-impact development methods to reduce loading by approximately 30% for the four land development scenarios. The following mitigation measured are designed to counter the effects of existing urban development by changing land use loading rates derived from these developments.

- The implementation of street maintenance programs to remove sediment-associated P from roadways prior to it being carried to the lake systems via stormwater runoff. Street sweeping and catch basin clean out are required routine maintenance for urban street systems to reduce sediment and TP transport to downstream receptors. Electric street sweeping and other street maintenance can be used to minimize the impact of the required maintenance operations.
- The implementation of structural Low-Impact Development (LID) measures would be expected to reduce TP loads for the development area to achieve TP loads of existing conditions. HESL (2014) provided guidelines to HRM which listed examples of LID such as:

    a. Infiltration Trenches

    b. Infiltration Basin or other surface infiltration practice

    c. Bioretention Practice

    d. Gravel wetland system

    e. Porous Pavement

    f. Wet Pond or wet detention basin

    g. Dry Pond or detention basin and

    h. Water Quality Swale

    i. Green Roofs

- It is recommended that that water management infrastructure be developed and assessed to result in no net increase in TP loads for the chosen development scenario.
- The promotion of green space creation or conservation of naturally forested areas within the new development scenarios. Native species should be used to maintain biodiversity within the watershed

in the implementation of green infrastructure and naturalization projects. The loading rate for P changes substantially from low-density residential developments (0.025 gm/m^2 yr) to green space (0.015 gm/m^2 yr), indicating the promotion of green space can reduce P loadings to downstream receptors.

- Reducing the footprint of development (i.e., buildings and roads) and conserving naturally forested areas within the development scenarios. As the empirical loading rates are calculated on an areal basis (Sections 2.4 and 2.5), limiting the affected area will limit the additional load produced within the watershed.

5.1.2 ON-GOING MONITORING

On-going monitoring provides a method to measure the success of implemented mitigation measures to while keeping record of water quality within the lake system. The following monitoring activities are recommended to be conducted on an on-going basis within the lake system:

- The extension of in-lake P monitoring at deep lake locations when the lake system is completely mixed (e.g., late fall, early spring). This is recommended to capture increasing trend in lake P concentrations and associated trophic status changes caused by a release of P from vegetation and algae decay. If conducted after seasonal lake turnover, this data can also capture increase in P concentrations from the lake epilimnion.
- The continuation of profiling, surface, and lake bottom sampling at deep-water lake locations. This will allow for the monitoring of P release from benthic sediments, through the identification of anoxic zones at lake bottom, and surface and lake bottom concentration comparison.
- The continuation of flow monitoring and grab sampling at select monitoring locations to track loading reductions as a result of mitigation measures and confirm they are performing as designed. Suggested locations would be headwall locations where roadway maintenance is being implemented. An example of this monitoring would be the continuation of HRM's LakeWatchers program in which Sandy Lake is monitored twice annually (Early May and August).
- During the monitoring within the SLSA, an adaptive management approach should be taken to target point and nonpoint sources of P within the watershed to improve water quality. As sources of P within the watershed are identified, management measures can be applied to reduce P loading in the watershed as described above.

5.2 *E.coli* Loading Mitigation

5.2.1 INFRASTRUCTURE-BASED MITIGATION

Fecal source identification is helpful in identifying changes to infrastructure that may aid in the reduction of *E.coli* loading to recreational water bodies. *E.coli* loading can be the result of animal, human, or industrial sources entering watercourses or waterbodies. The implementation of LID technologies within the watershed, as outlined in the previous section would also aid in the removal and sedimentation of fecal coliform within the watershed.

5.2.2 PUBLIC EDUCATION

Public education efforts are expected to be most effective regarding *E.coli* loading to the lake systems as bacteria loading has a direct and potentially serious implication to human health, it affects the use of recreational water bodies, and public involvement with mitigation measures is expected to be more possible than with P loading sources. The following public education items are recommended as a result of study findings:

- Increased public education on the need to pick-up droppings from domestic animals. Sandy Lake Park is a popular recreation area for many and signage within the park may help inform the public of risks relating to fecal coliform exceedances on human and animal health.
- Increased public education of the risk of swimming in areas where wildlife congregates. The SLSA is the habitat of many avian, and other wildlife species. Public risk awareness is needed to mitigate risk to human health from these sources.
- Continuation of public education with respect to public beach closures. Regardless of the source of bacteria loadings, high bacteria events represent a risk to public health when they occur in areas used for recreational purposes.

5.2.3 ON-GOING MONITORING

To further aid in the identification of watershed land suitability in the Sandy Lake Watershed, further monitoring is recommended as follows:

- Monitoring of fecal coliform markers to better understand the sources of fecal coliform within the watershed.
- The continuation of flow monitoring and grab sampling at select monitoring locations to track loading reductions as a result of mitigation measures. An example of this monitoring would be the continuation of HRM's LakeWatchers program in which Sandy Lake is monitored twice annually (Early May and August).
- The continuation of weekly fecal bacteria monitoring at Sandy Lake Beach during the summer months (July 1 to August 31) to track loading rates as a result of mitigation measures, and to ensure the lake is safe for recreational use.
- During the monitoring within the SLSA, an adaptive management approach should be taken to target point and nonpoint sources of FC and *E.coli* within the watershed to improve water quality. As sources of FC and *E.coli* within the watershed are identified, management measures can be applied to reduce FC loading in the watershed as described above.

5.3 Sediment Loading Mitigation

Baseline TSS concentrations are very low within the Sandy Lake Watershed due to the limited development within the watershed. If the SLSA is developed following the selection of one of the proposed development scenarios, it will be important to implement erosion and sedimentation control measures to mitigate effects from development. The expected increases in sediment loading from existing conditions are between 20 to 24%. The implementation of construction sequencing to minimize the quantity of soil exposed at any given time is the most effective way to prevent erosion from the proposed development. **Table 5-1** presents a list of effective sediment control mitigation measures and their efficiency of removing sediment load (if properly installed) (HESL 2012). It should be noted that these ESC measures also have the capacity reduce TP and *E.coli* loads through infiltration and filtering.

Table 5-1 Event-Based Sediment Loading Results (HESL 2012)

Measure Implemented		TSS Removal Efficiency (%)
Erosion Prevention	Establishing vegetative cover	99
	Mulch, geotextile mats	90
Capture of Sediment	Dry detention ponds	10
	Wet detention ponds	63
	Vegetative filter strips	65
	Silt fencing	70
	Filter tubes or bags	45

6 Background and SWM Criteria for Stormwater Management Design

The following summarizes the stormwater management (SWM) criteria and objectives for the Sandy Lake Development area as established in available background reports, the Halifax Regional Municipality's (HRM) Stormwater Management, and Municipal Design Guidelines and Halifax Water's (HW) Regulations and Guidelines for Stormwater Management.

6.1 Regulatory Considerations

6.1.1 HALIFAX WATER

HW's Stormwater Design Specifications and Supplementary Standard Specifications 2023 (DS & SSS) outline the following objectives relating to the design of new of storm drainage systems.

The storm drainage system shall:

- be designed to prevent loss of life and to protect structures and property from damage due to a major storm event;
- provide safe and convenient use of streets, lot areas and other land during and following rain and snow melt events;
- adequately convey stormwater flow from upstream sources;
- mitigate the adverse effects of stormwater flow, such as flooding and erosion, on downstream properties;
- preserve natural watercourses;
- minimize the long-term effect of development on receiving watercourses; and
- provide a safe, accessible outlet.

In order to ensure sustainable stormwater management and mitigate flooding risks, the following should be adhered to in the post-development phase:

- Post development peak flows up to the 100-year storm to be restricted to pre-development levels;
- Proposed publicly owned development submissions to balance pre-development and post-development stormwater runoff, within ± 10%, except where there is a pre-existing flooding condition, in which case the post development flow cannot exceed the pre-development flow.

- Size culverts to convey instantaneous peak flows with a headwater depth to culvert diameter ratio of 1.0, taking into account both inlet control and outlet control. Culverts located in drainage courses or natural watercourses are to be designed to accommodate the 1:100-year return period storm, unless otherwise directed by the Engineer.
- Dry ponds are preferred over wet ponds. If wet ponds are to be privately owned and operated, they will be considered on a case-by-case basis;
- Additional pond volume allowances must include a 300mm freeboard from the 100-year water level.

6.1.1.1 Rainfall

Rainfall data has been based on the Environment and Climate Change Canada climate station Shearwater RCS (ID: 8205092). As the primary stormwater infrastructure for this site will be ultimately owned and operated by HW, the design storms provided in the DS & SSS have been used. These design storms use the Chicago Storm distribution with the following intensity/duration/frequency (IDF) parameters, with a, b and c as the regression constants for each return period and Td as the time of duration in hours.

Storm	a	b	c
2YR	25.112	0.04959	0.578
5YR	31.196	0.03178	0.565
10YR	35.114	0.01905	0.553
25YR	40.265	0.01159	0.548
50YR	44.089	0.00874	0.544
100YR	47.924	0.00594	0.544

$$i = \frac{a}{(T_d + b)^c}$$

Figure 6-1 Halifax Water IDF Parameters, 2023

6.1.1.2 Climate Change Considerations

HW acknowledges that climate conditions are not static and with the life cycle expectation of the piped infrastructure to be 80-100 years, it is anticipated that there will be an increase in precipitation intensity due to climate change over that period. The above listed design storms from the 2023 DS & SSS include a 16% increase to the rainfall intensity based on projections for the 2080 horizon. These design storms are used in this report as bases for calculating the capacity of the stormwater management infrastructure.

6.1.2 HALIFAX REGIONAL MUNICIPALITY

In the design and implementation of stormwater management systems within the Halifax Regional Municipality (HRM), adherence to the following guidelines is important for ensuring effective stormwater conveyance and environmental sustainability:

- The use of Green Infrastructure and Low Impact Development (LID) measures is preferred and encouraged.

- Aim for an average removal of 80% Total Suspended Solids (TSS) from post-development runoff on an annual loading basis.

6.1.3 NOVA SCOTIA DEPARTMENT OF ENVIRONMENT AND CLIMATE CHANGE

Nova Scotia Environment (NSE) requires that culverts be designed to have a headwater/pipe diameter ratio (H_w/D) of 1.0 for the 100-year flow and that fish passage be maintained in alignment to provincial guidelines. It should also be noted that NSE has a preference for single barrel as opposed to multiple barrel crossing structures.

Clear span opening of a watercourse crossing beneath a roadway must have a hydraulic capacity large enough to pass the 100-year peak flow with a maximum velocity of 1.8 m/s, unless otherwise approved by the Minister of Environment.

NSE also stipulates that a Watercourse Alteration Permit must be obtained for construction work within the banks of a watercourse and for work involving diversion of an existing watercourse to a new location.

A Wetland Alteration Permit would be required by NSE for work within an existing wetland area.

6.1.4 NOVA SCOTIA STATEMENT OF PROVINCIAL INTEREST REGARDING FLOOD RISK AREAS

The goal of this particular statement of provincial interest is to protect public safety and property and to reduce the requirement for flood control works and flood damage restoration in floodplains. Given that the Sandy Lake Development Area is within the Sackville River watershed, which has experienced significant flooding in the past, the provisions outlined in the statement of provincial interest regarding flood risk areas as summarized below, will be taken into account in the preparation of this report and in the recommendations provided.

1. Planning documents must identify Flood Risk Areas consistent with the Canada-Nova Scotia Flood Damage Reduction Program mapping and any locally known floodplain.
2. For Flood Risk Area that have been mapped under the Canada-Nova Scotia Flood Damage Reduction Program, planning documents must be reasonably consistent with the following:
    a. within the *Floodway (i.e.,* inner portion of a flood risk area where the risk of flooding is greatest, on average once in twenty years, and where flood depths and velocities are greatest),
        i. development must be restricted to uses such as roads, open space uses, utility and service corridors, parking lots and temporary uses, and
        ii. the placement of off-site fill must be prohibited;

   b. within the *Floodway Fringe (i.e.,* outer portion of a flood risk area, between the floodway and the outer boundary of the flood risk area, where the risk of flooding is lower, on average once in one hundred years, and floodwaters are shallower and slower flowing),

      i. development, provided it is flood proofed, may be permitted, except for

         1. residential institutions such as hospitals, senior citizen homes, homes for special care and similar facilities where flooding could pose a significant threat to the safety of residents if evacuation became necessary, and

         2. any use associated with the warehousing or the production of hazardous materials,

      ii. the placement of off-site fill must be limited to that required for flood proofing or flood risk management.

3. Expansion of existing uses must be balanced against risks to human safety, property and increased upstream and downstream flooding. Any expansion in the *Floodway* must not increase the area of the structure at or below the required flood proof elevation.

4. For known floodplains that have not been mapped under the Canada-Nova Scotia Flood Damage Reduction Program, planning documents should be, at a minimum, reasonably consistent with the provisions applicable to the *Floodway Fringe.*

5. Development contrary to this statement may be permitted provided a hydrotechnical study, carried out by a qualified person, shows that the proposed development will not contribute to upstream or downstream flooding or result in a change to flood water flow patterns.

6.1.5 BEDFORD, BEAVER BANK, HAMMONDS PLAIN AND UPPER SACKVILLE ON-GOING LAND USE BY-LAWS

The Municipal Planning Strategy and Land Use By-laws for Bedford, Beaver Bank, Hammonds Plain and Upper Sackville contain policies and regulations that restrict development in the Sackville River's floodplain. These policies and regulations are in the process of being updated based on a recent floodplain study. While this project does not include floodplain mapping for the Sandy Lake sub-watershed, the updated policies and regulations will provide updated municipal standards that should be considered for the Sandy Lake Development Area through future planning reviews.

6.2 Background Reports

The following reports have been reviewed and used in determining the SWM design criteria for the Sandy Lake Development area.

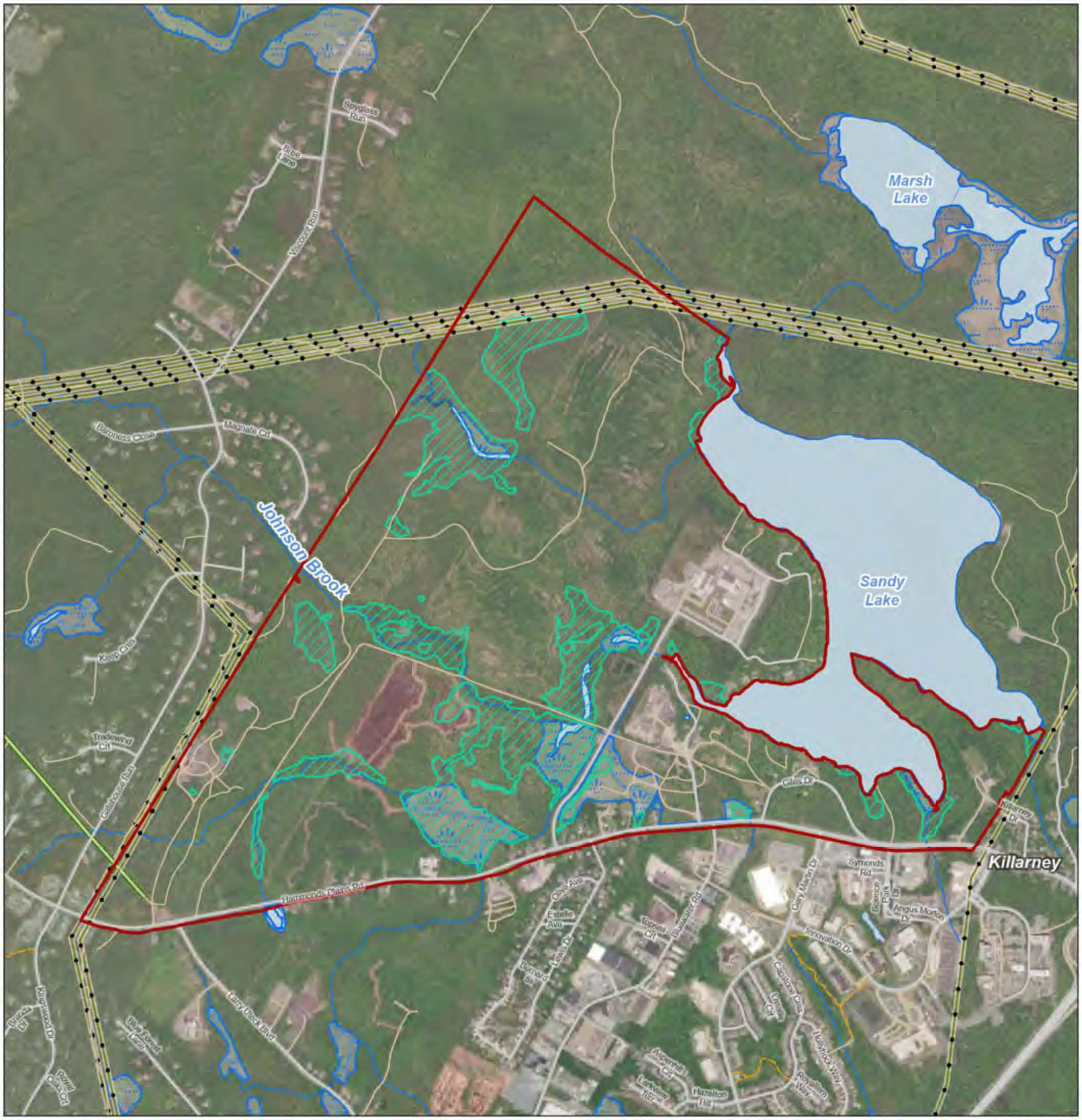
- **Sandy Lake Watershed Study Report, AECOM (2014):** This report prepared by AECOM provides an in-depth study of the Sandy Lake Watershed. The final report summarizes the potential impacts of proposed development within the watershed on Sandy Lake's water quality. The Sandy Lake watershed study assessed the impacts of future development on the lake's phosphorus levels, and proposed mitigation measures, such as providing advanced stormwater management and municipal wastewater services.

- **Sackville Rivers Floodplains Study, CBCL (2017):** This report produced updated floodplain maps for the Sackville River and Little Sackville River. The report provided flooding mitigation strategies, including restoring the natural shape of the rivers and surrounding riparian vegetation, purchasing affected properties, and introducing low impact development measures.
- **Hammonds Plains Road at Bluewater Road, WSP (2020):** This report focuses on the area near Hammonds Plains Road and Bluewater Road. It presents findings and suggestions derived from an examination of the road's structure and existing drainage system. The report outlines the preliminary design review of Hammonds Plains Road and recommends raising Hammonds Plains Road to an elevation outside the estimated flood water elevations.
- **Sackville River Mitigation Planning Study – Draft, Design Point Engineering & Surveying Ltd. (2020):** This draft study, conducted by Design Point in March 2020, focuses on mitigation planning for the Sackville River. It includes an in-depth analysis and strategic planning for flood mitigation and river management. The report outlines the use of Low Impact Development (LID) and Best Management Practices (BMPs) as part of a watershed-based Stormwater Management (SWM) strategy, as well as the enforcement of development restrictions within floodplains. These measures aim to ensure sustainable and effective flood management along the Sackville River.
- **Master Stormwater Management Plan, STRUM (2023):** This is the final version of the Master Stormwater Management Plan (Document No. 18-6361) developed by STRUM. The report, prepared by Strum Consulting on behalf of Sandy Lake Holdings Limited (SLHL), presents a conceptual stormwater management strategy for the Sandy Lake Development area.
- **Land Suitability Analysis, Englobe (2023):** This report provides a Land Suitability Assessment (LSA) for the Sandy Lake Development Area. The LSA identifies environmental constraints that could impact development, including wetlands, steep slopes, and wildlife habitats.
- **Sandy Lake Study Area Draft Report – Land Suitability Analysis, Stantec (March 2024)**: This report included both desktop and field components and included an evaluation of select biophysical characteristics (i.e., wetland habitat, watercourses, forest habitat, geology, topography, etc.), a review of contaminated sites, and a study of archaeological and cultural conditions for the study area. The objective of the land suitability analysis was to determine what portions of the study area are potentially suitable for new housing development.
- **Regional Flood Mapping Delineation Project – CBCL (on-going):** preliminary flood lines (i.e., subject to change) for the 5-year, 20-year, 100-year, and 200-year scenarios for both current climate conditions and projected climate conditions in the year 2100 were provided by HRM from the on-going Regional Flood Mapping Delineation project. These flood lines are derived from a high-level hydrologic and hydraulic analysis of flooding risks in the entire Halifax Regional Municipality and are based on a series of high-level assumptions regarding seasonal land cover, initial conditions at lakes, dam operation, coastal water levels, rainfall distribution (Chicago distribution – 24-hour, 5 min interval), and soil conditions.

7 Existing Conditions

7.1 Site Location

The Sandy Lake Development area is found in the southwest of HRM, within the communities of Hammonds Plains and Bedford. The proposed development area borders Sandy Lake to the east and Hammonds Plains Road to the south and is approximately 400 hectares of largely undeveloped land, see **Figure 7-1**. The entirety of the proposed development area falls within the Sandy Lake watershed, which is tributary to the Sackville River system.



Study Area

Utilities

Transmission Line

Pipeline

Transportation

Highway

Road

Resource / Seasonal Road

Trail

Other Features

Waterway

Waterbody

Wetland

Wetlands (Stantec, 2023)

0 250 500 Metres

(At original document size of 8.5x11)
1:21,000

N

Stantec

Project Location
Halifax Regional Municipality, Nova Scotia

Prepared by NW on 2024-10-04
QR by SW on 2024-10-07

Client/Project
Halifax Regional Municipality
Future Serviced Communities
Background Studies

160410459_3_1

Figure No.
7-1

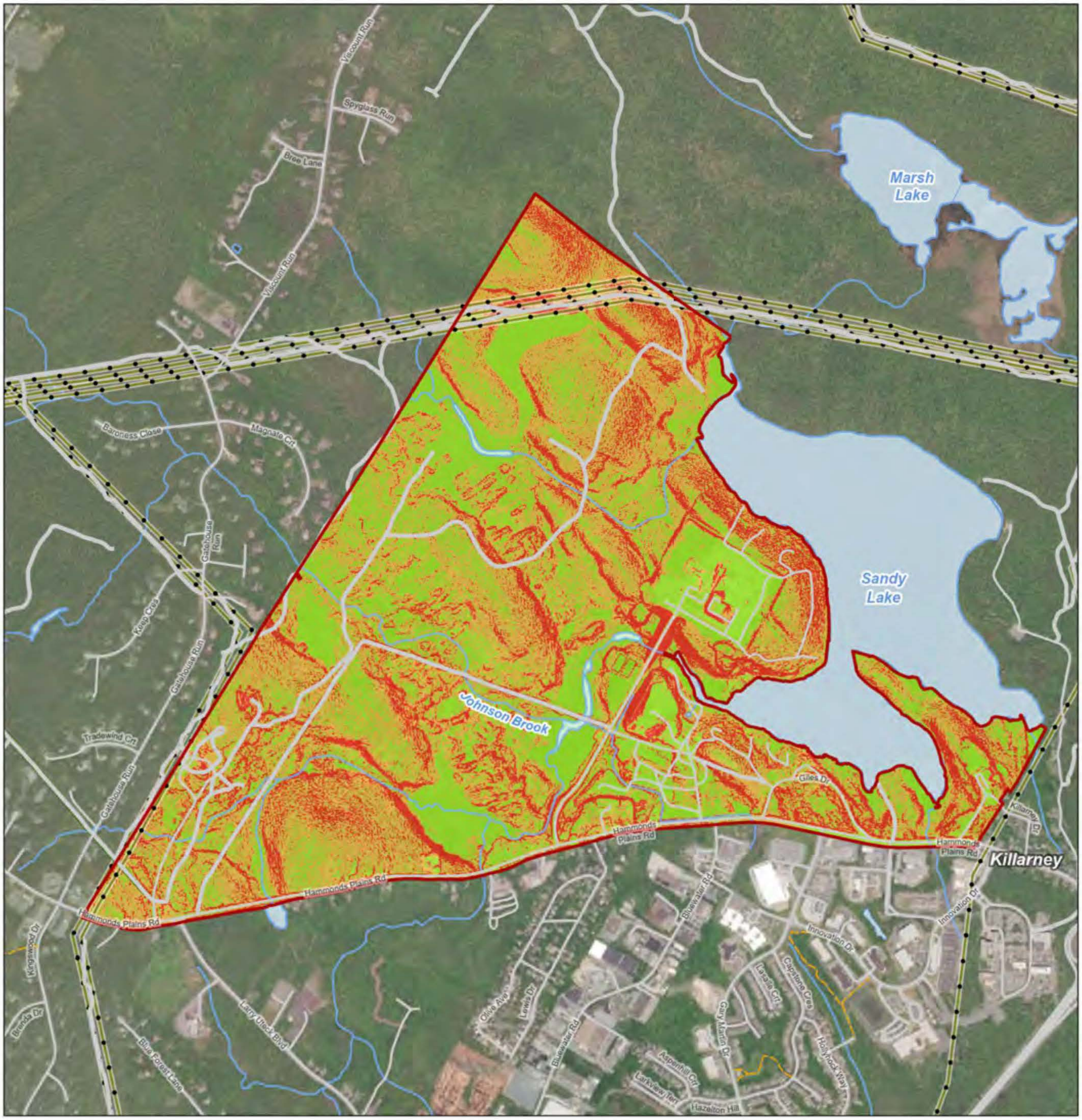
Title
Sandy Lake Study Area

Notes
1. Coordinate System: NAD 1983 CSRS UTM Zone 20N
2. Data Sources: Stantec, Government of Nova Scotia, Department of Service Nova Scotia and Internal Services
3. Background: ESRI; Government of Nova Scotia, Department of Service Nova Scotia and Internal Services

7.2 Topography

The Sandy Lake study area generally drains overland into Johnson's Brook and two unnamed watercourses that ultimately discharge into Sandy Lake.

Stantec has analyzed LiDAR data provided by HRM to categorize steep slopes. This task was entirely performed using ESRI ArcMAP, taking into account field observations. Field teams were directed to record notable slopes near water bodies and wetlands. Steep slopes were divided into three groups based on their percentage increase: 0.0%-5.0%, 5.1% - 15.0%, and above 15%. The slope mapping is illustrated in **Figure 7-2**, while **Figure 7-3** shows existing contours.



Study Area

Slope Analysis (Percent Rise)

- 0 - 5%
- 5.01 - 15%
- >15%

Transportation

- Trail
- Highway
- Other Road

Utilities

- Transmission Line
- Pipeline

Other Features

- Waterway
- Waterbody

0 250 500 Metres

(At original document size of 8.5x11)
1:21,000

N

Stantec

Project Location
Halifax Regional Municipality, Nova Scotia

Prepared by IP on 2023-11-09
Revised by NW on 2024-05-17
QR by SW on 2024-10-07

Client/Project
Halifax Regional Municipality
Future Serviced Communities
Background Studies

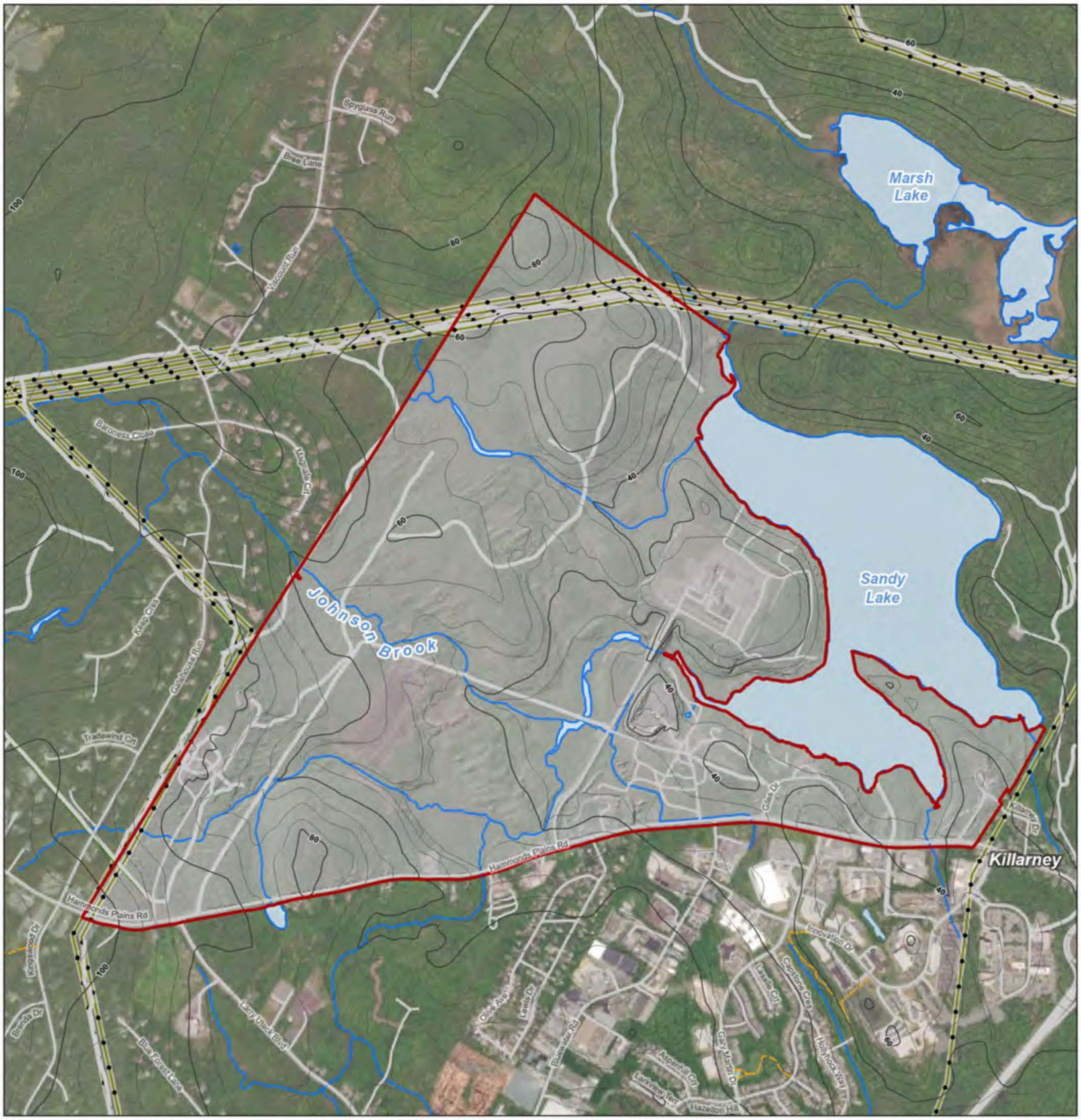
Fig ID: 160410459_014

Figure No.
7-2

Title
Slope Land Suitability Analysis - Sandy Lake

Notes

1. Coordinate System: NAD 1983 CSRS UTM Zone 20N
2. Data Sources: Government of Nova Scotia, Department of Service Nova Scotia and Internal Services.
3. Background: ESRI; Government of Nova Scotia, Department of Service Nova Scotia and Internal Services.



Notes
1. Coordinate System: NAD 1983 CSRS UTM Zone 20N
2. Data Sources: Government of Nova Scotia, Department of Service Nova Scotia and Internal Services
3. Background: ESRI; Government of Nova Scotia, Department of Service Nova Scotia and Internal Services

Study Area

Contour (5 m)

Transportation
- Trail
- Highway
- Other Road

Utilities
- Transmission Line
- Pipeline
- Waterway
- Waterbody

0 250 500 Metres
(At original document size of 8.5x11)
1:21,000

N

Stantec

Project Location
Halifax Regional Municipality, Nova Scotia

Prepared by NW on 2024-10-06
QR by SW on 2024-10-07

Client/Project
Halifax Regional Municipality
Future Serviced Communities
Background Studies

Fig ID: 160410459_014e

Figure No.
7-3

Title
Elevation Contours - Sandy Lake

7.3 Land Use

The subject site is predominantly covered with an Acadian Forest in its early to mid-successional stages. The forest comprises a typical local assortment of various hardwood and softwood species. According to the STRUM Master Stormwater Management Plan (2023), the site has experienced historical clearcutting, with the most recent event taking place in 2013 on lands previously owned by Armco.

The Sandy Lake watershed encompasses a substantial area upstream of the subject site. This area includes rural lands and properties designated for existing and future residential, commercial, and industrial use. This diverse land use within the watershed has significant implications for stormwater management and planning.

7.4 Soil Conditions

Soil conditions for the Sandy Lake study area were obtained from the "Nova Scotia Soil Survey Report #13 – Halifax County 1963". As depicted in **Figure 7-4**, the largest soil type in the study area is classified as Halifax, which corresponds to gently undulating to gently rolling sandy loam soil with good to excessive drainage. However, there is another fairly large area with soil type classified as Bridgewater, which corresponds to shaly loam till with good drainage, other areas with soil type classified as Riverport, which corresponds to gently undulating to gently rolling shaly loam till with imperfect drainage, as well as minor areas with soil type classified as Wolfville, which corresponds to gently undulating to gently rolling loam to sandy clay loam with good drainage. Based on the soils present within the study area as described here, the classification scheme has been used to categorize the overall soils in the area as Hydrologic Soil Group C.

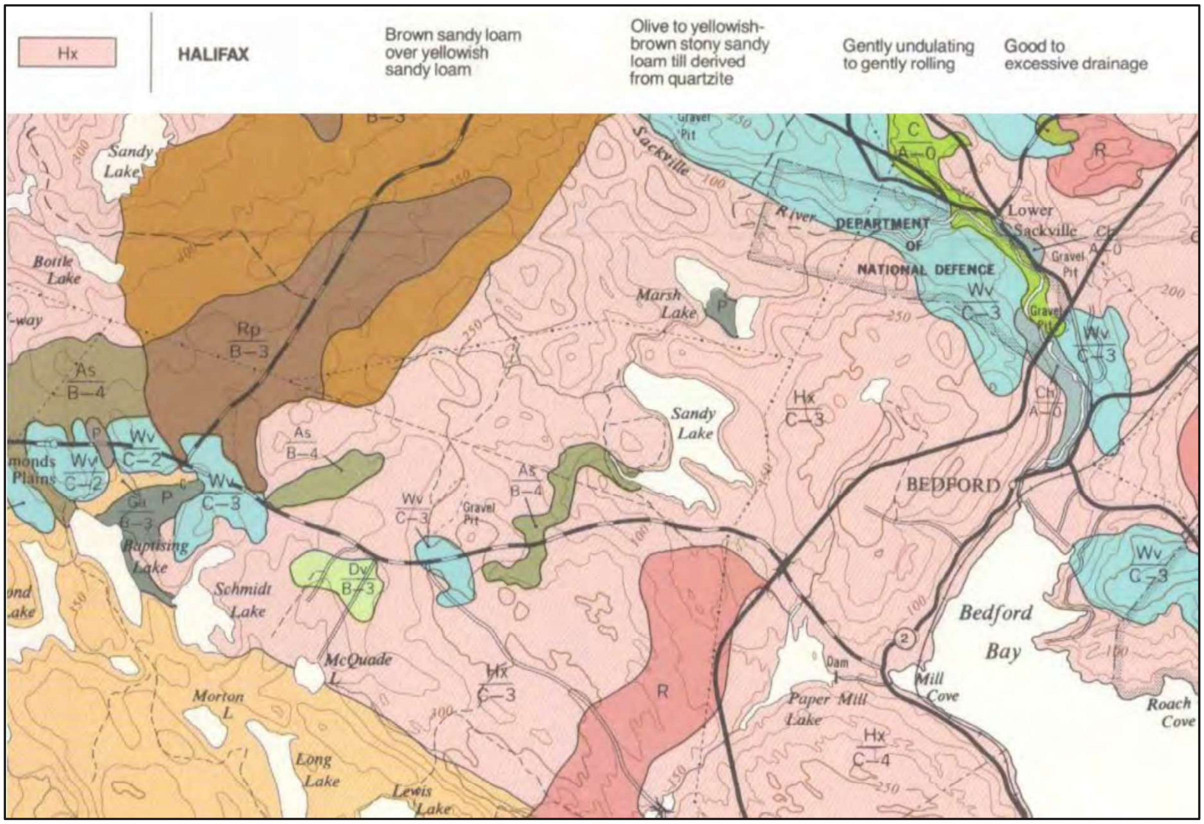


Figure 7-4 Soil Type (Nova Scotia Soil Survey Report #13 – Halifax County 1963)

7.5 Watercourses and Waterbodies

The data for wetlands and waterbodies were sourced from the Nova Scotia Open Data, complemented with the information presented in Stantec's 2024 Land Suitability Analysis and Watershed Study for the Sandy Lake Study Area (SLSA).

Twenty-four (24) wetlands were identified within the SLSA and thirteen (13) of these were evaluated due to operational constraints. While none of the evaluated wetlands in the SLSA were determined to be Wetlands of Special Significance (WSS), there are multiple factors that can result in a wetland being considered a WSS and further work and/or consultation with regulators may result in any of the wetlands within the SLSA being considered a WSS. Stantec's land suitability analysis recommended to engage with Nova Scotia Environment and Climate Change (NSECC) as early as possible to discuss potential wetland impacts (direct or indirect), the permitting process, and compensation requirements (e.g., potential opportunities for wetland restoration, enhancement, or creation).

Watercourse mapping was obtained from Stantec's Land Suitability Analysis for the SLSA, which identified nine mapped watercourses, one mapped waterbody and six topographic features which may contain water. Water quality monitoring along the different watercourses was completed as part of the field study and the results were complemented with a desktop study using historical water quality reports.

As outlined in Stantec's Land Suitability Analysis for the SLSA, riparian zones which are areas adjacent to watercourses were considered in the analysis, in addition to the bed and banks of the watercourse. Riparian zones provide a buffer that protects the watercourse from the impacts of adjacent development and also reduce the severity of flooding on adjacent lands. This resulted in the creation of watercourse setbacks and buffers as established in the Draft Regional Plan (Halifax Regional Municipality 2024) as the minimum criteria.

The PCSWMM software was used to create an existing drainage condition model composed of subcatchments, junctions, and conduits, which were partially parameterized based on features from the Digital Elevation Model (DEM).

The Watershed Delineation Tool (WDT) in PCSWMM was used to establish drainage patterns and channels, from which, the main channels were retained and transformed into ditches using the Transect Creator Tool. This tool utilizes the DEM to gather elevation data at each station along the transects. This comprehensive approach ensures accurate and efficient modeling of the watercourses.

7.6 Existing Drainage Areas

Existing drainage areas were delineated using LiDAR data (2019) sourced from the HRM Open Data portal, specifically the HRM 1044700063700_201901_CHM.tif file.

The Watershed Delineation Tool (WDT) was used to determine the tributary subcatchments to Sandy Lake. The flow length of these subcatchments were generated from the furthest point along the boundary to the outlet, following the direction of flow.

The hydrologic parameters, which are integral to the functioning of the drainage system's subcatchments, are detailed in **Table 7-1**.

Table 7-1 Global Hydrologic Parameter for Subcatchments

Global Hydrologic Parameter	Value
Infiltration Method Subcatchments	NRCS
Conductivity (mm/hr)	0.5
Drying Time (days)	7
Curve Number for Pasture / Open Grass Area	74
Curve Number for Wetland	98
Manning's Roughness	
Impervious Surface (-)	0.013
Pervious Surface – Woodlot Area (-)	0.08
Pervious Surface – Urban Area (-)	0.25 - 0.35
Depression Storage	
Impervious Surface (mm)	1.88
Pervious Surface (mm)	3.75

Global Hydrologic Parameter	Value
Zero Imperviousness (%)	0

The USDA Natural Resources Conservation Service (NRCS) method was selected in PCSWMM to estimate infiltration. Average Curve Number (CN) values were determined based on weighted areas for each land use within the pervious portion of the subcatchment. This approach ensures that the CN values used are representative of the variation of land uses in the watershed.

Depression storage refers to the capacity of a specific land area to retain water in its pits and depressions, thereby preventing it from flowing. The PCSWMM online help manual offers a range of values suitable for defining the depression storage for both pervious and impervious surfaces. An average value within the provided range was selected.

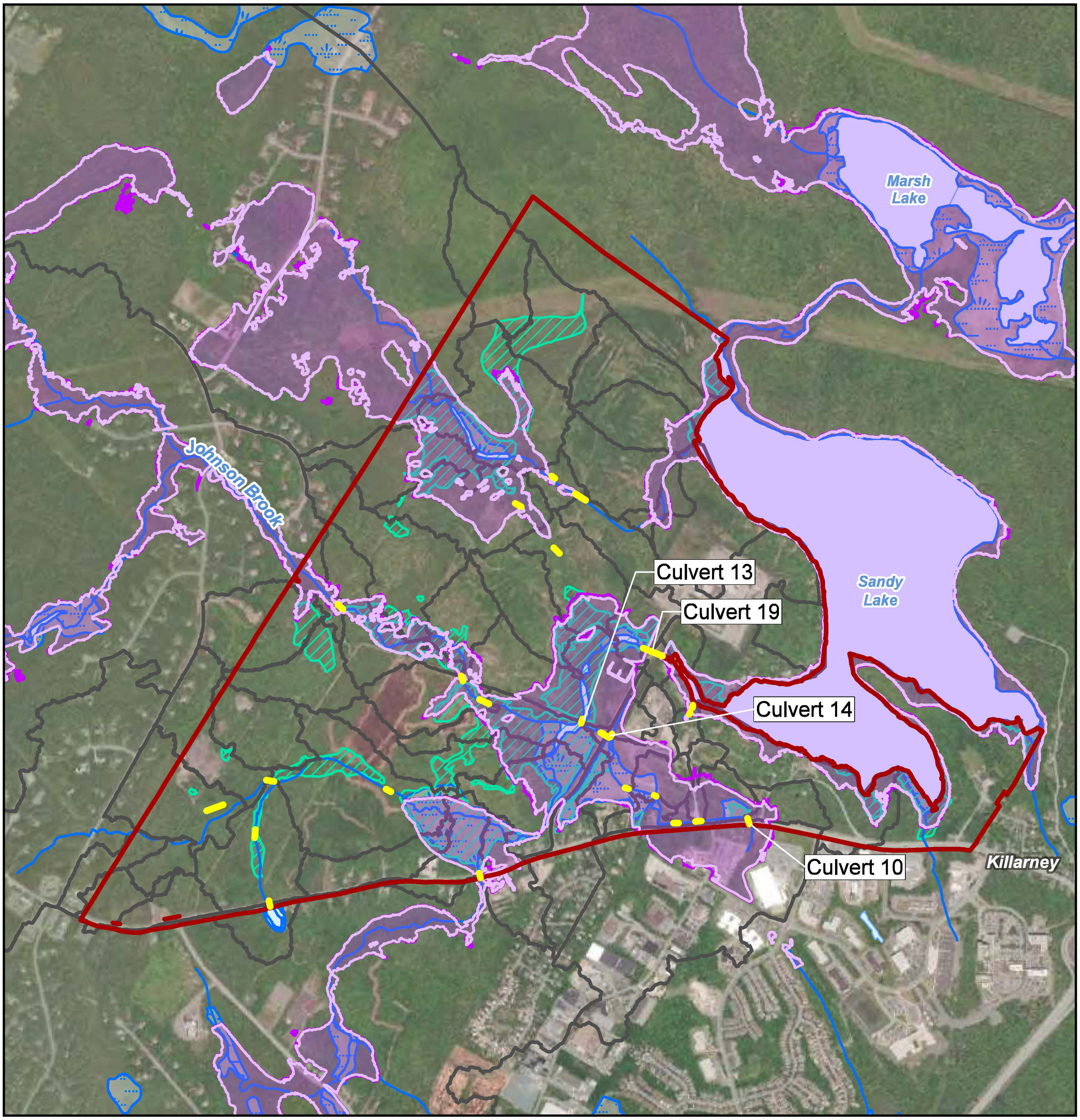
Drawing EX-SD-1 included in **Appendix C** illustrates the existing storm drainage conditions, including watercourses and the delineated subcatchments.

7.7 Boundary Conditions

The water elevation in Sandy Lake, along with its stage/discharge relationship at the outlet, significantly influences existing drainage conditions within the Sandy Lake watershed. Investigating the water elevation fluctuations in Sandy Lake as a result of runoff response, and the stage/discharge relationship of the lake outlet are outside the scope of this project. However, preliminary flood lines (i.e., subject to change) for the 5-year, 20-year, 100-year, and 200-year scenarios for both current climate conditions and projected climate conditions in the year 2100 were provided by HRM from the on-going Regional Flood Mapping Delineation project being completed by CBCL. These flood lines were derived from a high-level hydrologic and hydraulic analysis of flooding risks in the entire Halifax Regional Municipality and are based on a series of high-level assumptions regarding seasonal land cover, initial conditions at lakes, dam operation, coastal water levels, rainfall distribution (Chicago distribution – 24-hour, 5 min interval), and soil conditions.

The preliminary flood lines have been used to estimate the water levels in Sandy Lake during various return periods. These estimated water levels have been applied as fixed water elevations, also known as boundary conditions, at the Sandy Lake outfalls within the hydrologic/hydraulic PCSWMM model for the 100-yr storm event scenario. In the PCSWMM model, there are three stormwater outfalls that discharge into Sandy Lake. The water elevation at each of these outfalls is determined to be 30 m during a 100-year event, based on the topographic contours for both the current and climate change flood extent. For all other return periods, the boundary condition was assumed to be a Normal Outfall, hence the outfall stage was determined based on the normal flow depth in the upstream conduit.

Figure 7-5 illustrates the existing conditions with the preliminary floodplain extents for the 20-year and 100-year flood lines including climate change impacts.



Legend

- Study Area
- Culvert
- Existing Subcatchment
- 20yr Flood Extent (Draft, HRM 2023)
- 100yr Flood Extent (Draft, HRM 2023)

Wetlands and Waterways

- Waterway
- Waterbody
- Wetland
- Wetlands (Stantec, 2023)

0 500 1,000 Meters

(At original document size of 8.5x11)
1:21,000

N

Stantec

Project Location
Halifax Regional Municipality, Nova Scotia

Prepared by HB on 2024-02-13
Revised by NW on 2024-10-04
QR by SW on 2024-10-07

Client/Project
160410459_3_4
Halifax Regional Municipality
Future Serviced Communities
Sandy Lake Stormwater Management Plan

Figure No.
7-5

Title
Existing Conditions Preliminary Floodplain Extents

Notes

1. Coordinate System: NAD 1983 CSRS UTM Zone 20N
2. Data Sources: Stantec; Government of Nova Scotia, Department of Service Nova Scotia and Internal Services; Government of Nova Scotia Environment and Climate Change
3. Background: ESRI; Government of Nova Scotia, Department of Service Nova Scotia and Internal Services.

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7.8 Existing Culverts

As illustrated in the existing storm drainage plan (refer to **Drawing EX-SD-1** in **Appendix C**), the Study Area includes 18 existing culvert crossings, as identified from the HRM Open data source. Each of these culverts was surveyed, and the gathered data was incorporated into the existing condition hydraulic model. However, during the field survey, two culvert crossings could not be located. Consequently, they were modeled as open channels, aligning with the characteristics of the connected watercourse.

Upon reviewing the existing condition hydraulic model results, it was observed that several culverts might be undersized (i.e., H/D <1 in the 100-year storm) as shown in **Table 7-2**. However, the flood lines obtained from HRM imply that three of these undersized culverts in particular might be exacerbating the flooding extents in the Hammonds Plains area, which has been subject to flooding in the past. These culverts include Culvert 14 crossing Farmers Dairy Lane, Culvert 13 which is downstream of Culvert 14, and Culvert 19 located at the outfall, also crossing Farmers Dairy Lane. The flood lines provided indicate that the 100-year water level in the area between Hammonds Plains Road and Farmers Dairy Lane reaches an elevation of approximately 35 m.

Culvert 10, which is the existing culvert under Hammonds Plains Road is also undersized. This culvert, located immediately upstream of the Farmers Dairy Lane area, restricts peak flows downstream and as such, unrestricting these flows would result in higher peak flows and water levels downstream, further exacerbating existing drainage concerns in the area.

It is therefore recommended that upsizing Culverts 13, 14, and 19 to meet the H/D <1 design criteria during the 100-year storm be prioritized to provide adequate conveyance capacity and improve existing drainage conditions prior to further development in the area. However, it is important to note that culvert upgrades will result in peak flow increases and increased flooding risks downstream and as such, it is recommended that further hydraulic analyses be completed at the detailed design stage of these culvert upgrades to assess flooding impacts downstream. These upgrades were implemented in the existing condition PCSWMM model to assess their impact on the extent of flooding in the area between Hammonds Plains Road and Farmers Dairy Lane. **Table 7-2** shows that the 100-year water elevation in the area is reduced by approximately 2 m to an elevation of 33 m.

In the post development conditions, proposed development is being considered in the area located between Hammonds Plains Road and Farmers Dairy Lane, designated as area UNC-1 on **Drawing SD-1** (refer to **Appendix C**). However, this area is prone to flooding risks, particularly during a 100-year storm event, where the water elevation based on the provided flood lines can reach up to approximately 35 m. Even with a reduction of 2 m, achieved through the prioritized culvert upgrades mentioned above, the risk of flooding in this low-lying area remains significant. Therefore, further studies and potential additional measures such as avoiding residential, institutional or commercial uses at this location are recommended to effectively reduce flooding risks for new development.

Table 7-2 Existing Culverts and Recommended Upgrades

Culvert ID	Existing					Existing w/ Upgrade						HGL Reduction
	Shape	Barrels	Width (m)	Height (m)	H_W/D	Upgrade	Shape	Barrels	Width (m)	Height (m)	H_W/D	
Culvert 1	Circular	1	0.45	0.45	2.8		Circular	1	0.45	0.45	2.5	0.2
Culvert 2	Circular	1	0.45	0.45	3.8		Circular	1	0.45	0.45	3.4	0.2
Culvert 3	Circular	1	0.60	0.60	2.8		Circular	1	0.60	0.60	2.6	0.2
Culvert 4	Circular	1	1.20	1.20	0.3		Circular	1	1.20	1.20	0.3	0.0
Culvert 5	Box	1	1.85	1.30	3.2		Box	1	1.85	1.30	1.8	1.8
Culvert 6	Circular	1	0.90	0.90	3.7		Circular	1	0.90	0.90	1.6	2.0
Culvert 7	Circular	1	0.90	0.90	3.6		Circular	1	0.90	0.90	1.4	1.9
Culvert 8	Circular	1	0.90	0.90	3.2		Circular	1	0.90	0.90	1.4	1.6
Culvert 9	Circular	1	0.60	0.60	4.3		Circular	1	0.60	0.60	2.1	1.3
Culvert 10[1]	Circular	1	0.60	0.60	4.5		Circular	1	0.60	0.60	4.2	0.2
Culvert 12	Channel	1	0.00	0.00	-		Channel	1	0.00	0.00	-	0.2
Culvert 13	**Circular**	**4**	**1.20**	**1.20**	**3.4**	**Upgrade**	**Box**	**1**	**3.05**	**3.05**	**0.7**	**2.0**
Culvert 14	**Circular**	**1**	**1.05**	**1.05**	**3.3**	**Upgrade**	**Circular**	**1**	**3.60**	**3.60**	**0.4**	**2.0**
Culvert 15	Circular	1	0.80	0.80	2.7		Circular	1	0.80	0.80	0.7	1.6
Culvert 16	Circular	1	0.60	0.60	2.2		Circular	1	0.60	0.60	2.2	0.0
Culvert 17	Circular	1	0.30	0.30	5.7		Circular	1	0.30	0.30	5.7	-
Culvert 18	Channel	1	0.00	0.00	-		Channel	1	0.00	0.00	-	0.0
Culvert 19	**Circular**	**2**	**1.20**	**1.20**	**3.3**	**Upgrade**	**Box**	**1**	**3.05**	**3.05**	**0.7**	**1.8**

Note

[1] Culvert 10 is a cross culvert under Hammonds Plains Road

8 Post Development Conditions

Stantec's planning team engaged landowners to build a base development scenario for the Sandy Lake Study Area (SLSA) and built on that scenario to provide lower and higher densities scenarios.

For the purpose of this stormwater management assessment, the high-density scenario, which results in larger impermeable surfaces, has been selected given that it is the worst-case scenario and provides a comprehensive understanding of the most conservative conditions. It should be noted that the current development plan is conceptual and subject to change based on results of further analysis and studies within the SLSA and to adhere to the recommendations made in Stantec's 2024 Land Suitability Analysis and Watershed Study for the Sandy Lake Study Area (SLSA).

Moreover, it is anticipated that the stormwater management strategies for the high-density scenario will also be applicable and effective for both the low and medium density scenarios.

The subsequent subsections detail the various characteristics of the post-development conditions. The post-development storm drainage plan is present in **Appendix C**.

8.1 Site Grading & Land Use

The high-density development scenario has been used to create a master grading plan designed to follow existing drainage patterns as much as possible, provide sufficient cover over trunk sewers, provide an overland flow outlet, take into account sufficient cover over future culvert crossings and incorporate bottom and high water elevations at end of pipe SWM facilities.

The proposed development plan consists of a diverse mix of land uses that encompasses low-density residential areas, high density multi-unit residential areas, institutional areas, mixed-use/commercial areas, as well as park and open space areas.

8.2 Proposed Subcatchments

The general hydrologic parameters applied to the post-development drainage areas are consistent with those used in the existing conditions model, as detailed in **Section 7.6**. The proposed subcatchments and their corresponding runoff coefficients are illustrated on **Drawing SD-1**.

Given that the concept plans are preliminary and subject to change and do not provide details on location and width of driveways and sidewalks, a representative runoff coefficient based on proposed land use was used. Average runoff coefficients based on the proposed conceptual land use were obtained from the help file for ICM SWMM, ICM InfoWorks and SWMM5 software. The average runoff coefficients (C) based on the various land uses are as follows:

- Low Density Residential: 0.65
- Multi-Unit residential: 0.75

- Commercial: 0.85
- Institutional: 0.70
- Green Space: 0.20
- Community Park: 0.40

In the PCSWMM model, imperviousness values for the proposed subcatchments were calculated based on the equation below, where C correspond to the runoff coefficient:

$$Percent\ Impervious = \frac{(C - 0.2)}{0.7} \times 100$$

Additionally, the flow length parameter, which is the longest path that runoff is likely to follow, was calculated based on the area's topography and layout. The width was then computed as the total area divided by the flow length.

The slope parameter for the proposed subcatchments was estimated to be 2%. Additionally, for the pervious areas within the proposed subcatchments, a CN value of 74 was used.

8.3 Boundary Conditions

For the post-development hydrologic/hydraulic PCSWMM model, the boundary conditions remain consistent with the existing conditions. Refer to **Section 7.7** for detailed information about boundary conditions.

8.4 Proposed Crossing Structures

The conceptual storm drainage plan presented on **Drawing SD-1** in **Appendix C** shows the high-density development plan for the Sandy Lake Development area, which includes future crossings at the existing watercourses. **Table 8-1** and **Figure 8-1** present existing culverts to remain unchanged, and upgraded existing culverts to alleviate flooding extents in the Hammonds Plains/Farmers Dairy Lane area as discussed in **Section 7.8**, as well as proposed culverts within the study area, as a result of new road crossings.

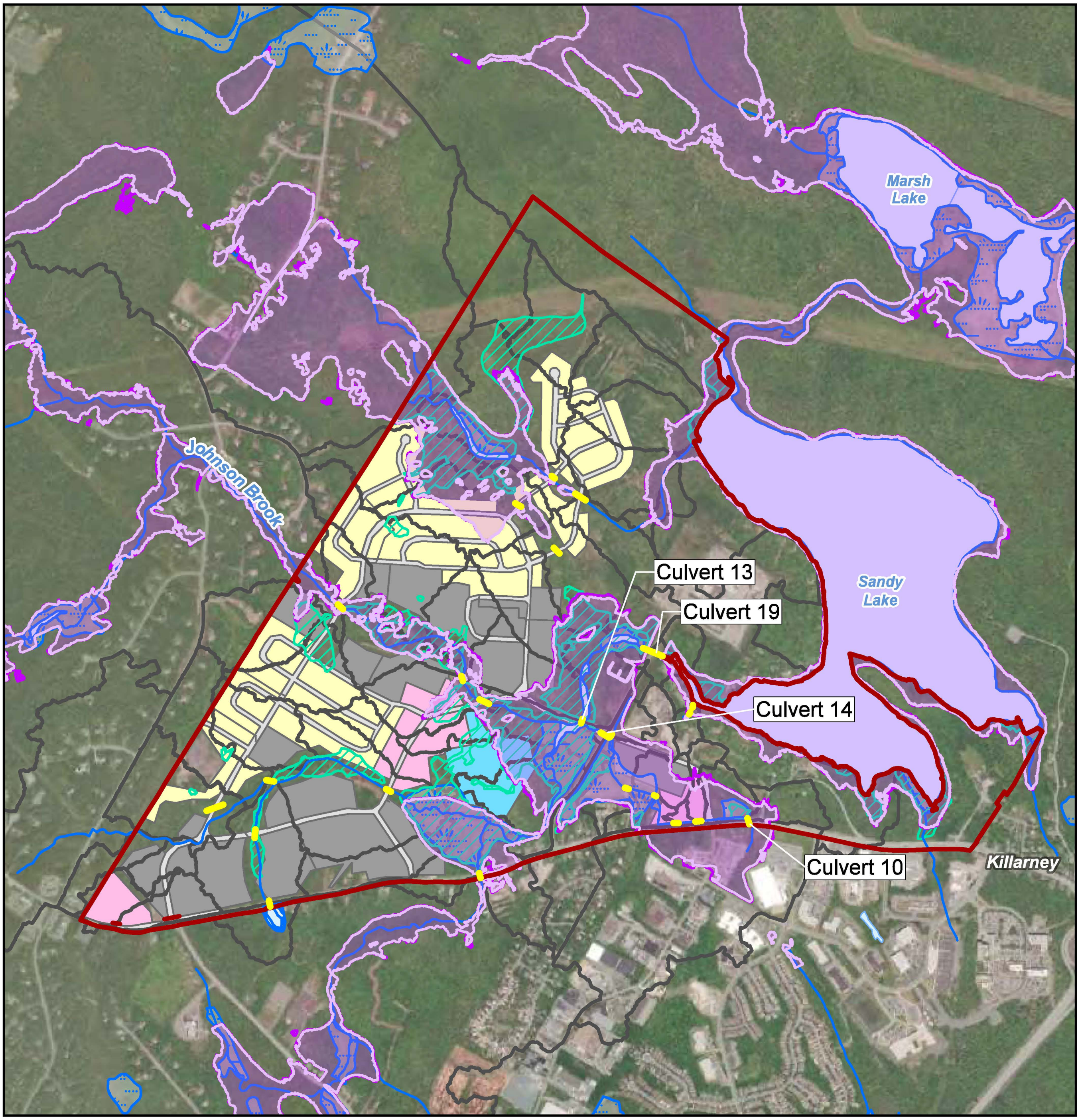
Table 8-1 Existing, Upgraded Existing and Proposed Culverts

Culvert ID	Shape	Barrels	Width (m)	Height (m)	H_W/D
Culvert_1	-	-	-	-	-
Culvert_2	-	-	-	-	-
Culvert_3	Circular	1	0.600	0.600	1.5
Culvert_4	Circular	1	1.200	1.200	0.3
Culvert_5	Box	1	1.300	1.300	1.6
Culvert_6	Circular	1	0.900	0.900	2.4

Culvert ID	Shape	Barrels	Width (m)	Height (m)	H_W/D
Culvert_7	Circular	1	0.900	0.900	2.2
Culvert_8	Circular	1	0.900	0.900	1.9
Culvert_9	Circular	1	0.600	0.600	2.4
Culvert_10[1]	Circular	1	0.600	0.600	4.4
Culvert_12	Irregular	1	0.000	0.000	-
Culvert_13 (Upgraded)	Box	1	3.048	3.048	0.9
Culvert_14 (Upgraded)	Circular	1	3.600	3.600	0.6
Culvert_15	Circular	1	0.800	0.800	1.2
Culvert_16	Circular	1	0.600	0.600	2.2
Culvert_17	Circular	1	0.300	0.300	5.7
Culvert_18	Circular	1	1.650	1.650	1.8
Culvert_19 (Upgraded)	Box	1	3.048	3.048	1.0
ProposedCulvert_1	**Circular**	**2**	**1.050**	**1.050**	**0.9**
ProposedCulvert_2	**Circular**	**1**	**0.525**	**0.525**	**0.9**
ProposedCulvert_3	**Circular**	**3**	**1.200**	**1.200**	**0.9**
ProposedCulvert_4	**Circular**	**2**	**2.100**	**2.100**	**0.9**
ProposedCulvert_5	**Circular**	**1**	**0.675**	**0.675**	**0.9**
ProposedCulvert_6	**Circular**	**1**	**0.375**	**0.375**	**0.9**
ProposedCulvert_7	**Circular**	**2**	**1.800**	**1.800**	**1.0**
ProposedCulvert_8	**Circular**	**2**	**1.650**	**1.650**	**1.0**

Note
[1] Culvert 10 is located at the boundary of the Study Area and upstream of the floodplain areas of interest. Though this culvert should likely be upgraded, it is not recommended at this time.

Culvert 10 is located under Hammonds Plains Road, near the Bluewater Road intersection, at the upstream end of the drainage system within the Study Area. This culvert, however, has not been identified for an upgrade as part of the scope of this project since it restricts peak flows to the low lying Farmers Dairy Lane area and as such, unrestricting these flows would result in higher peak flows and water levels downstream, further exacerbating existing drainage concerns in that area. **Section 9.2** of the report summarizes the results of a sensitivity analysis completed to assess the post development impacts of upgrading Culvert 10 on upstream and downstream water levels, as well as on downstream peak flows along the watercourse to the outlet to Sandy Lake. As part of the scope of this project, it is recommended to limit the culvert upgrades to culverts 13, 14 and 19 as shown in the table above. It is also recommended that any further culvert upgrades be completed based on further hydrologic/hydraulic analyses taking into account flow monitoring and model calibration to confirm peak flows, culvert sizes, and assess the impacts downstream.



Legend
- Study Area
- Culvert
- 20yr Flood Extent (Draft, HRM 2023)
- 100yr Flood Extent (Draft, HRM 2023)

Land Use
- Institutional
- Low Residential
- Mixed Use / Commercial
- Multi Residential
- Road
- Subcatchment

Wetlands and Waterways
- Waterway
- Waterbody
- Wetland
- Wetlands (Stantec, 2023)

0 500 1,000 Meters
(At original document size of 8.5x11)
1:21,000

N

Notes
1. Coordinate System: NAD 1983 CSRS UTM Zone 20N
2. Data Sources: Stantec, Government of Nova Scotia, Department of Service Nova Scotia and Internal Services; Government of Nova Scotia, Department of Environment and Climate Change.
3. Background: ESRI; Government of Nova Scotia, Department of Service Nova Scotia and Internal Services.

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Project Location
Halifax Regional Municipality, Nova Scotia

Prepared by HB on 2024-02-13
Revised by NW on 2024-10-04
QR by SW on 2024-10-07

Client/Project
160410459_4_1
Halifax Regional Municipality
Future Serviced Communities
Sandy Lake Stormwater Management Plan

Figure No.
8-1

Title
Existing, Upgraded and Proposed Culvert Locations

\\CA0213-PPFSS01\work_group\1214\active\160410459\gis_data\mapping\ArcGIS Pro\HRM_Stormwater_Mgmt.aprx   Revised: 2024-11-22 By: acuff

8.5 Stormwater Management Strategy

Urbanization inevitably leads to changes in the landscape and as such, minimizing sprawl in urbanization patterns and building up rather than out are key strategies in sustainable urban development. In addition, in order to successfully implement development plans that result in balanced and environmentally sustainable development, it is key to devise an effective management strategy. This section provides a general description of stormwater management measures which, when combined, form a comprehensive approach to stormwater management in order to meet established SWM criteria and protect the surrounding natural environment.

Following discussions with HRM and HW, it was agreed that quantity control measures would be implemented to limit post-development peak flows to pre-development levels up to the 100-year storm. It is therefore recommended that quantity control measures in the form of end-of-pipe stormwater management (SWM) dry ponds be implemented at key locations within the proposed development area to mitigate post development peak flows to pre-development levels.

The current SWM pond locations are conceptual (i.e., not an approved plan) and subject to change based on results of more detailed analysis as the development plan progresses. The SWM ponds should be located outside of the floodplain based on existing topography and proposed grading.

Urbanization typically alters the water balance, leading to increased runoff and decreased infiltration, primarily due to increased impervious surfaces associated with urban development. In addition, urbanization usually results in increased sediment and phosphorus loading in receiving watercourses. Retaining native and existing ground cover should be prioritized where possible to preserve ecosystem service function, reduce volume of runoff discharged into watercourses, promote infiltration and provide an opportunity for evapotranspiration. Where retaining native cover is not possible, it is recommended that a treatment train approach consisting of lot level best management practices (BMPs), such as directing residential roof runoff to vegetated surfaces, introducing vegetated swales, and low impact development (LID) measures such as infiltration trenches, bioswales, etc., be investigated at the detailed design stage to provide quality control of runoff prior to discharging into the receiving watercourses and to promote infiltration.

Please refer to **Section 5** for mitigation recommendations to reduce phosphorus (P) loading, *E.coli* loading, and sediment loading from the SLSA and achieve contaminant loads of existing conditions.

To reduce annual TP load to the watershed, future development scenarios must consider implementing a combination of measures such as a street maintenance program to remove sediment-associated P from roadways and catchbasins, along with the implementation of Low Impact Development (LID) measures to reduce TP loading.

The implementation of LID measures within the future developments would also aid in the removal of fecal coliform through sedimentation.

Erosion and sedimentation control measures are required during construction of all future developments to mitigate sediment loadings into the receiving water bodies.

Table 8-2, taken from the Credit Valley Conservation Low Impact Development Stormwater Management Planning and Design Guide (CVC, 2010, Table 3.4.1), provides a comparison of site constraints for a variety of structural LID SWM practices.

Table 8-2 Comparison of Site Constraints for a Range of Structural LID SWM Practices

LID Stormwater Management Practice	Depth to high water table or bedrock[1] (m)	Typical Ratio of Impervious Drainage Area to Treatment Facility Area	Native Soil Infiltration Rate (mm/hr)[3]	Head[4] (m)	Space[5] %	Slope[6] %	Pollution Hot Spots[7]	Set backs[8]
Rain barrel	Not applicable	[5 to 50 m^2][2]	Not applicable	1	0	NA	Yes	None
Cistern	1	[50 to 3000 m^2][2]	Not applicable	1 to 2	0 to 1	NA	Yes	U, T
Green roof	Not applicable	1:1	Not applicable	0	0	0	Yes	None
Roof downspout disconnection	Not applicable	[5 to 100 m^2][2]	Amend if < 15 mm/hr[9]	0.5	5 to 20	1 to 5	Yes	B
Soakaway, infiltration trench or chamber	1	5:1 to 20:1	Not a constraint	1 to 2	0 to 1	< 15%	No	B, U, T, W
Bioretention	1	5:1 to 15:1	Underdrain required if < 15 mm/hr	1 to 2	5 to 10	0 to 2	No	B, U, W
Biofilter (filtration only Bioretention design)	Not applicable	5:1	Not applicable	1 to 2	2 to 5	0 to 2	Yes	B, T
Vegetated filter strip	1	5:1	Amend if < 15 mm/hr[9]	0 to 1	15 to 20	1 to 5	No	None

LID Stormwater Management Practice	Depth to high water table or bedrock[1] (m)	Typical Ratio of Impervious Drainage Area to Treatment Facility Area	Native Soil Infiltration Rate (mm/hr)[3]	Head[4] (m)	Space[5] %	Slope[6] %	Pollution Hot Spots[7]	Set backs[8]
Permeable pavement	1	1:1 to 1.2:1	Underdrain required if < 15 mm/hr	0.5 to 1	0	1 to 5	No	U, W
Enhanced grass swale	1	5:1 to 10:1	Not applicable	1 to 3	5 to 15	0.5 to 6	No	B, U
Dry swale	1	5:1 to 15:1	Underdrain required if < 15 mm/hr	1 to 3	5 to 10	0.5 to 6	No	B, U, W
Perforated pipe system	1	5:1 to 10:1	Not a constraint	1 to 3	0	< 15%	No	B, U, T, W

Notes:

1. Minimum depth between the base of the facility and the elevation of the seasonally high water table or top of bedrock.
2. Values for rain barrels, cisterns and roof downspout disconnection represent typical ranges for impervious drainage area treated.
3. Infiltration rate estimates based on measurements of hydraulic conductivity under field saturated conditions at the proposed location and depth of the practice.
4. Vertical distance between the inlet and outlet of the LID practice.
5. Percent of open pervious land on the site that is required for the LID practice.
6. Slope at the LID practice location.
7. Suitable in pollution hot spots or runoff source areas where land uses or activities have the potential to generate highly contaminated runoff (*e.g.*, vehicle fueling, servicing or demolition areas, outdoor storage or handling areas for hazardous materials and some heavy industry sites).
8. Setback codes: B = Building foundation; U = Underground utilities; T = Trees; W = drinking water wellhead protection areas.
9. Native soils should be tilled and amended with compost to improve infiltration rate, moisture retention capacity and fertility.

For the Sandy Lake Development Area, which is underlain by the Taylors Head Formation, several LIDs are worth considering:

- Bioretention Cells and Rain Gardens are designed to imitate natural water cycles and are effective in removing various contaminants from runoff, while also reducing its volume and intensity;
- Permeable Pavements allow stormwater to seep through into a stone reservoir for temporary storage or infiltration;
- Vegetated Filter Strips and Swales are designed to process and reduce runoff from nearby impervious surfaces; and,

- Tree Plantings and Native Plantings can help absorb stormwater, decrease runoff, and enhance water quality.

However, the specific selection, design, and location of these LIDs should be further investigated at the detailed design stage. The assessment should take into account factors such as the infiltration capability of the native soils, the depth to bedrock, the depth to groundwater table, and local regulations. It should also be noted that LID measures that impact the overall drainage plan should be located within the right of way owned by the Municipality, since practices located at the lot level could be modified by property owners impacting the performance of the overall storm drainage plan.

9 Hydrologic and Hydraulic Modelling

The following sections provide a comprehensive overview of the conceptual stormwater management plan for the SLSA developer-proposed concept plan, including outlining measures required to restrict post development peak flows to pre-development levels, identifying flood risk areas, and summarizing the limitations associated with the modelling process.

This section provides a high-level estimate of the storage volume required to reduce post-development peak flows to pre-development conditions. While the proposed development concept plan serves as the basis for these calculations, it is understood that the final location and size of the SWM ponds may change based on recommendations from the various assessments that make up this project. These calculations are provided to aid in evaluating the feasibility of mitigating post-development impacts in the study area and do not represent firm conceptual designs.

9.1 Floodplain Identification

Based on the preliminary flood lines obtained from HRM, part of the proposed development lies within the floodplain. The area between Hammonds Plains Road and Farmers Dairy Lane is of particular concern since the entirety of the proposed subcatchment UNC-1 and part of subcatchment UNC-2 are within the preliminary 5-year flood extent. As outlined in **Section 7.8**, upgrading three of the existing downstream culverts (i.e., Culverts 13, 14 and 19) would potentially lower the 100-year water level from 35 m to 33 m in this area. However, in order to minimize the risk of flooding and ensure the proposed roads are safe for traffic during emergency conditions, it is recommended that the proposed roads within this area be raised above the 100-year flood line. Similarly, it is recommended that future development be restricted within the 100-year floodplain in consistency with municipal by-laws and the Nova Scotia Statement of Provincial Interest regarding flood risk areas.

9.2 Hammonds Plains Rd. and Bluewater Rd. Intersection

The 1-in-100-year flood extent provided by HRM indicates that the area around the intersection of Hammonds Plains Road and Bluewater Road lies within the floodplain of a tributary to Johnson Brook. Although this location is outside the defined study boundary, its flood risks are connected to those within the Study Area. The culvert under Hammonds Plains Road (i.e., Culvert 10) drains towards Sandy Lake, and water levels at the culvert's inlet and outlet will be influenced by future upgrades to the culvert, and changes to road alignment. However, because this location lies within a floodplain, the potential impact of man-made interventions to reduce flooding risks along the road and upstream is limited. Therefore, limiting development in the vicinity of this location is recommended.

A sensitivity analysis has been completed to assess the post development impacts of upgrading the culvert under Hammonds Plains Road (i.e., Culvert 10) on upstream and downstream water levels, as well as on downstream peak flows along the watercourse to the outlet to Sandy Lake, compared to the post development levels without the culvert upgrade.

In order to meet the required Hw/D of < 1.0 criterion, the existing culvert would need to be upgraded to a box culvert with an approximate size of 1500 mm x 2700 mm. There are significant impacts to the downstream system as a result of the culvert upgrade, due to the unrestricted peak flows and increased water levels in the downstream watercourse as can be seen in **Table 9-1** below.

Table 9-1 Culvert 10 Upgrade Sensitivity Analysis Results

Flow Point ID	100-year, 24hr Chicago Peak Flow (m^3/s)					Percent Peak Flow Increase (Proposed with Culvert 10 Upgrade)
	Existing Conditions	Proposed (No Upgrade for Culvert 10)	Proposed to Existing Difference	Proposed (Culvert 10 Upgraded	Proposed Culvert 10 Peak Flow Increase	
FP_7	34.323	32.783	-1.540	37.071	4.288	13.1%
FP_8	10.373	9.545	-0.828	12.595	3.050	32.0%
FP_9	23.853	23.699	-0.154	26.168	2.469	10.4%
FP_10	23.449	23.136	-0.313	25.398	2.263	9.8%

As can be seen above, unrestricting the peak flows upstream, by upsizing Culvert 10, significantly increases the peak flows in the downstream watercourse, which would result in further upsizing of the downstream culverts to meet the Hw/D criterion. As such, it is recommended that any culvert upgrades be completed based on further hydrologic/hydraulic analyses taking into account flow monitoring and model calibration to confirm peak flows, culvert sizes, and assess the impacts downstream.

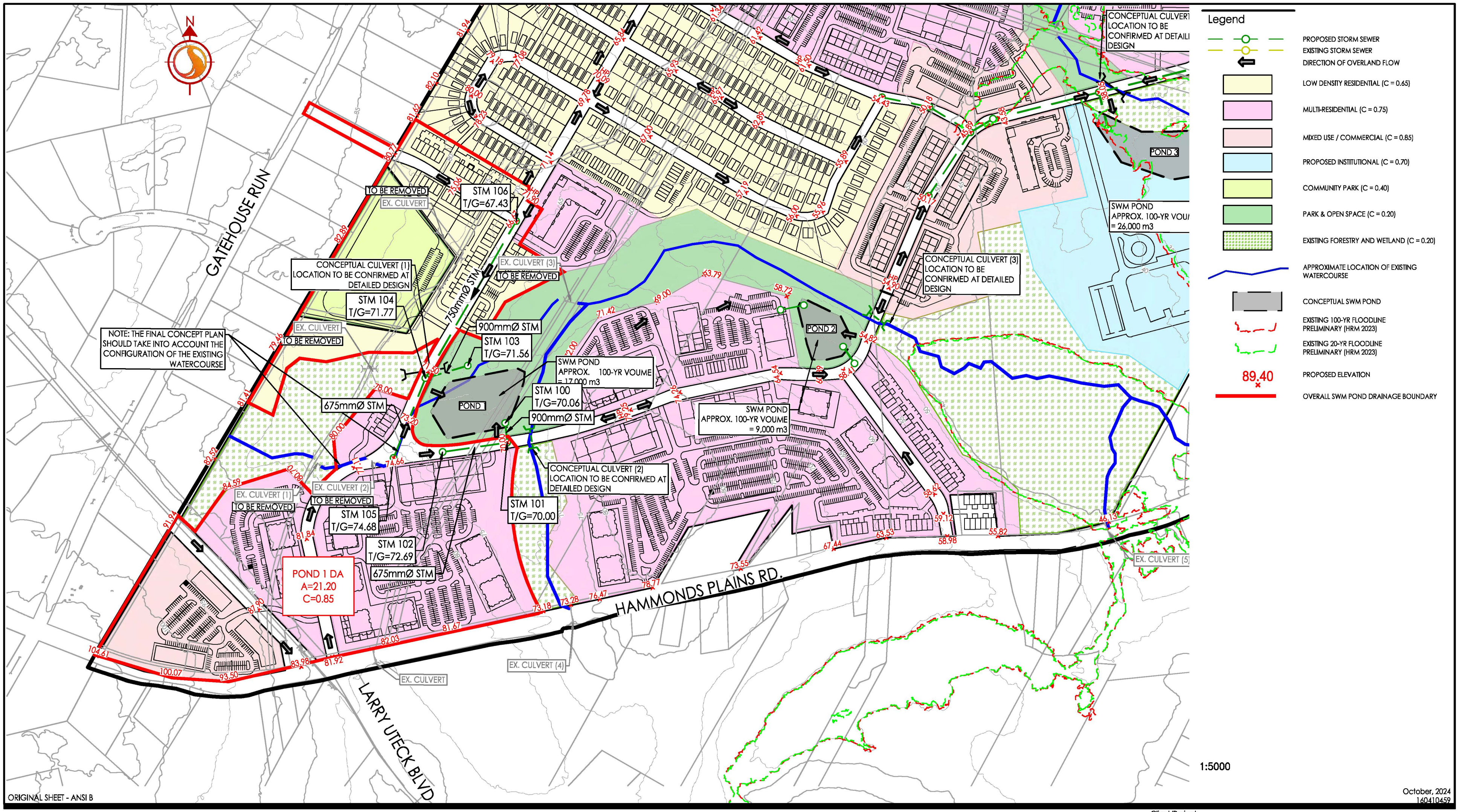
The potential Culvert 10 upgrade would result in an approximate 1.2 m reduction in the water level immediately upstream of the culvert and an approximate 0.2 m increase in the water level immediately downstream of the culvert. It is recommended to base future revisions to the stormwater management plan on the potential upgrade of Culvert 10 which could be deemed as necessary to reduce flooding risks upstream of the culvert.

9.3 Stormwater Management Dry Ponds

As presented on **Drawing SD-1** in **Appendix C**, the proposed development area would be serviced through storm sewers that would be sized to convey the 5-year runoff under free flow conditions to the proposed end of pipe SWM dry ponds for quantity control prior to discharging into the receiving watercourses. During major storm events, higher than the 5-year storm, peak overflows would be routed overland to the proposed SWM dry ponds.

A total of eight SWM dry ponds have been proposed for stormwater management based on existing drainage patterns and the conceptual development plan to mitigate post development peak flows to pre-development levels for all storms from the 2-year up to the 100-year storm event. Three SWM dry ponds would provide on-site storage for low-lying areas with mixed-use, commercial, and/or institutional land uses. The on-site SWM ponds are located within the institutional area (UNC-2), the mixed-use area comprising multi-unit residential and commercial land use (UNC-1), and a multi-unit residential block within area C306A as shown on **Drawing SD-1** in **Appendix C**. Five community SWM dry ponds would service the majority of the future development lands based on the available concept development plan, existing drainage patterns and the conceptual grading plan. The final number, location and size of the SWM dry ponds is to be confirmed based on best engineering principles and detailed floodplain mapping for the area, including flow monitoring and model calibration. The conceptual location and overall drainage area of the community SWM ponds are shown in **Figure 9-1, Figure 9-2, Figure 9-3, Figure 9-4** and **Figure 9-5**.

Any minor alterations to watercourses to create ponds and outlets proposed in future development phases will need to be carefully evaluated with site-specific information to confirm feasibility from an engineering and ecological perspective. For example, ponds 1 and 2 are located close to natural water courses and detailed modelling would be required to understand flooding risks at these locations as the current floodlines are based on a high level model. Generally, the option of locating pond close to watercourses and within floodplains can be avoided by considering a redistribution of the land uses and prioritizing high-density land uses that reduce sprawl and allow better alignment with the SLSA.



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2024/10/08 10:29 AM By: Palangi, Jupiter

Notes

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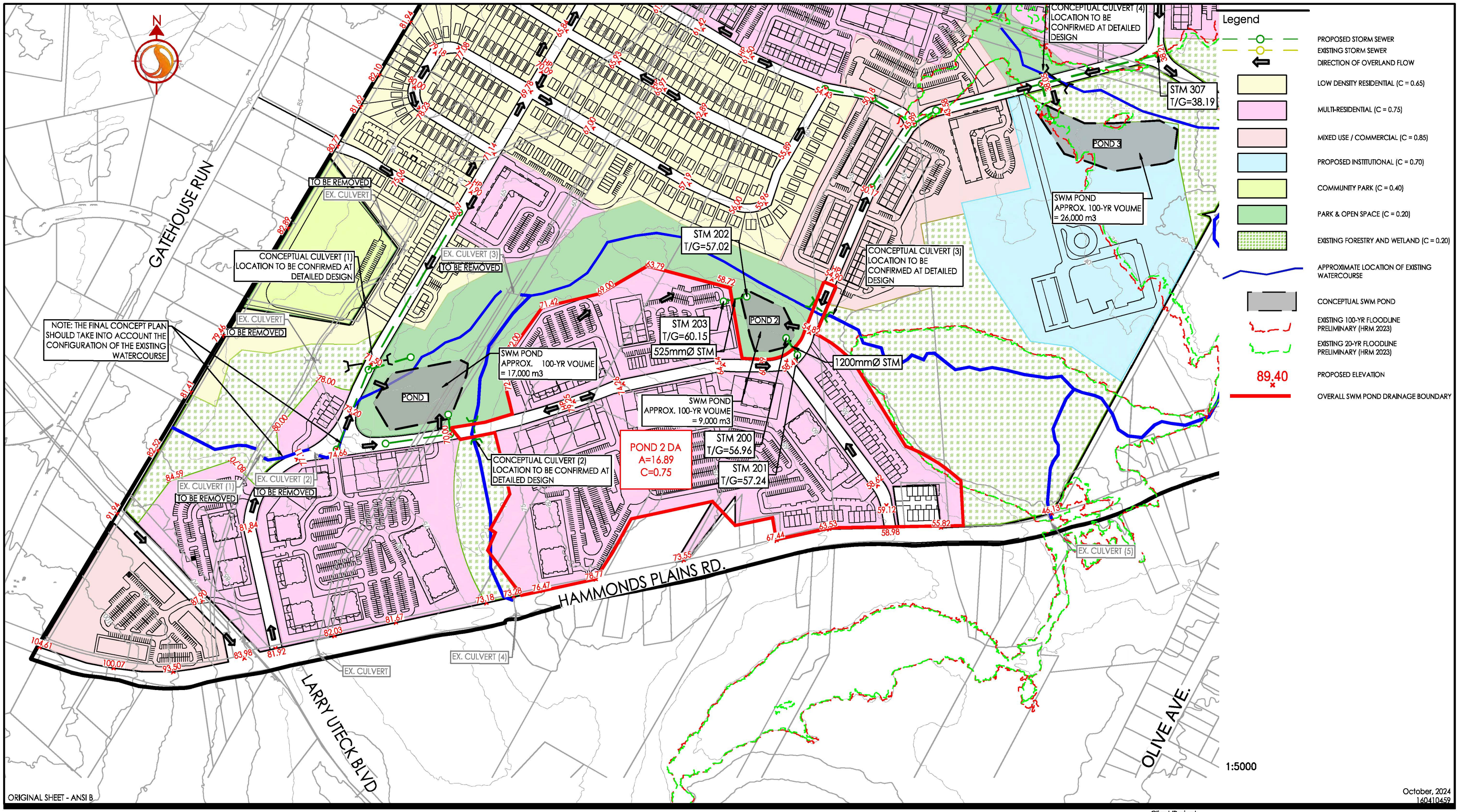
Client/Project
HRM
FUTURE SERVICED COMMUNITIES
STORM WATER MANAGEMENT

Figure No.
9-1

Title
OVERALL DRAINAGE AREA
TO SWM POND 1



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2024/10/08 10:30 AM By: Palangi, Jupiter

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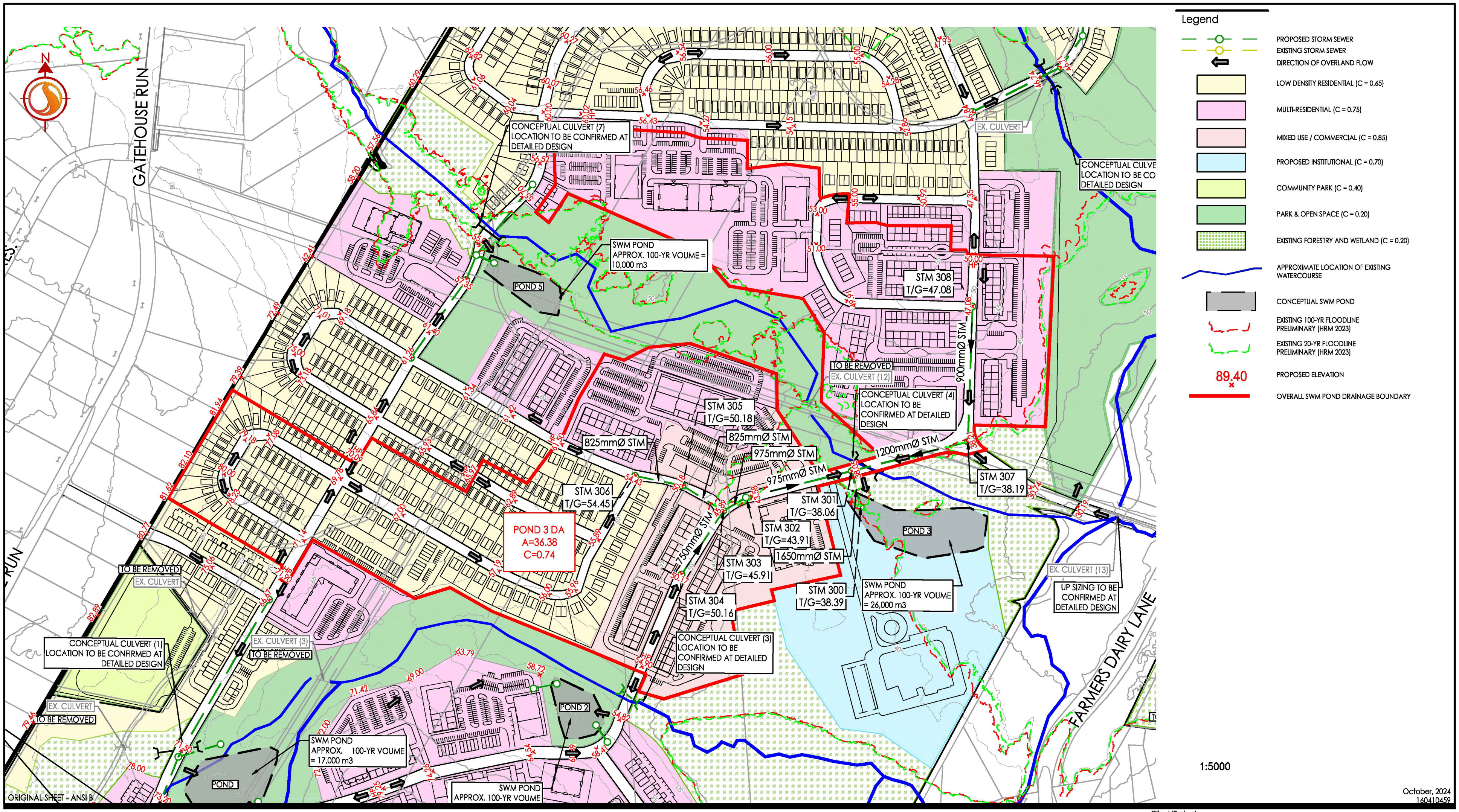
STORM WATER MANAGEMENT

Figure No.
9-2

Title
OVERALL DRAINAGE AREA TO SWM POND 2



Notes

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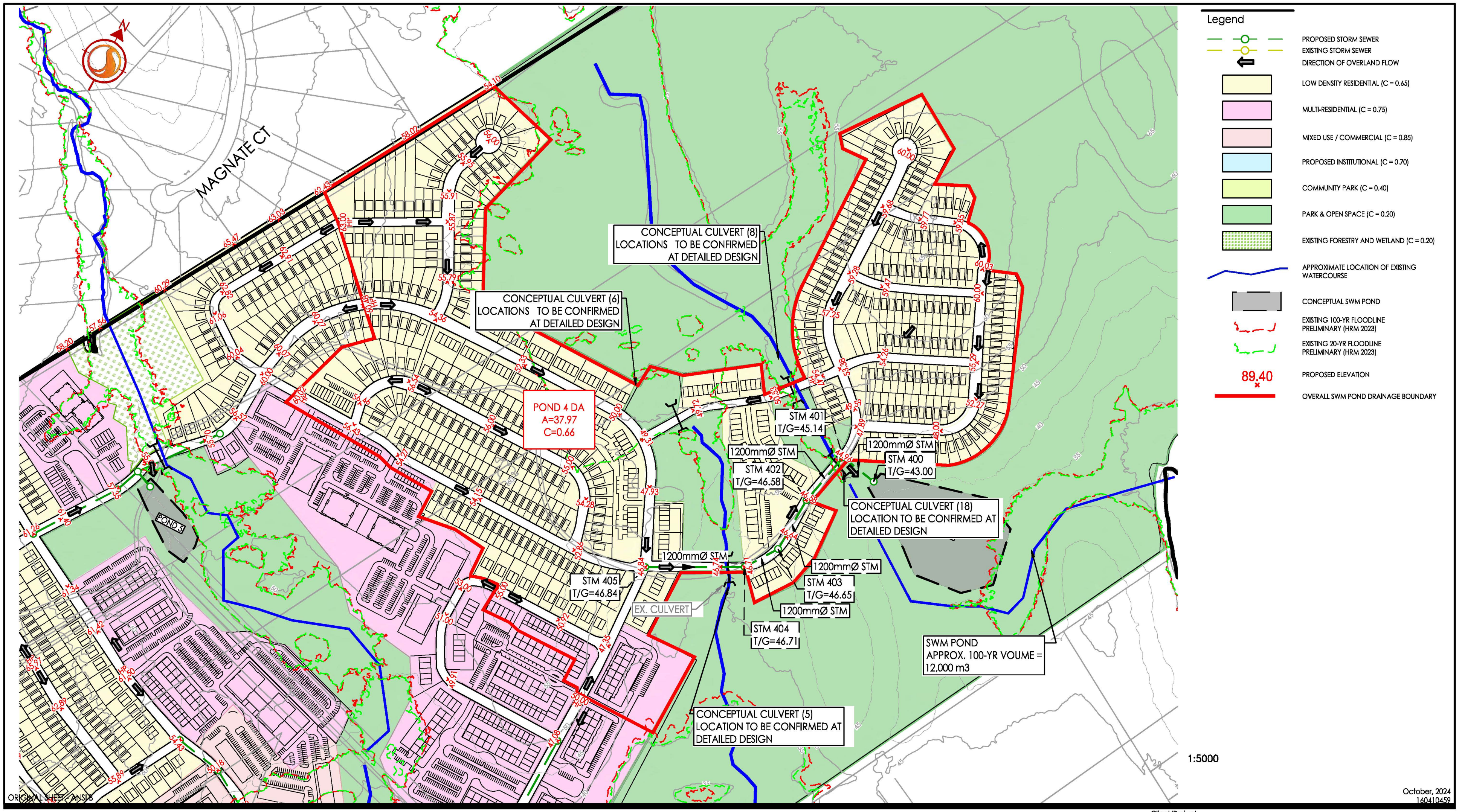
STORM WATER MANAGEMENT

Figure No.
9-3

Title
OVERALL DRAINAGE AREA
TO SWM POND 3



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2024/10/08 10:31 AM By: Palangi, Jupiter

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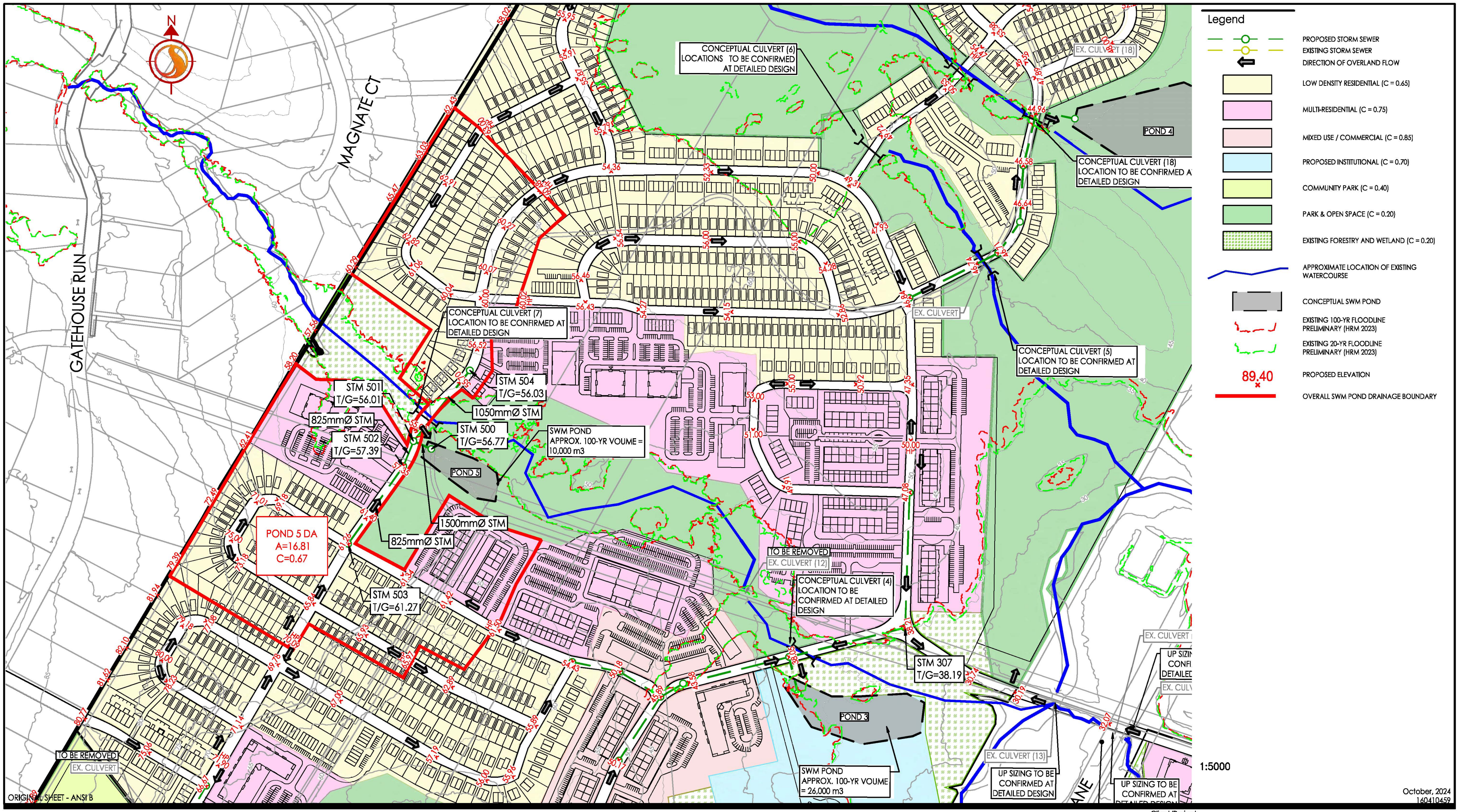
Figure No.

9-4

Title

OVERALL DRAINAGE AREA
TO SWM POND 4



Notes

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STORM WATER MANAGEMENT

Figure No.

9-5

Title

OVERALL DRAINAGE AREA
TO SWM POND 5

The drainage areas and approximate 100-year volume requirements for the proposed SWM dry ponds are summarized in **Table 9-2**.

Table 9-2 Proposed Pond 100-Year Volume

Pond ID	Drainage Area (ha)	100-yr Volume (m^3)
Pond 1	21.5	17,000
Pond 2	17.5	9,000
Pond 3	35.9	26,000
Pond 4	35.5	12,000
Pond 5	17.7	10,000
UNC-1-Pond	5.0	1,000
UNC-2-Pond	6.9	4,000
HD-Pond	1.6	1,000

The future conditions PCSWMM model includes a fixed water level as a boundary condition at Sandy Lake during the 100-year storm. This model is used to assess the hydraulic performance of the proposed SWM Ponds, and as such the effects of backwater from the watercourse on the SWM Ponds are reflected in the results. This is particularly of interest in the case of SWM Pond 3 which is located at the downstream end of the drainage system within a low-lying area that is subject to flooding, and this is reflected on the high volumetric requirements. For this reason, it is recommended that the feasibility of implementing two separate SWM Ponds at each side of the watercourse be investigated during future design stages to service the current development area tributary to SWM Pond 3. The SWM Ponds could potentially be moved upstream as long as proposed grades and site layout work to ensure sufficient cover over the storm sewers.

In addition, although SWM Pond 1 is currently outside of the HRM-provided 100-year floodline, this floodline is based on a high-level model and it is subject to change based on more detailed analysis that could result in Pond 1 being within the 100-year floodplain.

In general, it is recommended that the proposed development plans for the SLSA be revised to avoid residential, commercial and institutional land uses within the 100-year floodplain and to ensure that appropriately sized blocks are allocated for the SWM Ponds outside of the confirmed 100-year floodplain. In the further stages of planning and development of the site, the development plan should be revised to relocate residential development and ponds that is currently close to or within the potential flood line, such as those currently envisaged around Pond 1. By pulling back the development, and potentially adding density to the remaining, the population/development yield of the site could remain similar, and it could reduce the potential risks associated with flooding. The Land Suitability Report recommends that areas within 30 m of a watercourse have low suitability for development, so setbacks areas from watercourses have to be studied on a site-specific basis during subsequent area planning to determine suitability.

The conceptual stormwater management plan shown on **Drawing SD-1** includes trunk storm sewers at key locations such as watercourse crossings and SWM pond inlets. These trunk sewers have been sized to convey the 5-year storm under free flow conditions. However, pipe sizes and SWM pond locations will be confirmed at the detailed design stage, pending a revision of the site conceptual plan and land use distribution to reduce future risks of flooding and environmental degradation. **Table 9-3** shows preliminary trunk storm sewer characteristics.

Table 9-3 Storm Sewer Characteristics

U/S MH ID	D/S MH ID	U/S Invert Elevation (m)	D/S Invert Elevation (m)	Diameter (m)
101	POND-1-S	65.18	64.02	0.900
102	101	68.07	65.41	0.675
103	104	67.06	66.09	0.675
104	POND-1-S	65.94	64.15	0.900
105	104	70.17	66.09	0.675
201	POND-2-S	53.08	52.95	1.200
203	POND-2-S	54.73	53.45	0.525
301	POND-3	31.30	30.80	1.650
307	301	33.38	31.76	1.200
302	301	39.39	31.98	0.975
303	302	41.32	39.54	0.975
304	303	45.68	41.55	0.750
305	303	45.23	41.97	0.825
306	305	48.67	45.38	0.825
308	307	42.86	33.68	0.900
401	POND-4	37.85	36.00	1.200
402	401	40.59	37.91	1.200
403	402	41.54	40.62	1.200
404	403	42.19	41.57	1.200
405	404	43.84	42.22	1.200
501	Pond-5	51.70	51.00	1.500
504	501	52.00	51.75	1.050
502	501	53.84	52.92	0.825
503	502	57.15	53.92	0.825

9.4 Quantity Control Results

As shown on **Drawing SD-1**, flow points have been established along the existing watercourses at proposed crossings, watercourse intersections and at SWM pond outlet locations to compare pre-development and post-development peak flows. The stage-storage-discharge relationship of the proposed SWM ponds was iterated in PCSWMM in order to restrict post development peak flows close to pre-development levels for the 2, 5, 10, 25, 50 and 100-year design storms. **Table 9-4** presents the post to pre-development peak flow comparison at the different flow points along the watercourses for the 2-

year, 5-year, and 100-year design storm events. Refer to **Appendix D** for a table showing peak flow results for all storm events.

Table 9-4 Post to Pre-Development Peak Flow Comparison

Flow Point ID	2-year, 24hr Chicago Peak Flow (m^3/s)		5-year, 24hr Chicago Peak Flow (m^3/s)		100-year, 24hr Chicago Peak Flow (m^3/s)	
	Existing	Proposed	Existing	Proposed	Existing	Proposed
FP_1	0.490	0.790	1.037	1.144	4.398	2.889
FP_2	0.765	1.032	1.398	1.558	5.716	4.751
FP_3	0.968	1.403	1.659	2.280	6.812	6.044
FP_4	3.075	3.217	4.926	5.180	17.051	16.106
FP_5	4.593	3.849	6.481	5.020	17.211	14.112
FP_6	4.613	3.879	6.676	5.731	18.461	17.154
FP_7	6.791	7.002	10.610	10.788	34.323	32.783
FP_8	1.196	1.517	2.129	2.632	10.373	9.545
FP_9	5.159	5.584	8.189	8.678	23.853	23.699
FP_10	5.108	5.434	7.962	8.346	23.449	23.136
FP_11	1.786	1.569	3.027	2.566	12.938	10.495
FP_12	1.986	2.154	3.370	2.977	14.225	10.144
FP_13	0.210	0.209	0.366	0.424	1.155	1.723

As can be seen in the above table, post development peak flows exceed the existing condition levels at some locations along the watercourses during smaller rainfall events (i.e., 2-year, 5-year). It is expected that these exceedances will be substantially reduced once best management practices and LIDs designed to promote infiltration are incorporated at the detailed design stage.

Post development peak flows are lower than existing condition levels for major storm events (i.e., higher than 10-year storm) at all flow point locations with the exception of FP_13, which is located immediately downstream of Pond 1 along a smaller tributary. It should be noted that post development peak flows are lower than existing levels at FP_2, which is located at the confluence of the tributary with Johnson Brook, 90 m downstream of FP_13.

Final sizing and location of the SWM ponds should be confirmed at the detailed design stage, pending flow monitoring, model calibration and detailed floodplain mapping for the area to ensure that post development peak flows along the watercourses are balanced within 10% (+ or -) of pre-development levels.

9.5 Modelling Limitations

The following are some of the limitations associated with the current modelling approach:

- Boundary Conditions: The hydrologic/hydraulic PCSWMM models for the Sandy Lake Development area used a fixed water level at the Sandy Lake outfalls as a boundary condition for the 100-year storm event. This fixed 100-year water level was estimated from the preliminary flood lines obtained from HRM from their on-going Regional Flood Risk Mapping project. The hydrologic/hydraulic model should be refined at later stages of design to include rainfall-runoff response at the lake (i.e., stage-storage-discharge relationship at the lake).
- Calibration: Flow monitoring data for the Sandy Lake watershed is not available at this time and as such, the hydrologic/hydraulic PCSWMM model has not been calibrated. Hydrologic and hydraulic parameters used in this modeling exercise have been selected as discussed in this report based on available information. However, these parameters have not been calibrated to reflect the actual runoff response from the watershed, which includes significant external rural and urban catchments with watercourses and natural depressions and wetlands. Without calibration, the model's predictions are based solely on theoretical calculations and assumptions, which may not accurately reflect real-world conditions.
- The model was not designed to assess site-specific flooding risks. This report primarily relies on floodlines provided by HRM, which were generated using a high-level regional model that may underestimate flooding along smaller streams. A detailed floodline delineation is necessary to accurately evaluate flooding risks along the watercourses crossing the site.

10 Floodplain & Sustainable Development

Planning and development decisions should be guided by best practices in both floodplain management and sustainable development. This process should integrate the principles of resilience to climate change and commitment to environmental conservation at each planning stage.

To guide the HRM in planning, development and refinement of sustainable future development plans for the SLSA, it is recommended to develop a high-level map outlining opportunities to protect and improve the natural environment and associated limitations and constraints. It is important to note that most development constraints which include meander belt widths, existing wetlands and woodlots, and regulatory flood plains, greatly impact the environment and hence should not be altered. However other constraints such as modification to drainage may be permitted if carried out as part of an integrated planning approach such as a subwatershed study. Should there be a need to alter/affect development constraints, detailed investigation must be performed to evaluate the impact on natural features and downstream properties and infrastructure, and to establish corresponding measures to eliminate/compensate for the adverse impacts. Development constraint mapping for the SLSA has been provided in the Land Suitability Assessment (Stantec, 2024), as well as in this report. However, these studies do not quantify the impacts on stormwater/flooding resulting from any alterations that may be proposed as part of the development concept plans.

Wetlands effectively aid in reducing the negative impacts of frequent heavy rainfall events by collecting runoff in their naturally low-lying areas, allowing it to be slowly released into receiving watercourses, infiltrated into the soil to recharge groundwater systems, or absorbed by wetland vegetation. As a result, wetlands represent an important constraint for any development in Nova Scotia. Conservation of wetlands in the province is guided by the Nova Scotia Wetland Conservation Policy and supported by regulation under the provincial Environment Act and Activities Designation Regulations. The goals of the policy are to have no loss of Wetlands of Special Significance (WSS) and to prevent net loss in area and function for other wetlands.

As stated in the statement of provincial interest regarding flood risk areas, within the *Floodway*, development must be restricted to uses such as roads, open space uses, utility and service corridors, parking lots and temporary uses, and the placement of off-site fill must be prohibited. Within the *Floodway Fringe,* flood proofed development may be permitted except for residential institutions where flooding could pose a significant threat to the safety of residents if evacuation became necessary, and in any use associated with the warehousing or the production of hazardous materials. Additionally, the placement of off-site fill within the *Floodway Fringe* must be limited to that required for flood proofing or flood risk management.

Development contrary to the statement of provincial interest regarding flood risk areas may be permitted provided a hydrotechnical study, carried out by a qualified person, shows that the proposed development will not contribute to upstream or downstream flooding or result in a change to flood water flow patterns.

Based on the above, it is recommended that no active development be permitted within the limits of the 100-year regulatory floodplain. Some reduced risk uses may be considered in agreement with HRM by-laws and the Nova Scotia Statement of Provincial Interest regarding Flood Risk Areas. This is subject to design considerations that effectively mitigate and/or minimize the impact of such development on the floodplain and protect the riparian corridor functions. It is further recommended that future development phasing start in higher areas outside of the identified preliminary floodplain and that detailed floodplain mapping be completed to confirm floodplain extents and development setbacks as future developments move closer to the identified preliminary floodplain.

Moreover, any proposed development should adhere to the constraints identified in the Land Suitability Assessment constraint mapping for the SLSA (Stantec, 2024). This includes areas of significant wildlife habitat, wetlands, steep slopes, and other environmentally sensitive areas. In areas where development is proposed within or in proximity to the identified floodplain, suitable mitigation measures should be implemented.

In addition, the promotion of green space creation or naturally forested park areas greatly reduces volume of runoff and pollutant loading discharged into receiving watercourses and as such, it is recommended that green space be promoted within future development plans.

11 Conclusions and Recommendations

Sandy Lake is an important headwater lake within the Sackville River Watershed. The proposed development scenarios for Sandy Lake Study area present challenges to local water quality as land use change can impact the lake system, which has a history of municipal beach closures due to fecal bacteria. Existing TP concentrations in Sandy Lake are within the mesotrophic range.

The four development scenarios evaluated in this study resulted in increased loading of TP, FC, and sediment within the watershed. Of the four development scenarios evaluated, the areal land-use scenario resulted in the lowest increase in loading for all key parameters as it maintains more of the natural forest within the proposed development plans. The developer-requested scenario was the had the next lowest increase in loading for all key parameters as it also conserves forested area in the form of Parks and natural areas. The implementation of structural Low-Impact Development (LID) measures would be expected to reduce contaminant loads for the development area to achieve contaminant loads of existing conditions. The recommendation is to limit the amount of increase in contaminant loading from existing conditions. Mitigation measures and limitations to development for the conservation of naturally forested areas are the most effective methods to limit increases in contaminant loading. The no-net increase of loading approach as developed by HESL (2014) should be considered for any development scenario within the SLSA.

Key components of this report are described below:

- The stormwater management plan for the Sandy Lake Study Area includes storm sewers sized for the 5-year storm and overland flow routing to eight SWM dry ponds designed to restrict post development peak flows to pre-development levels up to the 100-year storm. However, the analysis has identified important limitations and vulnerabilities in the layout provided by the developer. Although this layout was used to assess the feasibility of controlling post-development peak flows, it requires critical consideration of key elements. The proposed development layout and associated stormwater management requires a thorough revision based on further analysis of the land use distribution and the siting of SWM ponds, as well as detailed hydraulic modeling, to confidently mitigate risks of flooding and reduce risks of degradation to the natural assets within the study area. High density land uses can potentially reduce the footprint of development and help to maintain development and stormwater management infrastructure away from flooding risk areas.
- Quality control for the SLSA is to be provided through best management practices, along with the use of LID measures to provide filtration and promote infiltration within public areas. Loading reduction tracking as a result of mitigation measures can be achieved through monthly grab samples at select monitoring locations during the summer months.
- Implementing a strategy to upsize the downstream culverts along Johnson Brook could potentially lower the water level by 2 meters in a 100-year flood scenario. This would result in a water level decrease from 35 m to 33 m between Hammond Plains Road and Farmers Dairy Lane. However, it is important to note that the existing grades in the area of concern indicate that even with a water level of 33 m, there remains a risk of flooding for the proposed development designated as area UNC-1 in

Drawing SD-1 (refer to **Appendix C**). This observation suggests that the extent of flooding in this area is primarily influenced by the lake's floodplain rather than the creek itself. Detailed hydrotechnical investigations should be completed at the detailed design stage of any existing culvert upgrades to assess impacts to downstream properties and infrastructure.

- The area surrounding the intersection of Hammond Plains Road and Bluewater Road is at high risk of flooding due to its location within a floodplain connected to the Johnson Brook tributary. While future infrastructure improvements, including upgrades to the culvert and road alignment, may help manage water flow, the effectiveness of these interventions in mitigating flood risks is limited by the natural floodplain characteristics of the area.
- The upgraded and proposed culverts were sized to meet the H/D < 1 criteria for the 100-year storm event. This criterion ensures that the culverts are adequately sized to handle the peak flow and velocity of runoff during extreme weather events, thereby reducing the risk of flooding and infrastructure damage.

Based on the discussion provided in this report, the following is a summary of recommendations:

- Flow monitoring in the watercourses and subsequent model calibration be completed to confirm regulatory floodplain limits, culvert sizing and proposed pond sizes and locations.
- No active development be permitted within the limits of the 100-year regulatory floodplain. Some reduced risk uses may be considered in agreement with HRM by-laws and the Nova Scotia Statement of Provincial Interest regarding Flood Risk Areas. This is subject to design considerations that effectively mitigate and/or minimize the impact of such development on the floodplain and protect the riparian corridor functions.
- An investigation into Sandy Lake's rain-runoff response and outlet structure is recommended to refine the boundary conditions in the model.
- A detailed geotechnical investigation is recommended to be completed at the detailed design stage. Geotechnical recommendations should be provided for the proposed Stormwater Management (SWM) ponds, grade-raise restrictions, and the feasibility of Low Impact Developments (LIDs) in the area.
- Detailed hydraulic modeling of the watercourses be completed to better understand flooding risks at the current location of SWM Pond 1 and SWM Pond 2 as the current 100-year floodlines are based on a high level model and are subject to change. A revision of land use distribution to increase high-density uses, reduce development footprint and allow the location of the proposed ponds is advised to inform the design of an effective and sustainable stormwater management plan.
- The feasibility of implementing two separate SWM Ponds at each side of the watercourse be investigated during future design stages to service the current development area tributary to SWM Pond 3. The SWM Ponds could potentially be moved upstream as long as proposed grades and site layout work to ensure sufficient cover over storm sewers.
- The development concept plan be revisited to ensure SWM Ponds are located outside of the 100-year floodplain and/or delineated wetlands, to maximize the use of natural areas considering the

recommendations of the LSA, to consider high-density land uses that reduce sprawl to achieve this purpose, and to inform the revision of the proposed development layout and stormwater management plan to reduce risk of flooding and degradation to natural assets in the study area. The current layout includes SWM ponds located in or close to areas under risks of flooding.

- To minimize future flood-related impacts, it is recommended to restrict development in the vicinity of Hammond Plains Road and Bluewater Road. By limiting new construction and structural modifications within this flood-prone area, the potential for property damage and adverse environmental impacts can be reduced, supporting a more sustainable and resilient infrastructure approach. It is recommended to base future revisions to the stormwater management plan on the potential upgrade of the culvert under Hammond Plains Road (i.e., Culvert 10), which could be deemed as necessary to reduce flooding risks upstream of the culvert.
- In future stages of planning and development of the site, the development plan should be revised to relocate residential development and ponds that are currently close to or within the potential floodplain, such as those currently envisioned around Pond 1. By pulling back the development, and potentially adding density to the remaining area, the population/development yield of the site could remain similar, and it could reduce the potential risks associated with flooding. The Land Suitability Report recommends that areas within 30 m of a watercourse have low suitability for development, so setback areas from watercourses must be studied on a site-specific basis during subsequent area planning to determine suitability.
- Retaining native and existing ground cover be prioritized where possible to preserve ecosystem service function, reduce volume of runoff discharged into watercourses, promote infiltration, and provide an opportunity for evapotranspiration.
- Future development phasing start in higher areas outside of the identified preliminary floodplain and detailed floodplain mapping be completed to confirm floodplain extents and development setbacks as future developments move closer to the identified preliminary floodplain. High density land uses potentially reduce the footprint of development and help to maintain development and stormwater management infrastructure away from flooding risk areas. Therefore, a revision of the proposed development layout is required to improve the effectiveness and safety of the proposed stormwater management plan.
- Implementing structural LID measures within public property to reduce contaminant loads for the development area to achieve contaminant loads of existing conditions.
- Implementing erosion and sedimentation control measures to mitigate effects from development during construction, as well as implementing construction sequencing to minimize the quantity of soil exposed at any given time to prevent erosion.

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APPENDICES

Appendix A Background Water Quality Data

SANDY LAKE WATERSHED STUDY - Historical Water Quality Results

Sample Name				Sandy Lake												
Lake Name	CCME Guideline (RWQ)	CCME Guidelines (FWAL)	Units	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake (Beach)	Sandy Lake (Lake Centre)	Sandy Lake (Farmers Inlet)	Sandy Lake (Northern Outlet)	Sandy Lake (Northern Inlet)
Easting	-	-	-	unknown	unknown	unknown	444574	444574	444574	unknown	unknown	unknown	unknown	unknown	unknown	unknown
Northing	-	-	-	unknown	unknown	unknown	4953566	4953566	4953566	unknown	unknown	unknown	unknown	unknown	unknown	unknown
Sampling Date	-	-	dd-mmm-yy	1-Jan-1980	1-Jan-1991	1-Jan-1991	2-Sep-1998	2-Sep-1998	2-Sep-1998	1-Jan-2000	1-Jan-2000	25-Nov-2001	25-Nov-2001	25-Nov-2001	25-Nov-2001	25-Nov-2001
Sampled By / Data Source	-	-	-	DFO	DFO	DFO	NSE	NSE	NSE	DFO	DFO	Dalhousie University	Dalhousie University	Dalhousie University	Dalhousie University	Dalhousie University
FIELD DATA																
Secchi Depth	1.20	-	Meters	-			3.05	3.05	3.05	-						
Temp	-	-	Celsius	4	6		22	22	22	5.1	5.7					
Dissolved Oxygen	-	5.5-9.5	mg/L	-			3	3	3							
pH	5.0-9.0	6.5-9	pH	4.9	5.3		5.7	6.2	5.9	5.81	5.65	5.85			5.25	
Specific Conductance	-	-	uS/cm	58.9	113.7		146	125	130	132.1	133					
TDS	-	-	g/L	-				0.069								
Salinity	-	-	ppt	-												
INORGANICS																
Total Alkalinity (as CaCO3)	-	-	mg/L	0.05	0.1		2	3	2.8	0.21	0.42	2.8	2	4	2.8	
Dissolved Chloride (Cl)				13.7	25		34	29	30	30.2	30					
Colour	-	-	TCU		22.5					8	12	25.9	29	27	24.6	
Nitrite + Nitrate	-	-	mg/L				0.09	<0.01	0.05			<0.05	<0.05	<0.05	<0.05	
Nitrite (N)	-	60.00	mg/L	0.05	0.08					0.1	0.1					
Nitrogen (Ammonia Nitrogen)	-	19.00	mg/L	0.02	0.023		0.01	0.03	0.021	0.019						
Nitrogen TKN - water (as N)	-	-														
Total Nitrogen	-	-	mg/L	0.24	0.25		0.332	0.2	0.22	0.1	0.17					
Total Organic Carbon	-	-	mg/L				3.9	4.4	4.4			4.7	4.7	5.4	4.6	
Orthophosphate (as P)	-	-	mg/L	0.002	0.02		0.004	<0.001	<0.001			<0.01	<0.01	<0.01	<0.01	
pH (Lab)	5.0-9.0	6.5-9	pH	4.9	5.29							6.3	6.3	6.3	6.3	
Total Calcium (Ca)	-	-	mg/L	1.8	3.3		3.92	3.9	3.92	4	3.9	4.2	4.3	5.6	4.3	
Total Magnesium (Mg)	-	-	mg/L	0.9	0.9		0.96	0.93	0.92	0.99	0.97	1	1	1.3	1	
Total Phosphorus	-	-	mg/L	0.007	0.019		0.012	0.001	0.005	0.008	0.008					
Total Phosphorus (1M depth)	-	-	mg/L													
Total Phosphorus (Deep)	-	-	mg/L													
Total Potassium (K)	-	-	mg/L	0.7	0.7		0.7	0.8	0.9	0.66	0.67	0.7	0.8	0.8	0.9	
Total Sodium (Na)	-	-	mg/L	8.4	15.3		19.5	17	18.1	17.1	18.4	20.8	21.1	20.1	21.2	
Reactive Silica (SiO2)	-	-	mg/L				3.2	2.1	2.6			2.7	2.7	4.5	2.7	
Total Suspended Solids	-	-	mg/L													
Dissolved Sulphate (SO4)	-	-	mg/L	3.9	3.3		9.8	10	9.8	9.07	8.97	10.2	9.9	14.2	9.7	
Lab Turbidity (NTU)	50.00	-	NTU													
Conductivity (uS/cm)	-	-	µS/cm													
Calculated Parameteres																
Anion Sum	-	-	me/L									1.23	1.23	1.28	1.24	
Bicarb. Alkalinity (calc. as CaCO3)	-	-	mg/L													
Calculated TDS	-	-	mg/L													
Carb. Alkalinity (calc. as CaCO3)	-	-	mg/L													
Cation Sum	-	-	me/L									1.22	1.24	1.28	1.24	
Hardness (CaCO3)	-	-	mg/L													
Ion Balance (% Difference)	-	-	%													
Langelier Index (@ 20C)	-	-	N/A													
Langelier Index (@ 4C)	-	-	N/A													
Saturation pH (@ 20C)	-	-	N/A													
Saturation pH (@ 4C)	-	-	N/A													
Metals (ICP-MS)																
Total Aluminum (Al)	-	5-100	µg/L				200	64	130	180	167					
Total Antimony (Sb)	-	5-100	µg/L													
Total Arsenic (As)	-	5.00	µg/L		0.1	0.2				0.3	0.3					
Total Barium (Ba)	-	-	µg/L							16.4	16.9					
Total Beryllium (Be)	-	-	µg/L							0.027	0.023					
Total Bismuth (Bi)	-	-	µg/L							<0.01	<0.01					
Total Cadmium (Cd)	-	0.02	µg/L		0.14	0.13				0.16	0.123					
Total Chromium (Cr)	-	1.00	µg/L							0.21	0.19					
Total Cobalt (Co)	-	-	µg/L							0.93	0.85					
Total Copper (Cu)	-	2.0-4.0	µg/L		3.6	2	0.01	<0.01	0.01	1.1	2.3	<0.002	<0.002	0.002	0.002	
Total Lead (Pb)	-	1.0-7.0	µg/L							0.25	0.3					
Total Molybdenum (Mo)	-	73.00	µg/L							<0.05	<0.05					
Total Nickel (Ni)	-	25-150	µg/L							2.2	2.1					
Total Selenium (Se)	-	1.00	µg/L							<1	<1					
Total Silver (Ag)	-	0.10	µg/L							<0.01	<0.01					
Total Thallium (Tl)	-	0.80	µg/L							<0.005	<0.005					
Total Tin (Sn)	-	-	µg/L													
Total Titanium (Ti)	-	-	µg/L							1.1	1					
Total Uranium (U)	-	-	µg/L		0.02	0.039				0.012	0.014					
Total Vanadium (V)	-	-	µg/L		0.41	0.92				0.27	0.23					
Total Zinc (Zn)	-	30.00	µg/L		23.7	22.1	0.04	<0.01	0.01	8.3	10.6	6	6	7	8	
MICROBIOLOGICAL																
Total coliform	-	-	MPN/100mL													
E. Coli	-	-	MPN/100mL													
Fecal Coliform	-	400	MPN/100mL													
Fecal Coliform	-	-	CFU/100 ml													
Chlorophyll A - Acidification method	-	-	µg/L													
Chlorophyll A - Welschmeyer method	-	-	µg/L													
Chlorophyll A	-	-	µg/L		0.93			2.3		0.66	0.85					
Pheophytin A	-	-	µg chl eq/L					0.8								
ORGANICS																
Biochemical Oxygen Demand	-	-	(mg/L)													
Disolved Organic Carbon	-	-	mg/L													
Source	-	-	-	DFO	DFO	DFO	NSE	NSE	NSE	DFO	DFO	Dalhousie 2002 (Conrad 2002)	Dalhousie 2002 (Conrad 2002)	Dalhousie 2002 (Conrad 2002)	Dalhousie 2002 (Conrad 2002)	Dalhousie 2002 (Conrad 2002)

Sample Name	Sandy Lake													
Lake Name	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake
Easting	444390	444390	444390	444390	444390	444390	444390	444390	444390	444390	444390	444390	444390	444390
Northing	4953507	4953507	4953507	4953507	4953507	4953507	4953507	4953507	4953507	4953507	4953507	4953507	4953507	4953507
Sampling Date	30-Aug-2005	30-Sep-2005	28-Oct-2005	5-Dec-2005	31-Mar-2006	6-May-2006	2-Jun-2006	5-Jul-2006	31-Jul-2006	1-Sep-2006	4-Oct-2006	2-Nov-2006	8-Jun-2007	13-Jul-2007
Sampled By / Data Source	Sandy Lake Resident	Sandy Lake Resident	Sandy Lake Resident	Sandy Lake Resident	Sandy Lake Resident	Sandy Lake Resident	Sandy Lake Resident	Sandy Lake Resident	Sandy Lake Resident	Sandy Lake Resident	Sandy Lake Resident	Sandy Lake Resident	Sandy Lake Resident	Sandy Lake Resident
FIELD DATA														
Secchi Depth	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dissolved Oxygen	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Specific Conductance	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TDS	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salinity	-	-	-	-	-	-	-	-	-	-	-	-	-	-
INORGANICS														
Total Alkalinity (as CaCO3)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dissolved Chloride (Cl)														
Colour	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrite + Nitrate	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrite (N)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrogen (Ammonia Nitrogen)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrogen TKN - water (as N)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Nitrogen	0.19	0.22	0.26	0.36	0.27	0.24	0.26	0.19	0.27	0.25	0.26	0.28	0.27	0.21
Total Organic Carbon	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orthophosphate (as P)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH (Lab)	6.50		6.40	6.50	7.30	6.30	6.90	7.00	6.50	6.60	6.90	6.50	6.40	6.60
Total Calcium (Ca)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Magnesium (Mg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Phosphorus	0.008	0.006	0.014	0.013	0.012	0.005		0.006	0.009	0.008	0.008	0.006	0.005	0.006
Total Phosphorus (1M depth)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Phosphorus (Deep)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Potassium (K)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Sodium (Na)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Reactive Silica (SiO2)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Suspended Solids	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dissolved Sulphate (SO4)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lab Turbidity (NTU)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conductivity (uS/cm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calculated Parameteres														
Anion Sum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bicarb. Alkalinity (calc. as CaCO3)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calculated TDS	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carb. Alkalinity (calc. as CaCO3)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cation Sum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hardness (CaCO3)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ion Balance (% Difference)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Langelier Index (@ 20C)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Langelier Index (@ 4C)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Saturation pH (@ 20C)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Saturation pH (@ 4C)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Metals (ICP-MS)														
Total Aluminum (Al)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Antimony (Sb)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Arsenic (As)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Barium (Ba)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Beryllium (Be)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Bismuth (Bi)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Cadmium (Cd)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Chromium (Cr)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Cobalt (Co)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Copper (Cu)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Lead (Pb)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Molybdenum (Mo)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Nickel (Ni)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Selenium (Se)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Silver (Ag)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Thallium (Tl)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Tin (Sn)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Titanium (Ti)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Uranium (U)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Vanadium (V)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Zinc (Zn)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MICROBIOLOGICAL														
Total coliform	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E. Coli	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fecal Coliform	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fecal Coliform	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorophyll A - Acidification method	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorophyll A - Welschmeyer method	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorophyll A	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pheophytin A	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ORGANICS														
Biochemical Oxygen Demand	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Disolved Organic Carbon	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Source	Sandy Lake Conservation Association													

SANDY LAKE WATERSHED STUDY -
Historical Water Quality Results

Sample Name				Sandy Lake																										
Lake Name	CCME Guideline (RWQ)	CCME Guidelines (FWAL)	Units	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake
Easting	-	-	-	444390	444390	444390	444550	444550	444550	444550	444550	444550	444550	444550	444550	444550	444550	444550	444550	444550	444018	444018	444018	444018	444018	444018	444018	444018	444018	444018
Northing	-	-	-	4953507	4953507	4953507	4953619	4953619	4953619	4953619	4953619	4953619	4953619	4953619	4953619	4953619	4953619	4953619	4953619	4953619	4954358	4954358	4954358	4954358	4954358	4954358	4954358	4954358	4954358	4954358
Sampling Date	-	-	dd-mmm-yy	10-Aug-2007	7-Sep-2007	5-Oct-2007	31-May-2006	24-Oct-2006	23-May-2007	1-Nov-2007	28-May-2008	3-Sep-2008	21-Oct-2008	2-Jun-2009	12-Aug-2009	18-Nov-2009	21-May-2010	24-May-2010	9-Nov-2010	19-Aug-2011	23-May-2007	1-Nov-2007	28-May-2008	3-Sep-2008	21-Oct-2008	2-Jun-2009	18-Nov-2009	21-May-2010	24-May-2010	9-Nov-2010
Sampled By / Data Source	-	-	-	Sandy Lake Resident	Sandy Lake Resident	Sandy Lake Resident	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM
FIELD DATA																														
Secchi Depth	1.20	-	Meters	-	-	-	4.0	1.5	3.0	2.00	3.8	2.0	2.4	2.7	N/A	1.8	3.2	2.6	1.7	1.5	-	-	-	-	-	-	-	-	-	-
Temp	-	-	Celsius	-	-	-	18.18	12.24	11.81	11.97	13.88	19.58	12.20	15.53	24.90	7.48	14.16	22.99	11.40	22.67	-	-	-	-	-	-	-	-	-	-
Dissolved Oxygen	-	5.5-9.5	mg/L	-	-	-	8.67	9.47	10.22	9.60	10.96	9.64	10.15	10.71	8.81	13.41	11.91	8.74	12.13	9.27	-	-	-	-	-	-	-	-	-	-
pH	5.0-9.0	6.5-9	pH	-	-	-	6.00	6.43	6.48	6.41	6.61	6.42	7.08	7.36	6.45	6.76	7.55	6.91	6.29	6.8	-	-	-	-	-	-	-	-	-	-
Specific Conductance	-	-	uS/cm	-	-	-	124	99	158	117	193	167	165	178	159	135	167	156	128	119	-	-	-	-	-	-	-	-	-	-
TDS	-	-	g/L	-	-	-	-	-	0.10	0.08	0.13	0.11	0.11	0.12	0.10	0.09	0.11	0.10	0.08	0.077	-	-	-	-	-	-	-	-	-	-
Salinity	-	-	ppt	-	-	-	-	-	0.07	0.06	0.09	0.08	0.08	0.08	0.07	0.06	0.08	0.07	0.06	0.06	-	-	-	-	-	-	-	-	-	-
INORGANICS																														
Total Alkalinity (as CaCO3)	-	-	mg/L	-	-	-	-	-	<5	5	<5	6	6	<5	<5	<5	<5	<5	<5	6	-	-	-	-	-	-	-	-	-	-
Dissolved Chloride (Cl)			mg/L				27	21	38	27	50	40	41	45	39	32	42	37	29	24	-	-	-	-	-	-	-	-	-	-
Colour	-	-	TCU	-	-	-	-	35	17	32	24	39	45	26	54	66	19	15	26	71	-	-	-	-	-	-	-	-	-	-
Nitrite + Nitrate	-	-	mg/L	-	-	-	-	-	0.16	0.08	0.16	<0.05	0.07	0.13	0.14	<0.05	0.11	<0.05	0.06	<0.05	-	-	-	-	-	-	-	-	-	-
Nitrite (N)	-	60.00	mg/L	-	-	-	<0.01	ND	-	-	<0.01	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-	-	-
Nitrogen (Ammonia Nitrogen)	-	19.00	mg/L	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.08	0.07	0.06	0.05	<0.05	-	-	-	-	-	-	-	-	-	-
Nitrogen TKN - water (as N)	-	-		-	-	-	0.3	0.3	0.4	0.6	0.3	0.4	0.4	<0.4	1	1.2	0.5	0.7	0.4	3.6	-	-	-	-	-	-	-	-	-	-
Total Nitrogen	-	-	mg/L	0.23	0.30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Organic Carbon	-	-	mg/L	-	-	-	-	-	3.4	6.2	3.4	5.3	5.7	4.6	10.5	8.6	5.9	6.8	8.4	10.4	-	-	-	-	-	-	-	-	-	-
Orthophosphate (as P)	-	-	mg/L	-	-	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	-	-	-	-	-	-
pH (Lab)	5.0-9.0	6.5-9	pH	6.50	-	-	-	-	6.26	6.61	6.55	6.52	6.66	6.8	7.2	7.0	6.8	7.0	6.6	7.1	-	-	-	-	-	-	-	-	-	-
Total Calcium (Ca)	-	-	mg/L	-	-	-	-	-	5.3	4	5.1	4.8	4.4	4.1	5	4.6	5.5	17.2	4.1	3.8	-	-	-	-	-	-	-	-	-	-
Total Magnesium (Mg)	-	-	mg/L	-	-	-	-	-	1.2	0.9	1	1.0	0.9	0.9	1	1.0	1	1.7	1.0	0.7	-	-	-	-	-	-	-	-	-	-
Total Phosphorus	-	-	mg/L	0.006	0.006	0.006	-	-	0.1	-	0.1	0.1	0.1	-	-	0.1	-	0.1	-	0.1	-	-	-	-	-	-	-	-	-	-
Total Phosphorus (1M depth)	-	-	mg/L	-	-	-	0.002	0.009	0.02	0.006	0.012	0.011	0.021	0.008	0.012	0.025	0.043	0.010	0.019	0.006	-	-	-	-	-	-	-	-	-	-
Total Phosphorus (Deep)	-	-	mg/L	-	-	-	-	-	-	-	-	0.015	-	-	N/A	-	-	0.026	-	0.005	-	-	-	-	-	-	-	-	-	-
Total Potassium (K)	-	-	mg/L	-	-	-	-	-	1.1	1.2	1.1	1.2	1.0	0.9	1	1.1	1	1.2	1.2	0.7	-	-	-	-	-	-	-	-	-	-
Total Sodium (Na)	-	-	mg/L	-	-	-	-	-	23	18	31	25	23	22.8	22.9	19.1	30.3	27.7	17.6	18.1	-	-	-	-	-	-	-	-	-	-
Reactive Silica (SiO2)	-	-	mg/L	-	-	-	-	-	2.9	3.6	2.4	2.6	3.2	2.5	2	3.5	3	2.3	3.4	2.2	-	-	-	-	-	-	-	-	-	-
Total Suspended Solids	-	-	mg/L	-	-	-	<2	2	<1	2	<1	1	1	<5	<5	<5	<5	<5	<5	<5	-	-	-	-	-	-	-	-	-	-
Dissolved Sulphates (SO4)	-	-	mg/L	-	-	-	-	-	9	7	9	9	8	8	7	7	8	7	7	5	-	-	-	-	-	-	-	-	-	-
Lab Turbidity (NTU)	50.00	-	NTU	-	-	-	0.5	0.9	0.7	1.3	0.7	1.0	1.2	1.3	2.7	3.2	0.8	1.3	3.0	1.8	-	-	-	-	-	-	-	-	-	-
Conductivity (uS/cm)	-	-	µS/cm	-	-	-	-	-	150	120	200	170	170	188	165	140	177	160	129	-	-	-	-	-	-	-	-	-	-	-
Calculated Parameteres																														
Anion Sum	-	-	me/L	-	-	-	-	-	1.27	1.02	1.6	1.44	1.44	1.45	1.27	1.05	1.36	1.19	0.97	0.9	-	-	-	-	-	-	-	-	-	-
Bicarb. Alkalinity (calc. as CaCO3)	-	-	mg/L	-	-	-	-	-	ND	5	<1	6	6	<1	<1	<1	<1	<1	<1	6	-	-	-	-	-	-	-	-	-	-
Calculated TDS	-	-	mg/L	-	-	-	-	-	82	65	100	88	86	82	243	206	266	253	61	56	-	-	-	-	-	-	-	-	-	-
Carb. Alkalinity (calc. as CaCO3)	-	-	mg/L	-	-	-	-	-	ND	ND	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-	-
Cation Sum	-	-	me/L	-	-	-	-	-	1.41	1.08	1.73	1.45	1.34	1.29	1.39	1.25	1.72	2.27	1.14	1.07	-	-	-	-	-	-	-	-	-	-
Hardness (CaCO3)	-	-	mg/L	-	-	-	-	-	18	14	17	16	15	14	17	16	18	50	14.4	12	-	-	-	-	-	-	-	-	-	-
Ion Balance (% Difference)	-	-	%	-	-	-	-	-	5.22	2.86	3.9	0.350	3.60	5.6	4.5	8.6	11.7	31.3	8.0	8.6	-	-	-	-	-	-	-	-	-	-
Langelier Index (@ 20C)	-	-	N/A	-	-	-	-	-	NC	-3.39	NC	-3.33	-3.26	-3.47	-3.73	-4.96	-6.09	-4.39	-3.66	-3.1	-	-	-	-	-	-	-	-	-	-
Langelier Index (@ 4C)	-	-	N/A	-	-	-	-	-	NC	-3.64	NC	-3.58	-3.51	-3.79	-4.05	-5.28	-6.41	-4.71	-3.98	-3.42	-	-	-	-	-	-	-	-	-	-
Saturation pH (@ 20C)	-	-	N/A	-	-	-	-	-	NC	10	NC	9.85	9.92	10.3	10.93	11.96	12.89	11.39	10.30	10.2	-	-	-	-	-	-	-	-	-	-
Saturation pH (@ 4C)	-	-	N/A	-	-	-	-	-	NC	10.3	NC	10.1	10.2	10.6	11.25	12.28	13.21	11.71	10.60	10.52	-	-	-	-	-	-	-	-	-	-
Metals (ICP-MS)																														
Total Aluminum (Al)	-	5-100	µg/L	-	-	-	-	-	180	-	120	77	97	-	-	234	-	142	-	171	-	-	-	-	-	-	-	-	-	-
Total Antimony (Sb)	-	5-100	µg/L	-	-	-	-	-	<2	-	<2	<2	<2	-	-	<2	-	<2	-	<2	-	-	-	-	-	-	-	-	-	-
Total Arsenic (As)	-	5.00	µg/L	-	-	-	-	-	<2	-	<2	<2	<2	-	-	<2	-	<2	-	<2	-	-	-	-	-	-	-	-	-	-
Total Barium (Ba)	-	-	µg/L	-	-	-	-	-	17	-	19	15	15	-	-	17	-	17	-	14	-	-	-	-	-	-	-	-	-	-
Total Beryllium (Be)	-	-	µg/L	-	-	-	-	-	<2	-	<2	<2	<2	-	-	<2	-	<2	-	<2	-	-	-	-	-	-	-	-	-	-
Total Bismuth (Bi)	-	-	µg/L	-	-	-	-	-	<2	-	<2	<2	<2	-	-	<2	-	<2	-	<2	-	-	-	-	-	-	-	-	-	-
Total Cadmium (Cd)	-	0.02	µg/L	-	-	-	-	-	<0.3	-	<0.3	<0.3	<0.3	-	-	0.037	-	0.076	-	0.031	-	-	-	-	-	-	-	-	-	-
Total Chromium (Cr)	-	1.00	µg/L	-	-	-	-	-	<2	-	<2	<2	<2	-	-	<1	-	18	-	1	-	-	-	-	-	-	-	-	-	-
Total Cobalt (Co)	-	-	µg/L	-	-	-	-	-	<1	-	<1	<1	<1	-	-	1	-	<1	-	<1	-	-	-	-	-	-	-	-	-	-
Total Copper (Cu)	-	2.0-4.0	µg/L	-	-	-	-	-	<2	-	<2	<2	<2	<2	<2	<2	<2	2	<2	<2	-	-	-	-	-	-	-	-	-	-
Total Lead (Pb)	-	1.0-7.0	µg/L	-	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	-	-	0.6	-	<0.5	-	<0.5	-	-	-	-	-	-	-	-	-	-
Total Molybdenum (Mo)	-	73.00	µg/L	-	-	-	-	-	<2	-	<2	<2	<2	-	-	<2	-	2	-	<2	-	-	-	-	-	-	-	-	-	-
Total Nickel (Ni)	-	25-150	µg/L	-	-	-	-	-	<2	-	<2	<2	<2	-	-	<2	-	14	-	2	-	-	-	-	-	-	-	-	-	-
Total Selenium (Se)	-	1.00	µg/L	-	-	-	-	-	<2	-	<2	<2	<2	-	-	<1	-	<1	-	<1	-	-	-	-	-	-	-	-	-	-
Total Silver (Ag)	-	0.10	µg/L	-	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	-	-	<0.1	-	<0.1	-	<0.1	-	-	-	-	-	-	-	-	-	-
Total Thallium (Tl)	-	0.80	µg/L	-	-	-	-	-	<0.1	-	<2	<2	<2	-	-	<0.1	-	<0.1	-	<0.1	-	-	-	-	-	-	-	-	-	-
Total Tin (Sn)	-	-	µg/L	-	-	-	-	-	<2	-	<2	<2	<2	-	-	<2	-	<2	-	<2	-	-	-	-	-	-	-	-	-	-
Total Titanium (Ti)	-	-	µg/L	-	-	-	-	-	<2	-	<2	<2	<2	-	-	2	-	<2	-	2	-	-	-	-	-	-	-	-	-	-
Total Uranium (U)	-	-	µg/L	-	-	-	-	-	<0.1	-	<0.1	<0.1	<0.1	-	-	<0.1	-	<0.1	-	<0.1	-	-	-	-	-	-	-	-	-	-
Total Vanadium (V)	-	-	µg/L	-	-	-	-	-	<2	-	<2	<2	<2	-	-	<2	-	<2	-	<2	-	-	-	-	-	-	-	-	-	-
Total Zinc (Zn)	-	30.00	µg/L	-	-	-	-	-	10	-	12	7	9	<5	12	6	<5	154	6	5	-	-	-	-	-	-	-	-	-	-
MICROBIOLOGICAL																														
Total coliform	-	-	MPN/100mL	-	-	-	-	-	-	-	-	-	-	-	-	344	111	1226	1733	-	-	-	-	-	-	-	332	102	>4838	2420
E. Coli	-	-	MPN/100mL	-	-	-	-	ND	-	-	-	-	-	-	-	<2	<2	<2	36	4	-	-	-	-	-	-	<2	<2	<2	41
Fecal Coliform	-	400	MPN/100mL	-	-	-	-	<1	7	2	<1	18	<1	-	-	-	-	-	-	-	1	5	<1	21	<1	-	-	-	-	-
Fecal Coliform	-	-	CFU/100 ml	-	-	-	ND	-	-	-	-	-	-	2	24	<2	-	-	-	-	-	-	-	-	-	2	<2	-	-	-
Chlorophyll A - Acidification method	-	-	µg/L	-	-	-	0.56	8.85	0.3	1.89	1.16	10.56	7.62	3.64	13.20	6.33	2.95	9.41	4.33	8.33	-	-	-	-	-	-	-	-	-	-
Chlorophyll A - Welschmeyer method	-	-	µg/L	-	-	-	-	-	0.34	2.11	1.07	10.29	7.82	3.47	12.70	6.14	2.92	9.05	4.02	7.59	-	-	-	-	-	-	-	-	-	-
Chlorophyll A	-	-	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pheophytin A	-	-	µg chl eq/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ORGANICS																														
Biochemical Oxygen Demand	-	-	(mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Disolved Organic Carbon	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Source	-	-	-										HRM Lakes Water Quality Sampling Program								HRM Lakes Water Quality Sampling Program									

SANDY LAKE WATERSHED STUDY -
Historical Water Quality Results

Sample Name				Sandy Lake	Sandy Lake Outlet 2			Sandy Lake										
Lake Name	CCME Guideline (RWQ)	CCME Guidelines (FWAL)	Units	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	NA	NA
Easting	-	-	-	444018	444014	444014	444014	unknown	unknown	unknown	444574	444574	444574	unknown	unknown	444576	unknown	unknown
Northing	-	-	-	4954358	4954340	4954340	4954340	unknown	unknown	unknown	4953566	4953566	4953566	unknown	unknown	4953804	unknown	unknown
Sampling Date	-	-	dd-mmm-yy	19-Aug-2011	27-Aug-2013	15-Nov-2013	20-May-2014	1-Jan-1980	1-Jan-1991	1-Jan-1991	2-Sep-1998	2-Sep-1998	2-Sep-1998	1-Jan-2000	1-Jan-2000	7-Apr-2011	10-Jan-2012	26-Jan-2012
Sampled By / Data Source	-	-	-	HRM	AECOM	AECOM	AECOM	DFO	DFO	DFO	NSE	NSE	NSE	DFO	DFO	DFO	Halifax Water	Halifax Water
FIELD DATA																		
Secchi Depth	1.20	-	Meters	-	-			-	-	-	3.05	3.05	3.05	-	-		-	-
Temp	-	-	Celsius	-	21.60	7.70	-	4	6	-	22	22	22	5.1	5.7		-	-
Dissolved Oxygen	-	5.5-9.5	mg/L	-	4.28	4.09	-	-	-	-	3	3	3	-	-		-	-
pH	5.0-9.0	6.5-9	pH	-	6.08	6.31	-	4.9	5.3	-	5.70	6.20	5.90	5.81	5.65		6.77	7.05
Specific Conductance	-	-	uS/cm	-	128	116	-	58.9	113.7	-	146	125	130	132.1	133		-	-
TDS	-	-	g/L	-	0.08	0.08	-	-	-	-	-	0.069	-	-	-		-	-
Salinity	-	-	ppt	-	-			-	-	-	-	-	-	-	-		-	-
INORGANICS																		
Total Alkalinity (as CaCO3)	-	-	mg/L	-	-			0.05	0.1	-	2	3	2.8	0.21	0.42	3.7	-	-
Dissolved Chloride (Cl)				-	34	28	47									53.6		
Colour	-	-	TCU	-	-			-	22.5	-	-	-	-	8	12	28.2	-	-
Nitrite + Nitrate	-	-	mg/L	-	<0.05	<0.05	0.07	-	-	-	0.09	<0.01	0.05	-	-	-	-	-
Nitrite (N)	-	60.00	mg/L	-	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-	-	-	-
Nitrogen (Ammonia Nitrogen)	-	19.00	mg/L	-	<0.05	<0.05	<0.05	0.02	0.023	-	-	0.01	0.03	0.021	0.019	0.01	2.20	3.30
Nitrogen TKN - water (as N)	-	-		-	<0.4	1.4	0.9	-	-	-	-	-	-	-	-	0.1612	-	-
Total Nitrogen	-	-	mg/L	-	-			0.24	0.25	-	0.32	0.2	0.22	0.1	0.17	0.3	-	-
Total Organic Carbon	-	-	mg/L	-	-			-	-	-	3.9	4.4	4.4	-	-		-	-
Orthophosphate (as P)	-	-	mg/L	-	<0.01	<0.01	<0.01	0.002	0.02	-	0.004	<0.001	<0.001	-	-		-	-
pH (Lab)	5.0-9.0	6.5-9	pH	-	-	6.7	7.0	4.9	5.29	-	-	-	-	-	-	6.12	-	-
Total Calcium (Ca)	-	-	mg/L	-	-			1.8	3.3	-	3.92	3.9	3.92	4	3.9	5.95	-	-
Total Magnesium (Mg)	-	-	mg/L	-	-			0.9	0.9	-	0.96	0.93	0.92	0.99	0.97	1.15	-	-
Total Phosphorus	-	-	mg/L	-	0.019	0.009	0.023	0.007	0.019	-	0.012	0.001	0.005	0.008	0.008	0.01	1.20	1.50
Total Phosphorus (1M depth)	-	-	mg/L	-	-			-	-	-	-	-	-	-	-		-	-
Total Phosphorus (Deep)	-	-	mg/L	-	-			-	-	-	-	-	-	-	-		-	-
Total Potassium (K)	-	-	mg/L	-	-			0.7	0.7	-	0.7	0.8	0.9	0.66	0.67	1.10	-	-
Total Sodium (Na)	-	-	mg/L	-	-			8.4	15.3	-	19.5	17	18.1	17.7	18.4	31.2	-	-
Reactive Silica (SiO2)	-	-	mg/L	-	-			-	-	-	3.2	2.1	2.6	-	-	0.1844	-	-
Total Suspended Solids	-	-	mg/L	-	<2			-	-	-	-	-	-	-	-		14.00	16.00
Dissolved Sulphate (SO4)	-	-	mg/L	-	-			3.9	3.3	-	9.8	10	9.8	9.07	8.97	7.7	-	-
Lab Turbidity (NTU)	50.00	-	NTU	-	-			-	-	-	-	-	-	-	-		-	-
Conductivity (uS/cm)	-	-	µS/cm	-	-			-	-	-	-	-	-	-	-	224.5	-	-
Calculated Parameteres																		
Anion Sum	-	-	me/L	-	-			-	-	-	-	-	-	-	-		-	-
Bicarb. Alkalinity (calc. as CaCO3)	-	-	mg/L	-	-			-	-	-	-	-	-	-	-		-	-
Calculated TDS	-	-	mg/L	-	-			-	-	-	-	-	-	-	-		-	-
Carb. Alkalinity (calc. as CaCO3)	-	-	mg/L	-	-			-	-	-	-	-	-	-	-		-	-
Cation Sum	-	-	me/L	-	-			-	-	-	-	-	-	-	-		-	-
Hardness (CaCO3)	-	-	mg/L	-	-			-	-	-	-	-	-	-	-		-	-
Ion Balance (% Difference)	-	-	%	-	-			-	-	-	-	-	-	-	-		-	-
Langelier Index (@ 20C)	-	-	N/A	-	-			-	-	-	-	-	-	-	-		-	-
Langelier Index (@ 4C)	-	-	N/A	-	-			-	-	-	-	-	-	-	-		-	-
Saturation pH (@ 20C)	-	-	N/A	-	-			-	-	-	-	-	-	-	-		-	-
Saturation pH (@ 4C)	-	-	N/A	-	-			-	-	-	-	-	-	-	-		-	-
Metals (ICP-MS)																		
Total Aluminum (Al)	-	5-100	µg/L	-	101			-	-	-	200	64	130	180	167	121	-	-
Total Antimony (Sb)	-	5-100	µg/L	-	<2			-	-	-	-	-	-	-	-		-	-
Total Arsenic (As)	-	5.00	µg/L	-	<2			-	0.1	0.2	-	-	-	0.3	0.3	0.26	-	-
Total Barium (Ba)	-	-	µg/L	-	16			-	-	-	-	-	-	16.4	16.9		-	-
Total Beryllium (Be)	-	-	µg/L	-	<2			-	-	-	-	-	-	0.027	0.023		-	-
Total Bismuth (Bi)	-	-	µg/L	-	<2			-	-	-	-	-	-	<0.01	<0.01		-	-
Total Cadmium (Cd)	-	0.02	µg/L	-	<0.017			-	0.14	0.13	-	-	-	0.16	0.123	0.041	-	-
Total Chromium (Cr)	-	1.00	µg/L	-	<1			-	-	-	-	-	-	0.21	0.19		-	-
Total Cobalt (Co)	-	-	µg/L	-	<1			-	-	-	-	-	-	0.93	0.85	0.374	-	-
Total Copper (Cu)	-	2.0-4.0	µg/L	-	2			-	3.6	2	0.01	<0.01	0.01	1.1	2.3	0.82	-	-
Total Lead (Pb)	-	1.0-7.0	µg/L	-	<0.5			-	-	-	-	-	-	0.25	0.3	0.27	-	-
Total Molybdenum (Mo)	-	73.00	µg/L	-	<2			-	-	-	-	-	-	<0.05	<0.05		-	-
Total Nickel (Ni)	-	25-150	µg/L	-	<2			-	-	-	-	-	-	2.2	2.1	1.18	-	-
Total Selenium (Se)	-	1.00	µg/L	-	<1			-	-	-	-	-	-	<1	<1		-	-
Total Silver (Ag)	-	0.10	µg/L	-	<0.1			-	-	-	-	-	-	<0.01	<0.01		-	-
Total Thallium (Tl)	-	0.80	µg/L	-	<0.1			-	-	-	-	-	-	<0.005	<0.005	<0.005	-	-
Total Tin (Sn)	-	-	µg/L	-	<2			-	-	-	-	-	-	-	-		-	-
Total Titanium (Ti)	-	-	µg/L	-	<2			-	-	-	-	-	-	1.1	1		-	-
Total Uranium (U)	-	-	µg/L	-	<0.1			-	0.02	0.039	-	-	-	0.012	0.014	0.0129	-	-
Total Vanadium (V)	-	-	µg/L	-	<2			-	0.41	0.92	-	-	-	0.27	0.23	0.23	-	-
Total Zinc (Zn)	-	30.00	µg/L	-	<5			-	23.7	22.1	0.04	<0.01	0.01	8.3	10.6	6.320	-	-
MICROBIOLOGICAL																		
Total coliform	-	-	MPN/100mL	-	1986	87	27	-	-	-	-	-	-	-	-		-	-
E. Coli	-	-	MPN/100mL	3	1	3	<1	-	-	-	-	-	-	-	-		-	-
Fecal Coliform	-	400	MPN/100mL	-	-			-	-	-	-	-	-	-	-		-	-
Fecal Coliform	-	-	CFU/100 ml	-	-			-	-	-	-	-	-	-	-		< 100	< 100
Chlorophyll A - Acidification method	-	-	µg/L	-	3.55	0.80	2.16	-	-	-	-	-	-	-	-		-	-
Chlorophyll A - Welschmeyer method	-	-	µg/L	-	-	0.80	2.07	-	-	-	-	-	-	-	-		-	-
Chlorophyll A	-	-	µg/L	-	-			-	0.93	-	-	2.3	-	0.66	0.85		-	-
Pheophytin A	-	-	µg chl eq/L	-	-			-	-	-	-	0.8	-	-	-		-	-
ORGANICS																		
Biochemical Oxygen Demand	-	-	(mg/L)	-				-	-	-	-	-	-	-	-		5.00	7.10
Disolved Organic Carbon	-	-	mg/L	-	8.2	8.1	0.5	-	-	-	-	-	-	-	-		-	-
Source	-	-	-		AECOM 2013 Sandy Lake and East Preston Sampling Program	AECOM 2013 Sandy Lake and East Preston Sampling Program	AECOM 2013 Sandy Lake and East Preston Sampling Program	DFO's Synoptic Water Quality Study of Fifty Lakes in the Halifax, NS Metro Area on 14 April 1980						DFO's Synoptic Water Quality Survey of Selected Halifax Regional Municipality Lakes on 28-29 March 2000		DFO's Synoptic Water Quality Survey of Selected HRM Lakes: 2011 Results	Halifax Water 's 2012/2013 Effluent Data	

SANDY LAKE WATERSHED STUDY - 2023 Sandy Lake Study Area Results

Stantec Consulting Ltd
Client Project #: 160410459
Site Location: HRM

Sampler Initials: NB

Bureau Veritas ID		VQE449	VXD437	WDX356	WKE141	WRO592	XAR256	XII935	XPQ843
Sampling Date		2023/04/24 17:10	5/24/2023 17:45	2023/06/20 16:50	2023/07/17 10:40	2023/08/15 10:15	2023/09/20 10:45	2023/10/19 09:40	2023/11/15 14:10
COC Number		N/A	N/A	938243-01-01	943089-01-01	948310-01-01	954351-01-01	N/A	C#963438-01-01
	UNITS	**SW-01**	**SW-01**	**SW-01**	**SW-01**	**SW-01**	**SW-01**	**SW-01**	**SW-01**
Microbiological									
Escherichia coli	CFU/100mL	<10	<10	10	100	30	200	200	<100
Total Coliforms	CFU/100mL	1200	1300	>2500	1400	>2500	3600	2000	1100
Inorganics									
Dissolved Chloride (Cl-	mg/L	140	100	95	77	54	40	50	59
Colour	TCU	20	20	23	40	37	41	31	26
Total Suspended Solids	mg/L	3.0	6.4	13	2	4	3	6.6	6.4
Turbidity	NTU	1.5	0.73	2.5	1.1	2.3	1.6	2.3	2
Total Phosphorous	mg/L	0.63	0.98	0.55	0.52	0.38	0.26	0.42	0.59

SANDY LAKE WATERSHED STUDY - 2023 Sandy Lake Study Area Results

Stantec Consulting Ltd
Client Project #: 160410459
Site Location: HRM

Sampler Initials: NB

Bureau Veritas ID		VQE450	VXD438	WDX357	WKE142	WRO593	XAR257	XII937	XPQ844
Sampling Date		2023/04/24 18:05	5/25/2023 17:25	2023/06/20 16:30	2023/07/17 10:10	2023/08/15 09:45	2023/09/20 10:20	2023/10/19 10:20	2023/11/15 14:00
COC Number		N/A	N/A	938243-01-01	943089-01-01	948310-01-01	954351-01-01	N/A	C#963438-01-01
	UNITS	**SW-03**	**SW-03**	**SW-03**	**SW-03**	**SW-03**	**SW-03**	**SW-03**	**SW-03**
Microbiological									
Escherichia coli	CFU/100mL	10	<10	10	20	80	<100	100	<100
Total Coliforms	CFU/100mL	370	340	810	1500	950	1600	900	500
Inorganics									
Dissolved Chloride (Cl-	mg/L	34	29	18	14	15	13	17	13
Colour	TCU	44	49	120	180	170	110	96	62
Total Suspended Solids	mg/L	<1.0	<1.0	<1.0	1.2	1	1.6	2	<1.0
Turbidity	NTU	0.36	0.44	0.71	0.94	2.3	2.2	1.5	1.3
Total Phosphorous	mg/L	0.014	0.021	0.019	0.033	0.024	0.017	<0.020	0.011

SANDY LAKE WATERSHED STUDY -
2023 Sandy Lake Study Area Results

Stantec Consulting Ltd
Client Project #: 160410459
Site Location: HRM

Sampler Initials: NB

Bureau Veritas ID		VQE452	VXD439	WDX358	WKE143	WRO594	XAR258	XII936	XPQ845
Sampling Date		2023/04/24 17:30	5/24/2023 18:05	2023/06/20 17:20	2023/07/17 11:00	2023/08/15 10:40	2023/09/20 11:20	2023/10/19 10:00	2023/11/15 13:40
COC Number		N/A	N/A	938243-01-01	943089-01-01	948310-01-01	954351-01-01	N/A	C#963438-01-01
	UNITS	**SW-04**	**SW-04**	**SW-04**	**SW-04**	**SW-04**	**SW-04**	**SW-04**	**SW-04**
Microbiological									
Escherichia coli	CFU/100mL	<10	20	70	530	30	1300	100	<100
Total Coliforms	CFU/100mL	480	850	1000	970	380	2300	1300	500
Inorganics									
Dissolved Chloride (Cl-	mg/L	36	37	33	27	26	20	25	24
Colour	TCU	21	33	52	200	210	150	170	130
Total Suspended Solid	mg/L	<1.0	1.2	1.2	5.2	7	8	10	<5.0
Turbidity	NTU	1.2	1.1	0.88	12	16	9	25	18
Total Phosphorous	mg/L	0.007	0.02	0.019	0.042	0.04	0.033	0.038	0.016

SANDY LAKE WATERSHED STUDY - 2023 Sandy Lake Study Area Results

Stantec Consulting Ltd
Client Project #: 160410459
Site Location: HRM

Sampler Initials: NB

Bureau Veritas ID		VQE453	VXD440	WDX359	WKE144	WRO595	XAR259	XKJ128	XPQ846
Sampling Date		2023/04/24 15:21	2023/05/24 16:35	2023/06/20 15:30	2023/07/17 09:00	2023/08/15 08:20	2023/09/20 09:25	2023/10/26 13:20	2023/11/16 10:50
COC Number		N/A	N/A	938243-01-01	943089-01-01	948310-01-01	954351-01-01	N/A	C#963438-01-01
	UNITS	**SW-05**	**SW-05**	**SW-05**	**SW-05**	**SW-05**	**SW-05**	**SW-05**	**SW-05**
Microbiological									
Escherichia coli	CFU/100mL	<10	10	20	80	<10	100	<100	<100
Total Coliforms	CFU/100mL	80	660	400	260	30	1200	<100	1000
Inorganics									
Dissolved Chloride (Cl-	mg/L	49	47	44	34	21	24	26	21
Colour	TCU	32	27	40	77	92	96	75	100
Total Suspended Solid	mg/L	1	2.8	1.4	1.2	1.4	1.8	1.2	2.4
Turbidity	NTU	0.93	0.97	1.1	1.1	1.4	2.2	1.6	10
Total Phosphorous	mg/L	0.004	<0.020	0.009	0.013	0.013	0.014	<0.020	0.022

SANDY LAKE WATERSHED STUDY - 2023 Sandy Lake Study Area Results

Stantec Consulting Ltd
Client Project #: 160410459
Site Location: HRM

Sampler Initials: NB

Bureau Veritas ID		VQE454	VXD441	WDX360	WKE145	WRO596	XAR260	XKJ129	XPQ847
Sampling Date		2023/04/24 15:32	2023/05/24 16:25	2023/06/20 15:42	2023/07/17 09:05	2023/08/15 08:25	2023/09/20 09:15	2023/10/26 13:10	2023/11/16 11:00
COC Number		N/A	N/A	938243-01-01	943089-01-01	948310-01-01	954351-01-01	N/A	C#963438-01-01
	UNITS	**SW-06**	**SW-06**	**SW-06**	**SW-06**	**SW-06**	**SW-06**	**SW-06**	**SW-06**
Microbiological									
Escherichia coli	CFU/100mL	10	10	200	420	80	2200	<100	<100
Total Coliforms	CFU/100mL	1300	1000	1100	1100	410	3700	100	<100
Inorganics									
Dissolved Chloride (Cl-	mg/L	32	31	26	22	20	18	27	29
Colour	TCU	25	40	85	240	200	150	84	63
Total Suspended Solids	mg/L	1.2	1.6	1.4	7.2	4	5.4	1.2	1.8
Turbidity	NTU	0.81	0.58	1.4	5.7	10	4.9	1.4	2.9
Total Phosphorous	mg/L	0.006	<0.020	0.017	0.031	0.033	0.02	<0.020	0.009

SANDY LAKE WATERSHED STUDY -
2023 Sandy Lake Study Area Results

Stantec Consulting Ltd
Client Project #: 160410459
Site Location: HRM

Sampler Initials: NB

Bureau Veritas ID		VQE455	VXD442	WDX361	WKE146	WRO597	XAR261	XKJ127	XPQ848
Sampling Date		2023/04/24 14:45	2023/05/24 15:00	2023/06/20 14:42	2023/07/17 08:20	2023/08/15 07:50	2023/09/20 08:00	2023/10/26 12:50	2023/11/16 10:20
COC Number		N/A	N/A	938243-01-01	943089-01-01	948310-01-01	954351-01-01	N/A	C#963438-01-01
	UNITS	**SW-07**	**SW-07**	**SW-07**	**SW-07**	**SW-07**	**SW-07**	**SW-07**	**SW-07**
Microbiological									
Escherichia coli	CFU/100mL	<10	<10	20	10	10	<100	<100	<100
Total Coliforms	CFU/100mL	20	60	240	140	60	300	200	<100
Inorganics									
Dissolved Chloride (Cl-	mg/L	47	47	45	33	20	24	**27**	30
Colour	TCU	32	29	36	72	96	100	**76**	75
Total Suspended Solid	mg/L	1.0000	1.0	<1.0	1.6	1.2	2.2	1.8	2
Turbidity	NTU	1.4	1.1	1.4	1	1.8	2.4	**2**	2.6
Total Phosphorous	mg/L	0.006	<0.020	0.005	0.018	0.013	0.015	<0.020	0.012

*bolded taken from full sample results (oct.)

SANDY LAKE WATERSHED STUDY -
2023 Sandy Lake Study Area Results

Stantec Consulting Ltd
Client Project #: 160410459
Site Location: HRM

Sampler Initials: NB

Bureau Veritas ID		VQE456	VXD443	WDX363	WKE148	WRO599	XAR263	XII939	XPQ850
Sampling Date		2023/04/24 16:11	2023/05/24 16:50	2023/06/20 14:00	2023/07/17 09:50	2023/08/15 09:00	2023/09/20 09:30	2023/10/19 10:55	2023/11/15 14:30
COC Number		N/A	N/A	938243-01-01	943089-01-01	948310-01-01	954351-01-01	N/A	C#963438-01-01
	UNITS	**SW-08**	**SW-08**	**SW-08**	**SW-08**	**SW-08**	**SW-08**	**SW-08**	**SW-08**
Microbiological									
Escherichia coli	CFU/100mL	10	30	140	120	160	400	<100	<100
Total Coliforms	CFU/100mL	540	630	1100	650	470	2200	800	600
Inorganics									
Dissolved Chloride (Cl-	mg/L	79	69	35	36	23	19	27	32
Colour	TCU	33	37	83	130	130	98	63	48
Total Suspended Solids	mg/L	1.0	3.0	1.6	1.6	1.2	1.8	<1.0	2.8
Turbidity	NTU	1.3	1.4	1	2	1.9	2	1.4	1.9
Total Phosphorous	mg/L	0.008	0.026	0.024	0.028	0.025	0.017	<0.020	0.009

SANDY LAKE WATERSHED STUDY - 2023 Sandy Lake Study Area Results

Stantec Consulting Ltd
Client Project #: 160410459
Site Location: HRM

Sampler Initials: NB

Bureau Veritas ID		VQE457	VXD444	WDX364	WKE149	WRO600	XAR264	XII938	XPQ851
Sampling Date		2023/04/24 16:30	2023/05/24 17:00	2023/06/20 16:10	2023/07/17 11:30	2023/08/15 09:20	2023/09/20 10:10	2023/10/19 10:35	2023/11/15 14:20
COC Number		N/A	N/A	938243-01-01	943089-01-01	948310-01-01	954351-01-01	N/A	C#963438-01-01
	UNITS	**SW-09**	**SW-09**	**SW-09**	**SW-09**	**SW-09**	**SW-09**	**SW-09**	**SW-09**
Microbiological									
Escherichia coli	CFU/100mL	540	120	190	50	40	100	100	300
Total Coliforms	CFU/100mL	950	680	1200	800	560	2000	700	400
Inorganics									
Dissolved Chloride (Cl-	mg/L	110	93	50	44	26	22	30	40
Colour	TCU	19	25	95	100	120	76	50	25
Total Suspended Solids	mg/L	<1.0	<1.0	<1.0	1	1.2	2.8	1.2	<1.0
Turbidity	NTU	0.25	0.23	1	1.5	1.9	5.4	2.1	<0.10
Total Phosphorous	mg/L	<0.004	<0.020	0.018	0.023	0.018	0.011	<0.020	0.005

SANDY LAKE WATERSHED STUDY - 2023 Sandy Lake Study Area Results

Stantec Consulting Ltd
Client Project #: 160410459
Site Location: HRM

Sampler Initials: NB

Bureau Veritas ID		VQE458	VXD445	WDX362	WKE147	WRO598	XAR262	XKJ126	XPQ849
Sampling Date		2023/04/24 15:00	2023/05/24 15:15	2023/06/20 14:50	2023/07/17 08:20	2023/08/15 07:50	2023/09/20 08:30	2023/10/26 12:45	2023/11/16 10:30
COC Number		N/A	N/A	938243-01-01	943089-01-01	948310-01-01	954351-01-01	N/A	C#963438-01-01
	UNITS	**SANDYLK**	**SANDYLK**	**Sandy Lk**	**Sandy Lk**	**Sandy Lk**	**Sandy Lk**	**SANDY LK**	**SANDY LK**
Microbiological									
Escherichia coli	CFU/100mL	<10	<10	<10	10	10	<100	<100	<100
Total Coliforms	CFU/100mL	20	110	270	50	20	100	100	<100
Inorganics									
Dissolved Chloride (Cl-)	mg/L	48	46	44	41	40	41	33	30
Colour	TCU	26	31	39	46	46	58	73	72
Total Suspended Solids	mg/L	2.2	35	1.6	12	1	39	2	<2.9 (1)
Turbidity	NTU	1.1	6.1	0.83	1.8	1.1	8.4	3.7	2.8
Total Phosphorous	mg/L	0.006	0.05	0.009	0.024	0.007	0.034	<0.020	0.006

Appendix B Nutrient Loading Model Results

Sandy Lake - Existing Conditions

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (Excl of Lake Area)	Ad	1768.8308	ha
Area Land Use Category 1- Commercial	Ad1	128.2276	ha
Area Land Use Category 2- Forest	Ad2	1104.843	ha
Area Land Use Category 3- Undeveloped/Grassed	Ad3	93.49242	ha
Area Land Use Category 4- Low Density Residential	Ad4	221.5319	ha
Area Land Use Category 5- Medium Density Residential	Ad5	23.61412	ha
Area Land Use Category 6 - Institutional	Ad6	9.705005	ha
Area Land Use Category 7- Road	Ad7	45.89832	ha
Area Land Use Category 8- Wetland	Ad8	53.03255952	ha
Area Land Use Category 9- Agriculture	Ad9	9.789741107	ha
Area Land Use Category 10- High Density Residential	Ad10	0	ha
Lake Surface Area	Ao	78.5	ha
Lake Volume	V	6.08	10^6 m3
Hydrology Inputs			
Upstream Hydraulic Inputs	Qi	0	m^3/yr
Annual Unit Precipitation	Pr	1.396	m/yr
Annual Unit Lake Evaporation	Ev	0.516	m^3/yr
Point Source Hydraulic Input	Qps	0	m^3/yr
Annual Unit Hydraulic Run Off - Developed	Ruv	1.1	m/yr
Annual Unit Hydraulic Run Off - Non- Developed	Ru	1.02	m/yr
Phosphorus Inputs			
Upstream P input	Ju	0	gm P / yr
Annual Unit Atmospheric Phosphorus Deposition	Da	0.017	gm P / M^2 * yr
Land Use Category 1 P Export Coefficient	E1	0.0202	gm P / M^2 * yr
Land Use Category 2 P Export Coefficient	E2	0.0024	gm P / M^2 * yr
Land Use Category 3 P Export Coefficient	E3	0.015	gm P / M^2 * yr
Land Use Catefory 4 P Export Coefficient	E4	0.025	gm P / M^2 * yr
Land Use Category 5 P Export Coefficient	E5	0.042	gm P / M^2 * yr
Land Use Category 6 P Export Coefficient	E6	0.03	gm P / M^2 * yr
Land Use Category 7 P Export Coefficient	E7	0.35	gm P / M^2 * yr
Land Use Category 8 P Export Coefficient	E8	0.0024	gm P / M^2 * yr
Land Use Category 9 P Export Coefficient	E9	0.0108	gm P / M^2 * yr
Land Use Category 10 P Export Coefficient	E10	0.035	gm P / M^2 * yr
Number of Dwellings	Nd	12	#
Average number of persons per dwelling	Nu	2.2	#
Average fraction of Year Dwellings occupied	Npc	1	/yr
Phosphorus load per capita per year	Si	800	gm / capita/yr
Septic system retention coefficient	Rsp	0.5	n/a
Point Source Input 1	PS1	0	gm/yr
Point Source Input 2	PS2	0	gm/yr
Point Source Input 3	PS3	0	gm/yr
Point Source Inpit 4	PS4	0	gm/yr
Lake Phosphorus Retention Coefficient	v	12.4	n/a
Model Outputs			
Total Precipitation Hydraulic Input	Ppti	1095860	m3/yr
Total Evaporation Hydraulic Loss	Eo	404667.5	m3/yr
Total Hydraulic Surface Runoff	Ql	13289376.77	m3/yr
Total Hydraulic Input	Qt	14385237	m3/yr
Areal Hydraulic Input	qs	17.81	m3/yr
Total Hydraulic Outflow	Qo	13980569	m3/yr
Total Atmospheric P Input	Jd	13345	gm/yr
Total Surface Run Off P Input	Je	297629	gm/yr
Total Development P Input	Jr	10560	gm/yr
Total P Input	Jt	321534	gm/yr
Lake P Retention Factor	Rp	0.41	-
Lake P Retention	Ps	131829	gm/yr
Predicted Lake P Concentration	[P]	**0.0136**	mg/L
Lake P Outflow	Jo	189705	gm/yr
Lake Mean Depth	z	7.7	m
Lake Flushing Rate	FR	0.43	times/year
Lake Turnover Time	TT	2.3	yr
Lake Response Time	RT(1/2)	0.19	yr

Budgets		
Hydraulic Budget (m^3)		
		% Total
Upstream Flow	0	
Precipitation	1095860	7.62
Surface Runoff	13289377	92.38
Evaporation	-404667.5	2.81
Total Outflow	13980569	97.19
Check		100
Phosphorus Budget (gm)		
		% Total
Upstream Flow	0	0
Atmospheric	13345	4.15
Land Run off	297629	92.57
Development	10560	3.28
Sedimentation	-131829	41
Total Outflow	189705	58.999981
Check		100.0
Model Validation		
Predicted P (mg/L)	0.0136	
Measured P (mg/L)	0.013	
%Difference	4.511	

Sandy Lake - Developer Requested Conditions

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (Excl of Lake Area)	Ad	1768.8308	ha
Area Land Use Category 1- Commercial	Ad1	182.455693	ha
Area Land Use Category 2- Forest	Ad2	931.9184645	ha
Area Land Use Category 3- Undeveloped/Grassed	Ad3	93.49242	ha
Area Land Use Category 4- Low Density Residential	Ad4	228.1141383	ha
Area Land Use Category 5- Medium Density Residential	Ad5	37.34880095	ha
Area Land Use Category 6 - Institutional	Ad6	25.5347519	ha
Area Land Use Category 7- Road	Ad7	61.91832	ha
Area Land Use Category 8- Wetland	Ad8	53.03255952	ha
Area Land Use Category 9- Agriculture	Ad9	9.789741107	ha
Area Land Use Category 10- High Density Residential	Ad10	66.52977633	ha
Lake Surface Area	Ao	78.5	ha
Lake Volume	V	6.08	10^6 m3
Hydrology Inputs			
Upstream Hydraulic Inputs	Qi	0	m^3/yr
Annual Unit Precipitation	Pr	1.396	m/yr
Annual Unit Lake Evaporation	Ev	0.511	m^3/yr
Point Source Hydraulic Input	Qps	0	m^3/yr
Annual Unit Hydraulic Run Off - Developed	Ruv	1.1	m/yr
Annual Unit Hydraulic Run Off - Non- Developed	Ru	1.02	m/yr
Phosphorus Inputs			
Upstream P input	Ju	0	gm P / yr
Annual Unit Atmospheric Phosphorus Deposition	Da	0.017	gm P / M^2 * yr
Land Use Category 1 P Export Coefficient	E1	0.0202	gm P / M^2 * yr
Land Use Category 2 P Export Coefficient	E2	0.0024	gm P / M^2 * yr
Land Use Category 3 P Export Coefficient	E3	0.015	gm P / M^2 * yr
Land Use Catefory 4 P Export Coefficient	E4	0.025	gm P / M^2 * yr
Land Use Category 5 P Export Coefficient	E5	0.042	
Land Use Category 6 P Export Coefficient	E6	0.03	
Land Use Category 7 P Export Coefficient	E7	0.35	
Land Use Category 8 P Export Coefficient	E8	0.0024	
Land Use Category 9 P Export Coefficient	E9	0.0108	
Land Use Category 10 P Export Coefficient	E10	0.035	
Number of Dwellings	Nd	12	#
Average number of persons per dwelling	Nu	2.2	#
Average fraction of Year Dwellings occupied	Npc	1	/yr
Phosphorus load per capita per year	Si	800	gm / capita/yr
Septic system retention coefficient	Rsp	0.5	n/a
Point Source Input 1	PS1	0	gm/yr
Point Source Input 2	PS2	0	gm/yr
Point Source Input 3	PS3	0	gm/yr
Point Source Inpit 4	PS4	0	gm/yr
Lake Phosphorus Retention Coefficient	v	12.4	n/a
Model Outputs			
Total Precipitation Hydraulic Input	Ppti	1095860	m3/yr
Total Evaporation Hydraulic Loss	Eo	400742.5	m3/yr
Total Hydraulic Surface Runoff	Ql	11387206.88	m3/yr
Total Hydraulic Input	Qt	12483067	m3/yr
Areal Hydraulic Input	qs	15.39	m3/yr
Total Hydraulic Outflow	Qo	12082324	m3/yr
Total Atmospheric P Input	Jd	13345	gm/yr
Total Surface Run Off P Input	Je	395951	gm/yr
Total Development P Input	Jr	10560	gm/yr
Total P Input	Jt	419856	gm/yr
Lake P Retention Factor	Rp	0.45	-
Lake P Retention	Ps	188935	gm/yr
Predicted Lake P Concentration	[P]	**0.0191**	mg/L
Lake P Outflow	Jo	230921	gm/yr
Lake Mean Depth	z	7.7	m
Lake Flushing Rate	FR	0.5	times/year
Lake Turnover Time	TT	1.99	yr
Lake Response Time	RT(1/2)	0.21	yr

Budgets

Hydraulic Budget (m^3)		
		% Total
Upstream Flow	0	
Precipitation	1095860	8.78
Surface Runoff	11387207	91.22
Evaporation	-400742.5	3.21
Total Outflow	12082324	96.79
Check		100
Phosphorus Budget (gm)		
		% Total
Upstream Flow	0	0
Atmospheric	13345	3.18
Land Run off	395951	94.31
Development	10560	2.52
Sedimentation	-188935	45
Total Outflow	230921	55.000048
Check		100.01
Model Validation		
Predicted P (mg/L)	0.0191	
Measured P (mg/L)	n/a	
%Difference		

Sandy Lake - Areal Land Use Scenario

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (Excl of Lake Area)	Ad	1768.8308	ha
Area Land Use Category 1- Commercial	Ad1	171.6100744	ha
Area Land Use Category 2- Forest	Ad2	963.2993716	ha
Area Land Use Category 3- Undeveloped/Grassed	Ad3	93.49242	ha
Area Land Use Category 4- Low Density Residential	Ad4	226.7976906	ha
Area Land Use Category 5- Medium Density Residential	Ad5	34.60186476	ha
Area Land Use Category 6 - Institutional	Ad6	22.36880252	ha
Area Land Use Category 7- Road	Ad7	61.91832	ha
Area Land Use Category 8- Wetland	Ad8	53.03255952	ha
Area Land Use Category 9- Agriculture	Ad9	9.789741107	ha
Area Land Use Category 10- High Density Residential	Ad10	53.22382107	ha
Lake Surface Area	Ao	78.5	ha
Lake Volume	V	6.08	10^6 m3
Hydrology Inputs			
Upstream Hydraulic Inputs	Qi	0	m^3/yr
Annual Unit Precipitation	Pr	1.396	m/yr
Annual Unit Lake Evaporation	Ev	0.511	m^3/yr
Point Source Hydraulic Input	Qps	0	m^3/yr
Annual Unit Hydraulic Run Off - Developed	Ruv	1.1	m/yr
Annual Unit Hydraulic Run Off - Non- Developed	Ru	1.02	m/yr
Phosphorus Inputs			
Upstream P input	Ju	0	gm P / yr
Annual Unit Atmospheric Phosphorus Deposition	Da	0.017	gm P / M^2 * yr
Land Use Category 1 P Export Coefficient	E1	0.0202	gm P / M^2 * yr
Land Use Category 2 P Export Coefficient	E2	0.0024	gm P / M^2 * yr
Land Use Category 3 P Export Coefficient	E3	0.015	gm P / M^2 * yr
Land Use Catefory 4 P Export Coefficient	E4	0.025	gm P / M^2 * yr
Land Use Category 5 P Export Coefficient	E5	0.042	
Land Use Category 6 P Export Coefficient	E6	0.03	
Land Use Category 7 P Export Coefficient	E7	0.35	
Land Use Category 8 P Export Coefficient	E8	0.0024	
Land Use Category 9 P Export Coefficient	E9	0.0108	
Land Use Category 10 P Export Coefficient	E10	0.035	
Number of Dwellings	Nd	12	#
Average number of persons per dwelling	Nu	2.2	#
Average fraction of Year Dwellings occupied	Npc	1	/yr
Phosphorus load per capita per year	Si	800	gm / capita/yr
Septic system retention coefficient	Rsp	0.5	n/a
Point Source Input 1	PS1	0	gm/yr
Point Source Input 2	PS2	0	gm/yr
Point Source Input 3	PS3	0	gm/yr
Point Source Inpit 4	PS4	0	gm/yr
Lake Phosphorus Retention Coefficient	v	12.4	n/a
Model Outputs			
Total Precipitation Hydraulic Input	Ppti	1095860	m3/yr
Total Evaporation Hydraulic Loss	Eo	400742.5	m3/yr
Total Hydraulic Surface Runoff	Ql	11732396.86	m3/yr
Total Hydraulic Input	Qt	12828257	m3/yr
Areal Hydraulic Input	qs	15.83	m3/yr
Total Hydraulic Outflow	Qo	12427514	m3/yr
Total Atmospheric P Input	Jd	13345	gm/yr
Total Surface Run Off P Input	Je	387424	gm/yr
Total Development P Input	Jr	10560	gm/yr
Total P Input	Jt	411329	gm/yr
Lake P Retention Factor	Rp	0.44	-
Lake P Retention	Ps	180985	gm/yr
Predicted Lake P Concentration	[P]	**0.0185**	mg/L
Lake P Outflow	Jo	230344	gm/yr
Lake Mean Depth	z	7.7	m
Lake Flushing Rate	FR	0.49	times/year
Lake Turnover Time	TT	2.04	yr
Lake Response Time	RT(1/2)	0.21	yr

Budgets

Hydraulic Budget (m^3)		
		% Total
Upstream Flow	0	
Precipitation	1095860	8.54
Surface Runoff	11732397	91.46
Evaporation	-400742.5	3.12
Total Outflow	12427514	96.88
Check		100

Phosphorus Budget (gm)		
		% Total
Upstream Flow	0	0
Atmospheric	13345	3.24
Land Run off	387424	94.19
Development	10560	2.57
Sedimentation	-180985	44
Total Outflow	230344	55.999942
Check		100.0

Model Validation		
Predicted P (mg/L)	0.0185	
Measured P (mg/L)	n/a	
%Difference		

Sandy Lake - Low Density Conditions

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (Excl of Lake Area)	Ad	1768.8308	ha
Area Land Use Category 1- Commercial	Ad1	182.455693	ha
Area Land Use Category 2- Forest	Ad2	878.1529291	ha
Area Land Use Category 3- Undeveloped/Grassed	Ad3	93.49242	ha
Area Land Use Category 4- Low Density Residential	Ad4	310.4841834	ha
Area Land Use Category 5- Medium Density Residential	Ad5	91.10381451	ha
Area Land Use Category 6 - Institutional	Ad6	9.705005	ha
Area Land Use Category 7- Road	Ad7	61.91832	ha
Area Land Use Category 8- Wetland	Ad8	53.03255952	ha
Area Land Use Category 9- Agriculture	Ad9	9.789741107	ha
Area Land Use Category 10- High Density Residential	Ad10	0	ha
Lake Surface Area	Ao	78.5	ha
Lake Volume	V	6.08	10^6 m3
Hydrology Inputs			
Upstream Hydraulic Inputs	Qi	0	m^3/yr
Annual Unit Precipitation	Pr	1.396	m/yr
Annual Unit Lake Evaporation	Ev	0.511	m^3/yr
Point Source Hydraulic Input	Qps	0	m^3/yr
Annual Unit Hydraulic Run Off - Developed	Ruv	1.1	m/yr
Annual Unit Hydraulic Run Off - Non- Developed	Ru	1.02	m/yr
Phosphorus Inputs			
Upstream P input	Ju	0	gm P / yr
Annual Unit Atmospheric Phosphorus Deposition	Da	0.017	gm P / M^2 * yr
Land Use Category 1 P Export Coefficient	E1	0.0202	gm P / M^2 * yr
Land Use Category 2 P Export Coefficient	E2	0.0024	gm P / M^2 * yr
Land Use Category 3 P Export Coefficient	E3	0.015	gm P / M^2 * yr
Land Use Catefory 4 P Export Coefficient	E4	0.025	gm P / M^2 * yr
Land Use Category 5 P Export Coefficient	E5	0.042	gm P / M^2 * yr
Land Use Category 6 P Export Coefficient	E6	0.03	gm P / M^2 * yr
Land Use Category 7 P Export Coefficient	E7	0.35	gm P / M^2 * yr
Land Use Category 8 P Export Coefficient	E8	0.0024	gm P / M^2 * yr
Land Use Category 9 P Export Coefficient	E9	0.0108	gm P / M^2 * yr
Land Use Category 10 P Export Coefficient	E10	0.035	gm P / M^2 * yr
Number of Dwellings	Nd	12	#
Average number of persons per dwelling	Nu	2.2	#
Average fraction of Year Dwellings occupied	Npc	1	/yr
Phosphorus load per capita per year	Si	800	gm / capita/yr
Septic system retention coefficient	Rsp	0.5	n/a
Point Source Input 1	PS1	0	gm/yr
Point Source Input 2	PS2	0	gm/yr
Point Source Input 3	PS3	0	gm/yr
Point Source Inpit 4	PS4	0	gm/yr
Lake Phosphorus Retention Coefficient	v	12.4	n/a
Model Outputs			
Total Precipitation Hydraulic Input	Ppti	1095860	m3/yr
Total Evaporation Hydraulic Loss	Eo	400742.5	m3/yr
Total Hydraulic Surface Runoff	Ql	10795785.99	m3/yr
Total Hydraulic Input	Qt	11891646	m3/yr
Areal Hydraulic Input	qs	14.64	m3/yr
Total Hydraulic Outflow	Qo	11490903	m3/yr
Total Atmospheric P Input	Jd	13345	gm/yr
Total Surface Run Off P Input	Je	409796	gm/yr
Total Development P Input	Jr	10560	gm/yr
Total P Input	Jt	433701	gm/yr
Lake P Retention Factor	Rp	0.46	-
Lake P Retention	Ps	199502	gm/yr
Predicted Lake P Concentration	[P]	**0.0204**	mg/L
Lake P Outflow	Jo	234199	gm/yr
Lake Mean Depth	z	7.7	m
Lake Flushing Rate	FR	0.53	times/year
Lake Turnover Time	TT	1.89	yr
Lake Response Time	RT(1/2)	0.22	yr

Budgets

Hydraulic Budget (m^3)

		% Total
Upstream Flow	0	
Precipitation	1095860	9.22
Surface Runoff	10795786	90.78
Evaporation	-400742.5	3.37
Total Outflow	11490903	96.63
Check		100

Phosphorus Budget (gm)

		% Total
Upstream Flow	0	0
Atmospheric	13345	3.08
Land Run off	409796	94.49
Development	10560	2.43
Sedimentation	-199502	46
Total Outflow	234199	54.0
Check		100

Model Validation

Predicted P (mg/L)	0.0204	
Measured P (mg/L)	n/a	
%Difference	n/a	

Sandy Lake - High Density Conditions

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (Excl of Lake Area)	Ad	1768.8308	ha
Area Land Use Category 1- Commercial	Ad1	182.455693	ha
Area Land Use Category 2- Forest	Ad2	855.6337018	ha
Area Land Use Category 3- Undeveloped/Grassed	Ad3	93.49242	ha
Area Land Use Category 4- Low Density Residential	Ad4	226.4727268	ha
Area Land Use Category 5- Medium Density Residential	Ad5	34.72764156	ha
Area Land Use Category 6 - Institutional	Ad6	9.705005	ha
Area Land Use Category 7- Road	Ad7	61.91832	ha
Area Land Use Category 8- Wetland	Ad8	53.03255952	ha
Area Land Use Category 9- Agriculture	Ad9	9.789741107	ha
Area Land Use Category 10- High Density Residential	Ad10	162.9068569	ha
Lake Surface Area	Ao	78.5	ha
Lake Volume	V	6.08	10^6 m3
Hydrology Inputs			
Upstream Hydraulic Inputs	Qi	0	m^3/yr
Annual Unit Precipitation	Pr	1.396	m/yr
Annual Unit Lake Evaporation	Ev	0.511	m^3/yr
Point Source Hydraulic Input	Qps	0	m^3/yr
Annual Unit Hydraulic Run Off - Developed	Ruv	1.1	m/yr
Annual Unit Hydraulic Run Off - Non- Developed	Ru	1.02	m/yr
Phosphorus Inputs			
Upstream P input	Ju	0	gm P / yr
Annual Unit Atmospheric Phosphorus Deposition	Da	0.017	gm P / M^2 * yr
Land Use Category 1 P Export Coefficient	E1	0.0202	gm P / M^2 * yr
Land Use Category 2 P Export Coefficient	E2	0.0024	gm P / M^2 * yr
Land Use Category 3 P Export Coefficient	E3	0.015	gm P / M^2 * yr
Land Use Catefory 4 P Export Coefficient	E4	0.025	gm P / M^2 * yr
Land Use Category 5 P Export Coefficient	E5	0.042	
Land Use Category 6 P Export Coefficient	E6	0.03	
Land Use Category 7 P Export Coefficient	E7	0.35	
Land Use Category 8 P Export Coefficient	E8	0.0024	
Land Use Category 9 P Export Coefficient	E9	0.0108	
Land Use Category 10 P Export Coefficient	E10	0.035	
Number of Dwellings	Nd	12	#
Average number of persons per dwelling	Nu	2.2	#
Average fraction of Year Dwellings occupied	Npc	1	/yr
Phosphorus load per capita per year	Si	800	gm / capita/yr
Septic system retention coefficient	Rsp	0.5	n/a
Point Source Input 1	PS1	0	gm/yr
Point Source Input 2	PS2	0	gm/yr
Point Source Input 3	PS3	0	gm/yr
Point Source Inpit 4	PS4	0	gm/yr
Lake Phosphorus Retention Coefficient	v	12.4	n/a
Model Outputs			
Total Precipitation Hydraulic Input	Ppti	1095860	m3/yr
Total Evaporation Hydraulic Loss	Eo	400742.5	m3/yr
Total Hydraulic Surface Runoff	Ql	10548074.49	m3/yr
Total Hydraulic Input	Qt	11643934	m3/yr
Areal Hydraulic Input	qs	14.32	m3/yr
Total Hydraulic Outflow	Qo	11243192	m3/yr
Total Atmospheric P Input	Jd	13345	gm/yr
Total Surface Run Off P Input	Je	421592	gm/yr
Total Development P Input	Jr	10560	gm/yr
Total P Input	Jt	445497	gm/yr
Lake P Retention Factor	Rp	0.46	-
Lake P Retention	Ps	204929	gm/yr
Predicted Lake P Concentration	[P]	**0.0214**	mg/L
Lake P Outflow	Jo	240568	gm/yr
Lake Mean Depth	z	7.7	m
Lake Flushing Rate	FR	0.54	times/year
Lake Turnover Time	TT	1.85	yr
Lake Response Time	RT(1/2)	0.22	yr

Budgets

Hydraulic Budget (m^3)

		% Total
Upstream Flow	0	
Precipitation	1095860	9.41
Surface Runoff	10548074	90.59
Evaporation	-400742.5	3.44
Total Outflow	11243192	96.56
Check		100

Phosphorus Budget (gm)

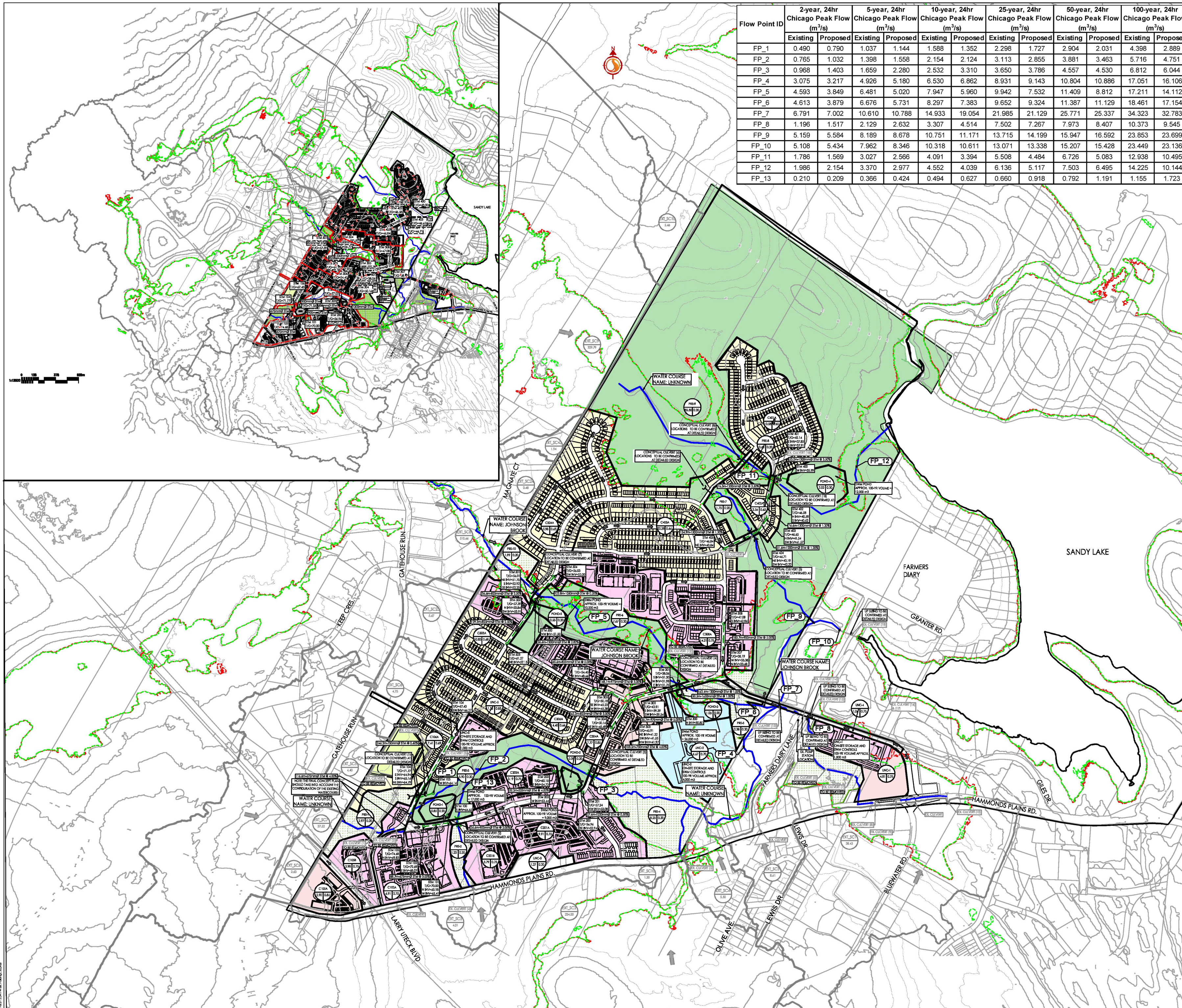
		% Total
Upstream Flow	0	0
Atmospheric	13345	3
Land Run off	421592	94.63
Development	10560	2.37
Sedimentation	-204929	46
Total Outflow	240568	53.9999147
Check		100

Model Validation

Predicted P (mg/L)	0.0214	
Measured P (mg/L)	n/a	
%Difference		

Appendix C Storm Drainage Drawings

Flow Point ID	2-year, 24hr Chicago Peak Flow (m^3/s)		5-year, 24hr Chicago Peak Flow (m^3/s)		10-year, 24hr Chicago Peak Flow (m^3/s)		25-year, 24hr Chicago Peak Flow (m^3/s)		50-year, 24hr Chicago Peak Flow (m^3/s)		100-year, 24hr Chicago Peak Flow (m^3/s)	
	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
FP_1	0.490	0.790	1.037	1.144	1.588	1.352	2.298	1.727	2.904	2.031	4.398	2.889
FP_2	0.765	1.032	1.398	1.558	2.154	2.124	3.113	2.855	3.881	3.463	5.716	4.751
FP_3	0.968	1.403	1.659	2.280	2.532	3.310	3.650	3.786	4.557	4.530	6.812	6.044
FP_4	3.075	3.217	4.926	5.180	6.530	6.862	8.931	9.143	10.804	10.886	17.051	16.106
FP_5	4.593	3.849	6.481	5.020	7.947	5.960	9.942	7.532	11.409	8.812	17.211	14.112
FP_6	4.613	3.879	6.676	5.731	8.297	7.383	9.652	9.324	11.387	11.129	18.461	17.154
FP_7	6.791	7.002	10.610	10.788	14.933	19.054	21.985	21.129	25.771	25.337	34.323	32.783
FP_8	1.196	1.517	2.129	2.632	3.307	4.514	7.502	7.267	7.973	8.407	10.373	9.545
FP_9	5.159	5.584	8.189	8.678	10.751	11.171	13.715	14.199	15.947	16.592	23.853	23.699
FP_10	5.108	5.434	7.962	8.346	10.318	10.611	13.071	13.338	15.207	15.428	23.449	23.136
FP_11	1.786	1.569	3.027	2.566	4.091	3.394	5.508	4.484	6.726	5.083	12.938	10.495
FP_12	1.986	2.154	3.370	2.977	4.552	4.039	6.136	5.117	7.503	6.495	14.225	10.144
FP_13	0.210	0.209	0.366	0.424	0.494	0.627	0.660	0.918	0.792	1.191	1.155	1.723



Stantec

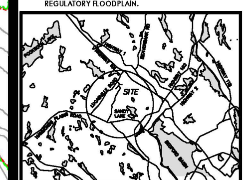
Stantec Consulting Ltd.
400 - 1331 Clyde Avenue
Ottawa ON
Tel. 613.722.4420
www.stantec.com

Legend

- 1-1 — PROPOSED AREA ID
- 0.60 — PROPOSED RUNOFF COEFFICIENT
- 1.13 — PROPOSED STORM DRAINAGE AREA ha.
- STORM DRAINAGE BOUNDARY
- EXISTING/FUTURE STORM DRAINAGE BOUNDARY
- PROPOSED STORM SEWER
- EXISTING STORM SEWER
- DIRECTION OF OVERLAND FLOW
- DIRECTION OF EXISTING OVERLAND FLOW
- LOW DENSITY RESIDENTIAL (C = 0.65)
- MULTI-RESIDENTIAL (C = 0.75)
- MIXED USE / COMMERCIAL (C = 0.85)
- PROPOSED INSTITUTIONAL (C = 0.70)
- COMMUNITY PARK (C = 0.40)
- PARK & OPEN SPACE (C = 0.20)
- EXISTING FORESTRY AND WETLAND (C = 0.20)
- APPROXIMATE LOCATION OF EXISTING WATERCOURSE
- FP_1 — WATERCOURSE FLOW POINT. REFER TO REPORT FOR DETAILS
- 1-1 — EXTERNAL DRAINAGE AREA ID
- 1.13 — EXTERNAL DRAINAGE AREA ha.
- CONCEPTUAL SWM POND
- EXISTING 100-YR FLOODLINE PRELIMINARY (HRM 2023)
- EXISTING 20-YR FLOODLINE PRELIMINARY (HRM 2023)

Notes

1. CONTOUR INTERVAL IS 5.0m,
2. SIZE AND LOCATION OF PROPOSED SWM PONDS TO BE CONFIRMED BASED ON FLOODPLAIN MAPPING FOR THE EXISTING WATERCOURSES.
3. NO ACTIVE DEVELOPMENT MAY BE PERMITTED WITHIN THE LIMITS OF THE 100-YEAR REGULATORY FLOODPLAIN. SOME REDUCED-RISK USES, SUCH AS RECREATIONAL SPORTS FIELDS AND TRAILS, MAY BE CONSIDERED. THIS IS SUBJECT TO DESIGN CONSIDERATIONS THAT EFFECTIVELY MITIGATE AND/OR MINIMIZE THE IMPACT OF SUCH DEVELOPMENT ON THE FLOODPLAIN AND PROTECT THE RIPARIAN CORRIDOR FUNCTIONS.
4. THE DEVELOPMENT CONCEPT PLAN HAS NOT BEEN APPROVED AND IS SUBJECT TO CHANGE.
5. THE SWM POND LOCATION SHOWN IS CONCEPTUAL AND SUBJECT TO CHANGE BASED ON RECOMMENDATIONS FROM FURTHER STUDIES. ALL SWM PONDS ARE TO BE LOCATED OUTSIDE OF THE REGULATORY FLOODPLAIN.



KEY PLAN

Revision		By	Appd.	YY.MM.DD
2	ISSUED FOR REVIEW	JP	DT	24.05.17
1	ISSUED FOR REVIEW	JP	DT	24.01.24

File Name: 16040XXXX-XX	Dwn.	Chkd.	Dsgn.	YY.MM.DD
	JP	DT	JP	24.01.15

Permit-Seal

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

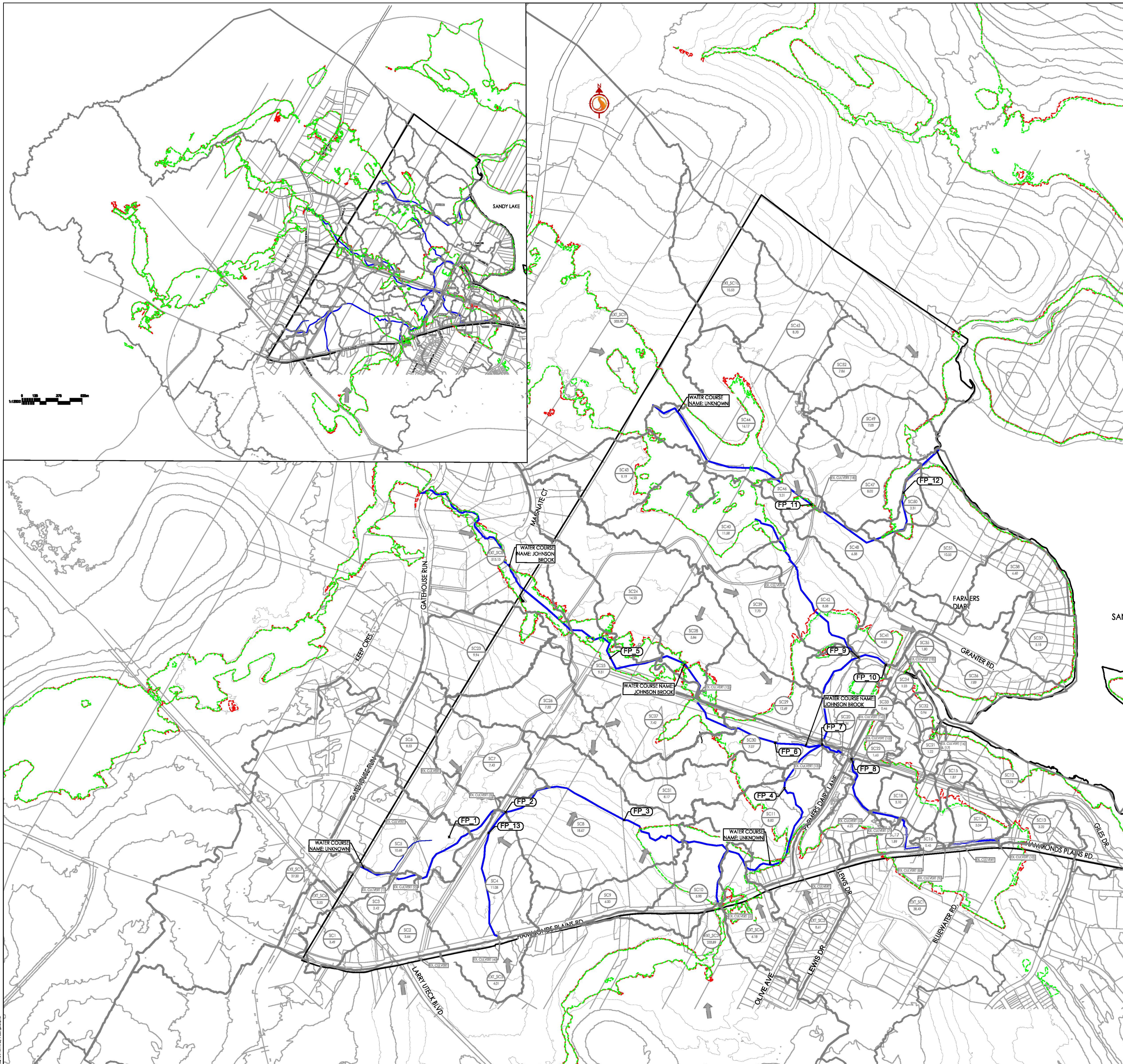
Client/Project
HALIFAX REGIONAL MUNICIPALITY

Future Serviced Communities
Sandy Lake
Halifax, Nova Scotia

Title
SANDY LAKE
CONCEPTUAL STORM DRAINAGE PLAN

Project No. 160410459
Scale 1:4000 (0 40 120 200m)

Drawing No. SD-1
Sheet 3 of 4
Revision 2



ID	Area (ha)	Percent Impervious (%)
Sc1	3.5	7.2
Sc2	3.7	17.0
Sc3	2.4	0.0
Sc4	11.1	4.6
Sc5	10.7	3.3
Sc6	8.5	4.0
Sc7	7.4	0.0
Sc8	18.7	0.0
Sc9	6.0	11.5
Sc10	6.0	11.0
Sc11	8.8	6.7
Sc12	12.8	14.2
Sc13	3.2	14.4
Sc14	3.0	7.9
Sc15	1.9	20.9
Sc16	0.5	26.4
Sc17	1.9	20.5
Sc18	3.1	4.3
Sc19	6.2	25.2
Sc20	0.4	32.3
Sc21	1.2	31.4
Sc22	1.7	42.5
Sc23	9.9	1.7
Sc24	14.2	1.2
Sc25	9.3	0.0
Sc26	7.3	0.0
Sc27	7.4	0.0
Sc28	5.9	0.0
Sc29	12.7	3.0
Sc30	7.1	2.5
Sc31	8.2	0.0
Sc32	1.0	28.9
Sc33	0.5	12.1
Sc34	1.2	19.2
Sc35	1.8	4.1
Sc36	7.9	32.6
Sc37	5.2	11.4
Sc38	6.6	55.4
Sc39	7.7	0.0
Sc40	11.6	0.0
Sc41	4.4	20.1
Sc42	8.6	0.0
Sc43	9.2	0.9
Sc44	16.2	0.0
Sc45	8.7	0.0
Sc46	2.2	0.0
Sc47	8.0	0.0
Sc48	6.6	10.3
Sc49	7.0	0.0
Sc50	2.3	0.0
Sc51	10.5	17.5
Sc52	7.9	0.0
Ext_Sc1	38.4	51.3
Ext_Sc2	233.9	11.1
Ext_Sc3	8.6	30.6
Ext_Sc4	6.2	16.6
Ext_Sc5	4.0	3.2
Ext_Sc6	3.6	8.4
Ext_Sc7	37.3	20.3
Ext_Sc8	513.2	5.7
Ext_Sc9	333.9	12.0
Ext_Sc10	10.5	0.0

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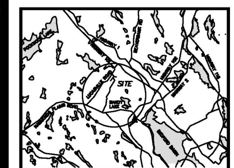
Legend

- DIRECTION OF OVERLAND FLOW
- APPROXIMATE LOCATION OF EXISTING WATERCOURSE
- FP_1 — WATERCOURSE FLOW POINT. REFER TO REPORT FOR DETAILS
- 1-1 / 1.13 — EXISTING DRAINAGE AREA ID; EXISTING DRAINAGE AREA ha.
- EXISTING DRAINAGE BOUNDARY
- EXISTING 100-YR FLOODLINE PRELIMINARY (HRM, 2023)
- EXISTING 20-YR FLOODLINE PRELIMINARY (HRM 2023)

Notes

1. CONTOUR INTERVAL IS 5.0m.



2 ISSUED FOR REVIEW	JP	DT	24.05.17
1 ISSUED FOR REVIEW	JP	DT	24.02.23
Revision	By	Appd.	YY.MM.DD

File Name: 16040XXXX-XX	JP	DT	JP	24.01.15
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

Client/Project
HALIFAX REGIONAL MUNICIPALITY

Future Serviced Communities
Sandy Lake
Halifax, Nova Scotia

Title
SANDY LAKE
EXISTING STORM DRAINAGE PLAN

Project No. 160410459
Scale 1:4000 (0, 40, 120, 200m)
Drawing No. EX-SD-1
Sheet 4 of 4
Revision 2

Appendix D Peak Flow Results

Flow Point ID	2-year, 24hr Chicago Peak Flow (m^3/s)			5-year, 24hr Chicago Peak Flow (m^3/s)			10-year, 24hr Chicago Peak Flow (m^3/s)			25-year, 24hr Chicago Peak Flow (m^3/s)			50-year, 24hr Chicago Peak Flow (m^3/s)			100-year, 24hr Chicago Peak Flow (m^3/s)			Peak Flow Percent Increase					
	Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference	2yr	5yr	10yr	25yr	50yr	100yr
FP_1	0.490	0.790	**0.300**	1.037	1.144	**0.107**	1.588	1.352	-0.235	2.298	1.727	-0.571	2.904	2.031	-0.873	4.398	2.889	-1.509	**61.4%**	**10.3%**	-14.8%	-24.9%	-30.1%	-34.3%
FP_2	0.765	1.032	**0.267**	1.398	1.558	**0.159**	2.154	2.124	-0.030	3.113	2.855	-0.259	3.881	3.463	-0.418	5.716	4.751	-0.966	**34.9%**	**11.4%**	-1.4%	-8.3%	-10.8%	-16.9%
FP_3	0.968	1.403	**0.434**	1.659	2.280	**0.621**	2.532	3.310	**0.778**	3.650	3.786	**0.136**	4.557	4.530	-0.027	6.812	6.044	-0.768	**44.9%**	**37.5%**	**30.7%**	3.7%	-0.6%	-11.3%
FP_4	3.075	3.217	**0.143**	4.926	5.180	**0.253**	6.530	6.862	**0.332**	8.931	9.143	**0.212**	10.804	10.886	**0.082**	17.051	16.106	-0.945	4.6%	5.1%	5.1%	2.4%	0.8%	-5.5%
FP_5	4.593	3.849	-0.744	6.481	5.020	-1.461	7.947	5.960	-1.987	9.942	7.532	-2.410	11.409	8.812	-2.596	17.211	14.112	-3.099	-16.2%	-22.5%	-25.0%	-24.2%	-22.8%	-18.0%
FP_6	4.613	3.879	-0.734	6.676	5.731	-0.945	8.297	7.383	-0.914	9.652	9.324	-0.328	11.387	11.129	-0.258	18.461	17.154	-1.307	-15.9%	-14.2%	-11.0%	-3.4%	-2.3%	-7.1%
FP_7	6.791	7.002	**0.211**	10.610	10.788	**0.178**	14.933	19.054	**4.121**	21.985	21.129	-0.855	25.771	25.337	-0.434	34.323	32.783	-1.540	3.1%	1.7%	**27.6%**	-3.9%	-1.7%	-4.5%
FP_8	1.196	1.517	**0.321**	2.129	2.632	**0.503**	3.307	4.514	**1.207**	7.502	7.267	-0.235	7.973	8.407	**0.435**	10.373	9.545	-0.828	**26.8%**	**23.6%**	**36.5%**	-3.1%	5.5%	-8.0%
FP_9	5.159	5.584	**0.425**	8.189	8.678	**0.489**	10.751	11.171	**0.420**	13.715	14.199	**0.484**	15.947	16.592	**0.644**	23.853	23.699	-0.154	8.2%	6.0%	3.9%	3.5%	4.0%	-0.6%
FP_10	5.108	5.434	**0.326**	7.962	8.346	**0.384**	10.318	10.611	**0.293**	13.071	13.338	**0.267**	15.207	15.428	**0.221**	23.449	23.136	-0.313	6.4%	4.8%	2.8%	2.0%	1.5%	-1.3%
FP_11	1.786	1.569	-0.217	3.027	2.566	-0.461	4.091	3.394	-0.697	5.508	4.484	-1.024	6.726	5.083	-1.642	12.938	10.495	-2.443	-12.2%	-15.2%	-17.0%	-18.6%	-24.4%	-18.9%
FP_12	1.986	2.154	**0.169**	3.370	2.977	-0.393	4.552	4.039	-0.513	6.136	5.117	-1.019	7.503	6.495	-1.008	14.225	10.144	-4.081	8.5%	-11.7%	-11.3%	-16.6%	-13.4%	-28.7%
FP_13	0.210	0.209	-0.001	0.366	0.424	**0.058**	0.494	0.627	**0.133**	0.660	0.918	**0.258**	0.792	1.191	**0.399**	1.155	1.723	**0.568**	-0.3%	**15.8%**	**26.8%**	**39.2%**	**50.4%**	**49.2%**