



**MORRIS LAKE WATERSHED AND  
STORMWATER MANAGEMENT STUDY**

May 29, 2025

Prepared for:  
Halifax Regional Municipality

Prepared by:  
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Project Number:  
160410459

## MORRIS LAKE WATERSHED AND STORMWATER MANAGEMENT STUDY

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May 29, 2025

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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, identify measures to improve or maintain water quality of water bodies within the watershed, and to mitigate the potential impact that future development may exert on these natural environments.

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. Three areas were remaining that had not yet undergone the comprehensive neighbourhood planning process. 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 report focuses on the Morris Lake Expansion in the communities of Eastern Passage, Cole Harbour and Cow Bay.

This study was prepared in conjunction with the Land Suitability Analysis (Stantec 2024) of the Morris Lake Study Area. More information regarding existing conditions of the site with respect to topography, geology, wildlife, wetlands, watercourses, forest habitat, species at risk, and contaminated sites 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 Morris Lake Future Serviced Community, which include:

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

### 1.1 Background

The Morris Lake Study Area (MLSA) is located in south Dartmouth between Portland Estates and Canadian Forces Base (CFB) Shearwater as shown in **Figure 1.1**. The 12 Wing Shearwater Airport lies to the southwest of the Study Area. The area is roughly bounded by Caldwell Road to the west, Morris Lake to the north, Atholea Drive to the northeast, Cow Bay River to the east and Cow Bay Road/Dyke Road to the south. The established community of Eastern Passage lies to the southwest across Cow Bay Road,



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the communities of Cow Bay and Eastern Passage lie to the south, and the community of Cole Harbour lies to the northeast.

The MLSA covers approximately 465.8 hectares (ha). Much of the land within the MLSA is undeveloped and is located within two provincial secondary watersheds that drain into Cow Bay; Cow Bay River and Shore Direct as shown in pink on **Figure 1.1**. Morris Lake which is located along the north border of the MLSA has a surface area of 140 ha, a maximum depth of 10 m and drains into the Cow Bay River, which borders the eastern boundary of the MLSA from north to south and ultimately discharges into Cow Bay and the Atlantic Ocean. Bisset Lake which is located north-east of the MLSA also drains into the Cow Bay River. Morris Lake provides public recreational water access, including swimming at two locations; the Kiwanis Centre Beach and Park Morris Lake.

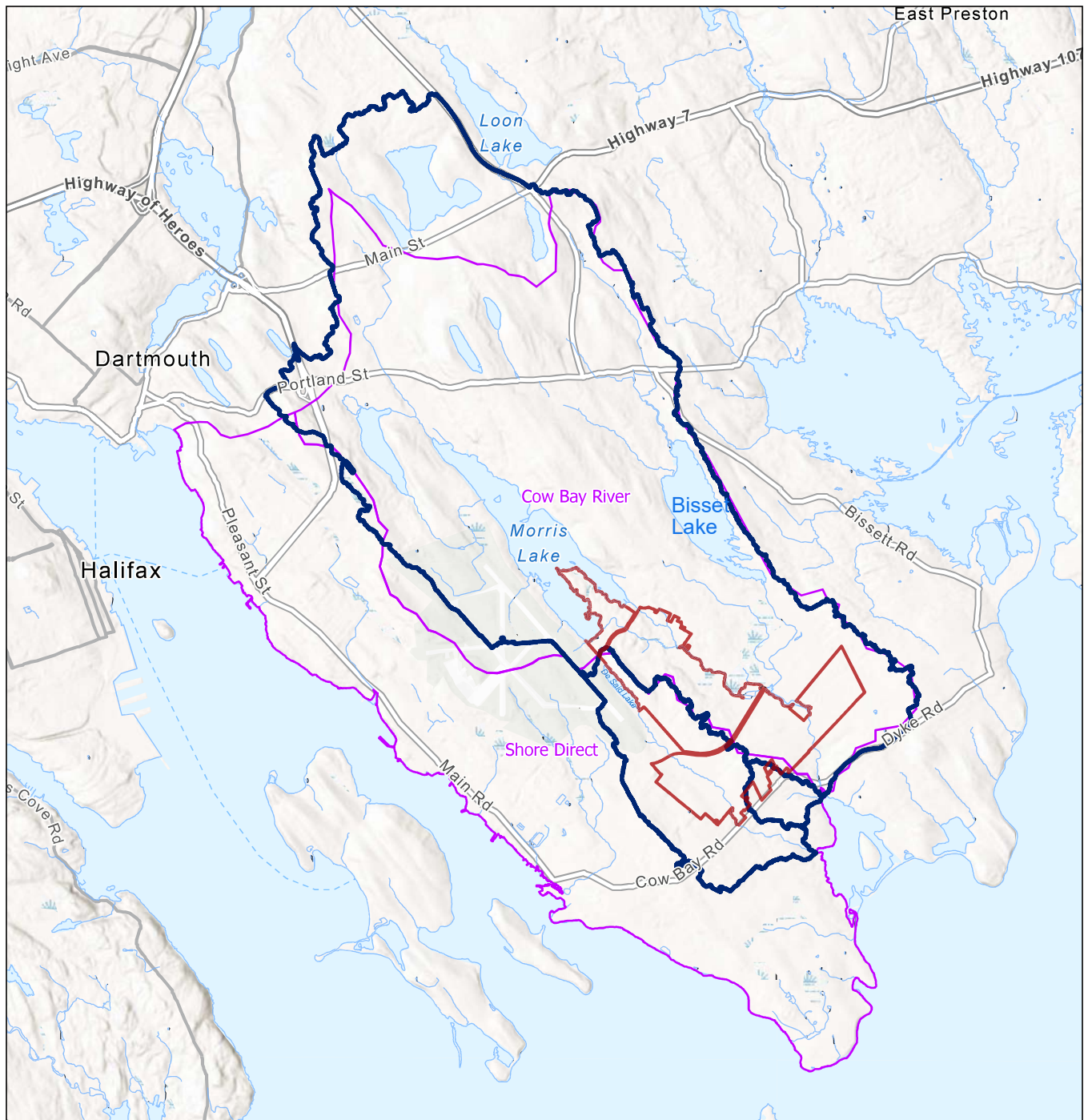
Smelt Brook (**Figure 2.1**) borders the western boundary of the MLSA from north to south and ultimately discharges into Cow Bay and the Atlantic Ocean. An unnamed watercourse is located between Cow Bay River and Smelt Brook, to the southeast of the MLSA boundary, crossing Cherylann Drive. The watercourse is located outside the MLSA, is approximately 0.40 km in length and drains into Cow Bay Lake. It runs roughly from the northeast to east and is narrow, typically less than 1.0 m wide.

De Said Lake which is located along the north-western border of the MLSA has a surface area of 6 ha and drains into Smelt Brook (**Figure 1.1** and **Figure 2.1**).

The Provincial Secondary Watershed and the Study Area Watershed boundaries are shown on **Figure 1.1**. Watershed delineations depend heavily on the accuracy and resolution of the underlying elevation data. Provincial datasets (Provincial Secondary Watershed mapping) were often generated from coarser-resolution DEMs (digital elevation models), older topographic maps, or interpolation methods. In contrast, lidar data typically provides a much more detailed view of the land surface. Consequently, when delineations are run using lidar-based DEMs such as for this Morris Lake Watershed Study, they often show different (and usually more precise) watershed boundaries compared to those derived from older, lower-resolution data. As a result, there is some discrepancy between the Provincial Secondary Watershed and the Study Area Watershed boundaries, where discrepancies exist the Study Area Watershed boundaries were used.

The model developed for the MLSA was designed to encompass the entire watershed, including upstream areas beyond the immediate MLSA boundary. While this upstream land not directly related to development within the MLSA and may not undergo direct land-use changes, these lands exert influence on downstream flow patterns and water quality. As a result the watersheds encompass an area beyond the MLSA.





### Legend

- Study Area
- Study Area Watershed Boundary
- Provincial Secondary Watershed (NSECC 2019)
- Boundary Watercourse
- Waterbody

0 1 2 km  
(At original document size of 8.5x11)  
1:80,000



*Project Location*  
Halifax Regional Municipality,  
Nova Scotia

Prepared by AC on 2024-04-17

*Client/Project*  
Halifax Regional Municipality  
Future Served Communities

160410459

*Figure No.*  
**1.1**

*Title*  
**MLSA Watershed Location**

### 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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## 2 Watershed Study

The objective of this watershed and stormwater management (SWM) study is to determine water quality impacts to sensitive or natural receptors within or downstream of the Morris Lake study area. The focus of this study is on sourcing and quantifying contaminant loadings of total phosphorus (Total P), fecal coliforms and sediment due to impacts of land-use change to the HSA and its contributing watershed area from proposed development scenarios. These specific contaminants were selected because of their documented adverse effects on waterbodies throughout the HRM.

In this study, contaminant loading models for three land development scenarios (developer-requested, low-density, high-density) were evaluated to understand the potential water quality effects resulting from each scenario; a fourth scenario (aerial land-use 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. The aerial land-use 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.

Water samples collected were intended to support the Morris Lake Watershed Study and the sampling program conducted may not be of sufficient duration or frequency to establish pre-development conditions. For areas where new or additional development could adversely impact watercourses, the Halifax Regional Municipal Planning Strategy mandates the completion of watershed or sub-watershed studies before undertaking secondary planning strategies. Developers must assess potential risks to water sources and establish monitoring programs to evaluate changes in water quality and quantity. This involves confirming parameters to be measured, determining sampling locations and frequency, and establishing baseline data prior to development.

### 2.1 Surface Water Quality

Data collection on surface water quality for the MLSA was completed by Stantec monthly from April to November 2023 (Stantec 2024) in conjunction with the historical surface water quality data collected upstream of the MLSA as part of the LakeWatchers program (HRM 2023).

The LakeWatchers water quality sampling related to the MLSA focused on Morris Lake itself: deep water and outlet. Data from LakeWatchers are comprised of 16 samples collected in 2022 (April and September) and two samples collected in 2023 (May and August), which were analyzed for the following parameters: dissolved oxygen, chloride, Chlorophyll *a*, conductivity, *E. coli*, pH, temperature, total phosphorus, and metals.

A description of local water quality and summary of the 2023 Stantec water quality results can be found in the *Morris Lake Land Suitability Analysis* (Stantec 2024). The results of the LakeWatchers water quality monitoring can be found online at HRM's OpenData webpage (HRM 2024) and a summary of results from the Stantec water quality monitoring can be found **Appendix A**. Water quality sampling began in April



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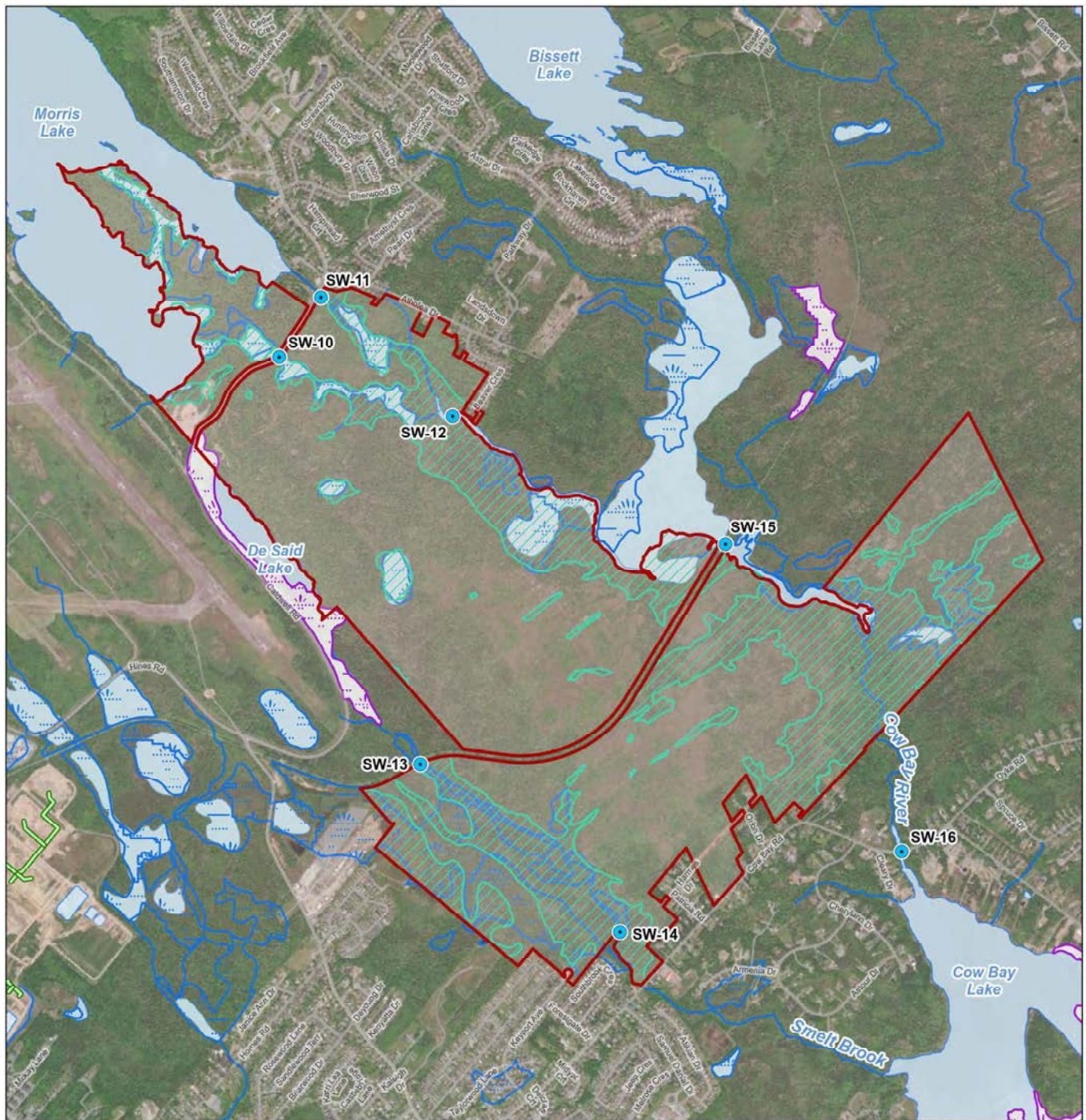
2023 and the final round of sampling was completed in November 2023 at seven locations across the MLSA (**Figure 2.1**). Water quality samples were submitted to Bureau Veritas Labs in Bedford, Nova Scotia (NS) for laboratory analysis of bacteria, total suspended solids (TSS), total P, turbidity, colour, and chloride. Mean, median, maximum, and minimum water quality results were calculated for six water quality stations (SW-10 to SW-16), based on eight monthly datasets.

Water quality stations SW-10, SW-11, SW-12, SW-15, and SW-16 are located on Cow Bay River. SW-10 and SW-11 are located at the two separate outlets of Morris Lake which meet at SW-12. SW-15 is located at the confluence of Cow Bay River and the outflow of Bissett Lake which is located outside of the MLSA. SW-16 is located outside of the MLSA at the point where the river flows into Cow Bay. Water quality stations SW-13 and SW-14 are located on Smelt Brook. SW-13 samples the brook as it enters the MLSA and SW-14 samples the brook as it flows out of the MLSA towards Cow Bay.

Mean, median, maximum, and minimum water quality results were calculated for the MLSA water quality stations, based on eight monthly datasets. Generally averages are used when describing water quality characteristics however in cases where water quality data does not follow a normal distribution (e.g., due to varying pollution sources, natural variation), the median provides a measure of the central tendency and reflects the typical water quality conditions providing an approximation of water quality within the watershed.

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, fecal coliform (represented by *E. coli*), and sediment 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 Total P loading of the lake including pH, dissolved oxygen (DO), temperature, and conductivity is provided in **Section 2.1.4**.





- Water Sampling Location
- Waterway
- Waterbody
- ▨ Wetlands (Stantec, 2023)
- ▨ Wetland (NSECC)
- ▨ Wetland of Special Significance (NSECC)
- ▭ Study Area

- Utilities
- Pipeline
- Transportation
- Road

0 250 500 Metres  
(At original document size of 8.5x11)  
1:25,000



**Project Location**  
Halifax Regional Municipality,  
Nova Scotia

Prepared by NWhite on 2023-07-19  
Revised by NWhite on 2024-07-25

**Client/Project**  
Halifax Regional Municipality  
Future Serviced Communities  
Background Studies

Fig ID: 160410459\_008

**Figure No**  
**2.1**

**Title**  
**Watercourse Mapping and Surface  
Water Sampling Locations in the  
MLSA**

**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: Government of Nova Scotia,  
Department of Service Nova Scotia and Internal  
Services

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**Table 2.1 Summarized Water Quality Results from the MLSA Collected During Spring/Summer 2023**

| Location                 |           | CCME CWQG-FAL                    | Cow Bay River<br>(Morris Lake Watershed)                                                                                            |                                  |                                  |                                  | Smelt Brook<br>(De Said Lake Watershed) |                                  | Cow Bay River<br>(Morris Lake Watershed) |                                  |
|--------------------------|-----------|----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|----------------------------------|----------------------------------|-----------------------------------------|----------------------------------|------------------------------------------|----------------------------------|
| Parameter                | Units     | Value                            | Guideline Value                                                                                                                     | SW-10                            | SW-11                            | SW-12                            | SW-13                                   | SW-14                            | SW-15                                    | SW-16                            |
| Microbiological          |           |                                  |                                                                                                                                     |                                  |                                  |                                  |                                         |                                  |                                          |                                  |
| <i>Escherichia coli</i>  | CFU/100mL | Mean*<br>Median*<br>Max*<br>Min* | 235 CFU/100mL <sup>A</sup>                                                                                                          | 80<br>90<br>110<br>30            | 200<br>160<br>300<br>140         | 190<br>130<br>680<br>10          | 397<br>240<br>1100<br>10                | 400<br>210<br>1500<br>20         | 187<br>165<br>430<br>10                  | 83<br>70<br>160<br>10            |
| Total Coliforms          | CFU/100mL | Mean*<br>Median*<br>Max*<br>Min* | N/A                                                                                                                                 | 706<br>600<br>1500<br>190        | 1062<br>1150<br>2100<br>210      | 813<br>750<br>1600<br>520        | 1181<br>980<br>2500<br>530              | 1504<br>920<br>5100<br>500       | 690<br>700<br>1000<br>300                | 825<br>625<br>1500<br>460        |
| Inorganics               |           |                                  |                                                                                                                                     |                                  |                                  |                                  |                                         |                                  |                                          |                                  |
| Dissolved Chloride (Cl-) | mg/L      | Mean*<br>Median*<br>Max*<br>Min* | maximum of 640 mg/L for short term exposures or 120 mg/L for long term exposures <sup>B</sup>                                       | 65<br>63<br>90<br>40             | 68<br>67<br>91<br>48             | 58<br>56<br>89<br>7.5            | 29<br>22<br>56<br>13                    | 40<br>33<br>61<br>24             | 63<br>54<br>86<br>47                     | 66<br>64<br>94<br>42             |
| Colour                   | TCU       | Mean*<br>Median*<br>Max*<br>Min* |                                                                                                                                     | 46.6<br>45.5<br>100.0<br>14.0    | 18.5<br>15.5<br>34.0<br>11.0     | 71<br>17<br>410<br>13            | 151<br>120<br>250<br>84                 | 120<br>100<br>250<br>57          | 49<br>28<br>150<br>17                    | 41<br>35<br>82<br>22             |
| Total Phosphorus         | mg/L      | Mean*<br>Median*<br>Max*<br>Min* | Trophic Status Ranges are provided in Table 2.2                                                                                     | 0.012<br>0.010<br>0.021<br>0.006 | 0.012<br>0.008<br>0.023<br>0.006 | 0.009<br>0.010<br>0.012<br>0.006 | 0.012<br>0.011<br>0.015<br>0.009        | 0.015<br>0.015<br>0.023<br>0.006 | 0.007<br>0.008<br>0.010<br>0.004         | 0.010<br>0.010<br>0.018<br>0.005 |
| Total Suspended Solids   | mg/L      | Mean*<br>Median*<br>Max*<br>Min* | maximum increase of 25 mg/L from background for short term exposures or 5 mg/L from background for long term exposures <sup>C</sup> | 4.8<br>3.0<br>12<br>1.2          | 1.8<br>2.0<br>2.4<br>1.0         | 1.56<br>1.2<br>2.6<br>1.0        | 2.2<br>2.0<br>3.6<br>1.2                | 166<br>1.5<br>660<br>1.0         | 1.4<br>1.4<br>1.4<br>1.4                 | 1.33<br>1.40<br>1.6<br>1.0       |
| Turbidity                | NTU       | Mean*<br>Median*<br>Max*<br>Min* |                                                                                                                                     | 2.26<br>1.65<br>5.9<br>0.67      | 1.68<br>1.10<br>3.7<br>0.56      | 1.2<br>1.05<br>2.1<br>0.46       | 2.55<br>2.40<br>4.0<br>1.60             | 5.31<br>1.3<br>33<br>0.36        | 0.93<br>0.88<br>1.5<br>0.4               | 0.88<br>0.83<br>1.6<br>0.2       |

Notes:

\* Mean, Median, Maximum, and Minimum were calculated from eight monthly results

<sup>A</sup> Health Canada 2024

<sup>B</sup> CCME 2011

<sup>C</sup> CCME 2009



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## 2.1.1 TOTAL PHOSPHORUS

Total P is a common water quality parameter associated with the growth and proliferation of algae and aquatic vegetation (SAV) in freshwater bodies. It is typically considered a limiting nutrient in natural freshwater systems, meaning 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 2.2**) (Brylinsky 2004). 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 2.2 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                  |

Total P levels in Morris Lake were obtained from the LakeWatchers data (HRM 2024). Total P for Morris Lake ranged from less than the laboratory detection limit (0.0001 mg/L) to 0.0082 mg/L, with an average of 0.004 mg/L using data collected from eight samples during the Spring and Summer of 2022 and 2023 (**Table 2.1**). The median Total P concentration in Morris Lake was 0.0038 mg/L, which is classified as ultra-oligotrophic (<0.004 mg/L).

Total P levels in Cow Bay River are reported from SW-10, SW-11, SW-12, SW-15, and SW-16. Total P for Cow Bay River ranged from 0.004 mg/L (SW-15) to 0.023 mg/L (SW-11), with an average of 0.010 mg/L using data collected from five surface water stations during the Spring and Summer of 2023 (**Table 2.1**). The median Total P concentration in Cow Bay River was 0.009 mg/L, which is classified as oligotrophic (0.004 to 0.010 mg/L).

Total P levels Smelt Brook are reported from SW-13 and SW-14. Total P for Smelt Brook ranged from 0.006 mg/L (SW-14) to 0.023 mg/L (SW-14), with an average of 0.013 mg/L using data collected from two surface water stations during the Spring and Summer of 2023 (**Table 2.1**). The median Total P concentration in Smelt Brook was 0.014 mg/L, which is classified as mesotrophic (0.010 to 0.020 mg/L).

Although Morris Lake is considered ultra-oligotrophic and thus not typically conducive to blue-green algae blooms, even small changes in Total P concentrations can disproportionately influence the biotic composition in low-nutrient lakes. This sensitivity may help explain the July 2023 BGA bloom reported in Morris Lake at Kiwanis Beach Park (Nova Scotia Environment and Climate Change n.d.). Oligotrophic



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lakes, despite their low baseline nutrient levels, can still experience rapid ecological shifts when P inputs increase, underscoring the importance of careful monitoring and management to maintain water quality.

### 2.1.1.1 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 trapped 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 into 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.

### 2.1.2 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 a fecal indicator bacteria (FIB), denoting the potential presence of fecal matter containing pathogens and an associated 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. The presence of *E. coli* in recreational waters may come from wild or domestic animals in proximity to a waterbody. In urbanized watersheds, stormwater runoff and domestic wastewater discharge represent additional sources of *E. coli*.

Fecal coliform levels for Morris Lake were obtained from the LakeWatchers data (HRM 2024), and all water quality results are presented in **Table 2.1**, and all water quality results are presented in **Appendix A**. *E. coli* levels for Morris Lake ranged from less than the laboratory detection limit (2 CFU/100mL) to 130 CFU/100mL, using data collected from seven samples during the Spring and Summer of 2022 and 2023. Total coliforms were not reported for Morris Lake as part of the HRM LakeWatchers program. The Health Canada Guidelines for Canadian Recreational Water Quality (2024) for *E. coli* is 235 CFU/100mL. The *E. coli* levels reported for Morris Lake are within this guideline.

Fecal coliform levels for Cow Bay River are presented in **Table 2.1**, and all water quality results are presented in **Appendix A**. *E. coli* levels for Cow Bay River ranged from less than the laboratory detection limit (10 CFU/100mL; SW-10 and SW-11) to >2500 CFU/100mL (SW-11), with an average of 229 CFU/100mL and a median of 55 CFU/100mL using data collected from five surface water stations during the Spring and Summer of 2023. Total coliforms ranged from 190 CFU/100mL (SW-10) to >2500 CFU/100mL (SW-11), with an average of 891 CFU/100mL and a median of 725 CFU/100mL using data collected from five surface water stations during the spring and summer of 2023. The *E. coli* levels



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reported for Cow Bay River exceeded the Health Canada Guideline for Canadian Recreational Water Quality at surface water stations SW-11 (August, September, October 2023), SW-12 (September 2023), and SW-15 (July, August 2023).

Fecal coliform levels for Smelt Brook are presented in **Table 2.1**, and all water quality results are presented in **Appendix A**. *E. coli* levels for Smelt Brook ranged from less than the laboratory detection limit (10 CFU/100mL; SW-13) to >2500 CFU/100mL (SW-13 and SW-14), with an average of 572 CFU/100mL and a median of 125 CFU/100mL using data collected from two surface water stations during the Spring and Summer of 2023. Total coliforms ranged from 500 CFU/100mL (SW-14) to >2500 CFU/100mL (SW-13 and SW-14), with an average of 1,488 CFU/100mL and a median of 1,090 CFU/100mL using data collected from two surface water stations during the Spring and Summer of 2023. The *E. coli* levels reported for Cow Bay River exceeded the Health Canada Guideline for Canadian Recreational Water Quality at surface water stations SW-13 (June, September 2023) and SW-14 (July, August, September 2023).

Potential sources of fecal coliform bacteria within the MLSA include runoff from human fecal sources from nearby land use (e.g., recreation), wildlife and avian.

### 2.1.3 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. The CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME CWQG-FAL) for suspended sediments is a maximum increase of 25 mg/L from background levels for short term exposures (e.g., 24 hours), and a maximum average increase of 5 mg/L from background levels for long term exposures (e.g., between 24 hours and 30 days) (CCME 1999).

Summary statistics for TSS concentrations in Cow Bay River are presented in **Table 2.1**, and all water quality results are presented in **Appendix A**. TSS for Cow Bay River ranged from less than the laboratory detection limit (1.0 mg/L; SW-10, SW-11, SW-12, SW-15, SW-16) to 6.8 mg/L (SW-16), with an average of 1.5 mg/L and a median concentration of 1.0 mg/L using data collected from five surface water stations during the Spring and Summer of 2023.

Summary statistics for TSS concentrations in Smelt Brook are presented in **Table 2.1**, and all water quality results are presented in **Appendix A**. TSS for Smelt Brook ranged from less than the laboratory detection limit (1.0 mg/L; SW-13, SW-14) to 660 mg/L (SW-14), with an average of 42.6 mg/L and a median concentration of 1.0 mg/L using data collected from two surface water stations during the Spring and Summer of 2023.

TSS was not reported for Morris Lake as part of the HRM LakeWatchers program.



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### BASELINE GENERAL WATER QUALITY

Baseline water quality profiles of the MLSA were collected between April and November 2023. The results from the monitoring are presented in **Appendix A**, and a comprehensive description of water quality for the MLSA is presented in the Land Suitability Analysis (Stantec 2024). The following section describes the results of the water quality stations within the MLSA for parameters that may affect the nutrient loading of the lake, including pH, dissolved oxygen (DO), temperature, and conductivity.

Water quality across the MLSA is quite variable with pH values ranging from a minimum of 4.79 observed at SW-13 to a maximum of 8.18 at SW-11. The average pH value across the MLSA was determined to be 6.84 which is within the Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (CWQG-FAL) (6.5 to 9.0). Dissolved oxygen values range from 4.07 mg/L (SW-10) to 14.62 mg/L (SW-16), with an average of 9.03 mg/L across the MLSA. The CCME CWQG-FAL for DO is 6.0 mg/L for early life stage aquatic life and 5.5 mg/L for other life stages. The lowest average DO concentrations were observed in July 2023 (6.65 mg/L), which is within the guidelines. Temperature measurements range from 0.8°C (SW-16 in November 2023) to 24.0°C (SW-11 in July 2023). Conductivity across the MLSA range from 160.4 µS/cm (SW-14) to 354.4 µS/cm (SW-10), with an average of 275.0 µS/cm. Higher surface water conductivity typically indicates higher concentrations of dissolved ions in the water which can be from a variety of natural and anthropogenic factors including: urban runoff, natural geology, evaporation, saltwater intrusion and stormwater/wastewater discharges



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## 3 Water Quality Assessment Methodology

### 3.1 Watershed Delineation

Watershed delineation was completed using LiDAR, aerial imagery, and flow accumulation mapping (also known as wet areas mapping) (Stantec 2024x). The wet areas mapping indicates depth to water table and can also be used to predict what areas may accumulate surface water in watercourses and wetlands.

The watercourses in this study were verified during field surveys conducted concurrently with the 2024 water sampling program. At each location where a watercourse was sampled for the water quality sampling program, the following information was collected:

- Channel and wetted width
- Water depth
- Substrate composition
- Bank description
- Functional in-water and riparian vegetation cover

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 3.1** and **Figure 3.2**.



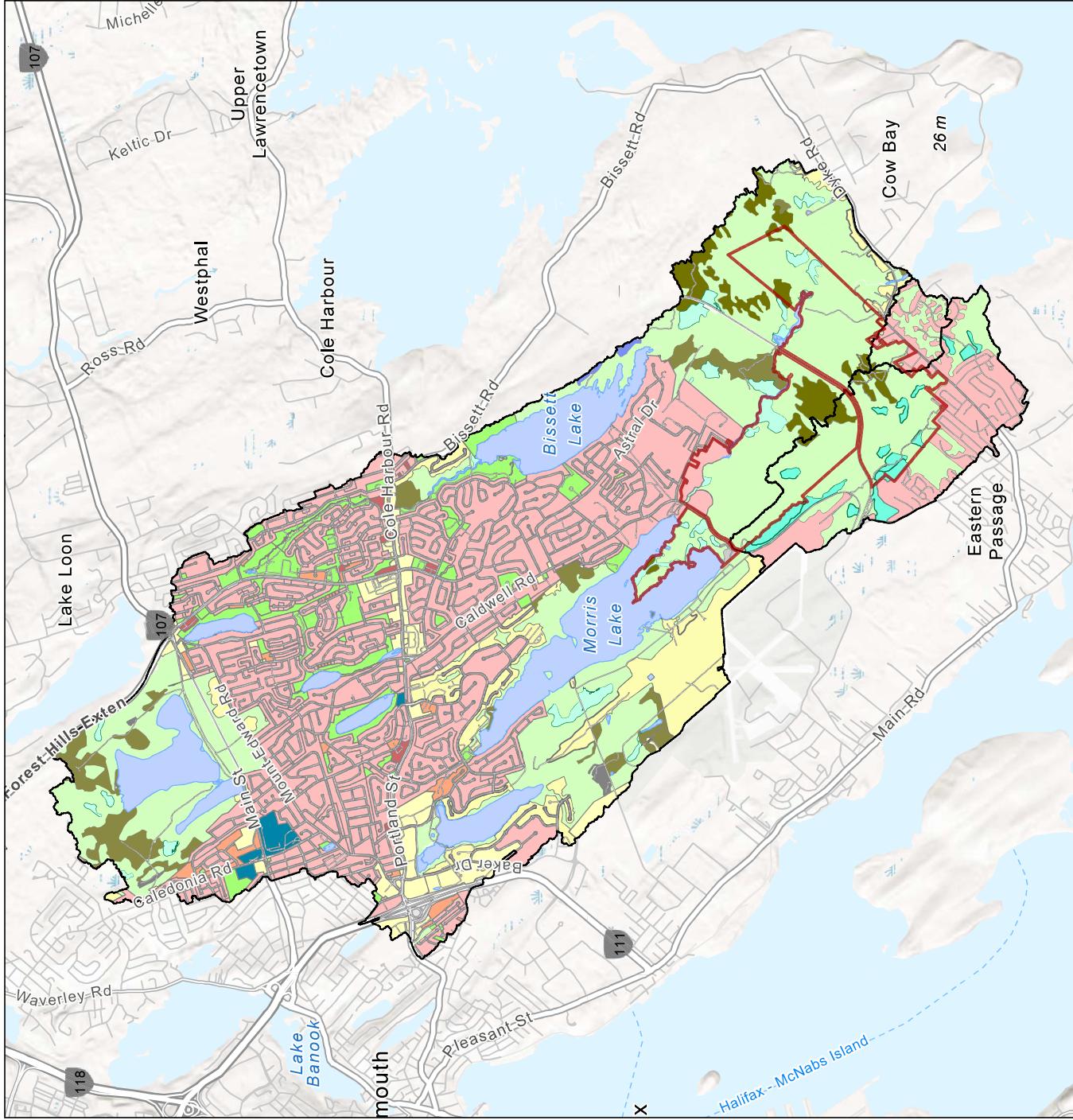


Figure No. 3.1  
Title

# **Morris Lake Study Area Watershed Land Use**

Client/Project  
Halifax Regional Municipality  
Future Services Communities  
160410459

Project Location  
Halifax Regional Municipality,  
Nova Scotia  
Prepared by AC on 2024-06-19



## **Legend**



## **Land Use**

- High Density Residential
- Medium Density Residential
- Low Density Residential
- Commercial
- Institutional
- Park
- Forest
- Agriculture
- Gravel Pit
- Rock/Dune/Barren
- Non-Forest Misc
- Other
- 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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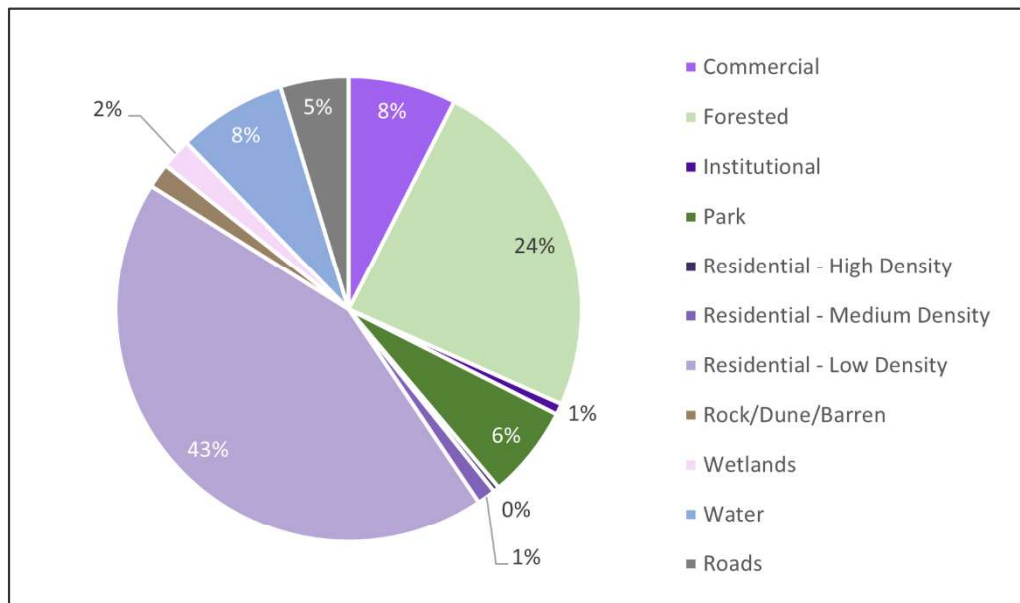


**Figure 3.2 Morris Lake Study Area Watershed Land Use Breakdown**

## 3.2 Climate

Climate normal data were used for an estimate of the annual rainfall in the study area. The Environment Canada Shearwater Climate Station (Composite Climate IDs: 8205090, 8205091, and 8205092) data from 1991 to 2020 were used. This station is located approximately 2 km from the MLSA and is the closest climate station to the study area with 30 years of climate normal data. For the thirty-year data period, the total annual precipitation is 1,414.2 mm (ECCC 2024), with an annual average temperature of 7.4°C. There are instances in Table 3.1 where the rainfall values exceed the total precipitation. The discrepancy arises because the total precipitation dataset covers a shorter period of records than the rainfall dataset at this location.

**Table 3.1 Climate Normals Data – Shearwater Airport (Composite IDs: 8205091, 8205092, 8205090)**

|                                                                                                   | Jan   | Feb  | Mar   | Apr   | May   | Jun   | Jul   | Aug  | Sep   | Oct   | Nov   | Dec   | Year    |
|---------------------------------------------------------------------------------------------------|-------|------|-------|-------|-------|-------|-------|------|-------|-------|-------|-------|---------|
| <b>R</b>                                                                                          | 87.5  | 69.9 | 107.0 | 94.7  | 122.5 | 102.0 | 101.0 | 81.8 | 109.8 | 141.4 | 123.0 | 110   | 1250.6  |
| <b>P</b>                                                                                          | 123.8 | 114  | 119.5 | 107.6 | 114.8 | 107.3 | 95.3  | 94.1 | 106.5 | 141   | 134.6 | 155.8 | 1,414.2 |
| <b>T</b>                                                                                          | -4.1  | -3.7 | -0.3  | 4.5   | 9.5   | 14.4  | 18.5  | 19.1 | 15.8  | 10.2  | 5     | -0.2  | 7.4     |
| Notes:<br>R = Total Rainfall (mm)<br>P = Total Precipitation (mm)<br>T = Average Temperature (°C) |       |      |       |       |       |       |       |      |       |       |       |       |         |

Annual precipitation amounts for 2023 at the Halifax Stanfield International Airport Climate Station were higher than the climate normal (1,396.2 mm) with a total annual precipitation of 1,575.2 mm – data for the



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Shearwater A Climate Station for 2023 was not available. Large precipitation events during the months of June and July caused flooding events within the Sackville River Watershed in HRM.

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 Halifax Regional Municipality. 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 3.2**.

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 3.2**, 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 3.2 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  |

## 3.3 Development Scenarios

The MLSA is being studied for future residential, commercial and industrial development. Three major owners in the northern half of the MLSA—Clayton/Morris Lake Holdings, A. J. Giles, and Brycon Development (Brian Naugle)—have declared their intentions to develop their land. Clayton/Morris Lake Holdings has the largest landholding within the MLSA. Four development scenarios were assessed for changes in annual contaminant loads in this study and the details of each development scenario are provided in the *Development Scenarios – Morris Lake Study Area* (Stantec 2023) report. **Table 3.3** provides a breakdown of the land use changes to the total watershed area of the MLSA for each development scenario. **Sections 3.3.1, 3.3.2, 3.3.3, and 3.3.4** provide short descriptions of each development scenario. It should be noted that between the low-density and high-density development scenarios, the primary change is the number of units considered and allocation of land between Low-, Medium- and High-Density Residential land uses.



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**Table 3.3 MLSA Development Scenarios Land Use Changes within Total Watershed Area**

| Land Use Type                                                                                                                                                                                                                                                                                                                           | Existing Land Uses (ha) | Low-Density Scenario (ha) | Developer Requested Scenario (ha) | High-Density Scenario (ha) | Areal Land Use Scenario (ha) |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|---------------------------|-----------------------------------|----------------------------|------------------------------|
| Commercial*                                                                                                                                                                                                                                                                                                                             | 385.88                  | 440.11                    | 454.25                            | 440.11                     | 440.57                       |
| Low-Density Residential (LDR)*                                                                                                                                                                                                                                                                                                          | 2231.77                 | 2342.02                   | 2255.71                           | 2236.71                    | 2250.92                      |
| Medium Density Residential (MDR)*                                                                                                                                                                                                                                                                                                       | 66.63                   | 134.12                    | 71.52                             | 77.74                      | 70.54                        |
| High Density Residential (HDR)*                                                                                                                                                                                                                                                                                                         | 21.11                   | 21.11                     | 130.69                            | 184.02                     | 108.77                       |
| Institutional*                                                                                                                                                                                                                                                                                                                          | 39.65                   | 39.65                     | 65.89                             | 39.65                      | 39.65                        |
| Forested**                                                                                                                                                                                                                                                                                                                              | 1245.17                 | 997.18                    | 996.13                            | 995.96                     | 1063.72                      |
| Undeveloped/Grass** <sup>1</sup>                                                                                                                                                                                                                                                                                                        | 330.47                  | 330.47                    | 330.47                            | 330.47                     | 330.47                       |
| Road*                                                                                                                                                                                                                                                                                                                                   | 243.59                  | 259.61                    | 259.61                            | 259.61                     | 259.61                       |
| Rock/Dune/Barren**                                                                                                                                                                                                                                                                                                                      | 88.36                   | 88.36                     | 88.36                             | 88.36                      | 88.36                        |
| Wetland**                                                                                                                                                                                                                                                                                                                               | 108.57                  | 108.57                    | 108.57                            | 108.57                     | 108.57                       |
| Water**                                                                                                                                                                                                                                                                                                                                 | 388.16                  | 388.16                    | 388.16                            | 388.16                     | 388.16                       |
| <b>Totals</b>                                                                                                                                                                                                                                                                                                                           |                         |                           |                                   |                            |                              |
| Developed Land                                                                                                                                                                                                                                                                                                                          | 2988.63                 | 3236.62                   | 3237.67                           | 3237.84                    | 3170.07                      |
| Undeveloped Land                                                                                                                                                                                                                                                                                                                        | 2160.72                 | 1912.73                   | 1911.68                           | 1911.51                    | 1979.27                      |
| Future Land Development by Scenario                                                                                                                                                                                                                                                                                                     | N/A                     | 247.99                    | 249.04                            | 249.21                     | 181.44                       |
| Notes:<br>* indicates land use types used in sum for Developed Land.<br>** indicates land use types used in sum for Undeveloped Land.<br><sup>1</sup> Undeveloped/Grass is a broad land-use classification encompassing areas with similar runoff characteristics, including Park, Non-Forest Miscellaneous, and other open-space uses. |                         |                           |                                   |                            |                              |



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### 3.3.1 LOW-DENSITY SCENARIO

A Low-Density scenario will consider an approach to development where a higher proportion of the developable land is allocated for Low- and Medium-density lands, such as single detached dwellings, townhouses and low-rise apartments. The overall developable area will be similar to the developer requested and high density scenarios. 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 10,461 within 4,550 dwelling units based on a density of 16 persons per acre (Stantec 2023).

### 3.3.2 DEVELOPER REQUESTED SCENARIO

The developer requested scenario explores the proposed intentions of developers that own lands within the Study Area.

The developer requested density scenario combines the A. J. Giles Investments Ltd., Morris Lake Holdings Ltd., and Brycon proposals (Stantec 2023). A. J. Giles has proposed 420 residential units within the Study Area, the Clayton plan for their Morris Lake Holdings lands calls for another 5,290 units, and Brycon provides 865 on land that is incorporated in the Clayton proposal. Together, the Giles and Clayton plans will create 5,710 dwelling units in a mixture of housing types. The estimated population of the combined proposals will be 13,133 as summarized in **Table 3.3**. If Brycon develops their land rather than Morris Lake Holdings, the unit count will be reduced by 132 and the population accommodated will be reduced by 304.

A. J. Giles Investments Ltd. does not propose commercial space on their concept, while Clayton (Morris Lake Holdings) and Brycon do intend to incorporate commercial space (Stantec 2023). If the Brycon land is developed in accordance with the Clayton plan, the commercial space will be approximately half the area than if Brycon were to develop their land independently (Stantec 2023).

Together, all proposed residential developments within the Study Area will total 5,710 dwelling units with an estimated population of 13,133 if the Morris Lake Holdings plan is implemented, but 5,578 dwelling with 12,829 residents if Brycon develops the area within the Morris Lake Holdings plan that is in their ownership. A summary of all developer proposals can be found in **Table 3.4**.



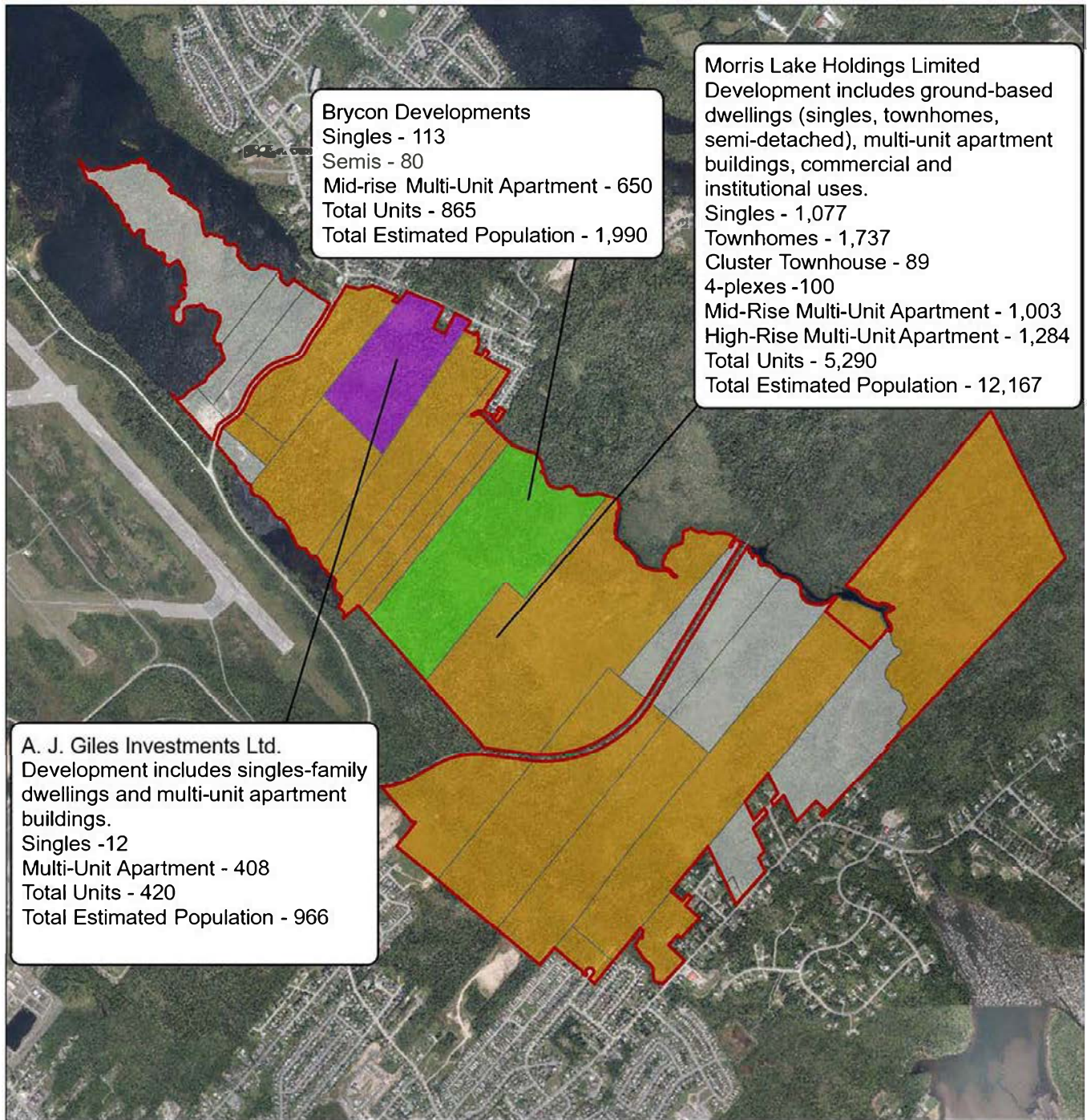
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**Table 3.4 Summary of MLSA Developer Proposals and Common Elements**

| <b>Developer</b>                                                                                                            | <b>Proposed Development</b>                                                                                                                                                                                   | <b>Unit Breakdown</b>                                                                                                                                                                                                              | <b>Total Estimated Population</b> |
|-----------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| <b>A. J. Giles Investment Limited</b><br><b>18.5 hectares</b><br>(21 ppa)                                                   | Development includes single-family dwellings and multi-unit apartment buildings                                                                                                                               | Singles – 12<br>Multi-Unit Apartment – 408<br><b>Total – 420</b>                                                                                                                                                                   | 966                               |
| <b>Morris Lake Holdings Limited</b><br><b>Area – 424.5 hectares</b><br><b>Developable Land – 221.4 hectares</b><br>(22 ppa) | Development includes ground-based dwellings (singles, townhomes, semi-detached), multi-unit apartment buildings, commercial and industrial uses (Industrial is included under commercial for this assessment) | Single – 1,077/964*<br>Townhouses – 1,737/1,443*<br>Cluster Townhouse – 89/81*<br>4-plexes – 100/100<br>Mid-rise Multi-Unit Apartment – 1,003/661*<br>High-rise Multi-Unit Apartment – 1,284/1,044*<br><b>Total – 5,290/4,293*</b> | 12,167/9,874*                     |
| <b>Brycon Development</b><br><b>Area – 38.7 hectares</b><br><b>Developable Land – 24.7 hectares</b><br>(21 ppa)             | Development includes ground-based dwellings (singles, townhomes, semi-detached), multi-unit apartment                                                                                                         | Singles – 113<br>Semis – 80<br>Mid-rise Multi-Unit Apartment – 650<br><b>Total – 865</b>                                                                                                                                           | 1,990                             |
| <b>TOTAL</b>                                                                                                                |                                                                                                                                                                                                               | <b>5,710/5,578</b>                                                                                                                                                                                                                 | <b>13,133/12,829*</b>             |
| <b>Commercial Space</b>                                                                                                     | <b>GLA/Resident</b>                                                                                                                                                                                           | <b>Residents</b>                                                                                                                                                                                                                   | <b>Approximate Total GLA</b>      |
| Study Area Total                                                                                                            | 3.2/9.1*                                                                                                                                                                                                      | 13,133/12,829*                                                                                                                                                                                                                     | 42,600/116,600*                   |
| Notes:<br>* Less Phases 8, 12, and 13 on Brycon Development lands.                                                          |                                                                                                                                                                                                               |                                                                                                                                                                                                                                    |                                   |





#### Legend

- Study Area
- A J Giles Investments Limited
- Morris Lake Holdings Limited
- Brycon Developments
- Private Land Owner

0 250 500 Metres  
 (At original document size of 8.5x11)  
 1:25,000



Project Location: Halifax Regional Municipality, Nova Scotia  
 Prepared by JSA on 2023-04-06

Client/Project: Halifax Regional Municipality  
 Future Serviced Communities Background Studies

Figure No.  
**3.3**

Title  
**Morris Lake Study Area Concept Plan**

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#### 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 2022

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### 3.3.3 HIGH-DENSITY SCENARIO

The High-Density scenario proposes a higher population density compared to the developer requested scenario. This approach accommodates a higher proportion of medium- to high density housing typologies. This scenario assumes a similar developable area to the low density scenario however increases the population density from 16 to 36 person per acre, the high-density scenario proposes to have an estimated population of 21,337 within 9,277 dwelling units (Stantec 2023).

### 3.3.4 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 institutional 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 approximately 13,000.

## 3.4 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:

$$P_{Event} = \sum R \times A_{LU} \times EMC_{LU} \times RC_{LU}$$

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<sup>2</sup>

$EMC_{LU}$  = 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 Morris Lake Stormwater Management Plan (Stantec 2024b) using PCSWMM (Computational Hydraulics Inc. of Guelph, Ontario, CA) to firstly estimate the runoff from the Morris Lake watershed. The 2-yr 24-hr Chicago design storm was used as it is one of the design storms



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used for the Morris 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 3.5**) (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 3.5**. The hydrologic model results were then used to validate the runoff volumes from the rain-event based model.

**Table 3.5 Land Use Runoff Parameters**

| Land Use                   | Curve Number <sup>1</sup> | Runoff Coefficient <sup>1</sup> |
|----------------------------|---------------------------|---------------------------------|
| Rock/Dune/Barren           | 83                        | 0.18                            |
| Commercial                 | 92                        | 0.85                            |
| Institutional              | 92                        | 0.70                            |
| Forested                   | 65                        | 0.14                            |
| Undeveloped/Grassed        | 67                        | 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                            |

<sup>1</sup> McCuen 1998

### 3.4.1 PARAMETER SELECTION FOR PRECIPITATION EVENT BASED PHOSPHORUS MODEL

EMC Total P 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 3.6**.



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**Table 3.6 Event Mean Total Phosphorous Concentrations for Select Land Uses**

| Land Use                   | Total Phosphorous Event Mean Concentration (mg/L) |
|----------------------------|---------------------------------------------------|
| Rock/Dune/Barren           | 0.12 <sup>3</sup>                                 |
| Commercial / Institutional | 0.30 <sup>1</sup>                                 |
| Forest                     | 0.15 <sup>2</sup>                                 |
| Undeveloped/Grassed        | 0.56 <sup>2</sup>                                 |
| High-Density Residential   | 0.22 <sup>2</sup>                                 |
| Medium-Density Residential | 0.45 <sup>2</sup>                                 |
| Low-Density Residential    | 0.36 <sup>2</sup>                                 |
| Roadway                    | 0.62 <sup>2</sup>                                 |
| Wetland                    | 0.10 <sup>1</sup>                                 |

<sup>1</sup> CH2M HILL 1993; <sup>2</sup> Pitt and MacLean 1986; <sup>3</sup> USEPA 2001

### 3.4.2 PARAMETER SELECTION FOR PRECIPITATION EVENT BASED FECAL COLIFORM LOADING MODEL

EMC FC data were sourced for the land use distribution found within the studied watersheds, as presented in **Table 3.7**. 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. FC 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 FC loading in urban watersheds in Quebec. Commonly referenced literature sources were used for the remaining EMC values. Barnhart et al. (n.d.) found higher bacteria counts in runoff from residential areas and attributed loadings to wildlife rather than domestic animals. Variation in bacterial loadings from specific land uses was 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 significant 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 FC EMCs vary greatly between studies and show a strong trend of seasonal fluctuation.



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**Table 3.7 Event Mean Fecal Coliform Concentrations for Select Land Uses**

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

<sup>1</sup> Theriault and Duchesne 2012; <sup>2</sup> CH2M HILL 1993; <sup>3</sup> Burnhart *et al.* nd

### 3.4.3 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<sup>3</sup>) and peak discharge (Q<sub>p</sub>) to calculate the rainfall factor (R<sub>w</sub>). 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<sup>-1</sup> year<sup>-1</sup>)
- R<sub>w</sub> is the MUSLE *rainfall factor* (MJ mm ha<sup>-1</sup> hour<sup>-1</sup>)
- K is the *soil erodibility factor* (tonnes hour MJ<sup>-1</sup> mm<sup>-1</sup>)
- LS is the *slope length and steepness factor* (dimensionless)
- C is the *cropping management factor* (dimensionless)
- P is the support practice factor (dimensionless)

**Table 3.8** provides the input parameters used to calculate the MUSLE precipitation event sediment load for total watershed area that includes the MLSA.



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**Table 3.8 MUSLE Input Parameters**

| Input                                                                         | Value  | Assumptions                                                                                                 | MUSLE Source                 |
|-------------------------------------------------------------------------------|--------|-------------------------------------------------------------------------------------------------------------|------------------------------|
| <b>Rainfall Factor (Rw)</b>                                                   | 424.39 | Calculated using the volume of runoff in m <sup>3</sup> and peak discharge                                  | Haan 1982                    |
| <b>Soil Erodibility Factor (K) (tonnes h MJ<sup>-1</sup> mm<sup>-1</sup>)</b> | 0.017  | Dominant soil type in the area is gravelly sandy loam till (Halifax/Danesville soils); Table K-1            | Wall et al. 2002, p56        |
| <b>Slope length and Steepness Factor (LS)</b>                                 |        |                                                                                                             |                              |
| General Forest Cover                                                          | 0.78   | General Forest cover is average slope across the watershed and average flow length (4% slope, 250 m length) | Wall et al. 2002 Table LS-1  |
| Roads (Paved and Gravel)                                                      | 0.60   | Roads and Transmission lines use the maximum slope and flow length in watershed, (3% 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 |
| <b>Cropping Management Factor (C)</b>                                         |        |                                                                                                             |                              |
| 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     |
| <b>Support Management Factor (P)</b>                                          | 1      | No management practices                                                                                     | Wall et al. 2002             |

### 3.5 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:

$$Load_{Annual} = \sum LR_{LU} \times A_{LU}$$

Where:

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

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

$A_{LU}$  = area associated with a specific land use, m<sup>2</sup>



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### 3.5.1 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 3.9**.

**Table 3.9 Area-based Phosphorous Loading Rates for Select Land Uses**

| Land Use                    | Phosphorous Loading Rate<br>(g/m <sup>2</sup> ·yr) |
|-----------------------------|----------------------------------------------------|
| Commercial *                | 0.0202 <sup>1</sup>                                |
| Forest*                     | 0.0024 <sup>2</sup>                                |
| Undeveloped/Grassed*        | 0.015 <sup>2</sup>                                 |
| High-Density Residential*   | 0.035 <sup>1</sup>                                 |
| Medium-Density Residential* | 0.030 <sup>1</sup>                                 |
| Low-Density Residential*    | 0.025 <sup>1</sup>                                 |
| Institutional*              | 0.042 <sup>2</sup>                                 |
| Roadway                     | 0.35 <sup>3</sup>                                  |
| Agriculture                 | 0.0108 <sup>3</sup>                                |
| Wetland*                    | 0.0024 <sup>2</sup>                                |
| Barren                      | 0.0166 <sup>2</sup>                                |

<sup>1</sup> Waller and Hart 1986; <sup>2</sup> Reckhow *et al.* 1980; <sup>3</sup> MDEP 2000; \* - indicates loading rate from Brylinsky (2004)

### 3.5.2 PARAMETER SELECTION FOR ANNUAL FECAL COLIFORM LOADING MODEL

As there is limited areal-loading data available for land use associated FC loading, event mean concentration (EMC) values were used to determine the annual loading of FC from the studied watershed. Rainfall amounts reflective of climate change projections were not modelled however the climate normal average annual precipitation value of 1,414.2 mm (**Section 3.2**), was used to calculate the FC loading associated with the annual depth of rainfall.

Input parameters are presented in **Table 3.10** below. Due to limited available data, FC loading from wetlands and partially cleared forest land uses were assumed to be similar to forest/park land use. Similarly, FC loading from institutional land use was assumed to be similar to commercial development land use.



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**Table 3.10 Area-based Fecal Coliform Loading Rates for Select Land Uses**

| Land Use                   | Fecal Coliform Loading Rate (CFU/ha·yr) |
|----------------------------|-----------------------------------------|
| Commercial / Institutional | 5.60E+11                                |
| Forest                     | 7.78E+09                                |
| Agriculture                | 3.81E+11                                |
| High-Density Residential   | 3.18E+11                                |
| Medium-Density Residential | 3.51E+11                                |
| Low-Density Residential    | 3.56E+10                                |
| Roadway                    | 7.89E+10                                |

### 3.5.3 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:

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

Where:

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

**Table 3.11** summarizes the inputs, assumptions, and sources used for the RUSLEFAC calculations.



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**Table 3.11 RUSLEFAC Input Parameters**

| Input                                                                               | Value | Assumptions                                                                                                  | RUSLEFAC Source              |
|-------------------------------------------------------------------------------------|-------|--------------------------------------------------------------------------------------------------------------|------------------------------|
| <b>Rainfall Factor (R)</b><br>(MJ mm ha <sup>-1</sup> hour <sup>-1</sup> )          | 1790  | Table R-1 - Erosivity index and monthly distribution (%) for sites in the Prairie Region and Eastern Canada  | Wall et al. 2002, p. 44      |
| <b>Soil Erodibility Factor (K)</b><br>(tonnes h MJ <sup>-1</sup> mm <sup>-1</sup> ) | 0.017 | Dominant soil type in the area is gravelly sandy loam till (Halifax/Danesville soils); Table K-3             | Wall et al. 2002, p56        |
| <b>Slope length and Steepness Factor (LS)</b>                                       |       |                                                                                                              |                              |
| General Forest Cover                                                                | 0.78  | 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)                                                            | 0.60  | 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 |
| <b>Cropping Management Factor (C)</b>                                               |       |                                                                                                              |                              |
| 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     |
| <b>Support Management Factor (P)</b>                                                | 1     | No management practices                                                                                      | Wall et al. 2002             |



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## 4 Water Quality Modeling Results

The MLSA is located within three watersheds (Morris Lake, unnamed watercourse and De Said Lake/Smelt Brook). The pollutant loads are estimated for the existing condition, low-density, developer requested, high-density and areal land use scenarios for the combined three watershed areas that comprise the MLSA and eventually discharge to Cow Bay.

### 4.1 Storm-Event Model

#### 4.1.1 PHOSPHOROUS

Precipitation event-based Total P loading was completed for a design storm event with a 2-year 24hr precipitation depth occurring over the studied watershed, with results given in **Table 4.1**. Resultant Total P loading for the existing conditions, low-density, developer requested, high-density, and areal-land use scenarios are predicted as shown in **Table 4.1**. Compared to the existing conditions Total P loading, the development scenarios result in an increase of Total P loading of 7%, 6%, 5%, and 4% for the low-density, developer requested, high-density, and areal-land use scenarios, respectively. When compared to the annual phosphorous load, the event-based Total P loading is approximately 13% of the annual load for each scenario, including existing condition (see **Section 4.2** for annual load results).

**Table 4.1 Predicted Storm Event P Loading for Existing Condition and Development Scenarios**

| Development Scenario | Land Use                   | Area (ha)     | P Loading (kg) | Land Use Percentage | P Load Percentage |
|----------------------|----------------------------|---------------|----------------|---------------------|-------------------|
| Existing Conditions  | Commercial + Institutional | 425.5         | 26.5           | 8.3%                | 11.7%             |
|                      | Low-Density Residential    | 2231.8        | 148.1          | 43.3%               | 65.7%             |
|                      | Medium-Density Residential | 66.6          | 4.1            | 1.3%                | 1.8%              |
|                      | High-Density Residential   | 21.1          | 0.8            | 0.4%                | 0.4%              |
|                      | Forest                     | 1245.2        | 3.7            | 24.2%               | 1.7%              |
|                      | Undeveloped/Grass          | 330.5         | 8.3            | 6.4%                | 3.7%              |
|                      | Road                       | 243.6         | 31.0           | 4.7%                | 13.7%             |
|                      | Rock/Dune/Barren           | 88.4          | 0.3            | 1.7%                | 0.1%              |
|                      | Wetland                    | 108.6         | 2.7            | 2.1%                | 1.2%              |
|                      | Water                      | 388.2         | -              | 7.5%                | -                 |
|                      | <b>Total</b>               | <b>5149.4</b> | <b>225.6</b>   | <b>100.0%</b>       | <b>100.0%</b>     |
| Low-Density Scenario | Commercial + Institutional | 479.8         | 29.9           | 9.3%                | 12.4%             |
|                      | Low-Density Residential    | 2342.0        | 155.5          | 45.5%               | 64.3%             |
|                      | Medium-Density Residential | 134.1         | 8.3            | 2.6%                | 3.4%              |
|                      | High-Density Residential   | 21.1          | 0.8            | 0.4%                | 0.3%              |
|                      | Forest                     | 997.2         | 3.0            | 19.4%               | 1.2%              |
|                      | Undeveloped/Grass          | 330.5         | 8.3            | 6.4%                | 3.4%              |



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| Development Scenario         | Land Use                   | Area (ha)     | P Loading (kg) | Land Use Percentage | P Load Percentage |
|------------------------------|----------------------------|---------------|----------------|---------------------|-------------------|
|                              | Road                       | 259.6         | 33.0           | 5.0%                | 13.6%             |
|                              | Rock/Dune/Barren           | 88.4          | 0.3            | 1.7%                | 0.1%              |
|                              | Wetland                    | 108.6         | 2.7            | 2.1%                | 1.1%              |
|                              | Water                      | 388.2         | -              | 7.5%                | -                 |
|                              | <b>Total</b>               | <b>5149.4</b> | <b>241.8</b>   | <b>100.0%</b>       | <b>100.0%</b>     |
| Developer Requested Scenario | Commercial + Institutional | 520.1         | 32.4           | 10.1%               | 13.6%             |
|                              | Low-Density Residential    | 2255.7        | 149.7          | 43.8%               | 62.7%             |
|                              | Medium-Density Residential | 71.5          | 4.4            | 1.4%                | 1.9%              |
|                              | High-Density Residential   | 130.7         | 5.0            | 2.5%                | 2.1%              |
|                              | Forest                     | 996.1         | 3.0            | 19.3%               | 1.3%              |
|                              | Undeveloped/Grass          | 330.5         | 8.3            | 6.4%                | 3.5%              |
|                              | Road                       | 259.6         | 33.0           | 5.0%                | 13.8%             |
|                              | Rock/Dune/Barren           | 88.4          | 0.3            | 1.7%                | 0.1%              |
|                              | Wetland                    | 108.6         | 2.7            | 2.1%                | 1.1%              |
|                              | Water                      | 388.2         | -              | 7.5%                | -                 |
|                              | <b>Total</b>               | <b>5149.4</b> | <b>238.8</b>   | <b>100.0%</b>       | <b>100.0%</b>     |
| High-Density Scenario        | Commercial + Institutional | 479.8         | 29.9           | 9.3%                | 12.6%             |
|                              | Low-Density Residential    | 2236.7        | 148.5          | 43.4%               | 62.5%             |
|                              | Medium-Density Residential | 77.7          | 4.8            | 1.5%                | 2.0%              |
|                              | High-Density Residential   | 184.0         | 7.0            | 3.6%                | 2.9%              |
|                              | Forest                     | 996.0         | 3.0            | 19.3%               | 1.3%              |
|                              | Undeveloped/Grass          | 330.5         | 8.3            | 6.4%                | 3.5%              |
|                              | Road                       | 259.6         | 33.0           | 5.0%                | 13.9%             |
|                              | Rock/Dune/Barren           | 88.4          | 0.3            | 1.7%                | 0.1%              |
|                              | Wetland                    | 108.6         | 2.7            | 2.1%                | 1.1%              |
|                              | Water                      | 388.2         | -              | 7.5%                | -                 |
|                              | <b>Total</b>               | <b>5149.4</b> | <b>237.5</b>   | <b>100.0%</b>       | <b>100.0%</b>     |
| Areal – Land Use Scenario    | Commercial + Institutional | 480.2         | 29.9           | 9.3%                | 12.7%             |
|                              | Low-Density Residential    | 2250.9        | 149.4          | 43.7%               | 63.5%             |
|                              | Medium-Density Residential | 70.5          | 4.4            | 1.4%                | 1.9%              |
|                              | High-Density Residential   | 108.8         | 4.1            | 2.1%                | 1.8%              |
|                              | Forest                     | 1063.7        | 3.2            | 20.7%               | 1.4%              |
|                              | Undeveloped/Grass          | 330.5         | 8.3            | 6.4%                | 3.5%              |
|                              | Road                       | 259.6         | 33.0           | 5.0%                | 14.0%             |
|                              | Rock/Dune/Barren           | 88.4          | 0.3            | 1.7%                | 0.1%              |
|                              | Wetland                    | 108.6         | 2.7            | 2.1%                | 1.1%              |
|                              | Water                      | 388.2         | -              | 7.5%                | -                 |
|                              | <b>Total</b>               | <b>5149.4</b> | <b>235.3</b>   | <b>100.0%</b>       | <b>100.0%</b>     |



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## 4.1.2 FECAL COLIFORM

Precipitation event-based FC loading was completed for a design storm event with a 2-year 24-hr duration precipitation depth occurring over the studied watershed, with results given in **Table 4.2**. Resultant FC loading for the existing conditions, low-development, developer requested, high-development, and areal-land use scenarios are predicted as  $3.30 \times 10^{13}$ ,  $3.57 \times 10^{13}$ ,  $3.58 \times 10^{13}$ ,  $3.60 \times 10^{13}$  CFU, and  $3.50 \times 10^{13}$  CFU respectively. From existing conditions, this represents an increase in FC load of 8%, 8%, 9%, and 6% for the low-density, developer requested, high-density scenarios, and areal-land use scenarios, respectively.

**Table 4.2 Predicted FC Loading during Storm Event for Existing Condition and Development Scenarios**

| Development Scenario         | Existing Condition Land Use | Area (ha)     | FC Loading (CFU) | Land Use Percentage | FC Load Percentage |
|------------------------------|-----------------------------|---------------|------------------|---------------------|--------------------|
| Existing Conditions          | Commercial + Institutional  | 425.5         | 3.97E+12         | 8.3%                | 12.0%              |
|                              | Low-density Residential     | 2231.8        | 2.55E+13         | 43.3%               | 77.3%              |
|                              | Medium-density Residential  | 66.6          | 8.91E+11         | 1.3%                | 2.7%               |
|                              | High-density Residential    | 21.1          | 2.82E+11         | 0.4%                | 0.9%               |
|                              | Forest/Wetland              | 1353.7        | 1.35E+11         | 26.3%               | 0.4%               |
|                              | Undeveloped/Grassed         | 330.5         | 1.54E+12         | 6.4%                | 4.7%               |
|                              | Road                        | 243.6         | 6.99E+11         | 4.7%                | 2.1%               |
|                              | Rock/Dune/Barren            | 88.4          | 1.33E+10         | 1.7%                | 0.0%               |
|                              | Water                       | 388.2         | -                | 7.5%                |                    |
|                              | <b>Total</b>                | <b>5149.4</b> | <b>3.30E+13</b>  | <b>100.0%</b>       | <b>100.0%</b>      |
| Low-Density Scenario         | Commercial + Institutional  | 479.8         | 4.48E+12         | 9.3%                | 12.5%              |
|                              | Low-density Residential     | 2342.0        | 2.68E+13         | 45.5%               | 75.1%              |
|                              | Medium-density Residential  | 134.1         | 1.79E+12         | 2.6%                | 5.0%               |
|                              | High-density Residential    | 21.1          | 2.82E+11         | 0.4%                | 0.8%               |
|                              | Forest/Wetland              | 1105.8        | 1.11E+11         | 21.5%               | 0.3%               |
|                              | Undeveloped/Grassed         | 330.5         | 1.54E+12         | 6.4%                | 4.3%               |
|                              | Road                        | 259.6         | 7.45E+11         | 5.0%                | 2.1%               |
|                              | Rock/Dune/Barren            | 88.4          | 1.33E+10         | 1.7%                | 0.0%               |
|                              | Water                       | 388.2         | -                | 7.5%                | -                  |
|                              | <b>Total</b>                | <b>5149.4</b> | <b>3.57E+13</b>  | <b>100.0%</b>       | <b>100.0%</b>      |
| Developer Requested Scenario | Commercial + Institutional  | 520.1         | 4.86E+12         | 10.1%               | 13.6%              |
|                              | Low-density Residential     | 2255.7        | 2.58E+13         | 43.8%               | 72.1%              |
|                              | Medium-density Residential  | 71.5          | 9.56E+11         | 1.4%                | 2.7%               |
|                              | High-density Residential    | 130.7         | 1.75E+12         | 2.5%                | 4.9%               |
|                              | Forest/Wetland              | 1104.7        | 1.10E+11         | 21.5%               | 0.3%               |
|                              | Undeveloped/Grassed         | 330.5         | 1.54E+12         | 6.4%                | 4.3%               |
|                              | Road                        | 259.6         | 7.45E+11         | 5.0%                | 2.1%               |
|                              | Rock/Dune/Barren            | 88.4          | 1.33E+10         | 1.7%                | 0.0%               |



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| Development Scenario    | Existing Condition Land Use | Area (ha)     | FC Loading (CFU) | Land Use Percentage | FC Load Percentage |
|-------------------------|-----------------------------|---------------|------------------|---------------------|--------------------|
|                         | Water                       | 388.2         | -                | 7.5%                |                    |
|                         | <b>Total</b>                | <b>5149.4</b> | <b>3.58E+13</b>  | <b>100.0%</b>       | <b>100.0%</b>      |
| High-Density Scenario   | Commercial + Institutional  | 479.8         | 4.48E+12         | 9.3%                | 12.5%              |
|                         | Low-density Residential     | 2236.7        | 2.56E+13         | 43.4%               | 71.1%              |
|                         | Medium-density Residential  | 77.7          | 1.04E+12         | 1.5%                | 2.9%               |
|                         | High-density Residential    | 184.0         | 2.46E+12         | 3.6%                | 6.8%               |
|                         | Forest/Wetland              | 1104.5        | 1.10E+11         | 21.4%               | 0.3%               |
|                         | Undeveloped/Grassed         | 330.5         | 1.54E+12         | 6.4%                | 4.3%               |
|                         | Road                        | 259.6         | 7.45E+11         | 5.0%                | 2.1%               |
|                         | Rock/Dune/Barren            | 88.4          | 1.33E+10         | 1.7%                | 0.0%               |
|                         | Water                       | 388.2         | -                | 7.5%                |                    |
|                         | <b>Total</b>                | <b>5149.4</b> | <b>3.60E+13</b>  | <b>100.0%</b>       | <b>100.0%</b>      |
|                         |                             |               |                  |                     |                    |
| Areal Land Use Scenario | Commercial + Institutional  | 480.2         | 4.48E+12         | 9.3%                | 12.8%              |
|                         | Low-density Residential     | 2250.9        | 2.57E+13         | 43.7%               | 73.5%              |
|                         | Medium-density Residential  | 70.5          | 9.43E+11         | 1.4%                | 2.7%               |
|                         | High-density Residential    | 108.8         | 1.45E+12         | 2.1%                | 4.2%               |
|                         | Forest/Wetland              | 1172.3        | 1.17E+11         | 22.8%               | 0.3%               |
|                         | Undeveloped/Grassed         | 330.5         | 1.54E+12         | 6.4%                | 4.4%               |
|                         | Road                        | 259.6         | 7.45E+11         | 5.0%                | 2.1%               |
|                         | Rock/Dune/Barren            | 88.4          | 1.33E+10         | 1.7%                | 0.0%               |
|                         | Water                       | 388.2         | -                | 7.5%                |                    |
|                         | <b>Total</b>                | <b>5149.4</b> | <b>3.50E+13</b>  | <b>100.0%</b>       | <b>100.0%</b>      |
|                         |                             |               |                  |                     |                    |

## 4.1.3 SEDIMENT

The total event-based soil loss load (tonnes) for each development scenario is presented in **Table 4.3**. The low-density, developer requested, and high-density scenarios reported the same total storm event load (361 tonnes). The areal land use scenario resulted in a slightly lower sediment load of 358 tonnes. 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 low-density, developer requested, and high-density scenarios represent a sediment load increase of 5% when compared to the existing condition, as low, medium and high-density residential are assumed to have the same sediment loading rates, and the other land uses (forest general, roads and disturbed forest) having the same areas for each scenario. The areal land use scenario represents a sediment load increase of 4% when compared to the existing condition as it maintains the greatest amount of forested area of the development scenarios.



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**Table 4.3 Event-Based Sediment Loading Results for Existing Condition and Development Scenarios**

| Development Condition               | Land Use                       | A (tonnes/ha) | Area (ha) | Total Storm Event Load (tonnes) |
|-------------------------------------|--------------------------------|---------------|-----------|---------------------------------|
| <b>Existing Condition</b>           | Forest General (Non-Disturbed) | 0.0069        | 1442.10   | 344                             |
|                                     | Roads                          | 0.3704        | 243.59    |                                 |
|                                     | Disturbed Forest Land          | 0.2752        | 330.47    |                                 |
|                                     | Urban                          | 0.0556        | 2745.04   |                                 |
| <b>Low-Density Development</b>      | Forest General (Non-Disturbed) | 0.0069        | 1194.11   | 361                             |
|                                     | Roads                          | 0.3704        | 259.61    |                                 |
|                                     | Disturbed Forest Land          | 0.2752        | 330.47    |                                 |
|                                     | Urban                          | 0.0556        | 2977.01   |                                 |
| <b>Developer Requested Scenario</b> | Forest General (Non-Disturbed) | 0.0069        | 1193.06   | 361                             |
|                                     | Roads                          | 0.3704        | 259.61    |                                 |
|                                     | Disturbed Forest Land          | 0.2752        | 330.47    |                                 |
|                                     | Urban                          | 0.0556        | 2978.06   |                                 |
| <b>High-Density Development</b>     | Forest General (Non-Disturbed) | 0.0069        | 1192.89   | 361                             |
|                                     | Roads                          | 0.3704        | 259.61    |                                 |
|                                     | Disturbed Forest Land          | 0.2752        | 330.47    |                                 |
|                                     | Urban                          | 0.0556        | 2978.23   |                                 |
| <b>Areal Land-Use Scenario</b>      | Forest General (Non-Disturbed) | 0.0069        | 1260.65   | 358                             |
|                                     | Roads                          | 0.3704        | 259.61    |                                 |
|                                     | Disturbed Forest Land          | 0.2752        | 330.47    |                                 |
|                                     | Urban                          | 0.0556        | 2910.46   |                                 |

## 4.2 Annual Watershed Loading Model

Modelling was completed to predict changes in land use associated contaminant loadings for the proposed development scenarios. Models were completed for Total P, FC, and sediment using methods described in **Section 3**.

### 4.2.1 PHOSPHORUS

The annual Total P loading from the Morris Lake watershed was completed, with results given in **Table 4.4**. The existing condition annual Total P load corresponds to an annual loading rate of 0.0316 gm P/m<sup>2</sup>-yr. This loading rate is generally higher than the P export loading rates measured by Scott et. al. (2000) for watersheds in the Halifax area as presented in Brylinsky (2004).



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**Table 4.4 Predicted Annual P Loads for Existing Condition and Development Scenarios**

| Development Scenario         | Land Use                   | Area (ha)     | Annual P Loading (kg/year) | Land Use Percentage | P Load Percentage |
|------------------------------|----------------------------|---------------|----------------------------|---------------------|-------------------|
| Existing Condition           | Commercial                 | 385.9         | 78.0                       | 7.5%                | 4.8%              |
|                              | Institutional              | 39.7          | 16.7                       | 0.8%                | 1.0%              |
|                              | Low-Density Residential    | 2231.8        | 557.9                      | 43.3%               | 34.3%             |
|                              | Medium-Density Residential | 66.6          | 20.0                       | 1.3%                | 1.2%              |
|                              | High-Density Residential   | 21.1          | 7.4                        | 0.4%                | 0.5%              |
|                              | Forested                   | 1245.2        | 29.9                       | 24.2%               | 1.8%              |
|                              | Undeveloped/Grassed        | 330.5         | 49.6                       | 6.4%                | 3.0%              |
|                              | Road                       | 243.6         | 852.6                      | 4.7%                | 52.3%             |
|                              | Rock/Dune/Barren           | 88.4          | 14.7                       | 1.7%                | 0.9%              |
|                              | Wetland                    | 108.6         | 2.6                        | 2.1%                | 0.2%              |
|                              | Water                      | 388.2         | -                          | 7.5%                | -                 |
|                              | <b>Total</b>               | <b>5149.4</b> | <b>1629.2</b>              | <b>100.0%</b>       | <b>100.0%</b>     |
| Low-Density Condition        | Commercial                 | 440.1         | 88.9                       | 8.6%                | 5.1%              |
|                              | Institutional              | 39.7          | 16.7                       | 0.8%                | 1.0%              |
|                              | Low-Density Residential    | 2342.0        | 585.5                      | 45.5%               | 33.7%             |
|                              | Medium-Density Residential | 134.1         | 40.2                       | 2.6%                | 2.3%              |
|                              | High-Density Residential   | 21.1          | 7.4                        | 0.4%                | 0.4%              |
|                              | Forested                   | 997.2         | 23.9                       | 19.4%               | 1.4%              |
|                              | Undeveloped/Grassed        | 330.5         | 49.6                       | 6.4%                | 2.9%              |
|                              | Road                       | 259.6         | 908.6                      | 5.0%                | 52.3%             |
|                              | Rock/Dune/Barren           | 88.4          | 14.7                       | 1.7%                | 0.8%              |
|                              | Wetland                    | 108.6         | 2.6                        | 2.1%                | 0.2%              |
|                              | Water                      | 388.2         | -                          | 7.5%                | -                 |
|                              | <b>Total</b>               | <b>5149.4</b> | <b>1738.1</b>              | <b>100.0%</b>       | <b>100.0%</b>     |
| Developer Requested Scenario | Commercial                 | 454.3         | 91.8                       | 8.8%                | 5.2%              |
|                              | Institutional              | 65.9          | 27.7                       | 1.3%                | 1.6%              |
|                              | Low-Density Residential    | 2255.7        | 563.9                      | 43.8%               | 32.2%             |
|                              | Medium-Density Residential | 71.5          | 21.5                       | 1.4%                | 1.2%              |
|                              | High-Density Residential   | 130.7         | 45.7                       | 2.5%                | 2.6%              |
|                              | Forested                   | 996.1         | 23.9                       | 19.3%               | 1.4%              |
|                              | Undeveloped/Grassed        | 330.5         | 49.6                       | 6.4%                | 2.8%              |
|                              | Road                       | 259.6         | 908.6                      | 5.0%                | 51.9%             |
|                              | Rock/Dune/Barren           | 88.4          | 14.7                       | 1.7%                | 0.8%              |
|                              | Wetland                    | 108.6         | 2.6                        | 2.1%                | 0.2%              |
|                              | Water                      | 388.2         | -                          | 7.5%                | -                 |
|                              | <b>Total</b>               | <b>5149.4</b> | <b>1750.0</b>              | <b>100.0%</b>       | <b>100.0%</b>     |
| High-Density Condition       | Commercial                 | 440.1         | 88.9                       | 8.6%                | 5.1%              |



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| Development Scenario    | Land Use                   | Area (ha)     | Annual P Loading (kg/year) | Land Use Percentage | P Load Percentage |
|-------------------------|----------------------------|---------------|----------------------------|---------------------|-------------------|
|                         | Institutional              | 39.7          | 16.7                       | 0.8%                | 1.0%              |
|                         | Low-Density Residential    | 2236.7        | 559.2                      | 43.4%               | 31.9%             |
|                         | Medium-Density Residential | 77.7          | 23.3                       | 1.5%                | 1.3%              |
|                         | High-Density Residential   | 184.0         | 64.4                       | 3.6%                | 3.7%              |
|                         | Forested                   | 996.0         | 23.9                       | 19.3%               | 1.4%              |
|                         | Undeveloped/Grassed        | 330.5         | 49.6                       | 6.4%                | 2.8%              |
|                         | Road                       | 259.6         | 908.6                      | 5.0%                | 51.9%             |
|                         | Rock/Dune/Barren           | 88.4          | 14.7                       | 1.7%                | 0.8%              |
|                         | Wetland                    | 108.6         | 2.6                        | 2.1%                | 0.2%              |
|                         | Water                      | 388.2         | -                          | 7.5%                | -                 |
|                         | <b>Total</b>               | <b>5149.4</b> | <b>1751.9</b>              | <b>100.0%</b>       | <b>100.0%</b>     |
| Areal Land Use Scenario | Commercial                 | 440.6         | 89.0                       | 8.6%                | 5.2%              |
|                         | Institutional              | 39.7          | 16.7                       | 0.8%                | 1.0%              |
|                         | Low-Density Residential    | 2250.9        | 562.7                      | 43.7%               | 32.6%             |
|                         | Medium-Density Residential | 70.5          | 21.2                       | 1.4%                | 1.2%              |
|                         | High-Density Residential   | 108.8         | 38.1                       | 2.1%                | 2.2%              |
|                         | Forested                   | 1063.7        | 25.5                       | 20.7%               | 1.5%              |
|                         | Undeveloped/Grassed        | 330.5         | 49.6                       | 6.4%                | 2.9%              |
|                         | Road                       | 259.6         | 908.6                      | 5.0%                | 52.6%             |
|                         | Rock/Dune/Barren           | 88.4          | 14.7                       | 1.7%                | 0.9%              |
|                         | Wetland                    | 108.6         | 2.6                        | 2.1%                | 0.2%              |
|                         | Water                      | 388.2         | -                          | 7.5%                | -                 |
|                         | <b>Total</b>               | <b>5149.4</b> | <b>1728.6</b>              | <b>100.0%</b>       | <b>100.0%</b>     |

**Figure 4.1** presents the land use breakdown of Total P loading for each development scenario. Roadways and low-density residential areas account for approximately 85% of annual loading within the watershed for the existing condition and development conditions. Of the proposed development scenarios, the areal land use scenario has the lowest annual Total P load (1,728 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 developer requested scenario having less high-density residential units, the developer requested and high-density annual Total P loading rates are similar (1,749 and 1,751 kg P/yr). The density of the developments is the main difference between development scenarios as the high-density scenario does not necessarily spread over a larger area, rather houses a greater population within the same area.



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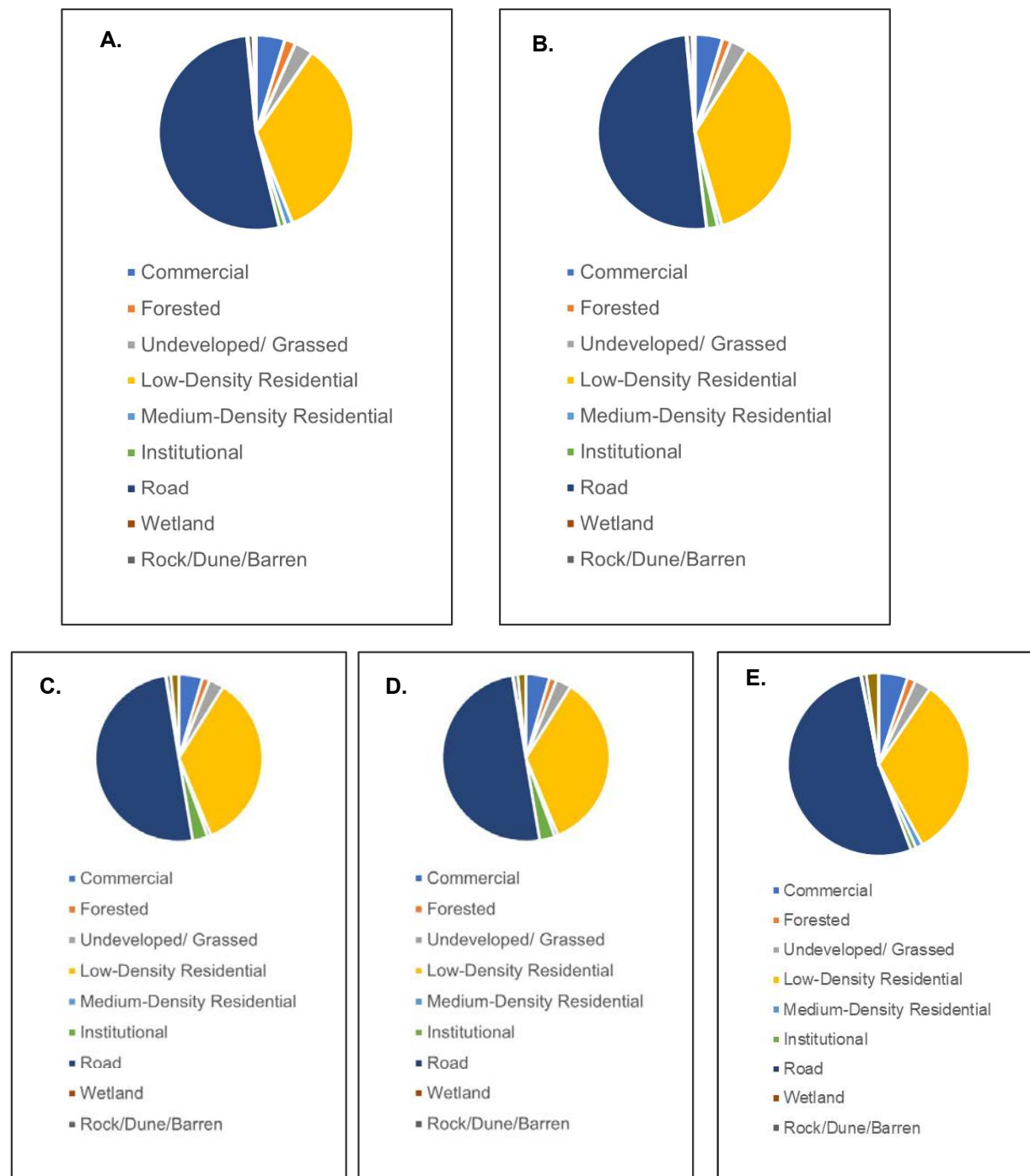


**Figure 4.1 Total P Loading - Existing Conditions (A), Low-Density (B), Developer Requested (C), High-Density (D), Areal Land Use (E)**

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## 4.2.2 FECAL COLIFORM

The annual FC loading from the Morris Lake watershed was completed, with results given in **Table 4.5**. More than 80% of the annual loading is estimated to be generated from commercial/institutional and low-density residential land use types within the watershed for existing condition and the development scenarios. Commercial/institutional areas account for approximately 8 to 10% of the land use within the watershed and contribute to approximately 21 to 24% of the annual FC loading within the MLSA.

**Table 4.5 Predicted Annual FC Loads for Existing Condition and Development Scenarios**

| Development Scenario          | Land Use                   | Area (ha)     | Annual FC Loading (CFU/year) | Land Use Percentage | FC Load Percentage |
|-------------------------------|----------------------------|---------------|------------------------------|---------------------|--------------------|
| Existing Condition            | Commercial + Institutional | 425.5         | 2.38E+14                     | 8.3%                | 21.2%              |
|                               | Low-Density Residential    | 2231.8        | 7.09E+14                     | 43.3%               | 63.1%              |
|                               | Medium-Density Residential | 66.6          | 2.34E+13                     | 1.3%                | 2.1%               |
|                               | High-Density Residential   | 21.1          | 5.52E+11                     | 0.4%                | 0.0%               |
|                               | Forest/Wetlands            | 1353.7        | 1.05E+13                     | 26.3%               | 0.9%               |
|                               | Undeveloped/ Grassed       | 330.5         | 1.26E+14                     | 6.4%                | 11.2%              |
|                               | Road                       | 243.6         | 8.68E+12                     | 4.7%                | 0.8%               |
|                               | Rock/Dune/Barren           | 88.4          | 6.97E+12                     | 1.7%                | 0.6%               |
|                               | Water                      | 388.2         | -                            | 7.5%                | 0.0%               |
|                               | <b>Total</b>               | <b>5149.4</b> | <b>1.12E+15</b>              | <b>100.0%</b>       | <b>100.0%</b>      |
| Low-Density Condition         | Commercial + Institutional | 479.8         | 2.69E+14                     | 9.3%                | 22.1%              |
|                               | Low-Density Residential    | 2342.0        | 7.44E+14                     | 45.5%               | 61.3%              |
|                               | Medium-Density Residential | 134.1         | 4.70E+13                     | 2.6%                | 3.9%               |
|                               | High-Density Residential   | 21.1          | 8.56E+12                     | 0.4%                | 0.7%               |
|                               | Forest/Wetlands            | 1105.8        | 8.60E+12                     | 21.5%               | 0.7%               |
|                               | Undeveloped/ Grassed       | 330.5         | 1.26E+14                     | 6.4%                | 10.4%              |
|                               | Road                       | 259.6         | 9.25E+12                     | 5.0%                | 0.8%               |
|                               | Rock/Dune/Barren           | 88.4          | 1.12E+12                     | 1.7%                | 0.1%               |
|                               | Water                      | 388.2         |                              | 7.5%                | 0.0%               |
|                               | <b>Total</b>               | <b>5149.4</b> | <b>1.21E+15</b>              | <b>100.0%</b>       | <b>100.0%</b>      |
| Developer Requested Condition | Commercial/ Institutional  | 520.1         | 2.91E+14                     | 10.1%               | 23.7%              |
|                               | Low-Density Residential    | 2255.7        | 7.17E+14                     | 43.8%               | 58.2%              |
|                               | Medium-Density Residential | 71.5          | 2.51E+13                     | 1.4%                | 2.0%               |
|                               | High-Density Residential   | 130.7         | 5.30E+13                     | 2.5%                | 4.3%               |
|                               | Forest/Wetlands            | 1104.7        | 8.59E+12                     | 21.5%               | 0.7%               |
|                               | Undeveloped/ Grassed       | 330.5         | 1.26E+14                     | 6.4%                | 10.2%              |
|                               | Road                       | 259.6         | 9.25E+12                     | 5.0%                | 0.8%               |
|                               | Rock/Dune/Barren           | 88.4          | 1.12E+12                     | 1.7%                | 0.1%               |
|                               | Water                      | 388.2         |                              | 7.5%                | 0.0%               |
|                               | <b>Total</b>               | <b>5149.4</b> | <b>1.23E+15</b>              | <b>100.0%</b>       | <b>100.0%</b>      |



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| Development Scenario    | Land Use                   | Area (ha)     | Annual FC Loading (CFU/year) | Land Use Percentage | FC Load Percentage |
|-------------------------|----------------------------|---------------|------------------------------|---------------------|--------------------|
| High-Density Condition  | Commercial + Institutional | 479.8         | 2.69E+14                     | 9.3%                | 21.9%              |
|                         | Low-Density Residential    | 2236.7        | 7.11E+14                     | 43.4%               | 58.0%              |
|                         | Medium-Density Residential | 77.7          | 2.73E+13                     | 1.5%                | 2.2%               |
|                         | High-Density Residential   | 184.0         | 7.46E+13                     | 3.6%                | 6.1%               |
|                         | Forest/Wetlands            | 1104.5        | 8.59E+12                     | 21.4%               | 0.7%               |
|                         | Undeveloped/ Grassed       | 330.5         | 1.26E+14                     | 6.4%                | 10.3%              |
|                         | Road                       | 259.6         | 9.25E+12                     | 5.0%                | 0.8%               |
|                         | Rock/Dune/Barren           | 88.4          | 1.12E+12                     | 1.7%                | 0.1%               |
|                         | Water                      | 388.2         | -                            | 7.5%                | 0.0%               |
|                         | <b>Total</b>               | <b>5149.4</b> | <b>1.23E+15</b>              | <b>100.0%</b>       | <b>100.0%</b>      |
| Areal Land-Use Scenario | Commercial + Institutional | 480.2         | 2.69E+14                     | 9.3%                | 22.4%              |
|                         | Low-Density Residential    | 2250.9        | 7.15E+14                     | 43.7%               | 59.7%              |
|                         | Medium-Density Residential | 70.5          | 2.47E+13                     | 1.4%                | 2.1%               |
|                         | High-Density Residential   | 108.8         | 4.41E+13                     | 2.1%                | 3.7%               |
|                         | Forest/Wetlands            | 1172.3        | 9.12E+12                     | 22.8%               | 0.8%               |
|                         | Undeveloped/ Grassed       | 330.5         | 1.26E+14                     | 6.4%                | 10.5%              |
|                         | Road                       | 259.6         | 9.25E+12                     | 5.0%                | 0.8%               |
|                         | Rock/Dune/Barren           | 88.4          | 1.12E+12                     | 1.7%                | 0.1%               |
|                         | Water                      | 388.2         | -                            | 7.5%                | 0.0%               |
|                         | <b>Total</b>               | <b>5149.4</b> | <b>1.20E+15</b>              | <b>100.0%</b>       | <b>100.0%</b>      |

### 4.2.3 SEDIMENT

The estimated total annual sediment loss load (tonnes/year) for each development scenario are presented in **Table 4.6**. For the existing conditions, the total annual loading rate is 1,186 tonnes/year leaving the watershed, with no mitigation measures in place. The low-density, developer requested, and high-density scenarios all had a total annual sediment loading rate of 1,245 tonnes/year. The areal land-use scenario had a total annual sediment loading rate of 1,233 tonnes/year. The development scenarios have the same annual loads due to the same total developed areas for total developed areas with the same sediment loading rates applied to the different densities (low, medium and high density residential) and therefore the reason why the areal land use scenario is smaller, is due to the larger amount of naturally preserved forested land within the watershed.



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**Table 4.6 Predicted Annual Sediment Loads for Existing Condition and Development Scenarios**

| Development Condition               | Land Use                       | A<br>(tonnes/ha/yr) | Area<br>(ha) | Total Annual Load<br>(tonnes/yr) |
|-------------------------------------|--------------------------------|---------------------|--------------|----------------------------------|
| <b>Existing Condition</b>           | Forest General (Non-Disturbed) | 0.024               | 1442.10      | 1,186                            |
|                                     | Roads                          | 1.278               | 243.59       |                                  |
|                                     | Disturbed Forest Land          | 0.949               | 330.47       |                                  |
|                                     | Urban                          | 0.192               | 2745.04      |                                  |
| <b>Low-Density Development</b>      | Forest General (Non-Disturbed) | 0.024               | 1194.11      | 1,245                            |
|                                     | Roads                          | 1.278               | 259.61       |                                  |
|                                     | Disturbed Forest Land          | 0.949               | 330.47       |                                  |
|                                     | Urban                          | 0.192               | 2977.01      |                                  |
| <b>Developer Requested Scenario</b> | Forest General (Non-Disturbed) | 0.024               | 1193.06      | 1,245                            |
|                                     | Roads                          | 1.278               | 259.61       |                                  |
|                                     | Disturbed Forest Land          | 0.949               | 330.47       |                                  |
|                                     | Urban                          | 0.192               | 2978.06      |                                  |
| <b>High-Density Development</b>     | Forest General (Non-Disturbed) | 0.024               | 1192.89      | 1,245                            |
|                                     | Roads                          | 1.278               | 259.61       |                                  |
|                                     | Disturbed Forest Land          | 0.949               | 330.47       |                                  |
|                                     | Urban                          | 0.192               | 2978.23      |                                  |
| <b>Areal Land Use Scenario</b>      | Forest General (Non-Disturbed) | 0.024               | 1260.65      | 1,233                            |
|                                     | Roads                          | 1.278               | 259.61       |                                  |
|                                     | Disturbed Forest Land          | 0.949               | 330.47       |                                  |
|                                     | Urban                          | 0.192               | 2910.46      |                                  |



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## 5 Water Quality Discussion

### 5.1 Total Phosphorus

Area- and concentration-based total phosphorus (P) loadings in the three MLSA watersheds—Morris Lake, unnamed watercourses, and De Said Lake/Smelt Brook—are primarily generated by anthropogenic sources, particularly low-density residential areas and roadways. Under both existing conditions and projected development scenarios, these two land uses account for about 85% of the total P loadings in the Morris Lake Watershed.

The annual Total P loading for the existing condition scenario was calculated to be 1,629 kg/year. For the proposed development scenarios, the areal land use scenario resulted in the lowest increase in Total P loading for both event-based and annual loading calculations. This is primarily due to its reduced development footprint compared to the other three scenarios, resulting in the retention of more naturally vegetated areas. Other scenarios could be amended to further reduce the development footprint while retaining the housing supplied to reduce the loss of vegetated areas. The low-density, developer requested, and high-density development scenarios resulted in an increase in Total P load of less than 7% for the annual and storm-event models.

Future development for the MLSA 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 implementation of mitigation measures will be required for developments to reduce Total P loads to match existing or background conditions.

### 5.2 Fecal Coliform

According to the EMC-based model results, area and concentration-based FC loadings within Morris Lake are largely generated by residential developments, commercial developments, and undeveloped/grassed areas for the existing conditions and development scenarios. It is noted, however, that model parameters used for FC have a high degree of variability. Results from rainfall-event modeling in Morris Lake give a calculated loading of  $3.30 \times 10^{13}$  CFU/100 mL during a 2yr-24hr Chicago design storm event. When compared to annual loading calculations within the watershed, at  $1.12 \times 10^{15}$  CFU/100 mL, the annual model results appear to overestimate FC loading from the watershed. The storm event FC load modelling accounts for approximately 1.5% of the annual FC loading for the existing conditions scenario.

Similarly, the rainfall-event based FC loading resulted in approximately 1.5% of the annual FC loads for the development scenarios. The increase in annual FC load from baseline conditions for each of the development scenarios was 8%, 10%, 7%, and 10% for the low-density, developer requested, areal land use and high-density scenarios, respectively.

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



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### 5.3 Sediment

Sediment load modelling using MUSLE and RUSLEFAC calculations for the low-density, developer requested and high-density development scenarios resulted in sediments loads of 1,245 tonnes/year on an annual basis and 361 tonnes per storm-event. This equates to an increase in annual sediment loading of 5% from existing conditions. The areal land use scenario resulted in sediment loads of 1,233 tonnes/year on an annual basis and 358 kg per storm event. The storm-event loading represents approximately 29% of the total annual sediment load. Baseline sediment loading was estimated to be 1,186 tonnes per year, with approximately 344 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 (**Section 6.3**) 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 greatly 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.



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## 6 Water Quality Conclusions and Recommendations

### 6.1 Phosphorous Loading Mitigation

#### 6.1.1 LAND USE-BASED MITIGATION

Low-density residential and road land uses are estimated to contribute the highest percentage of Total P loading to the lake system on an annual basis for the development scenarios. To reduce annual Total P load to the watershed, the development scenarios must consider implementation of LID methods to reduce loading by approximately 5% for land development scenarios. The following mitigation measures 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 total phosphorus 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 LID measures would be expected to reduce Total P loads for the development area to achieve Total P 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
  - h. Water Quality Swale, and
  - i. Green Roofs
- It is recommended that that water management infrastructure be developed and assessed to result in no net increase in Total P loads for the chosen development scenario. Where possible water management infrastructure should be created to mimic natural wetlands and their ecological functionality.



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- Green space creation or the retention of naturally forested park areas within the new development scenarios. When planting, 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 ( $0.025 \text{ gm/m}^2 \text{ yr}$ ) to green space ( $0.015 \text{ gm/m}^2 \text{ yr}$ ), 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 3.4 and 3.5**), limiting the affected area will limit the additional load produced within the watershed.

### 6.1.2 ON-GOING MONITORING

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

- 1) The extension of in-lake P monitoring at deep lake locations when the lake system is completely mixed (e.g., late fall, early spring) An example of this monitoring would be the continuation of HRM's LakeWatchers program in which Morris Lake is monitored in early May. This is recommended to capture any increasing trend in lake P concentrations and associated trophic status changes caused by a release of P from vegetation and algae decay. If carried out after seasonal lake turnover, this data can also capture any increase in P concentrations from the lake epilimnion.
- 2) The continuation of profiling and 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 HRM LakeWatchers monitoring program conducts monitoring in Morris Lake in August, which would meet this monitoring need.
- 3) 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.
- 4) As part of monitoring within the MLSA, an adaptive management approach should be applied to target point and nonpoint sources of P within the MLSA to improve water quality. As sources of P within the watersheds are identified, management measures can be applied to reduce P loading in the watersheds containing the MLSA as described above.



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## **6.2 *E. coli* Loading Mitigation**

### **6.2.1 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 FC within the watershed.

### **6.2.2 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:

- 1) Increased public education on the need to pick-up droppings from domestic dogs. Kiwanis Centre Beach and Park - Morris Lake is a popular recreation area for many and signage within the park may help inform the public of risks relating to FC exceedances on human and animal health.
- 2) Increased public education of the risk of swimming in areas where wildlife congregates. The MLSA is the habitat of many avian, and other wildlife species. Public risk awareness is needed to mitigate risk to human health from these sources, particularly within Morris Lake.
- 3) 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.

### **6.2.3 ON-GOING MONITORING**

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

- 1) Monitoring of fecal coliform markers to better understand the sources of FC within the watershed.
- 2) 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 Morris Lake is monitored twice annually (early May and August).
- 3) During the monitoring within the MLSA, 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



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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.

### 6.3 Sediment Loading Mitigation

Baseline TSS concentrations are relatively low in watercourses within the Morris Lake watershed, including the Cow Bay River. De Said Lake/Smelt Brook watershed had higher TSS concentration (average 166 mg/L) at SW-14 for baseline conditions. If the MLSA is developed following the selection of one of the proposed development scenarios, it will be important to implement ESC Measures to mitigate any effects from development. The expected increases in sediment loading from existing conditions are up to 3%. 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 6.1** 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 Total P and *E. coli* loads through infiltration and filtering.

**Table 6.1 Event-Based Sediment Loading Results (HESL 2012)**

| Measure Implemented |                                               | Percent Efficiency of TSS Removal |
|---------------------|-----------------------------------------------|-----------------------------------|
| Erosion Prevention  | Establishing and maintaining 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                                |



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## 7 Stormwater Management Background and Design Criteria

This portion of the report outlines the results from the review of the existing storm drainage conditions within the Morris Lake Study Area and summarizes the conceptual stormwater management (SWM) plan measures required to meet the established SWM design criteria. The Morris Lake Study Area is within the Smelt Brook and Cow Bay River watersheds.

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

### 7.1 Regulatory Considerations

#### 7.1.1 HALIFAX WATER

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



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- For ponds to be taken over by Halifax Water, the preference is for dry ponds. If wet ponds are to be privately owned and operated, they will be considered on a case-by-case basis; and;
- Additional pond volume allowances must include a 300 mm freeboard from the 100-year water level.

## 7.1.1.1 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  $T_d$  as the time of duration in hours (see **Figure 6.1**).

| 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**

## 7.1.1.2 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.

## 7.1.2 HALIFAX REGIONAL MUNICIPALITY

In the design and implementation of stormwater management systems within the Halifax Regional Municipality (HRM), adherence to the following guidelines as per Administrative Order Number 2020-010-OP is important for ensuring effective stormwater conveyance and environmental sustainability:

- Multi-unit, commercial and industrial sites are required to demonstrate that the stormwater system is designed to provide an average annual removal of 80% Total Suspended Solids (TSS) from post-development runoff; and,
- The use of Green Infrastructure and Low Impact Development (LID) measures is preferred and encouraged.



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## 7.1.3 NOVA SCOTIA DEPARTMENT OF ENVIRONMENT AND CLIMATE CHANGE

Nova Scotia Environment (NSE) requires that culverts be designed to have a headwater/pipe diameter ratio (Hw/D) of 1.0 for the 100-year flow return period. 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.

## 7.1.4 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 Morris Lake Study Area is within the floodplain of two watercourses, 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 Areas* 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



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- (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.

### 7.1.5 EASTERN PASSAGE/COW BAY MUNICIPAL PLANNING STRATEGY AND LAND USE BY-LAW

The Municipal Planning Strategy for Eastern Passage/Cow Bay contains recommendations to establish floodplain zones for the Cow Bay River and Smelt Brook and provides development restrictions within the floodplain. Permitted uses include forestry and agricultural uses (excluding buildings), passive and active recreational uses and conservation uses, with no infilling, excavation or grade alteration permitted to occur within one hundred (100) feet of Cow Bay River and Smelt Brook.

Similarly, the Land Use By-law for Eastern Passage/Cow Bay contains policies and regulations regarding watercourse and coastal area setbacks and buffers, as well as development restrictions. While this project does not include floodplain mapping for the Cow Bay River or Smelt Brook, the policies and regulations included in the municipal standards should be considered for the Morris Lake Study Area through future planning reviews.

## 7.2 Background Reports

The following reports have been reviewed and used in determining the SWM design criteria for the Morris Lake Study Area.

- **Master Stormwater Management Plan, Strum Consulting (2023):** This Master Stormwater Management Plan (MSWMP) developed by Strum Consulting for Morris Lake East Holdings Limited (MLEHL). The report outlines a comprehensive stormwater management system for the site and illustrates how this system aligns with the stormwater management objectives outlined in the Halifax Municipal Planning Strategy for Eastern Passage/Cow Bay. The report has been compiled with reference to HRM Stormwater Management Guidelines (Dillon, 2006), and previous MSWMPs for areas within the HRM with similar stormwater management sensitivities,



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including West Bedford Sub-Areas 1 & 12, West Bedford Sub-Area 2, Bedford South, and the Parks of Lake Charles.

- **Morris 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 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.

### 7.3 Additional Available Data

The Nova Scotia Department of Municipal Affairs and Housing (NSDMAH) commissioned the collection of hydrologic data in the Halifax Regional Municipality (HRM) as part of the Municipal Flood Line Mapping Program (MFLMP). The scope of this project covers several different types of data collection for locations in HRM watersheds, including some of 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. Data collected included water levels, stage-discharge curves, and topographic and bathymetric surveys. This data will be of significant value in the development of detailed flood delineation in these areas.



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## 8 Existing Conditions

### 8.1 Site Location

The Morris Lake Study Area is situated to the south of Dartmouth, nestled between Portland Estates and CFB Shearwater. The Study Area presented in **Figure 8.1** is in close proximity to the 12 Wing Shearwater Airport, which is located to the southwest. The area's boundaries are defined by Caldwell Road and Smelt Brook to the west, Morris Lake to the north, Atholea Drive to the northeast, Cow Bay River to the east, and Cow Bay Road/Dyke Road to the south. The Morris Lake Study Area extends to the southwest, abutting the community of Eastern Passage, with the communities of Cow Bay and Cole Harbour situated to the south and northeast, respectively.

### 8.2 Topography

Based on the STRUM Master Stormwater Management Plan (2023), a detailed topographic survey by SDMM in 2023 outlined the site's rolling topography, sloping towards Smelt Brook and Cow Bay River from the center. Slope mapping created from available LIDAR shows most of the site has slopes less than 15%, with some embankments over 15% and low-lying areas near Cow Bay River and Smelt Brook with slopes under 2%. The slope mapping is illustrated in **Figure 8.2**, while **Figure 8.3** shows existing contours.

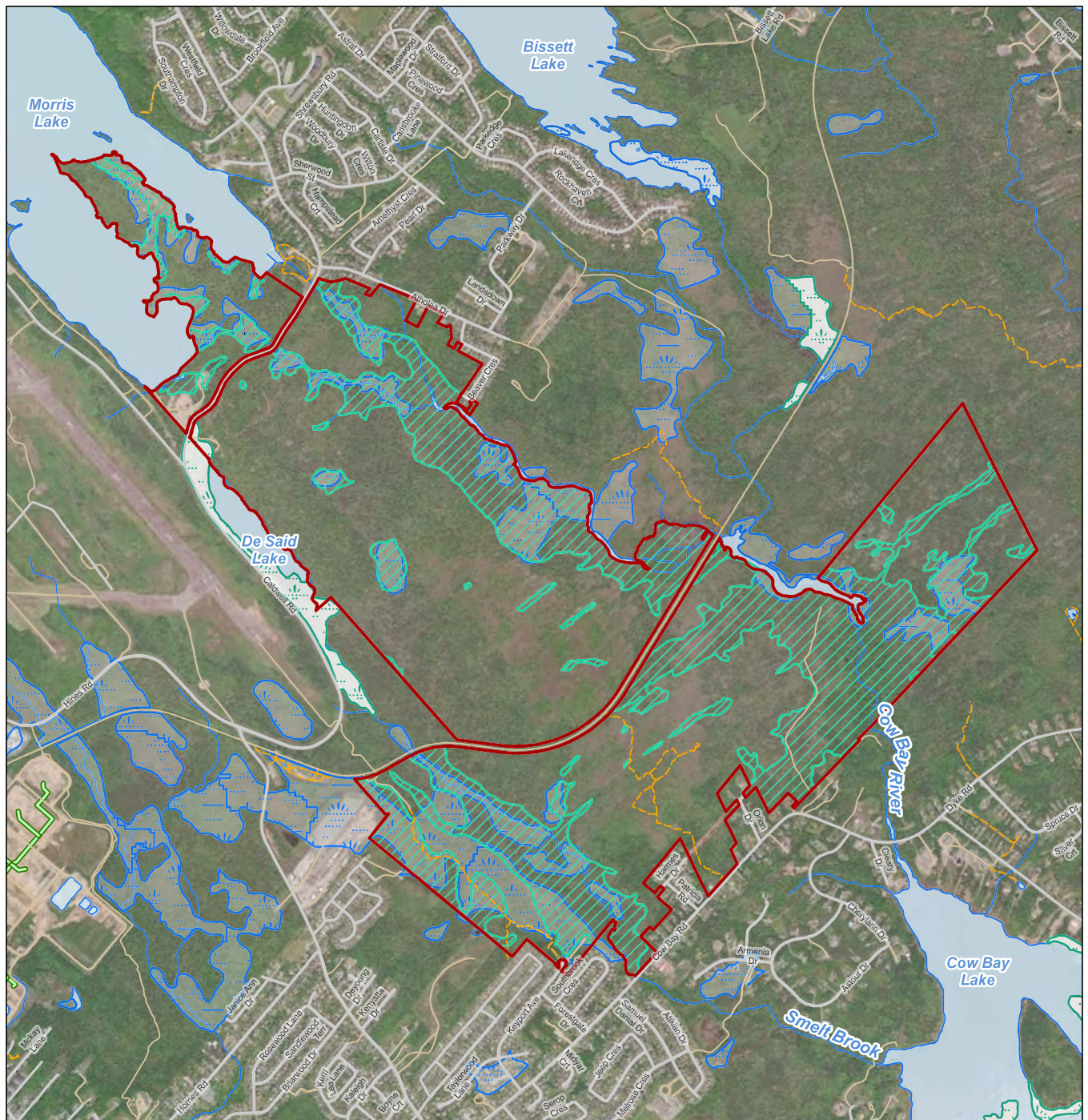
### 8.3 Land Use

The Morris Lake Study Area, spanning approximately 529 hectares, is primarily undeveloped. Caldwell Road cuts across the northern portion of the area, connecting to Atholea Drive, which delineates the northeast boundary of the site. The junction of Caldwell Road and Atholea Drive is highlighted by the Kiwanis Centre Beach and Park Morris Lake. The northeastern boundary is characterized by low density residential areas accessible from Atholea Drive, south of Caldwell Road. Caldwell Road extends through the Study Area, curving south past De Said Lake to join Hines Road, which leads westward, away from the Study Area (see **Figure 8.5**).

The Shearwater Flyer Trail runs along the southern perimeter of Hines Road and Caldwell Road before cutting through the southern half of the Study Area. The Cow Bay River, originating from Morris Lake within Kiwanis Park, winds its way through the Study Area, flowing towards Cow Bay Lake and ultimately discharging to the Atlantic Ocean. The beach is a popular recreational area and is utilized by Water Ski Wakeboard Nova Scotia for their summer water ski programs.

As per the STRUM Master Stormwater Management Plan (2023), the site, largely forested, is home to a diverse mix of hardwood and softwood species. The ecological landscape is classified as a blend of spruce pine flats, hummocks, and tolerant hardwood drumlins (Englobe, 2023).





- Study Area
- Utilities**
- Pipeline
- Transportation**
- Road
- Resource / Seasonal Road
- Trail

- Other Features**
- Waterway
- Waterbody
- Designated Wetland of Special Significance
- Wetland
- Wetlands (Stantec, 2023)

0 250 500 Metres  
(At original document size of 8.5x11)  
1:25,000



**Project Location**  
Halifax Regional Municipality,  
Nova Scotia

Prepared by AC on 2024-10-29  
QR by NW on 2024-10-29

**Client/Project**  
Halifax Regional Municipality  
Future Serviced Communities  
Background Studies

160410459

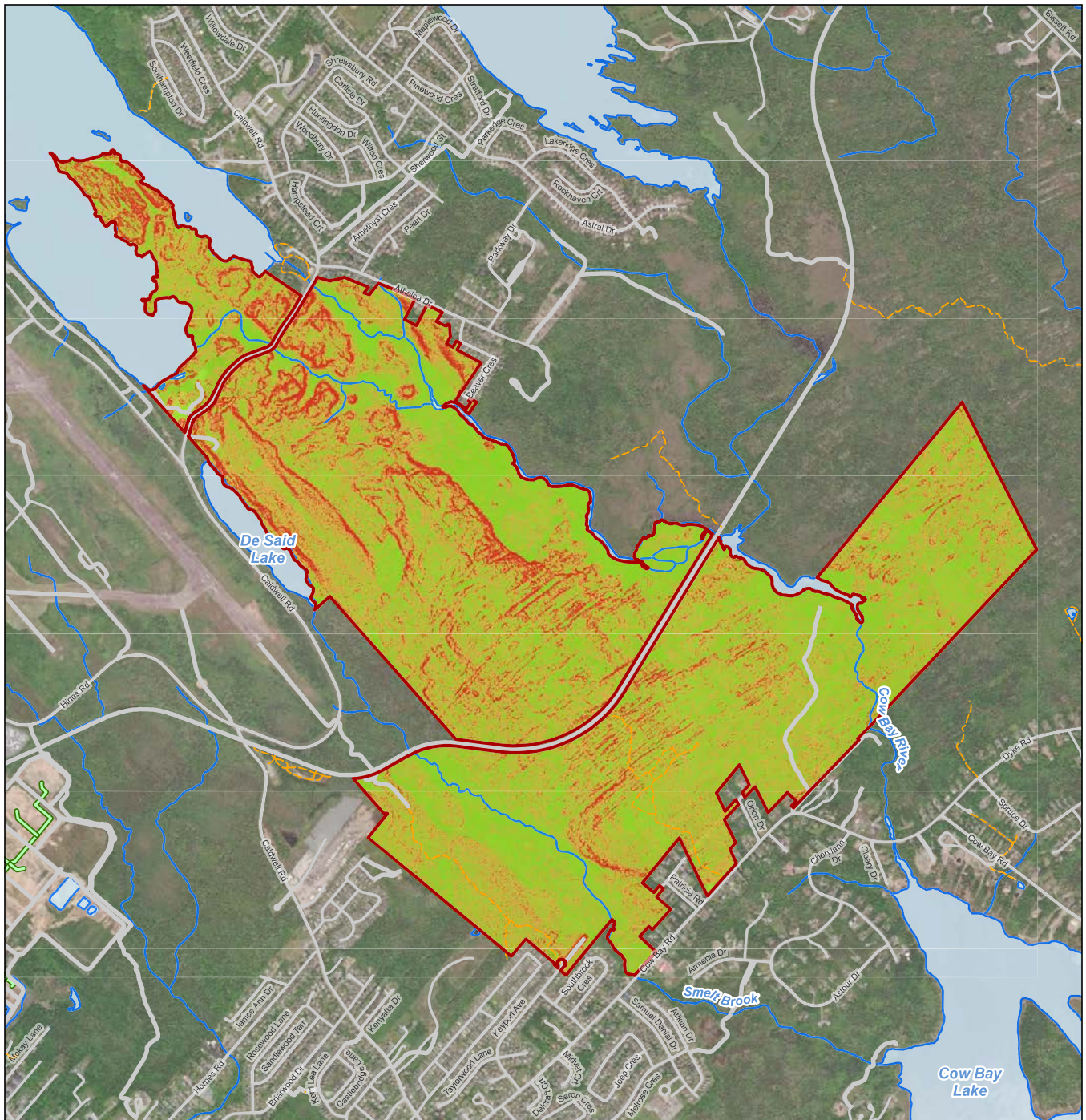
**Figure No.**  
**8.1**

**Title**  
**Morris 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

\\ao2013-pblss01\work\_group\1214\active\160410459\gis\_data\mapping\ArcGIS Pro\HRM\_Stormwater\_Mgmt.aprx: Morris\_Lake\_Fig3-1\_Study\_AreaRevised: 2024-10-29 By: aculf

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.



 Study Area

**Slope Analysis (Percent Rise)**

 0 - 5%

 5.01 - 15%

 >15%

**Transportation**

 Trail

 Highway

 Other Road

**Utilities**

 Pipeline

**Other Features**

 Waterway

 Waterbody

0 250 500  
Metres  
(At original document size of 8.5x11)  
1:25,000



**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

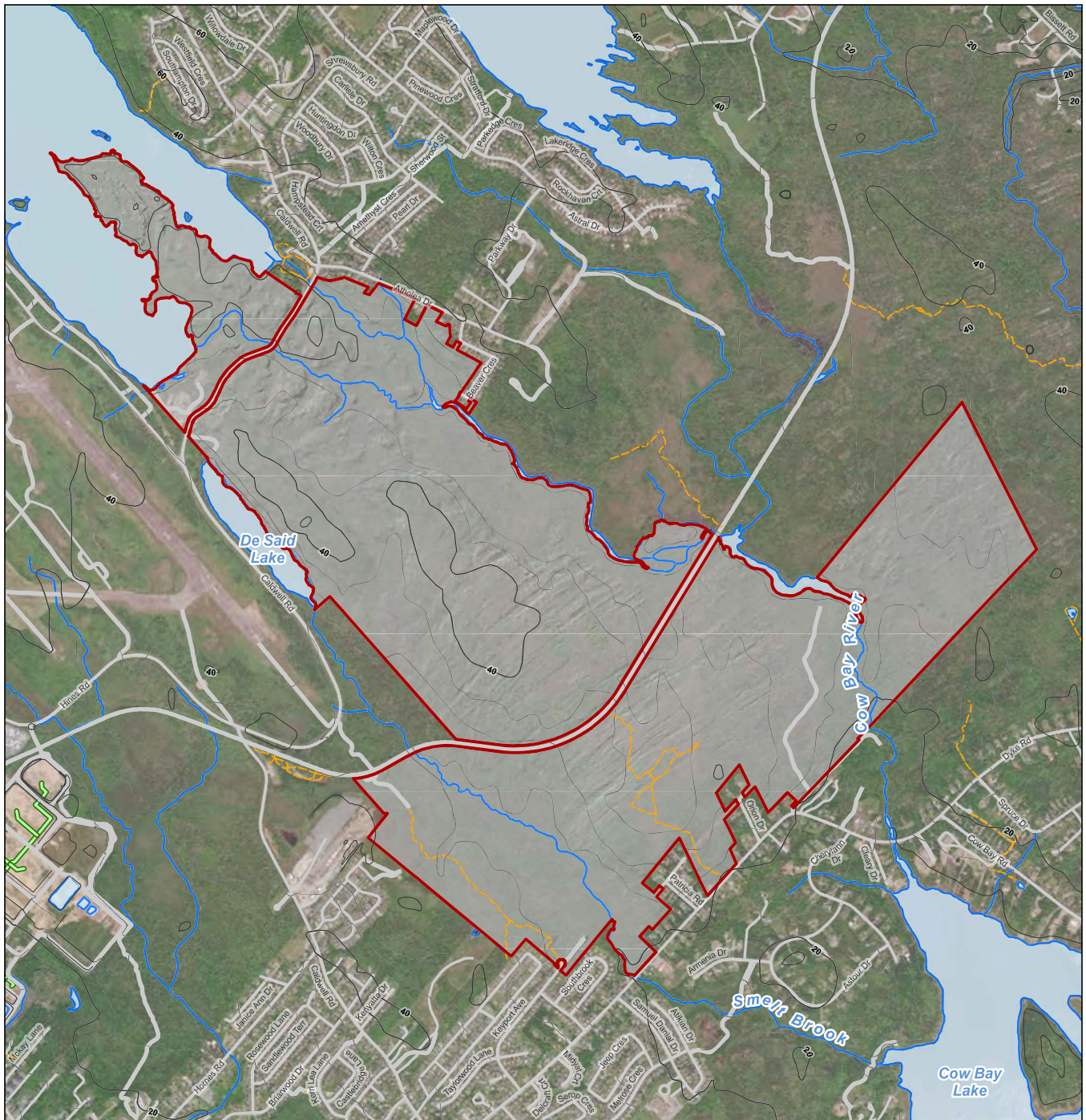
FIG ID: 160410459\_14

**Figure No.**  
8.2

**Title**  
**Slope Land Suitability Analysis -  
Morris 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



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Study Area  
 Contour (20 m)

**Transportation**  
 Trail  
 Highway  
 Other Road  
**Utilities**  
 Pipeline  
 Waterway  
 Waterbody

0 250 500 Metres  
 (At original document size of 8.5x11)  
 1:25,000



Project Location  
 Halifax Regional Municipality,  
 Nova Scotia

Prepared by AC on 2024-10-29  
 QR by NW on 2024-10-29

Client/Project  
 Halifax Regional Municipality  
 Future Serviced Communities  
 Background Studies

160410459

Figure No.  
**8.3**

Title  
**Elevation Contours - Morris Lake**

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## 8.4 Soil Conditions

Soil conditions for the Morris Lake Study Area were obtained from the “Nova Scotia Soil Survey Report #13 – Halifax County 1963”. As depicted in **Figure 8.4**, the soil type is generally classified as Halifax (Hx), which corresponds to a sandy loam soil with good to excessive drainage, and Rockland (R) which corresponds to areas where at least 60% of the land is exposed bedrock or where the till is extremely stony with variable drainage. There are also small areas classified Hantsport (Ha) and Wolfville (Wv). Ha corresponds to sandy loam to sandy clay loam with imperfect drainage, and Wv corresponds to brown loam to sandy clay loam with good drainage. Consequently, the classification scheme has been used to categorize this as Hydrologic Soil Group C.

Additionally, the bedrock beneath the site predominantly belongs to the Meguma Supergroup, a collection of gold-bearing metasediments. More specifically, it is part of the Taylors Head Formation (Strum Consulting, 2023).

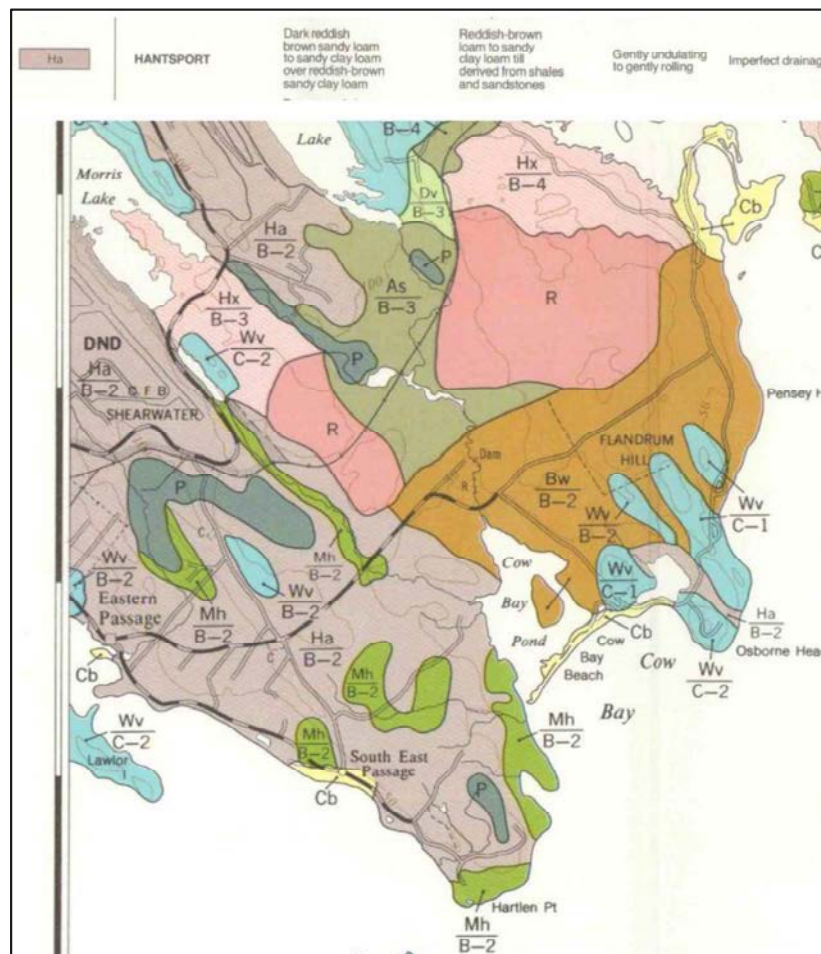


**Figure 8.4 Soil Type (Nova Scotia Soil Survey Report #13 – Halifax County 1963)**

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### 8.5 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 for the Morris Lake Study Area (MLSA).

Twenty-six (26) wetlands were identified but due to operational constraints, only thirteen (13) were evaluated within the Study Area. While none of the evaluated wetlands 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 MLSA 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). It should be noted that the MLSA abuts a known WSS, which surrounds DeSaid Lake, and is thus closely hydrologically tied to the study site and vulnerable from any anthropogenic disturbance within the study site.

Watercourse mapping was obtained from Stantec's Land Suitability Analysis for the Morris Lake Study Area, which identified two mapped watercourses, and one mapped waterbody. Water quality monitoring along the 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, 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 development of watercourse setbacks and buffers as established in the the Eastern Passage / Cow Bay Land Use By-Laws and proposed policies of the draft Regional Plan (Halifax Regional Municipality 2023) 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.

The proposed site is within the Cow Bay River watershed which includes Morris Lake, Bisset Lake and De Said Lake. Morris Lake is located at the north-western property line, from which Cow Bay River flows. Bissett Lake is located at the north-eastern property line, from which the eastern branch of the Cow Bay River flows. The Cow Bay River crosses the Study Area from north to south, prior to discharging into the Cow Bay Lake and ultimately into Cow Bay in the Atlantic Ocean. The western property line of the Study Area is bordered by De Said Lake and Smelt Brook, which discharges into Cow Bay Lake. The lakes are



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part of a complex drainage system, with significant runoff contribution from external upstream areas, and there is not sufficient data available regarding their hydrologic and hydraulic response to rainfall events. However, an effort has been made to include these water bodies and their contributions to their respective downstream watercourses. Refer to **Section 8.7.1** for more details on the assumptions made to account for external drainage contributions.

## 8.6 Existing Drainage Areas

Existing drainage areas were delineated using LiDAR data (2019) sourced from the HRM Open Data portal, specifically the HRM 1044600063400\_201901\_CHM.tif file.

The Watershed Delineation Tool (WDT) was used to determine the tributary subcatchments to the watercourses within the Study Area. The flow length of these subcatchments was 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 8.1**.

**Table 8.1 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 (-)        | 0.80        |
| Pervious Surface – Urban Area (-)          | 0.25 - 0.35 |
| Depression Storage                         |             |
| Impervious Surface (mm)                    | 1.88        |
| Pervious Surface (mm)                      | 3.75        |
| 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 is used to estimate the site's ability to absorb rainfall, which is primarily influenced by the pervious surfaces.

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



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values suitable for defining the depression storage for both pervious and impervious surfaces. Average value within the provided range was selected.

The existing storm drainage plan present in **Drawing EX-SD-1** in **Appendix B** illustrates the existing storm drainage plan, showcasing the watercourses and the delineated subcatchments.

### 8.7 Boundary Conditions

The water elevations in Cow Bay were obtained from the preliminary floodlines (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 provided by HRM as part of the on-going Regional Flood Mapping Delineation project being completed by CBCL. These floodlines 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 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 floodlines have been used to estimate the water levels at the storm outfall locations during various return periods. These estimated water levels have been used as boundary conditions in the form of fixed water levels at the outfalls within the hydrologic/hydraulic PCSWMM model for the 100-year storm event scenario. There are three stormwater outfalls that discharge into or just upstream of Cow Bay at different locations in the PCSWMM model. The water elevation at each of these outfalls is determined to be between 5 m and 17 m during the 100-year event, based on the topographic contours for both the current and climate change flood extent. For all other return periods, the normal flow depth within the outletting conduit or watercourse transect was used as a boundary condition at these locations.

**Figure 8.5** illustrates existing drainage conditions along with preliminary floodlines for the 20-year and 100-year storm including climate change impacts. The 20-year and 100-year floodlines are also shown in **Drawing EXSD-1** in **Appendix B**.

#### 8.7.1 EXTERNAL DRAINAGE CONTRIBUTION

Morris Lake and Bissett Lake are situated at the upstream end of the Study Area, and they are integrated in the PCSWMM model as upstream storage nodes with outlet weirs that contribute drainage to the Cow Bay River.

As shown on **Drawing EXSD-1**, there are significant upstream drainage areas tributary to Morris Lake and Bissett Lake. These upstream subcatchments have been delineated based on available LIDAR and their runoff contribution has been allocated directly into the storage nodes representing the lakes in the PCSWMM model.

Initial volume values were assigned to the storage nodes representing the lakes based on available contours and surface areas. Spillway weirs were used in the PCSWMM model as outlets from the lakes discharging into the downstream watercourses crossing the site. These hydraulic structures permit water to overflow into the watercourses when the water level in the lakes attains the top of bank elevation at the



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watercourse outlet location. This approach aims to simulate the hydraulic interconnectivity between the lakes and the downstream watercourses. Initial weir lengths for the lake outlets were estimated by measuring the width of the 100-year floodplain at the upstream end of the watercourses as obtained from HRM's preliminary flood lines.

Due to the absence of flow data and limited information on the lakes' rainfall-runoff response and/or outlet configuration, adjustments were made to the spillway weir and the storage in the lakes iteratively in the PCSWMM model, until the resulting water levels in Morris and Bissett lakes were close to the estimated water levels obtained from HRM's preliminary floodlines for the different return periods. These adjustments were necessary to improve model representation of the hydraulic performance of the lakes and their impact on the downstream watercourses during extreme weather events.

