# Queen's Royal Beach (M00090)

## 2019 Water Quality Monitoring & Data Analysis Report

By: Kennedy Laufman and Paula Moura

# Executive Summary

Queen's Royal Beach is a popular recreational area located within Old Town Niagara-on-the- Lake (NOTL), along the shores of the Niagara River near Lake Ontario. The beach was sampled and tested for *E. coli* throughout the summer of 2019 as a component of the Niagara River Remedial Action Plan (NRRAP). The NRRAP goals indicate that at least 80% of the geometric mean results of samples (taken at least once per week) must meet provincial water quality guidelines each swimming season for at least three years. This study is the second year of monitoring toward assessing the NRRAP goal.

In 2019, two Environmental Technician students employed by the Town of NOTL conducted water quality sampling at Queen's Royal Beach (QRB) (following established recreational water quality protocols) and two locations at a storm sewer outlet discharging stormwater from the King Street area into the Niagara River at QRB. Water sampling at the beach was completed three times per week (Monday, Wednesday, Friday) from June 7th to August 30th, 2019. Additional in-field parameters such as air and water temperature, wind speed, wave height and turbidity were also collected and reported for each sampling day.

Over the course of the sampling season, 81.1% of samples collected at QRB met the recreational water quality guideline for safe swimming. The beach was 'Posted' (meaning samples did not meet the guideline of <200 E. coli/100 mL) a total of 7 times during the duration of the study which seem to be linked to rain events. Precipitation data for QRB was tracked during the course of the study and all 'Posted' dates except for July 30th and August 15th occurred within 48 hours of a significant rain event (i.e., more than 10 mm of precipitation within 24 hours). Other observed spikes in *E. coli* levels occurred during periods of high wave action/high wind speeds, and thus may be related to the presence of sediment-bound environmentally persistent *E. coli* resuspended from beach sand into the beach water.

High levels of *E. coli* were usually detected in the samples taken from the mouth of the stormwater outlet and where the outlet flow met the beach water. Based on in-field observations, possible causes of high *E. coli* levels in the outlet could include the presence of wildlife and fecal matter within the stormwater system or human sewage due to unknown cross-connections or upstream sewer infrastructure issues impacting the King St. drainage area.

This study shows that QRB met the NRRAP water quality goal for its second year of monitoring. This data also provides an important indicator that the actions the Town of NOTL has taken has resulted in improvements over the past two years at QRB. Given actions are ongoing, it is recommended that water quality sampling of QRB and its nearby outfall continue in 2020 in order to assess the 'Beach Closings' indicator to acquire data for a third year. This monitoring could continue to include microbial source tracking to determine the source of *E. coli* (i.e., human or wildlife) and to reflect changes that are resulting from the Town's actions. Lastly, sampling in wet weather conditions at the beach and outfall is recommended to gain a further understanding of weather-related impacts to water quality at QRB.

Suggested citation: Laufman K. and P. Moura. 2020. Queen's Royal Beach Water Quality 2019 Monitoring and Data Analysis Report. Town of Niagara-on-the-Lake, Ontario, Canada.

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# Introduction

Queen's Royal Beach (QRB) is a small recreational beach located in the Town of Niagara-on-the- Lake (NOTL) (Figure 1). It is often used for wading, sightseeing, and as a put-in for paddleboards and kayaks. Up until the end of 2017, water quality at the beach was monitored weekly by the Niagara Region Public Health Unit (NRPHU). At that time, it was determined that a number of beaches would need to be removed from the NRPHU sampling schedule (including QRB) to allow for increased sampling and data accuracy at the other more popular beaches in the Niagara Region (i.e., Bay/Crystal, Lakeside, Nickel, Long Beach).

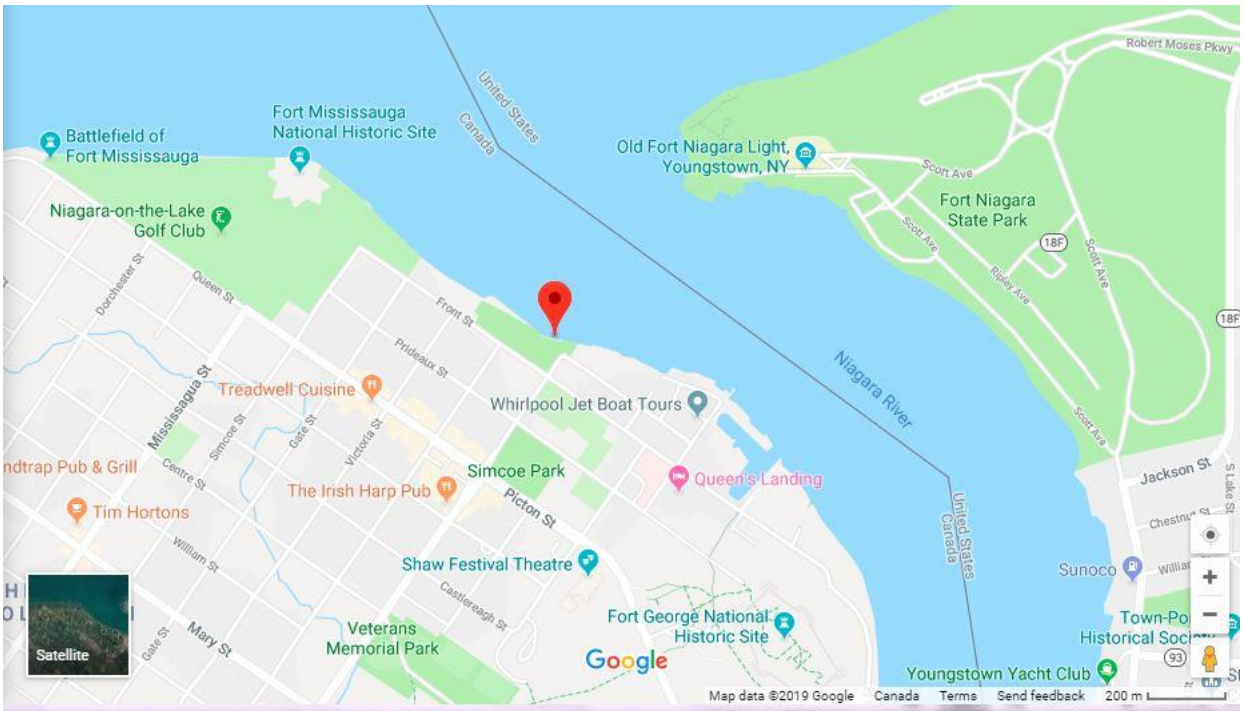


**Figure 1.** Map of the area showing the location of Queen's Royal Beach (red marker) in the Town of Niagara-on-the-Lake, Ontario.

In the interest of protecting the safety and health of both residents and tourists visiting the beach and to support the Niagara River (Ontario) Remedial Action Plan (RAP) goals, the Town of NOTL took over regularly collecting water samples at QRB to monitor the levels of *Escherichia coli* (*E. coli*) bacteria at the beach during the swimming season (May to September). To maintain consistency and comparability, sample analysis continues to be conducted by the Niagara Region Public Health Unit (NRPHU).

Bacteria at beaches can come from natural sources (e.g., wind, wave, wildlife) and/or anthropogenic sources (e.g., untreated raw sewage). High levels of *E. coli* bacteria pose a potential health risk because they are indicators of the potential occurrence of waterborne pathogens that can cause infection and illness in people. *E. coli* bacteria can be spread via exposure to contaminated surfaces (including liquids), infected people/animals, and ingestion of contaminated food and water (Public Health Agency of Canada, 2019). Elevated levels of bacteria at beaches, in particular, can pose a risk of infection to the public due to amount of contact with contaminated water during recreational swimming. In Ontario, the water quality guidelines are set by the Ontario Ministry of Health and Long-Term Care (OMHLTC) (Health Canada, 2012; OMHLTC, 2018). People are advised to avoid using recreational waters when *E. coli* levels are higher than 200 colony forming units (CFU) per 100 mL and the beach is 'Posted' (i.e. swimming/recreational water contact should

be avoided due to unsafe conditions). The NRPHU is responsible for communicating results and beach postings via announcements on their website and physical signage at the beach.

Queen's Royal Beach is the only public swimming beach along the Canadian side of the Niagara River AOC. The Niagara River RAP uses beach water quality as an indicator of the overall health of the Niagara River, as part of its goal to remove it from the list of the Great Lakes' Areas of Concern. The RAP Team developed specific goals to address several water quality issues in the Niagara River. Related to beach closings, the RAP Team can remove this beneficial use impairment when:

1. Prominent sources of fecal pollution that could contaminate the beach or recreational waters are known and remedial actions to address known sources are identified and completed;
2. At least 80% of the geometric mean results of recreational water samples (when sampled at least once per week) meet the Ontario Ministry of Health Recreational Water Quality Guideline (<200CFU/100 mL) each swimming season for a minimum of three years; and
3. Risk management actions (e.g. postings, signage, education, rain rule) are in place to protect human health.

This monitoring project was completed to determine whether QRB meets the Niagara River RAP's criterion 2 noted above in 2019. This project is the second year of a three-year monitoring plan. As such, the objectives of this study were to: (1) monitor and report on *E. coli* levels at QRB over the course of the 2019 summer season (beginning of June to the end of August), and (2) collect water samples at a nearby storm sewer outfall to ascertain the impacts of recent remedial actions in the catchment area.

# Methodology

## Study Area

The Queen's Royal Beach study area is located at 16 Front Street (UTM 656774, 4791261) in the Town of Niagara-on- the-Lake, Ontario, along the shoreline of the Niagara River (Fig. 2). Access to the beach is available from King Street into Queen's Royal Park.

**Figure 2** Photo taken from Western edge of QRB on June 19, 2019 (credit: Kennedy Laufman).

## Field Observations

General field observations were taken to identify consistent and notable characteristics of the study area, such as the presence of potential sources of contamination (including presence of wildlife), the general uses and amount of use of the study area by residents and tourists, shoreline erosion control methods, etc. Below are some general field observations:

- A stormwater outflow pipe at the Western shoreline is known as a potential source of contamination. It was actively flowing during each site visit.
- Queen's Royal Beach is frequented by tourists and residents for recreational use and access to Lake Ontario; visitors were observed swimming, kayaking, paddle boarding, walking, etc. On multiple visits, kayaking and paddle boarding groups were using the beach as a launching point. The primary launching point for recreational watercraft users was directly adjacent to, or in front of, the outfall.
- Riprap (the placement of stone along a shoreline to protect it from erosion) is present along at least half of the shoreline.
- The water level was consistently high throughout the season; approximately half of the beach was covered in water during the sampling/swimming season. The water levels recorded for Lake Ontario during this study ranged from 75.91 to 75.53 metres (Fisheries and Oceans Canada, 2019).

Detailed field observations and photos were noted during each sampling visit including (but not limited to) air temperature, weather, water colour, presence of algae, dead fish, or water with film or foam (**Appendix A**). Photos of notable field observations are available upon request from the Town of NOTL or the Niagara River RAP (info@ourniagarariver.ca).

## Sampling

Water quality sampling was conducted at QRB and two locations near the King Street Storm Outlet (KSSO) from May 27 to August 30, 2019. The May 27$^{th}$ water sampling from QRB was conducted by Niagara Peninsula Conservation Authority staff following the proper NRPHU protocol, as the NOTL staff were not hired yet. These samples were analyzed by the NRPHU and are included in this report.

A team of two Environmental Technicians from the Town of NOTL conducted water quality monitoring 3 days per week throughout the swimming season. As per the NRPHU protocol, samples were collected from 5 sites in the water parallel to the beach (Fig. 3). The water samples were submitted to NRPHU for same-day analysis of *E. coli* concentration (*E. coli* CFU per 100 mL) and calculation of the geometric mean for comparison to the provincial guideline (<200CFU/100 mL) (OMHLTC, 2018). The geometric mean results were provided by the NRPHU and used for this report. Figures 4-5 are examples of staff collecting water quality samples at the beach. In addition to the beach sampling, one water sample was collected from the mouth of the stormwater outlet pipe draining to the beach (Fig. 6) and one sample representative of the runoff from the outfall was collected before it meets the shoreline (Fig. 7). The sampling methodology was conducted as instructed by the NRPHU as described in **Table 1.** Precipitation data was sourced from the Vine & Tree Fruit INnovations webpage operated by Weather INnovations Consulting LP (www.vineandtreefruitinnovations.com).

**Table 1**: Sampling methodology for QRB, as instructed by Niagara Region Public Health.

| | |
|---|---|
| **Dates of sample collection** | Every Monday, Wednesday and Friday, where possible (i.e. sampling shifted to next available day on statutory holidays) |
| **Time of sample collection** | Completed from 8:20 to approx. 9:00am; submitted to lab by 10:45am at the latest to ensure submission to lab courier on time |
| **Location of sample collection** | 5 sites in the water (thigh to waist deep) labelled QR1 through QR5<br>1 site at the mouth of the outlet pipe draining to the beach, labelled QRS for 'source'<br>1 site at the point where the beach water meets the drainage from the outlet, labelled QRO |
| **Type of sample collection device** | Collection by hand, wearing nitrile gloves |
| **Type of sample container** | Sterile plastic bottle with a 200 mL fill line and 30 mg sodium thiosulphate |
| **Types of sample to be collected** | Grab samples |
| **Sampling method** | Collect sample at mid- thigh to waist depth (approximately 0.75 m), 15-30 cm below the surface of the water, in a direction away from the body. Fill bottle to fill line, then place in cooler immediately after collection. |
| **Sample preservation** | Samples preserved in a cooler with ice packs below 10 degrees, ideally around 4 degrees. |
| **In-situ field parameter measurements and notes** | Turbidity, wind speed, precipitation, air temperature, water temperature and wave height were measured at sampling site #3; field observations and photographs were also recorded/taken throughout sampling<br>Also note, when applicable:<br>→ if health hazards present<br>→ if sampling was not possible in any location, and reason why<br>→ if potential pollution sources present |


**Figure 3**: Map indicating sampling locations (blue dots) as well as the two outfall locations.

**Figure 4**: Sampling QRB with the 12-foot-long sampling pole from the shore on July 17, 2019 (credit: Paula Moura).

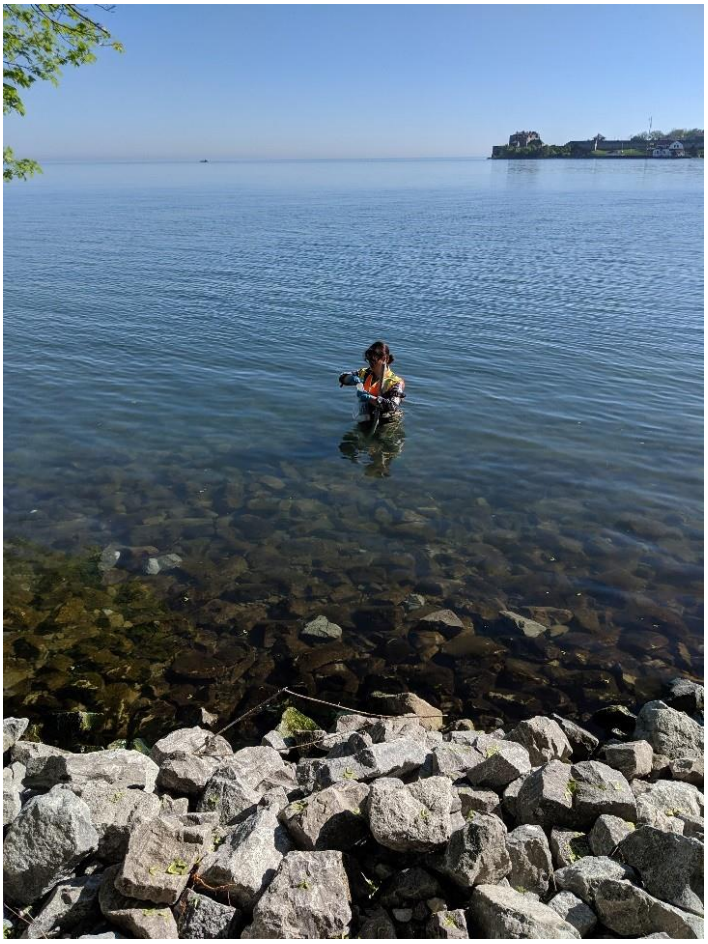

**Figure 5**: Sampling at QR4 on June 7, 2019 (credit: Kennedy Laufman).

**Figure 6**: Sampling from QRS, inside of the outlet pipe, on July 22, 2019 (credit: Kennedy Laufman).

**Figure 7**: Sampling runoff water from the outfall (QRO) where it meets the shoreline on July 9, 2019 (credit: Kennedy Laufman).

## Limitations

Limitations encountered during the study were documented and, to the fullest extent possible, mitigated through QA and QC measures. Limitations encountered during the study included maximum *E. coli* concentration detection limits of 1,000 CFU/100ml as per the method used by NRPHU, and the occasional inaccessibility of sampling sites due to safety concerns during poor weather. During poor weather/unsafe conditions, a 12-foot-long sampling pole was used to collect samples from the shoreline; the bottles were affixed to the sanitized end of the pole and submerged into the water as close as possible to the original sampling point.

## Health and Safety

Due to the nature of the sampling sites (i.e., working around and in water), health and safety was paramount during the study. Most importantly, the Environmental Technicians worked as a team and were never left alone working near water. As per the Town of NOTL policies, no outside work was conducted without long pants, long sleeved shirts, safety vest, safety boots, safety gloves and a hard hat.

## Quality Assurance and Quality Control

Quality assurance and quality control (QA and QC) are a key component in ensuring the accuracy of the study data. To this end, QA and QC measures were employed throughout every stage of this study. Primarily, all instructions provided by the Niagara Region Public Health department were followed closely throughout preparation, collection and transportation of the samples to ensure the accuracy and replicability of the data.

Sample analysis was conducted by qualified, trained staff at the NRPHU following established protocols.

## Qualifications of Technicians

The team of Environmental Technicians completing the water quality sampling on behalf of the Town of NOTL were two recent graduates from the Environmental Management and Assessment (EMA) program at Niagara College: Kennedy Laufman and Paula Moura.

Kennedy Laufman possesses a background in environmental and biomedical science; she obtained her Bachelor in Honours Science from the University of Guelph in 2017, majoring in Biomedical Sciences. Shortly thereafter, she completed the Environmental Management and Assessment Post-Graduate Certificate program at Niagara College in 2019, where she received training and in-field experience in surface water/groundwater quality analysis, sediment and soil analysis, and environmental project management.

Paula Moura has a Master's degree in Biological Water Resources and experience in water sampling in both controlled and natural environments. Paula completed the Environmental Management and Assessment program at Niagara College which provided experience in watercourse quality assessment, environmental legislation and technical report writing.

Kennedy and Paula were trained by staff from Niagara Region Public Health on the correct procedures for equipment handling, sample collection, sample transportation and sample delivery to the lab in 2019.

# Results & Discussion

Over the course of this study, the beach and storm outfall were sampled 37 separate times from May to September 2019. Monitoring shows that 81.1% of sampling events were below the provincial recreational water quality guideline (200 *E. coli* CFU per 100mL) (Fig. 8).

There were 7 sampling dates that resulted in the beach being 'Posted' (above 200 *E. coli* CFU per 100mL), five of those (71.4%) occurred following or during a significant rain event, defined as precipitation greater than 10mm within 24 hours (the exceedances were recorded on June 10, June 21, July 17, August 7, and August 8). Rainfall can exacerbate bacterial levels in bodies of water due to stormwater runoff or combined sewer overflows upstream in the Niagara River. High levels of bacteria are present in stormwater runoff because sources of bacterial pollution (e.g., wildlife fecal matter, livestock manure, pet waste, etc.) accumulate in runoff during periods of significant precipitation. For example, equine manure and bird guano present on streets and sidewalks in Old Town NOTL can be washed into the stormwater system during significant rainfall, and raccoon fecal matter present in the stormwater system can be washed away by high volumes of runoff during rainstorms; thus, by the time the stormwater runoff drains from the outlet during rainfall, it contains high concentrations of bacteria.

In some places, the sanitary sewer infrastructure can also be in poor condition, not connected properly, or built in such a way that conveys human waste to the storm sewer system—leading to contaminated waters. For example, during significant rainfall, combined sewer overflows (CSOs) can result in the release of contaminated runoff into receiving bodies of water. CSOs are most often found in older sewer infrastructure, where the sanitary and storm water sewers drain into the same system to be processed in a sewage treatment plant before being released. Large volumes of stormwater can exceed the capacity of these combined sewers, and CSOs are used to prevent flooding caused by sewer overloads. Consequently, CSO releases also result in the discharge of contaminated water (the combined sanitary and stormwater runoff) into receiving water bodies. During periods of heavy precipitation, CSO releases in the Niagara River could represent an additional potential source of E. coli at QRB.

There were two instances where *E. coli* levels did not meet the water quality limit but there was no rainfall recorded, indicating the potential presence of other bacterial sources such as CSOs in the Niagara River, wildlife at the beach, and/or sediment-bound *E. coli* disturbed by strong wind and waves. Past microbial source tracking studies completed in the Niagara River by Dr. Thomas Edge (ECCC, retired) indicated that the Niagara River delivers low concentrations of *E. coli* to the beach but was more frequently associated with low level human sewage impacts (NRRAP 2019). Other studies have shown that *E. coli* binds very well to loose particles such as sand and can be re-suspended during windy/wavy weather (Vogel et al., 2016). Anecdotal observations indicate that bacterial exceedances did coincide with other turbulent weather conditions in the absence of significant precipitation on at least one occasion (e.g., high winds and strong waves). For example, on August 14$^{th}$ high winds or waves were recorded which coincided with high *E. coli* levels at the beach in the absence of a significant precipitation event (Fig. 9).

In addition to sampling the beach, one grab sample was taken from the mouth of the stormwater outlet which flows into QRB and from the point where the stormwater runoff from the outlet meets the beach water at the shoreline. Overall, grab samples taken from the mouth of the storm outfall had higher levels of bacteria compared to the beach samples but were generally the same as the outfall runoff samples taken on the same day. The results indicate higher levels of *E. coli* detected in the outflow water irrespective of

precipitation/rainfall (Table 2) which could potentially be due to anthropogenic sources such as untreated raw sewage from broken laterals in the stormwater/sanitary sewers and/or to the presence of wildlife (e.g., racoons, geese, gulls, and ducks) at the beach. Notably, higher levels of bacteria in the outfall water did not necessarily translate to higher bacteria levels at the beach, indicating that there are several factors impacting stormwater and beach water quality including potential dilution of bacteria at the beach.

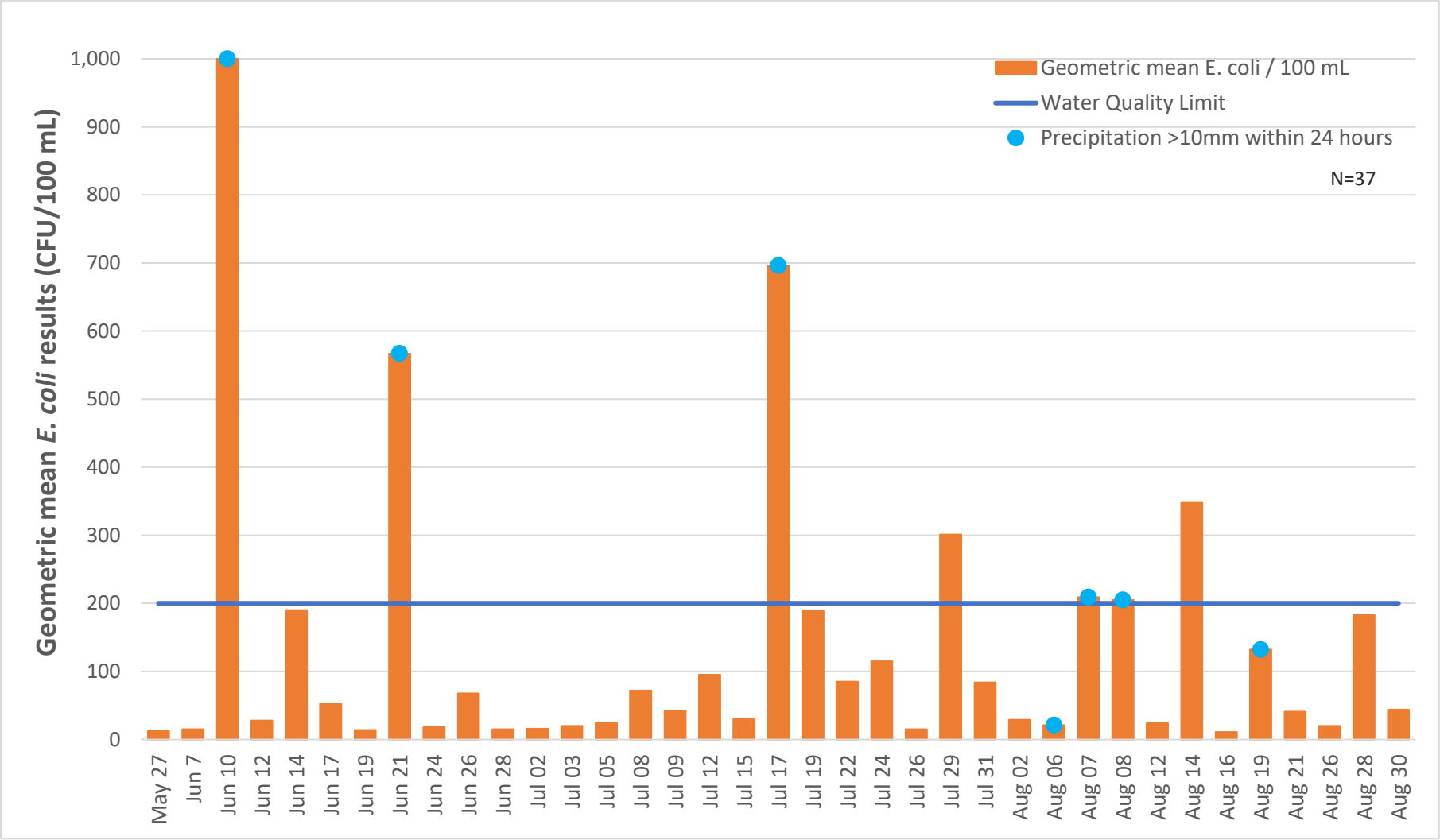


**Figure 8**: Geometric mean *E. coli* levels of each sampling event at Queen's Royal Beach during the 2019 swimming season. Blue dot markers indicate days with significant precipitation (i.e., greater than 10mm within 24 hours)

**Table 2**: Results of samples collected at the mouth of the storm outfall and the runoff sample where flow met the Niagara River. Sample analysis conducted and prepared by NRPHU. Results include one sampling event collected by NPCA staff (May 27). Please note that the detection limit by NRPHU for *E. coli* is 1000 CFU/100mL as noted on page 7 (Limitations).

| Date Sampled | Shoreline/Beach-Outlet Interface (QRO) | Outlet/Source (QRS) | Outlet Flowing? | Significant Precipitation w/in 24 hrs? |
|---|---|---|---|---|
| May 27 | 90 | 20 | YES | N/A |
| June 7 | 90 | 40 | YES | NO |
| June 10 | 1000 | 1000 | YES | YES |
| June 12 | 110 | 120 | YES | NO |
| June 14 | 1000 | 1000 | YES | YES |
| June 17 | 10 | 10 | YES | NO |
| June 19 | 10 | 10 | YES | NO |
| June 21 | 250 | 280 | YES | YES |
| June 24 | 80 | 100 | YES | NO |
| June 26 | 240 | 200 | YES | NO |
| June 28 | 420 | 330 | YES | NO |
| July 2 | 90 | 110 | YES | NO |
| July 3 | 420 | 100 | YES | NO |
| July 5 | 1000 | 520 | YES | NO |
| July 8 | 80 | 560 | YES | NO |
| July 9 | 270 | 460 | YES | NO |
| July 12 | 190 | 180 | YES | NO |
| July 15 | 30 | 160 | YES | NO |
| July 17 | 1000 | 1000 | YES | YES |
| July 19 | 80 | 450 | YES | NO |
| July 22 | 1000 | 1000 | YES | NO |
| July 24 | 200 | 380 | YES | NO |
| July 26 | 100 | 100 | YES | NO |
| July 29 | 1000 | 800 | YES | NO |
| July 31 | 280 | 380 | YES | YES |
| August 2 | 540 | 760 | YES | NO |
| August 6 | 1000 | 1000 | YES | YES |
| August 7 | 1000 | 1000 | YES | YES |
| August 8 | 1000 | 1000 | YES | YES |
| August 12 | 1000 | 930 | YES | NO |
| August 14 | 1000 | 540 | YES | NO |
| August 16 | 590 | 170 | YES | NO |
| August 19 | 1000 | 1000 | YES | YES |
| August 21 | 560 | 540 | YES | NO |
| August 26 | 1000 | 1000 | YES | NO |
| August 28 | 1000 | 1000 | YES | NO |
| August 30 | 1000 | 1000 | YES | NO |


**Figure 9**: Comparison of calm conditions (top, August 8th) and windy conditions where an exceedance was measured in the absence of precipitation (bottom, August 14th). Water is notably turbulent and opaque on August 14th. (Credit: Kennedy Laufman)

# Conclusions

This study represents the second year of a three-year monitoring plan for Queen's Royal Beach water quality sampling. Overall, 81.1% of the sampling events from May 2019 to September 2019 met established water quality targets (i.e. geometric mean *E. coli* levels less than 200 CFU/100mL). The study indicates that, in 2019, the QRB also met the Niagara River RAP's criterion #2: "at least 80% of the geometric mean results of recreational water samples (when sampled at least once per week) meet the Ontario Ministry of Health Recreational Water Quality Guideline (<200CFU/100 mL) each swimming season for a minimum of three years)".

The QRB was 'Posted' a total of 7 times during the swimming season. Five of those bacterial exceedances coincided with significant rainfall or weather-related events. Peaks of *E. coli* levels at QRB may be due to the runoff of gull, raccoon and horse feces accumulated in the storm sewer catchment area, from the Niagara River upstream of the beach, or from the presence of human sewage in the Niagara River or within the storm sewer catchment area. Peaks of *E. coli* levels during periods of low precipitation could indicate the potential presence of other bacterial sources such as discharges in the Niagara River, wildlife at the beach, and/or environmentally persistent sediment-bound *E. coli* disturbed and resuspended by strong wind and waves.

Samples taken from the outfall often had higher *E. coli* levels than the beach irrespective of significant precipitation events. Additionally, high levels of bacteria in the outfall water did not necessarily translate to high bacteria levels at the beach, indicating that there are several factors impacting stormwater and beach water quality. The low water quality of the outlet may be due to the presence of wildlife in the stormwater sewer system, and/or anthropogenic sources such as untreated raw sewage stemming from broken laterals between the stormwater and sanitary sewer systems in Old Town NOTL. Remedial actions to resolve issues with the storm sewer system are currently still underway; further testing is recommended following the completion of remedial actions.

It is recommended that water quality monitoring at the beach continue into 2020 as the Niagara River RAP's criterion #2 requires a minimum of three years of data. Furthermore, the Town of NOTL should consider the following recommendations based on the data gathered during this study:

- Given the presence of wildlife at QRB, it is recommended that continued measures be put into place to deter wildlife from using the area and prevent future intrusions by wildlife into the system. To deter waterfowl, measures such as reflective streamers and artificial owls/prey birds could be considered.
- To help protect public health, a sign should be posted at the mouth of the outlet, advising residents not to rest or allow their pets to rest or drink from the flow of water coming from the storm outlet. Additionally, general educational signage advising against recreational swimming shortly following significant rainfall could be implemented.
- To more conclusively ascertain if human sewage is a major source of *E. coli* at QRB, more thorough testing should be conducted. Namely, microbial source tracking techniques should be conducted at more regular intervals throughout the course of a swimming season, with at least 3 wet weather events captured to provide a more accurate understanding of conditions and sources impacting QRB.

# Acknowledgements

This project was made possible through funding provided by Environment and Climate Change Canada and the Ontario Ministry of the Environment, Conservation and Parks.

We would like to extend special thanks to Josh Diamond and Eric Augustino of the Niagara Peninsula Conservation Authority for conducting water quality sampling at QRB in May 2019 before NOTL staff were hired. Thank you to Natalie Green (NRRAP Project Manager) for her guidance and support in preparing this report.

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Regional Municipality of Niagara. King Street, Queen's Royal Beach [map]. Layers used: 2018 Imagery, 2015 Imagery, 2010 Imagery, 2002 Imagery, 2000 Imagery, 1934 Imagery. Scale 1: 5,000. Generated by Paula Moura; using "Niagara Navigator" <http://maps.niagararegion.ca/Navigator/> (Accessed September 23, 2019).

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# Appendices

## Appendix A: Detailed Field Observations

**Table A-1**: Summary of field observations in June, organized by sampling date.

| Date | Temperature (ºC) | Wind Speed (km/h) | Weather Conditions | Observations |
|---|---|---|---|---|
| June 7th | 21.2 | 3.6 | Clear, sunny, warm | Water was clear (low turbidity) at shoreline and outflow pipe; outflow pipe flow was low, however steady. Residents and tourists were present around the beach, and riprap was evident along significant areas of the shoreline. The water level was very high; much of the beach was submerged. At the time of the visit, the outflow pipe was approx. 5-6 metres from the shoreline. Water was calm; few waves were present. |
| June 10th | 16.5 | 5 | Overcast, raining | Water was opaque (high turbidity) at shoreline and outflow pipe; flow from outflow pipe was significant and considerably larger in volume in comparison to Friday. Water level was very high still; outflow pipe was approx. 5-6 metres from the shoreline. Water was calm; few waves were present. Small flock of geese present on arrival; few signs of goose droppings and feathers throughout, may have been washed into water by rain. |
| June 12th | 21.6 | 0.7 | Clear, sunny, warm | Water was clear (low turbidity) at shoreline and outflow pipe; outflow pipe flow was low but steady. People were present around the beach (many dog owners, group of kayakers, etc.). The water level was very high; much of the beach was submerged, though level was evidently lower than previously based on algae line along rocks. Cladophora (green, filamentous algae) was noted covering submerged rocks; some Cladophora was also washed up on the shore, though not a significant quantity. At the time of the visit, the outflow pipe was approx. 5-6 metres from the shoreline. Water was calm; few waves were present. Mid-size flock of Canadian Geese were present on arrival; eventually moved down the shoreline as beach became busier with human activity, however there was clear evidence of goose droppings and feathers along the extent of the shore. Previous rainfall near outlet pipe caused significant alterations in sedimentation around the pipe, and along one of the paved/gravel pathways; some debris present on pipe and sedimentation noted inside of the pipe. |
| June 14th | 13.9 | 13.3 | Intermittent clouds, windy, chilly | Water was turbid at shoreline and significant waves were present; undertow was strong. Flow from outflow pipe was translucent, however tinted brown in colour; flow was heavy. The water was high, though lower than previously based on algae line along rocks. Algae noted on rocks; a flock of geese was present towards the end of sampling, however there were no signs of geese (e.g. feathers, droppings, etc.) present on the shoreline itself. At the time of the visit, the outflow pipe was approx. 6 metres from the shoreline. Rainfall from previous day and wave action caused alterations in sedimentation near the outflow pipe and along one of the paved/gravel pathways. Debris and sedimentation still present in pipe. |

| Table A-1 (continued) | | | | |
|---|---|---|---|---|
| June 17th | 16.6 | 2.8 | Some clouds, sunny, warm, very light wind | Water was clear at shoreline and calm; no waves were present. Mid-size flock of Canadian Geese were present on arrival; moved into the water as beach became busier with human activity. There was little evidence of the geese on the shoreline (e.g. little to no droppings or feathers present). Beach was busy with locals, including residents walking their dogs, a kayaker, etc. Flow from outflow pipe was steady, however lower than previous visits. Water from outflow was also clear and not particularly discoloured. Water level was noticeably lower than previous visits based on algae level on rocks and visibility of beach; outflow pipe was approx. 6 metres from the shoreline. |
| June 19th | 18.5 | 8.6 | Some clouds, sunny, warm, light wind | Water was clear at shoreline and calm; no waves were present. Small flock of Canadian Geese were present on arrival; moved into the water as beach became busier with human activity. There was evidence of the geese on the shoreline (e.g. droppings and feathers present). Flow from outflow pipe was steady, however lower than previous visits. Water from outflow was also clear and not particularly discoloured. Water level was noticeably lower than previous visits based on algae level on rocks and visibility of beach; outflow pipe was approx. 6 metres from the shoreline. Clumps of Cladophora was present in the water; it appears to have fallen off of the algae-covered rocks due to wave action. |
| June 21st | 17.5 | 10.1 | Scattered clouds, sunny, warm, light wind gusts | Water was clear at shoreline; some waves were present and white caps were observed farther out into the lake. A small flock of gulls were in the water some distance from the shore on arrival, and footprints were evident on the beach. Flow from outflow pipe was steady, though lower than previous visits; outflow water was clear and not particularly discoloured. Beach was relatively busy with people on arrival. Water level maintained at lower height based on algae level on rocks and visibility of beach. Outflow pipe was approx. 6 metres from the shoreline. |
| June 24th | 18.5 | 3.9 | Cloudy/overcast, warm, very light wind | Water was clear at shoreline and calm; no waves were present. Small flock of Canadian Geese were observed on the lake; evidence of geese (e.g. droppings, etc.) were present on shoreline. Beach was busy with residents and tourists, as well as a Paddle Niagara outing for kids. Flow from outflow pipe was steady, however flow had clearly been much heavier in previous days based on erosion of gravel around the outflow stream. Water was "grimy"; contained Cladophora, some dead fish, etc. A film was observed on a small pool water in the outflow stream. |
| June 26th | 24.2 | 8.6 | Sunny, hot/humid, light wind | Water was clear at shoreline; some waves were present, though they were very gentle/light. Flow from outflow pipe was steady; faster than on Monday. A film was observed inside of the outflow pipe, however not in the outflow stream today. |
| June 28th | 24.7 | 3.2 | Sunny, hot/humid | Water was clear at shoreline and calm; no waves were present. Beach had some people on it, but was otherwise quiet. Some (10ish) live fish were spotted near the shore. Flow from outflow pipe was slow, but still steady. |

**Table A-2**: Summary of field observations in July, organized by sampling date.

| Date | Temperature (ºC) | Wind Speed (km/h) | Weather Conditions | Observations |
|---|---|---|---|---|
| July 2nd | 22.3 | 5.4 | Overcast, humid, warm, light wind | Water was clear at shoreline; some waves were present. A large flock of Canadian geese came onto the shoreline as we departed; some tourists on the walking path appeared to be feeding them. Flow from outflow pipe was steady; outflow water was clear and not particularly discoloured, though did appear to have a film over it immediately outside of the pipe. Beach was somewhat busy with residents and tourists. |
| July 3rd | 21.1 | 2.5 | Sunny, hot, arid | Water was clear at shoreline and very calm; 10+ live fish were observed near the shore. A large flock of Canadian geese were departing from the shoreline as we arrived; a bus of tourists were present on the beach on arrival. Flow from outflow pipe was steady; outflow water was clear and not particularly discoloured, though did appear to have a film over it immediately outside of the pipe. Foam was also observed at the point where the outflow stream met the Niagara River shoreline. |
| July 5th | 26.9 | 1.8 | Sunny, hot, humid | Water was clear at shoreline and calm. Flow from outflow pipe was steady; outflow water was clear and not particularly discoloured. Some people were present & swimming; a person and her dog were at the outfall, the dog was laying down in the outflow water on arrival. We asked them to move farther down the beach, however it would likely be prudent to post a sign not to walk or allow animals in the outfall water, as it is often very high in *E. coli* |
| July 8th | 19.5 | 5.7 | Sunny, warm, light breeze | Water was clear at shoreline with small waves; substantial Cladophora was found on the shore (bright green, wet, stringy/mossy). The water level appeared to be lower, based on the exposed algae level of the rocks. A dead seagull was found near sampling point 3, and a large dead fish was found washed up on shore near the outfall stream. A kayaking group was arriving as we were departing from the beach. Some foam was observed in the water at the shoreline. |
| July 9th | 22.1 | 2.5 | Sunny, warm, very light breeze | Water was clear at shoreline and calm. Flow from outflow pipe was steady; outflow water was translucent, however tinted brown. Old algae was present on the shoreline, as well as goose guano. The dead seagull was still present. A large group of tourists were present on arrival to the beach. |
| July 12th | 19.8 | 10.4 | Overcast, warm, light breeze | Water was clear at shoreline and somewhat wavy; a few people were present at the beach on arrival. Flow from outflow pipe was steady and relatively clear, though discoloured brown. Algae present in the flow from the outfall pipe and along the beach to the right (East) of the outfall |

| Table A-2 (continued) | | | | |
|---|---|---|---|---|
| July 15th | 20.8 | 6.8 | Sunny, warm, light breeze | Water was clear at shoreline and somewhat wavy; a few people were present at the beach on arrival. Flow from outflow pipe was steady and relatively clear, though discoloured brown. Old algae was present on the shoreline, as well as goose guano. A duck was present on the shore on arrival, and a flock of geese were present in the water near the shore. A moderate amount of algae was present in the shallower water near the shore, and appeared to have grown substantially compared to previous visits. |
| July 17th | 23.7 | 2.1 | Humid, intermittent rain, overcast | Water was clear at shoreline and very calm; rain was intermittent and ranged from light to very heavy. Flow from outfall was strong, turbid, and brown. A flock of Canadian geese and a flock of seagulls were present on the shoreline on arrival and lingered in the water near the shore after we left. |
| July 19th | 28.5 | 5 | Hot, humid, intermittent clouds, sunny | Water was clear at shoreline and slightly wavy. Flow from outflow pipe was steady and clear, though it appears much of the gravel in the outflow stream was shifted by the storm, leading to the formation of a larger, slow-flowing puddle in the middle of the stream. Outfall sample taken directly from pipe due to changes in gravel/water pooling. Algae was present on the shoreline and floating in the water; water was largely clear though slightly discoloured green. |
| July 22nd | 22.3 | 0 | Cool, some humidity, overcast | Water was clear and calm at the shoreline; algae was observed on the beach, but not floating in the water. A group of tourists arrived during sampling. Two small fish were found dead near the meeting point of the outfall flow with the beach shoreline. Flow from the outfall was steady and clear, though the larger puddle had increased in size from Friday. Outfall sample taken directly from pipe due to changes in gravel/water pooling. |
| July 24th | 21.7 | 9.7 | Warm, sunny, very windy/gusts of wind | Water was relatively clear, however very wavy; white caps were observed farther into the lake. Subsequently, the sampling pole was used to collect samples due to safety concerns. Filamentous algae was washed up on the shoreline, as well as a dead fish (possibly trout). The flow from the outfall was steady and clear, however contained some algae. Outfall sample taken directly from pipe due to changes in gravel/water pooling. |
| July 26th | 23.4 | 2.8 | Warm, sunny, light wind | Water was clear and calm at the shoreline; old algae was observed on the beach. A group of tourists arrived during sampling. The outfall was clear, however algae continued to grow in the ponded water. Outfall sample taken directly from pipe due to changes in gravel/water pooling. |
| July 29th | 26 | 4.6 | Hot, humid, sunny, light wind | Water was clear and calm at the shoreline; old algae observed on the beach. A group of people arrived during sampling. The outfall was clear, however tinted a greyish colour; the algae previously noted had turned black/grey. Outfall sample taken directly from pipe. |
| July 31st | 21.5 | 3.6 | Warm, humid, sunny, light wind | Water was clear and slightly wavy at the shoreline; algae was washed up on the shore. It was greenish-brown, fresh, and filamentous; more algae was present floating in the waves. The outfall was clear, however tinted a greyish colour in the pooling water area. Outfall sample taken directly from pipe. |

**Table A-3**: Summary of field observations in August, organized by sampling date.

| Date | Temperature (ºC) | Wind Speed (km/h) | Weather Conditions | Observations |
|---|---|---|---|---|
| August 2nd | 22.6 | 5.7 | Sunny, warm, light wind | Water was clear at shoreline and somewhat wavy. Significant amounts of algae were washed up on the shoreline, and loose algae was present in large quantities on the beach near the shoreline; the algae was greenish-brown and filamentous. A group of tourists was present on arrival to the beach; multiple residents were walking their dogs through the area, and Paddle Niagara arrived as were departing. The water from the outlet was clear, though tinted slightly brown; algae was present in the water pooling between the outfall and the beach shoreline. |
| August 6th | 28.3 | 1.8 | Sunny, humid, hot | Water was clear at shoreline and calm. Old algae was present on the beach in some areas, however most appears to have settled on beach near the shoreline. A group of people arrived while we were conducting sampling. The water from the outlet was clear, and flow was lower than average. Some small fish were noted in the water close to the shoreline. |
| August 7th | 22.3 | Below detection limit | Warm, humid, overcast, rainy | Water was clear at shoreline and relatively calm; old algae was present on the beach in some areas. Rivulets in the gravel and sand were present, presumably due to runoff from recent heavy rainfall. Significant amounts of gravel and sand from the outlet were washed out into the shoreline. Water from outlet was clear and flow was higher than usual; water immediately outside of outlet pipe was tinged brown. |
| August 8th | 23.2 | 2.1 | Warm, humid, sunny | Water was clear at shoreline and relatively calm; old algae was present on the beach in some areas. Rivulets in the gravel and sand were present, presumably due to runoff from recent heavy rainfall. Significant amounts of gravel and sand from the outlet were washed out into the shoreline. Water from outlet was clear and flow was higher than usual; water immediately outside of outlet pipe was tinged brown and had a white film over it. |
| August 12th | 23.7 | Below detection limit | Warm, humid, overcast, pre-rain | Water was mostly clear at shoreline, with some suspended sediment and algae, and relatively calm; old algae was present on the beach in some areas. A group of tourists arrived while we were conducting sampling. No fish were noted close to the shoreline. Washed out gravel and sand were leveled by the water. Only a small stream was connecting the pond just outside the outlet pipe to the shoreline. Flow from the outlet was clear and higher than usual; water pooling immediately outside the outlet pipe was tinged brown and had a white film over it. |
| August 14th | 21.2 | 12.2 | Warm, windy, sunny | Water was turbid due to waves; significant algae washed up along shoreline (wet, filamentous, greenish-brown). Sediment was clearly visible in the waves. Samples at QR1 and QR4 were taken via the sampling pole due to safety concerns related to the water conditions (current, undertow, etc.). Water from outlet was flowing and clear, though a white film was present near the pipe, as well as cream/white coloured bubbles. |

| Table A-3 (continued) | | | | |
|---|---|---|---|---|
| August 16th | 20.8 | 13.3 | Warm, windy, sunny | Water was mostly clear at shoreline, with some suspended algae; some waves were present. Significant amounts of algae were washed up along the shoreline (greenish-brown, filamentous). Water from outlet was clear (though somewhat filmy) and flow was comparatively low. A raccoon was removed from a nearby garbage can and immediately fled into the QRB storm outlet, crawling up one of the smaller inner pipes once inside. |
| August 19th | 24.4 | 4.6 | Warm, sunny, light wind, humid | Water was clear at shoreline; some waves were present, though water was largely calm. Water from outlet was clear and flow was average; film was present on ponding water immediately outside of storm outlet. |
| August 21st | 22.2 | 2.8 | Warm, sunny, humid | Water was clear and calm at shoreline; a family was present paddleboarding near the outlet. Water from outlet was clear and flow was average; film was present on ponding water immediately outside of storm outlet. |
| August 26th | 19.3 | 2.5 | Warm, sunny | Water was clear and calm at shoreline; paddleboarders/kayakers present on arrival. Significant amount of algae (greenish-brown, filamentous) was washed up on shore, though algae present in water seemed to have settled on to lake bottom. Water from outlet was clear and flow was low; plank was found near end of outlet, blocking flow somewhat, and seemed intentionally placed. |
| August 28th | 22.7 | 3.9 | Warm, sunny, light wind | Water was clear and calm at shoreline. Significant amount of algae washed up, though appears old and is likely remnant from previous sampling day. Water from outlet was clear, but very filmy; plank is causing ponding and reducing flow, resulting in build-up of film over water. Flow was low. |
| August 30th | 20.1 | 6.4 | Warm, sunny, windy | Water was somewhat turbid due to strong waves; fresh algae (green) was present on the shoreline. Algae was also present in the waves. Water from outlet was clear and flow was low. |

# Appendix B: In-Field Measurement Data for Surface Water Parameters

**Table B-1**: 2019 field measurements for surface water parameters. 'BDL' represents a reading that was below the level of detection for the instrument being used.

| Date Surveyed | Air Temperature (ºC) | Wind Speed (km/h) | Currently Raining | Daily Precipitation (mm) | Water Temperature (ºC) | Wave Height (in) | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|
| June 7 | 21.2 | 3.6 | NO | 0 | 14.6 | 1.181 | 3.78 |
| June 10 | 16.5 | 5.0 | YES | 31.8 | 16.0 | 1.970 | 16.90 |
| June 12 | 21.6 | 0.7 | NO | 0 | 14.8 | 0.787 | 2.18 |
| June 14 | 13.9 | 13.3 | NO | 0.6 | 14.8 | 7.874 | 6.54 |
| June 17 | 16.6 | 2.8 | NO | 0 | 15.2 | 0.591 | 3.25 |
| June 19 | 18.5 | 8.6 | NO | 0 | 16.0 | 0.591 | 2.25 |
| June 21 | 17.5 | 10.1 | NO | 0.8 | 16.0 | 2.756 | 3.38 |
| June 24 | 18.5 | 3.9 | NO | 5.0 | 16.3 | 0.394 | 1.35 |
| June 26 | 24.2 | 8.6 | NO | 0 | 17.5 | 1.575 | 1.41 |
| June 28 | 24.7 | 3.2 | NO | 0 | 18.7 | 0.197 | 1.68 |
| July 2 | 22.3 | 5.4 | NO | 0.4 | 19.5 | 2.756 | 2.55 |
| July 3 | 21.1 | 2.5 | NO | 0 | 20.1 | 0.984 | 1.45 |
| July 5 | 26.9 | 1.8 | NO | 0 | 21.8 | 0.394 | 1.59 |
| July 8 | 19.5 | 5.7 | NO | 0 | 22.0 | 1.575 | 1.31 |
| July 9 | 22.1 | 2.5 | NO | 0 | 21.3 | 0.591 | 1.35 |
| July 12 | 19.8 | 10.4 | NO | 0 | 21.1 | 3.543 | 4.67 |
| July 15 | 20.8 | 6.8 | NO | 0 | 21.8 | 0.787 | 2.00 |
| July 17 | 23.7 | 2.1 | YES | 25.4 | 22.8 | 0.079 | 2.10 |
| July 19 | 28.5 | 5.0 | NO | 2.0 | 23.6 | 1.969 | 3.63 |
| July 22 | 22.3 | BDL | NO | 1.4 | 23.5 | 0.394 | 1.68 |
| July 24 | 21.7 | 9.7 | NO | 0 | N/A | 7.874 | 19.8 |
| July 26 | 23.4 | 2.8 | NO | 0 | 23.5 | 0.394 | 5.21 |
| July 29 | 26.0 | 4.6 | NO | 0 | 24.3 | 0.197 | 2.71 |

| Table B-1 (continued) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date Surveyed | Air Temperature (ºC) | Wind Speed (km/h) | Currently Raining | Daily Precipitation (mm) | Water Temperature (ºC) | Wave Height (in) | Turbidity (NTU) |
| July 31 | 21.5 | 3.6 | NO | 0 | 24.1 | 3.150 | 2.63 |
| August 2 | 22.6 | 5.7 | NO | 0 | 23.9 | 1.575 | 3.05 |
| August 6 | 28.3 | 1.8 | NO | 116.2 | 24.2 | 0.197 | 1.65 |
| August 7 | 22.3 | NDL | YES | 3.6 | 23.9 | 1.181 | 3.54 |
| August 8 | 23.2 | 2.1 | NO | 10.2 | 23.6 | 0.394 | 1.70 |
| August 12 | 23.7 | BDL | NO | 1.2 | 23.5 | 0.500 | 16.70 |
| August 14 | 21.2 | 12.2 | NO | 0 | 23.2 | 5.906 | 16.00 |
| August 16 | 20.8 | 13.3 | NO | 0.4 | 23.1 | 1.575 | 7.20 |
| August 19 | 24.4 | 4.6 | NO | 7 | 23.4 | 0.787 | 4.78 |
| August 21 | 22.2 | 2.8 | NO | 2.2 | 23.9 | 0.394 | 7.11 |
| August 26 | 19.3 | 2.5 | NO | 0 | 22.6 | 1.969 | 9.65 |
| August 28 | 22.7 | 3.9 | NO | 0 | 22.5 | 1.181 | 8.53 |
| August 30 | 20.1 | 6.4 | NO | 0 | 21.7 | 5.906 | 9.96 |

# Appendix C: *E. coli* Data

**Table C-1**: 2019 Beach water quality results provided by NRPHU based on samples collected during this study as well as the sample collected by NPCA (May 27). Results of 'ND' indicate a lack of data.

| Date Sampled | QR1 | QR2 | QR3 | QR4 | QR5 | Geometric Mean | Exceeds MOHLTC Guidelines? |
|---|---|---|---|---|---|---|---|
| May 27 | 20 | 10 | 10 | 10 | 20 | 13 | NO |
| June 7 | 10 | 20 | 20 | 10 | 20 | 15 | NO |
| June 10 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | YES |
| June 12 | 10 | 50 | 60 | 10 | 60 | 28 | NO |
| June 14 | 140 | 240 | 200 | 120 | 310 | 190 | NO |
| June 17 | 80 | 50 | 60 | 20 | 80 | 52 | NO |
| June 19 | 10 | 20 | 30 | 10 | 10 | 14 | NO |
| June 21 | 720 | 530 | 490 | 560 | 560 | 567 | YES |
| June 24 | 20 | 20 | 50 | 10 | 10 | 18 | NO |
| June 26 | 50 | 80 | 120 | 50 | 60 | 68 | NO |
| June 28 | 40 | 10 | 10 | 10 | 20 | 15 | NO |
| July 2 | 10 | 30 | 10 | 30 | 10 | 16 | NO |
| July 3 | 10 | 10 | 30 | 100 | 10 | 20 | NO |
| July 5 | 50 | 70 | 10 | 10 | 30 | 25 | NO |
| July 8 | 70 | 80 | 70 | 70 | 70 | 72 | NO |
| July 9 | 20 | 40 | 30 | 140 | 40 | 42 | NO |
| July 12 | 70 | 70 | 120 | 90 | 150 | 95 | NO |
| July 15 | 20 | 20 | 50 | 30 | 40 | 30 | NO |
| July 17 | 1000 | 1000 | 1000 | 420 | 390 | 696 | YES |
| July 19 | 230 | 150 | 150 | 260 | 180 | 189 | NO |
| July 22 | 60 | 60 | 40 | 110 | 280 | 85 | NO |
| July 24 | 40 | ND | 190 | 210 | 110 | 115 | NO |
| July 26 | 10 | 10 | 10 | 20 | 40 | 15 | NO |
| July 29 | 110 | 180 | 440 | 470 | 600 | 301 | YES |
| July 31 | 90 | 50 | 80 | 130 | 90 | 84 | NO |
| August 2 | 30 | 10 | 10 | 80 | 90 | 29 | NO |
| August 6 | 20 | 10 | 20 | 50 | 20 | 21 | NO |
| August 7 | 120 | 230 | 260 | 200 | 280 | 209 | YES |
| August 8 | 260 | 180 | 220 | 120 | 290 | 205 | YES |
| August 12 | 10 | 20 | 20 | 70 | 30 | 24 | NO |
| August 14 | 380 | 490 | 450 | 290 | 210 | 348 | YES |
| August 16 | 10 | 20 | 10 | 10 | 10 | 11 | NO |
| August 19 | 130 | 100 | 140 | 170 | 130 | 132 | NO |
| August 21 | 50 | 50 | 80 | 10 | 60 | 41 | NO |
| August 26 | 10 | 10 | 30 | 50 | 20 | 20 | NO |
| August 28 | 150 | 90 | 130 | 280 | 420 | 183 | NO |
| August 30 | 10 | 10 | 110 | 30 | 480 | 44 | NO |