WATERBORNE ILLNESS AND INJURY: A FEASIBILITY STUDY OF A SITE-SPECIFIC PREDICTIVE MODEL FOR BEACH WATER QUALITY AT BEACHWAY PARK IN THE CITY OF BURLINGTON

By

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Author's Declaration

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Abstract

Waterborne Illness and Injury: A Feasibility Study of a Site-Specific Predictive Model for Beach Water Quality at Beachway Park in the City of Burlington

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It is commonly assumed that the persistence model, using day-old monitoring results, will provide accurate estimates of real-time bacteriological concentrations in beach water. However, the persistence model frequently provides incorrect results.

This study: 1. develops a site-specific predictive model, based on factors significantly influencing water quality at Beachway Park; 2. determines the feasibility of the site-specific predictive model for use in accurately predicting near real-time *E. coli* levels.

A site-specific predictive model, developed for Beachway Park, was evaluated and the results were compared to the persistence model. This critical performance evaluation helped to identify the inherent inaccuracy of the persistence model for Beachway Park, which renders it an unacceptable approach for safeguarding public health from recreational water-borne illnesses. The persistence model, supplemented with a site-specific predictive model, is recommended as a feasible method to accurately predict bacterial levels in water on a near real-time basis.

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1.0 Introduction

The Ministry of Health and Long-Term Care (MOHLTC) developed the *Ontario Public Health Standards* (OPHS), under the authority of the *Health Protection and Promotion Act R.S.O. 1990* (HPPA), to establish the required fundamental public health programs and services for delivery by boards of health (MOHLTC, 2014). Within the OPHS, the Safe Water Standard sets one of its goals as the prevention or reduction of the burden of water-borne illness and injury related to recreational water use. Also identified within the OPHS are a series of protocols, that is, program specific documents, which provide guidance on how boards of health must put into practice the necessary requirements outlined in the OPHS. The *Beach Management Protocol* sets out the goal of preventing or reducing the burden of water-borne illness and injury related to recreational water use at public beaches (MOHLTC, 2014). The Halton Region Health Department delivers its beach management program in accordance with the *Beach Management Protocol*, which mandates each board of health to notify the owner of the beach to post unsafe notice signs when beach water contains bacterial levels above the provincial standard of 100 *E. coli* per 100 mL of water.

While swimming at the beach can be a pleasurable recreational water activity, the risk of contracting water-borne illness is possible if bathing occurs in beaches with elevated bacterial levels (>100 *E. coli* per 100 mL). Therefore, it is important to monitor beach water quality and safeguard public health. According to the Halton Region Health Department (2013), surface waters may contain elevated bacterial concentrations, and swimmers may be at an increased risk of ear, eye, nose, and throat infections. There is also a risk of gastrointestinal, or stomach illnesses if the water is ingested. The Halton Region Health Department's conventional beach water quality monitoring program, namely the persistence model, assumes that water quality persists from the time the water was sampled to the time it was analyzed. In other words, the persistence model entails a time-lag between the collection of water samples and the release of results to the public. This 24-hour time delay, stemming from analyzing indicator organism levels, is problematic. Changes in weather and water conditions, such as a significant rainstorm activity, can contribute to a variation in pathogen levels in the water during this 24-hour time delay. After a significant rainstorm, pollutants, such as geese feces on shore, can be washed into beach water, thereby leading to bacterial contamination. Consequently, Public Health Officials make decisions regarding beach water postings, closings and re-openings based not on current conditions but on indicator organisms from a day earlier. In contrast, according to the United States Environmental Protection Agency (USEPA) (2002b), a near real-time water quality predictive model would shorten analysis time, utilize statistical methods, and convey beach/recreational water quality information to the public on a near real-time basis.

The microbiological standard for posting unsafe notices on public beaches in Ontario is a count of >100 *E. coli* per 100 mL, calculated as the daily geometric mean, that is, at least five sampling locations per beach per week (Ministry of the Environment, 1994). The daily geometric mean is a logarithmic average as opposed to an arithmetic value. It provides an average to prevent high fluctuations between bacterial levels. For example, a series of *E. coli* levels as follows—10, 10, 10, 10, 1000—will yield an arithmetic average of 208 colonies per 100mL. However, a geometric mean of the above cited *E. coli* levels will yield a logarithmic average of 25 colonies per 100 mL.

The persistence model, despite its scientific laboratory method, has three specific limitations (Wong, 2009). The first limitation has to do with the 24-hour delay between the time the beach water sample is collected and the time when the laboratory conducts culture-based analysis and issues the report. Public health inspectors decide to post the public beach as unsafe based on a bacteriological analysis of beach water indicating high bacterial counts (>100 *E. coli* per 100 mL of water) from the previous day. Of concern to public health is the possibility that the persistence model may indicate that the beach water is safe, while swimmers may actually be bathing in contaminated water. In other words, the time gap between collecting beach water samples and notifying the public of sample results may expose swimmers to elevated bacterial levels in the water and result in water-borne illnesses and outbreaks. It has been clearly shown, that the bacteriological concentration in beach water can fluctuate greatly within a short time period (Boehm *et al*., 2002; Leecaster and Weisberg 2001; Rosenfeld *et al*., 2006).

A possible solution to this problem is to move towards reducing the 24-hour lag-time to a 4-6 hour time frame for notifying the public by implementing molecular techniques, namely a quantitative polymerase chain reaction (qPCR) (Boehm *et al*., 2007). According to the USEPA (2010), the qPCR molecular technique requires rigorous epidemiological evaluation to link health effects with beach users, prior to being considered as an accepted method for detecting FIB in recreational surface waters. Currently the qPCR molecular technique is not an accepted method for detecting FIB in Ontario beaches due to its high costs and lack of epidemiological evidence linking it to health effects of beach users.

The second limitation arises from the limited frequency of beach water sampling of using the persistence model. To reiterate, the microbiological standard for posting beaches as unsafe in Ontario is a count of >100 *E. coli* per 100 mL, calculated as the daily geometric mean, from at least five sampling locations per beach per week (Ministry of the Environment, 1994). In other words, some beaches in Ontario are tested only on a weekly basis. As noted previously, even during a short span of time, there is considerable variability in the fecal indicator organism levels in recreational surface waters (Bohem, 2007; Nevers and Whitman, 2008). Beach postings may reflect concentration levels from periods of time much earlier than previous-day bacteriological concentrations. For example, if the beach waters were sampled on June 2, and the results received the next day indicate elevated bacterial levels (>100 *E. coli* per 100 mL), the beach would be posted as unsafe on June 3. The next scheduled sampling day would be June 9, and if the results (received the next day) indicate bacterial levels below the provincial standard, the beach would be posted safe on July 10. The unsafe posting on June 9 is actually reflective of bacteriological concentrations seven days earlier (June 2). Beachgoers swimming in beach waters on June 9 will assume the postings are reflective of current-day water quality conditions, when in fact, postings are reflective of bacteriological concentrations from seven days earlier (June 2). See Figure 1 for an illustration of the limited frequency of sampling.

Figure 1. Diagram of Limited Sampling Frequency

It is impractical and non-cost effective, according to Wong (2009), to put considerable financial and staff resources into beach monitoring programs consisting of intensive or an increased frequency of water sampling. Even if an intensive (increased frequency of sampling to 7 days per week) sampling program is implemented, there will always be an inherent 24-hour delay with the persistence model as previously discussed. It is important to note that some boards of health may be lacking the required resources (financial and staff) to implement an intensive beach sampling policy.

The third limitation is that neither the persistence model nor the rapid molecular technique has the ability to accurately forecast bacterial levels in beach water.

A feasible solution to overcome the above-mentioned limitations is to implement a predictive model to accurately estimate bacterial levels in the water on a near real-time basis. According to a recent publication released by the Ontario Ministry of the Environment (2012), entitled "Technical Bulletin: Is Your Beach a Candidate for Predictive Modeling?" predictive modelling is defined as "a statistical technique used to predict beach water quality (*E. coli* concentrations) based on multiple predictor variables, primarily hydrologic or meteorological (e.g., rainfall, wind speed and direction, stream flow and water level, turbidity, temperature) and other site-specific data" (p. 1). Halton Region is attempting to implement a predictive model for assessing beach water quality on a near real-time basis. The USEPA (2009) has already implemented a solution to the above mentioned time-lag problem by proposing predictive models designed to provide a better estimate of recreational beach water quality on a near real-time basis. According to Wong (2009), what an accurate predictive model can do is provide a reliable and rapid forecast of bacterial levels in beach water quality.

2.0 Problem Statement

A growing public concern has arisen in the past decade over the accuracy of using the persistence model, since the assumption is that day-old monitoring results will provide accurate estimates of near real-time bacteriological concentrations in beach water (Mas and Baker, 2011). In brief, the persistence model uses previous-day *E. coli* concentrations to determine current day conditions of the microbial contamination levels of recreational surface waters (Mas and Baker, 2011). According to the USEPA (2010), the 24-hour time gap between collecting beach water samples and notifying the public of sample results may lead to the following: 1. swimmers may be exposed to elevated bacterial levels in the water, even though the posting inaccurately indicates safe bacterial levels; 2. swimmers may be inconvenienced and misinformed when beaches are posted as unsafe for elevated bacterial levels, even though the posting is inaccurate; in this case the actual bacteriological concentrations are below the provincial standard. Either way, these inaccurate postings can have adverse economical and public health impacts on local municipalities and their tourism potential. According to Sly (2000), "the ability to communicate effectively about risks is emerging as a high priority for local official health agencies. Communities increasingly demand full access to information and decision-making, while at the same time, public trust in traditional institutions is at a very low level."

3.0 Tests for Model Performance

Local boards of health should ideally test for the performance of the persistence model. A performance evaluation can be successfully completed by assessing the number of Type I (false positives) and Type II (false negatives) errors. A Type I error results when the beach is posted as unsafe due to elevated bacterial levels, but the bacterial levels have subsequently dropped below the provincial standard. This type of error is also known as a false positive, that is, an unwarranted posting for elevated bacterial levels. A Type II error results when the beach is declared to be below the provincial standard (posted safe for swimming), but the bacterial levels in fact are above the provincial standard. This type of error is also known as a false negative, in this case, a failure to post unsafe for swimming when such posting is warranted. Local boards of health should also ideally calculate the *sensitivity* (true positive rate) and *specificity* (true negative rate) for the beach water sampling season, in order to further determine the efficacy of the persistence model. True positive results when the beach is correctly posted as unsafe for swimming due to elevated bacterial levels, and bacterial levels are in fact above the provincial standard. True negative results when the beach is correctly posted as safe for swimming, and bacterial levels are in fact below the provincial standard. Sensitivity is important for public health, as it helps protects beach users from water-borne illnesses. Specificity is important for local residents and beach users, as it helps to maximize beach use.

3.1 Model Performance for Beachway Park

The persistence model frequently provides incorrect results for Beachway Park. Staff at Beachway Park frequently post notices regarding beach water quality that turns out to be inaccurate (incorrect postings). This inaccuracy is due to the unreliability of the persistence model. To reduce or prevent the burden of waterborne illnesses related to recreational water use, sensitivity (true positives) and false negatives are of important evaluation indicators for local boards of health. Moreover, they are necessary in determining the efficacy of the local board of health's beach water quality monitoring program from a public health standpoint. An analysis of the persistence model dataset from 2013 and 2014 inclusive indicates that sensitivity is at relatively low rates of 38% and 0% respectively. False negatives (Type II errors) are identified at relatively high rates of 30% and 25% respectively. False positives (Type I errors) are also identified at relatively high rates of 60% and 100% respectively. Specificity (true negatives) are identified at relatively high rates of 72% and 75% respectively. Table 1 and Table 2 provide an illustration of the overall performance of Beachway Park's persistence model from 2013 and 2014 inclusive. Statistical regression models/predictive models, on the other hand, are often more accurate (Frick *et al*., 2008).

Table 1. Performance of 2013 Persistence Model at Beachway Park

Confirmed by Ontario Public Health Lab*

Persistence Model

	>100 *E. coli* per 100 mL	**≤100 *E. coli* per 100 mL**	**Total**
Posted-Unsafe	6 (True +ve)	9 (False +ve)	15
Posted-Safe	10 (False -ve)	23 (True –ve)	33
Total	16	32	48

*Based on the provincial *E. coli* standard

Table 2. Performance of 2014 Persistence Model at Beachway Park

Confirmed by Ontario Public Health Lab*

Persistence Model

	>100 *E. coli* per 100 mL	**≤100 *E. coli* per 100 mL**	**Total**
Posted-Unsafe	0 (True +ve)	5 (False +ve)	5
Posted-Safe	5 (False -ve)	15 (True –ve)	20
Total	5	20	25

*Based on the provincial *E. coli* standard

4.0 Literature Review

4.1 Fecal Indicator Organism and Public Health Impact

According to Zepp *et al*. (2010), one means for assessing microbial contamination in recreational waters is to monitor for fecal indicator bacteria (FIB) such as *E. coli*, fecal coliforms, or fecal enterococci. According to Francy *et al*. (1993), epidemiological investigations clearly associate *E. coli* with swimming-related illnesses, whereas fecal coliform bacteria are not as clearly associated with swimming-related illnesses. For this reason, fecal coliform bacteria cannot be used for setting standards. Thus, recreational water quality standards use *E. coli* as a FIB to establish the acceptable level of risk associated with swimming-related illnesses. Furthermore, *E. coli* is a more specific indicator of fecal contamination in comparison to the more general test for fecal coliform bacteria (Francy *et al.*, 1993). A systemic review and meta-analysis of FIB and their use for regulating recreational water quality was conducted by Wade *et al.* (2003); the goal of this study was to quantify and link FIB of recreational water quality with the occurrences of gastro-intestinal illness. The use of fecal enterococci in marine water at the U.S. Environmental Protection Agency Guideline Levels was considered an acceptable FIB concentrations, and this was clearly supported by the results of their study. However, at fresh water beaches, *E. coli* was a better predictor of gastrointestinal illness than fecal enterococci and fecal coliforms.

Halton Region uses *E. coli* as its fecal indicator organism for laboratory analysis, testing and monitoring of its fresh water beaches. *E. coli* are the indicator bacteria for: 1. fecal contamination of recreational surface waters; and 2. the potential presence of pathogens (Thomann and Mueller, 1987). The presence of FIB at levels above standards indicates that adverse health effects are likely to result from pathogenic bacteria, viruses, or protozoans associated with fecal matter (Zepp *et al*., 2010). Gastroenteritis, cryptosporidiosis, hepatitis, and fever as well as a variety of infections of the ears, skin, and respiratory system can be the result of swallowing or contact with polluted waters during swimming or other recreational activities

(USEPA, 2002a). In brief, as the concentration of FIB increases, there is an increased risk of illness, particularly for swimmers (Stevenson, 1953; Cheung *et al*., 1990; Prauss, 1998).

Kleinheinz *et al*. (2006) argue that children are especially susceptible to recreational water-borne diseases. This is not only because they are more likely to be fully submerged or to ingest water where pathogenic organisms may be present, but also because their immune systems may not have fully developed. According to the Public Health Agency of Canada (2004), the first reported outbreak of verotoxin-producing *E. coli* infections associated with swimming at a local public beach in Montreal, took place during the period of August 15-21, 2001. The outbreak was reported to the Montreal-Centre Public Health Department, an epidemiological investigation was initiated, and four young boys between 3 and 7 years of age were identified as cases. Three of the four boys were hospitalized. The epidemiologic investigations narrowed down the source of the outbreak to swimming water at a Montreal public beach. Although verotoxin-producing *E. coli* infections fall under the list of reportable diseases, the number of cases associated with this Montreal outbreak was likely underestimated, with only the most severe cases seeking medical attention and thus being reported. According to the International Society for Infectious Diseases (2013), public health officials in Broome County, New York reported in July 17, 2013 that at least two swimmers at Nathaniel Cole Park were hospitalized for *E. coli* infections. Broome County public health officials consequently increased water sampling to every three days from its previous twice-monthly testing schedule. Monitoring beach water quality for bacterial levels is important in order to prevent or reduce the burden of water-borne illness related to recreational water use.

4.2 Potential Sources of *E. coli*

Malfunctioning private septic systems (Weiskel *et al*., 1996; Whitman and Nevers, 2003; Boehm *et al*., 2004), malfunctioning sewage treatment plants, sewer overflow and urban runoff are among potential sources of *E. coli*, leading to bacterial contamination and unsafe beach water postings at public beaches (Marsalek and Rochfort 2004; McLellan and Salmore 2003). A study by Whitman *et al*. (2003) clearly links *E. coli* densities in *Cladophora* (algae) mats along beaches bordering Lake Michigan. *E. coli* is able to survive in sun-dried *Cladophora* mats stored at 4°C for over six months. Given the ability of *Cladophora* mats to harbor *E. coli* under these harsh conditions, it is clearly understandable how *E. coli* would thrive under warm, more favorable summer conditions. In their most recent study of bacterial levels in *Cladophora* mats, Whitman *et al*. (2014) concludes that there is significant bacterial growth within the three-week study period. According to Assistant Professor Berat Haznedaroglu of the University at Buffalo: "In samples of water from the Niagara River containing 1,000 units of *E. coli* per milliliter, without the protection of algae, the bacteria survived for nearly six hours. However, when algae were introduced, the *E. coli* lasted for 16 hours" (Haznedaroglu, 2014).

Studies also make a link between bacterial contamination of beach water quality and agricultural/urban runoff and storm water drainage (USEPA, 2003; Irvine and Pettibone, 1996; Inamdar *et al.*, 2002; Haile *et al.*, 1999; Marsalek and Rochfort, 2004).

The largest freshwater agency in Canada is the Canada Center for Inland Water (CCIW) in Burlington, Ontario and includes staff from Environment Canada's National Water Research Institute (NWRI). According to Milne and Crowe (2007) of the NWRI, private residences on the western shore of Lake Ontario along Burlington Beach date to the early 1800s and had traditionally relied on individual septic systems. They were not connected to the municipal wastewater sewer system. Since it is not known whether septic systems were removed when residences were demolished, it may be that there is soil contamination if the septic systems are still in place (Milne and Crow, 2007). This could mean that contaminated groundwater, possibly *E. coli*, could be discharged into the shoreline area of Burlington Beach. Due to the potential of contamination from former septic systems, Milne and Crowe (2007) found it necessary to confirm whether *E. coli* bacteria were flowing into the groundwater at Burlington Beach, reaching the shoreline of Lake Ontario and causing unsafe beach postings. After careful research, Milne and Crowe (2007) confirmed that there was no presence of *E. coli* either in the groundwater or down-gradient from a former septic system. Thus, groundwater flow was not carrying *E. coli* from former septic systems at Burlington Beach towards the shoreline and therefore was not identified as a potential source of contamination. In relation to this finding, Mubiru *et al*. (2000) determined that *E. coli* do not survive well in natural environments and die off quickly. According to Becker and Nennich (2006), there are many factors that influence the survival rate of *E. coli* in natural environments. These include but are not limited to:

1. <u>sensitivity to direct UV-light</u>: direct exposure of *E. coli* to high amounts of UV light in shallow bodies of water or even lakes and streams often leads to a decrease in their population. However, *E. coli* can avoid the effects of direct exposure to UV light by sheltering within floating algae mats, in sand, or even in coral reefs when in marine waters. *E. coli* may also be resistant to the lethal effects of common water treatments, including chlorine, when sheltered.

2. high oxygen levels: *E. coli* are sensitive to increased oxygen levels, and their population generally decreases when present in moving waters. Stagnant waters tend to provide a more favourable environment, thus promoting a higher *E. coli* survival rate.

Milne and Charlton (2005) from Environment Canada's NWRI conducted a study at Burlington's Beachway Park to determine *E. coli* concentrations at different sampling locations. They collected offshore, nearshore, and pore water samples and concluded that pore water samples contained the highest *E. coli* concentrations (above the provincial standard). While conducting their study Milne and Charlton (2005) observed large *Cladophora* mats, which had washed up on the shoreline of Beachway Park. According to Whitman *et al.* (2003), *Cladophora* mats can shelter a significant amount of *E. coli* bacteria, which can increase their likelihood of survival to six months or possibly longer. Given the evidence from the site-specific study at Beachway Park noted above, it appears that the *Cladophora* mats and the sand on the shorelines of Beachway Park may both act as storage facilities for bacteria, particularly in the wave run-up zone. According to Burton *et al.* (1987) and Whitman and Nevers (2003), there may be high bacterial levels in the top surface layers of the shoreline sand, which may be released in surface waters due to agitation of the sand by either heavy wave action, or beachgoers/animals.

The fact that the sewage treatment plant of Burlington discharges only into Hamilton Harbour (Charlton and LeSage, 1996) has been a prime reason for minimizing the degradation of western Lake Ontario waters. As for the source of bacterial contamination leading to unsafe beach postings, Edge and Hill (2005) from the NWRI examined the source of bacterial contamination and conducted microbial source tracking. Rather than municipal wastewater as the cause of contamination, their results indicated that bird feces were the leading contributor of *E. coli* at Bayfront Beach located at Hamilton Harbour. According to Rao *et al.* (2003), even if the sewage treatment plant at Burlington proposes an outfall location in Lake Ontario, while abiding by the stringent Ministry of the Environment requirements of a minimum 3km distance from a potable water intake, and minimum 900m distance from the shoreline, no far-field contamination will be observed near the Burlington beaches or nearby drinking water intakes.

4.3 Predictive Modelling and Environmental Variables

In the United States and Canada, predictive tools, such as statistical models, are used to evaluate beach water quality and have been proven to be a highly reliable means of providing estimates of FIB densities based on current environmental conditions. This is intended to facilitate the release of time-relevant public health decisions with regard to beach water quality (Zepp *et al*., 2010). Predictive models have proven to be both cost-effective and accurate, and have already been employed and successfully implemented, especially in the Great Lakes: Lake Michigan and Lake Erie (Francy, 2009; Nevers and Whitman, 2005). The advantage of using predictive models is the ability to develop a statistical association between FIB concentrations, namely *E. coli*, (dependent variable) and various environmental variables influencing beach water quality (independent variables). Another major feature of statistical models is the capacity to predict near real-time bacteriological levels and potentially forecast short-term bacterial contamination levels in the water. According to the USEPA (2002b), “these statistical models and other predictive tools can be run as frequently as data are available for measured independent variables and as long as models are shown to be producing reliable predictions that protect public health."

In the United States, health departments have applied several solutions while acknowledging the need for quick, accurate assessments of recreational water quality. These solutions involve the use of rapid indicator organism methods, such as quantitative polymerase chain reaction (qPCR), and/or statistical predictive models, which are beach specific. Predictive modelling exists along a spectrum from complex process-based/deterministic models to basic single-variable models, such as rainfall thresholds. Predictive models include: 1. the rainfall-based alerts 2. multivariate statistical models, and 3. process-based/deterministic models.

For decades, wide use of rainfall-based closures and notifications has been the norm at freshwater and marine beaches. Based on an analysis of historical data, rainfall threshold levels are used at some beaches where there is likely to be high FIB densities following a certain amount of rainfall (USEPA, 1999). The objective of a rain threshold level is to identify a level of runoff at which FIB levels are likely to exceed the water quality standard. That is achieved if a statistical relationship between rainfall events and FIB densities can be observed or if a level of rainfall and rainfall conditions is consistently shown to be associated with increased FIB densities (USEPA, 2010).

Multivariable predictive statistical models, according to a recent publication released by the Ontario Ministry of the Environment (2012), entitled "Technical Bulletin: Is Your Beach a Candidate for Predictive Modeling?" are defined as "…[a] statistical technique used to predict beach water quality (*E. coli* concentrations) based on multiple predictor variables, primarily hydrologic or meteorological (e.g., rainfall, wind speed and direction, stream flow and water level, turbidity, temperature) and other site-specific data" (p. 1).

According to the USEPA (2010), process-based/deterministic models use mathematical representations to determine the fate and transport mechanisms that affect bacterial densities in beach water quality. These models require highly technical expertise and substantial amounts of data in order to be developed as a predictive tool for beach water quality. It is for this reason, according to the USEPA (2010) that process-based/deterministic models are inappropriate predictive models for determining bacterial levels in beach water.

No single rapid-assessment solution will fit every beach location for a community. The technical expertise of staff available at the time and willingness of the community to accept non-traditional methods will determine the type of rapid assessment selected for the beach site (Francy, 2009). Even during a short span of time, there is considerable variability in the fecal indicator organism levels in recreational surface waters (Bohem, 2007; Nevers and Whitman, 2008). According to Mas and Baker (2011), "even rapid methods of indicator organism quantification, such as quantitative polymerase chain reaction (qPCR), currently take 4-6 hours exclusive of sample transport and laboratory preparation time, so the lag time between sampling and quantitative indicator organism information is several hours at best" (p. 2).

Mas and Baker (2011) assisted Toronto Public Health and Niagara Public Health in developing site-specific predictive models to accurately estimate *E. coli* levels at their public beaches. According to Mas and Baker (2011), the City of Toronto, Niagara Region, and York Region are all using site-specific predictive models at their beaches as a supplement to their persistence model. St. Lawrence and Lambton County are still developing their site-specific predictive models. All the above mentioned public health units continue to collect water samples for posting their beaches; however, York Region has piloted the use of predictive models for posting three of their beaches, namely De La Salle, Holmes Point, and Franklin. York Region continues to collect water samples at these three beaches solely for performance evaluation purposes, that is, comparing the performance of the predictive model with the performance of the persistence model. The persistence model is still used to post York Region's remaining 11 beaches. Table 3 illustrates the performance of predictive models in Ontario. These models represent the full range of currently available predictive models in Ontario. Based on a current literature review, no other data pertaining to predictive models exist in Ontario at this time. *Percent correct classification* refers to the accuracy of the site-specific predictive model to predict postings based on the provincial standard of >100 *E. coli* per 100 mL of water. In other words, percent correct classification refers to the performance rate of the predictive model's overall specificity rates and sensitivity rates.

Table 3. Performance of Predictive Models in Ontario

Citation	**Water Body**	**Indicator Organism**	**% Correct Classification**
City of Toronto, Mas and Baker (2011)	Lake Ontario	*E. coli*	68%
Niagara Region, Orlando and Hudgin (2013)	Lake Ontario	*E. coli*	82%
York Region, Paget (2012)	Lake Simcoe	*E. coli*	79-92%

According to Mas and Baker (2011), the performance rate of the predictive model for City of Toronto at Sunnyside Beach was evaluated as 68% to correctly identify postings. According to Paget (2012), the performance rate (percent correct classification of postings) of the site-specific predictive models developed for De La Salle, Holmes Point, and Franklin Beach are as follows: De La Salle 87%, Holmes Point 79%, and Franklin 92%. According to Orlando and Hudgin (2013), the performance rate of the predictive model developed for Lakeside Beach was 82% in correctly identifying postings. It is important to note that the review carried out for this research study reveals a total absence of research in the field of recreational water predictive modelling for the Regional Municipality of Halton. A better understanding of the feasibility of predictive modelling for Halton Region is required, especially for Beachway Park. Further to this point, Table 4 cited from Mas and Baker (2011), illustrates the performance of several predictive models analyzed by researchers in the United States.

Table 4. Comparison of Performance of Selected Predictive Models

Citation	**Water Body**	**Indicator Organism**	**% Correct Classification**
Eleria and Vogel (2005)	Charles River, Massachusetts	*E. coli*	44-64%
Francy *et al*. (2002)	Lake Erie	*E. coli*	71-93%
Francy *et al*. (2006)	Lake Erie	*E. coli*	64-88%
Olyphant (2005)	Lake Erie	*E. coli*	85-88%

The USEPA (2010) has found that

> "most predictive models are regression models, which involve a combination of numerous environmental variables with some direct or indirect relationship to concentrations of FIB. These include the following variables: air temperature, solar radiation, wind direction and speed, wave height, lake levels and rainfall".

In Table 5, Mas and Baker (2011) illustrate the relationship of some variables to beach water quality. Note that the order of the variables, as listed in Table 5, does not indicate a ranking association with the dependent variable *E. coli*.

Table 5. Environmental Variables for Beach Predictive Modeling and Relationship to Water Quality

Variable	Relationship to Water Quality
Rainfall	Significant rainfall produces storm-water runoff and other surface water runoff (i.e. streams and rivers), which are primary pathways for indicator bacteria and pathogens to reach beaches. Depending on the land use in the beach watershed, the storm-water runoff can contain animal feces and other bacterial sources that were deposited on land between storm events.
Turbidity	Turbidity can be increased by storm-water input or stream inflow, wind speed and direction, wave activity, swimmer activity, and other factors. Some of these factors might be associated with input of pollution sources such as storm-water, stream-flow, and swimming.
Water temperature	Water temperature may indicate favorable or unfavorable conditions for indicator bacterial persistence in the environment, since some are intolerant of extreme high or low temperatures. Additionally, large changes in water temperature can indicate storm-water or stream-flow inputs that may discharge indicator bacterial loads.
Sunlight	Some bacteria are sensitive to high levels of sunlight or irradiance.
Wave Action	The three main characteristics of waves are their height, wavelength, and the direction from which they approach. Wave action can cause polluted storm-water runoff to remain in the near-shore zone or indicator bacteria in bottom sediments or sand to be re-suspended by wave action.
Wind speed and direction	Wind can be a good predictor of water quality since wind influences wave formation.

Francy (2009) refers to several challenges involved in the widespread implementation of predictive models, even though these models are becoming more widely accepted and have demonstrated successful site-specific results at some beaches. While the USEPA Beach Grant program has provided funding to develop and implement predictive models, continued funding is still required to maintain and fine-tune these models (USEPA, 2002a). This funding is vital since not all agencies have the technical expertise to develop and maintain predictive models or the management skills to make sure that these models are used effectively. To offer the necessary financial and technical resources and oversight, coordinated leadership is needed at both the state and regional levels of government in the United States. Similar financial and technical resources and oversight is worth considering for Canada at both the provincial and municipal levels of government. This would help ensure that high quality and consistent data are collected. Resistance to these new methods may be due to their complexity and unfamiliarity, which various organizations and agencies find challenging and differ from those used in the past. Specialized professional training is therefore required (Francy, 2009).

5.0 Research Objectives

The research objectives of this study are: 1. to develop a site-specific predictive model, based on factors significantly influencing water quality at Beachway Park; 2. to determine the feasibility of the site-specific predictive model for use in accurately predicting *E. coli* levels. The site-specific predictive model takes into account an analysis of the independent variables most adversely influencing the dependent variable, that is, the geometric mean of *E. coli*. These independent variables are: water temperature, air temperature, rainfall during sampling and the previous 24/48 hours, wind speed, wind direction, wave height, UV index, turbidity, bather density, presence of algae, water fowl density and presence of waterfowl feces, wildlife/domestic animal density, and presence of wildlife/domestic animal feces (MOHLTC, 2014).

6.0 Materials and Methods

The annual beach water sampling program extends from the first week of June until the last week of August. This field observational study consisted of approximately 730 water samples, which were collected for bacteriological analysis during the 2013 and 2014 summer seasons at Beachway Park within the City of Burlington. The 2013 summer season involved collecting samples Monday-Thursday inclusive. An enhanced sampling frequency was implemented only for the 2013 summer season to increase the study sample size. The sample size obtained was sufficient to build the predictive model. According to a recent publication released by the Ontario Ministry of the Environment (2012), entitled "Technical Bulletin: Is Your Beach a Candidate for Predictive Modeling?" the minimum sample size requirement for a multivariate regression model is 20. This study yielded a sample size of 48.

The 2014 summer season involved collecting samples only on Tuesdays and Thursdays. The data collected for the 2014 sampling season were used to test the performance of the predictive model. Thus, ten samples were collected each day Monday-Thursday inclusive during the 2013 summer season and on Tuesdays and Thursdays during the 2014 summer season. Collecting samples on Fridays was not feasible, since government offices were closed the following day, Saturday.

Beach water samples were collected from 10 fixed reference sites in 100 mL plastic bottles containing sodium thiosulphate (preservative). Quality assurance of beach water bacteriological results was overseen by Halton Region public health inspectors who: 1. placed the water samples in a insulated container with ice; and 2. and delivered the container within 0.5 hours to the Hamilton Public Health Lab, 250 Fennell Road, Hamilton, ON. Over the subsequent 24-hour period, bacteriological analysis was processed at the laboratory. Laboratory staff recorded water sample results on a *Bacteriological Analysis of Water Form* (Appendix A) and faxed it to the Halton Region Health Department. Halton Region public health inspectors calculated the geometric mean of the water sample results using a pre-set formula on Microsoft Excel®, and a decision was taken whether to post the beach as unsafe or safe based on the provincial standard of 100 *E. coli* per 100 mL of water. The City of Burlington was notified via email of the beach water quality results. If results were greater than the provincial standard, City of Burlington Staff posted the beach as unsafe. If results were below the provincial standard, the beach would be posted as safe.

Routine Beach Surveillance−Field Data Report (Appendix B) is a form created by the Halton Region Health Department to collect outcome data, i.e., the factors/independent variables that influence beach water quality. The *Routine Beach Surveillance−Field Data Report* was completed every time public health inspectors collected water samples at Beachway Park. The data were then entered into a Microsoft Excel® data spreadsheet. The geometric mean of *E. coli* corresponds with the collected environmental data for the specific sampling day. These data are organized in the Microsoft Excel® spreadsheet to facilitate data analysis. Table 6 outlines data collection sources and field-testing equipment used for this study.

Table 6. Data Collection Sources and Field-testing Equipment

Air temperature	Kestrel Handheld 4500 weather meter
Water temperature	Kestrel Handheld 4500 weather meter
Water clarity/turbidity	Turbidity meter
Rainfall previous 24-hours	Environment Canada-historical climate data
Rainfall previous 48-hours	Environment Canada-historical climate data
Rainfall intensity during sampling	Standard Canadian Rain Gauge, a cylindrical container 40cm in height and 11.3cm diameter.
UV index	Environment Canada-historical climate data
Wind speed	Kestrel Handheld 4500 weather meter
Wind direction	Kestrel Handheld 4500 weather meter
Waterfowl density	Observed at the beach
Waterfowl feces count	Observed at the beach
Wildlife/domestic density	Observed at the beach
Wildlife/domestic feces count	Observed at the beach
Bathers	Observed at the beach
Presence of algae	Observed at the beach
Wave action	Meter stick

6.1 Data Analysis

The step-by-step process, as outlined by Mas and Baker (2011) in their *Guidance Document for Developing Predictive Models for Ontario Beaches, Ontario Ministry of the Environment*, serves as the basis for the data analysis section of this study. The first step of the data analysis for this study involves a detailed exploratory data analysis (EDA), which provides summary statistics for *E. coli* concentrations during the 2013 and 2014 summer seasons. The results provided by EDA from the 2013 and 2014 summer seasons, period of model development and testing, offers a thorough understanding of the behavior of the beach water quality site, namely Beachway Park. Furthermore, these results help identify any potential outliers in the dataset.

In using the results from the EDA, one can also determine if the beach water quality conditions have remained fairly constant over the course of the study period or have changed significantly. If potential outliers are evident, the dataset can be reviewed and cross-referenced with available evidence to determine their validity, an example of an outlier might be a water sample dataset reflecting the day of a sewage spill. These types of outliers should be omitted in order to create a valid model that is representative of the prevailing normal conditions on which predictions are to be made (Mas and Baker, 2011). The 2013 and 2014 summary statistics include an analysis of the following:

1. Minimum *E. coli* concentrations
2. Maximum *E. coli* concentrations
3. Mean of Geo-mean *E. coli* concentrations
4. Number of times beach posted as unsafe

The consistency of *E. coli* concentrations across each of the10 sampling sites at Beachway Park are also analyzed during the 2013 and 2014 summer seasons.

The second step of this study involves regression analysis to determine candidate variables for model development. According to Montgomery *et al.* (2012), multivariate regression analysis is one of the most widely used techniques for water quality predictive modelling. Furthermore, according to Mas and Baker (2011), multivariate regression models have been utilized at beaches throughout the Great Lakes region and are recognized as one of the most widely accepted beach water quality modeling techniques. According to the United States Geological Survey (USGS) (2009), the importance of performing statistical tests using multiple variables is that it indicates the relationships between several indicators/variables. This study takes into account the significant variables that influence beach water quality and which are necessary to develop the site-specific predictive model for Beachway Park. The following variables are analyzed for this study:

1. dependent variable: geometric mean of *E. coli*;
2. independent variables: water temperature, air temperature, rainfall during sampling, 24-hour rainfall, 48-hour rainfall, wind speed, wind direction, wave height, UV index, turbidity, bather density, presence of algae, waterfowl density, presence of waterfowl feces, wildlife/domestic animal density, and presence of wildlife/domestic animal feces.

The variable selection procedure (stepwise) for this study uses the commercially available SPSS Statistical Software Program to identify candidate variables. This is an automated selection process that removes variables and tests their significance, in other words, a screening tool. A stepwise statistical approach is intended to narrow down the variables that are statistically significant. Variables with the greatest explanatory power, and which are statistically significant, are retained for predictive model development. According to Mas and Baker (2011), selecting independent variables with a p value of <0.05 (95% confidence interval) is the standard.

However, the possibility exists to make the *p* value standard either more stringent or less stringent (Mas and Baker, 2011). Given the preliminary stages of the model development, taking into account variables with a *p* value of <0.2 (80% confidence interval) at the single-variable regression analysis stage, is good scientific practice. Variables with *p* values of <0.2 and *p* values of <0.05 at the single-variable analysis stage are selected for multivariate regression analysis. The stepwise selection procedure automatically removes the variables to make the final predictive model statistically significant ($p < 0.05$).

The third step is model diagnostics. The following criteria are to be met in order for the predictive model to be selected: 1. Statistically significant--*p* value of <0.05; 2. Scatterplot normally distributed, based on visual inspection; 3. “model goodness of fit test” R-squared values >10%; and 4. Standard error of coefficients.

The fourth step is model performance evaluation. The evaluation criteria for model performance are based on:

1. Type I (false positives) errors;
2. Type II (false negatives) errors;
3. Sensitivity (true positives); and
4. Specificity (true negatives).

7.0 Results and Discussion

<u>Step 1</u>

EDA was completed, and summary statistics for *E. coli* concentrations were analyzed from 2013 and 2014 inclusive. Table 7 below provides an illustration of said summary statistics.

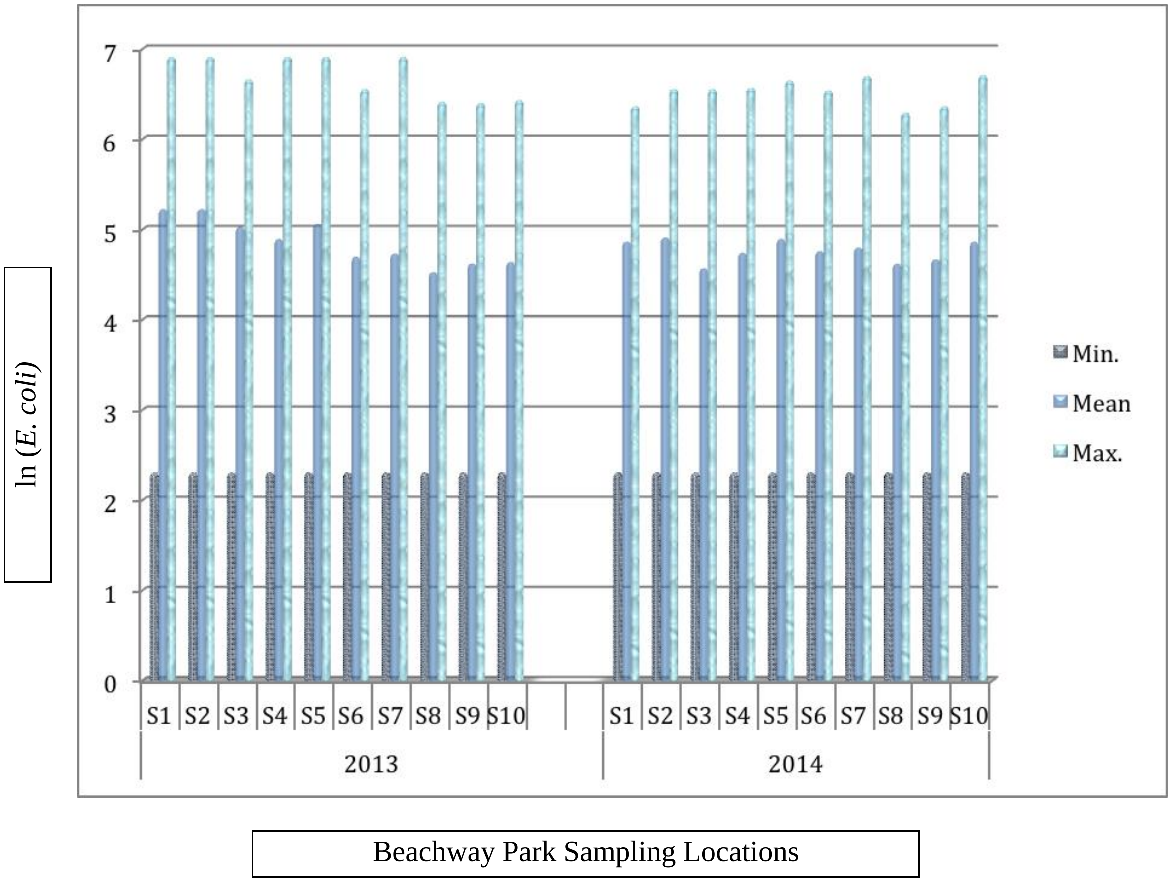
Table 7. Summary Statistics for Beachway Park June-August 2013 and 2014

Year	**Number of Samples**	**ln (GM of *E. coli* Mean)**	**ln (GM of *E. coli* Minimum)**	**ln (GM of *E. coli* Maximum)**	**# Unsafe Postings**
2013	480	4.62	2.30	6.18	16
2014	250	4.65	2.30	6.30	5

It can be observed from Table 7 that *E. coli* minimum, *E. coli* maximum, and mean of Geo-mean *E. coli* concentrations were relatively consistent throughout the 2013 and 2014 beach water sampling seasons. Note that an enhanced sampling frequency was implemented during the 2013 beach water sampling season, which likely explains the higher percentage of days the beach was posted as unsafe. The purpose of this enhanced sampling frequency was to collect the required data in order to develop the predictive model.

It can be observed from Figure 2 that the *E. coli* concentrations were relatively consistent with little temporal variability during the 2013 and 2014 beach water sampling seasons. It is important to note that this study used the 2013 data to build the predictive model; the 2014 data were used to test the predictive model.

Figure 2. Consistency of E. coli Concentrations across Sampling Locations vs. ln (E. coli) June-Aug 2013 and 2014



<u>Step 2</u>

Table 8 below provides an illustration of the single-variable statistical results (*p* values) for each independent variable with the dependent variable *E. coli.* Variables with *p* values of <0.2 (highlighted) and *p* values of <0.05 (highlighted and italicized) at the single-variable analysis stage are selected for multivariate regression analysis. The stepwise selection procedure automatically removes the variables to make the final predictive model statistically significant (*p* <0.05).

Table 8. Single-variable Results-Natural Log (ln) E. coli and Independent Variables at Beachway Park June-August 2013

Independent Variable	**ln (*E. coli*)**
	p-values
CLARITY	***0.007***
WAVE_HT	***0.039***
DOMESTIC_ANIMALS	0.166
UV_INDEX	0.180
ALGAE	0.197
W_DIRECT	0.255
AIR_TEMP	0.372
WF_FECES	0.416
WATERFOWL_DENSITY	0.417
RAIN_INT	0.496
WATER_TEMP	0.586
24HR_RAIN	0.677
W_SPEED	0.723
BATHERS	0.774
48HR_RAIN	0.999

A stepwise regression analysis was performed using the SPSS statistical software and the final model was developed. Each of the included variables was entered and tested to see if the model would be stronger if it was excluded. The process of removing variables ends when it is not possible to make improvements that are statistically significant to the model. Table 9 provides an illustration of the coefficients along with the confidence limits of the single-variables selected for multivariate regression analysis.

Table 9. Selected Single-variable Results-Natural Log (ln) E. coli and Independent Variables at Beachway Park June-August 2013

Independent Variable	ln (*E. coli*) *p-values*	Coefficients	Confidence Intervals
CLARITY	***0.007***	0.054	(0.0152, 0.0924)
WAVE_HT	***0.039***	0.030	(0.0016, 0.0591)
DOMESTIC_ANIMALS	0.166	-0.148	(-0.2074, 1.1692)
UV_INDEX	0.180	-0.091	(-0.2259, 0.0437)
ALGAE	0.197	0.052	(-0.2456, 1.1583)

It is evident from Table 9 that the independent variables (domestic animals, UV index, and algae) with coefficients that are at a p value <0.2 have confidence limits that include zero. Confidence limits including zero indicate that there is no association between the independent variable and dependent variable (*E. coli)*. Clarity and wave height have coefficients that are at a p value <0.05, and the confidence limits do not include zero. UV index, domestic animals, algae, and wave height were all automatically excluded. The model was generated and below describes the predictive model:

ln (*E. coli*)= 3.582 + (0.054*x)

Where: x= CLARITY

Step 3

Table 10. Model Diagnostics for Predictive Model

Predictor	Coefficient	Standard Error Coefficient	T-value	P-value	Model R-Square
Constant	3.582	0.206	17.375	0.001	20%
Clarity	0.054	0.019	2.803	0.007	

Table 10 above and Figure 3 reveals that the predictive model diagnostics meets the selection criteria. A scatterplot is generated to visually assess for normal distribution, see Figure 3.

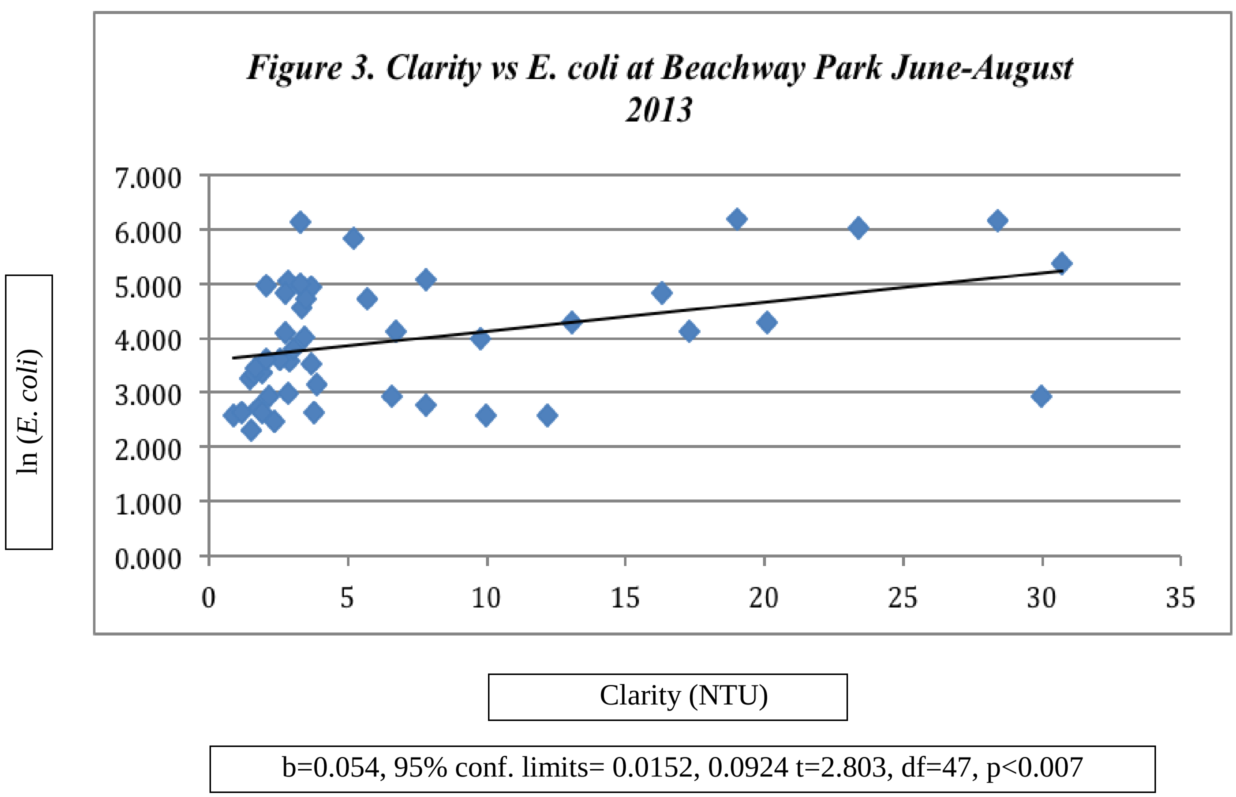


Figure 3. Clarity vs E. coli at Beachway Park June-August 2013

Step 4

Table 11 and Table 12 provide an illustration of the performance evaluation results for both the persistence model and predictive model during the 2014 beach water sampling season.

Table 11. Predictive Model Performance at Beachway Park, 2014 Beach Water Season

Confirmed by Ontario Public Health Lab*

Predictive Model	>100 *E. coli* per 100 mL	≤100 *E. coli* per 100 mL	Total
Posted-Unsafe	1 (True +ve)	0 (False +ve)	1
Posted-Safe	4 (False -ve)	20 (True –ve)	24
Total	5	20	25

*Based on the provincial *E. coli* standard

Table 12. Persistence Model Performance at Beachway Park, 2014 Beach Water Season

Confirmed by Ontario Public Health Lab*

Persistence Model	>100 *E. coli* per 100 mL	≤100 *E. coli* per 100 mL	Total
Posted-Unsafe	0 (True +ve)	5 (False +ve)	5
Posted-Safe	5 (False -ve)	15 (True –ve)	20
Total	5	20	25

*Based on the provincial *E. coli* standard

The persistence model frequently provides incorrect results for Beachway Park. The true positive rate (sensitivity) of the persistence model was at a rate of 0%. During the 2014 beach water sampling season, the beach was never correctly posted as unsafe for elevated bacterial levels. However, the predictive model was able to correctly identify elevated bacterial levels for Beachway Park at a true positive rate (sensitivity) of 20%. The false negative rate (type II errors), indicates a failure to post the beach as unsafe due to elevated bacterial levels when such postings were warranted. The false negative rate of the persistence model was greater (25%) than the false negative rate of the predictive model (17%). The false positive rates (type I errors), an unwarranted posting for elevated bacterial levels (unsafe postings), of the predictive model was at a rate of 0%, while the false positive rates (type I errors) of the persistence model was at a rate of 100%. The predictive model correctly identified safe levels at a true negative rate of 100%, while the true negative rate of the persistence model was at 75%.

7.1 Conclusions

In order to respond to the current environmental health policy challenges related to recreational water quality, Pushchak and Bardecki (2014) state that governments must develop an improved scientific and technical understanding of environmental health issues and demonstrate an expertise in environmental analysis and decision-making. To be effective, an environmental systems management approach must integrate a number of approaches to successfully respond to the environmental policy challenges associated with recreational water quality. According to Wong (2009), "policy makers worldwide in environmental management are aware of the shortcomings of the current sampling-based monitoring protocol and endorse the use of predictive models to supplement routine water quality sampling." According to Mas and Baker (2011), in nearly all cases predictive models are used as a supplement to existing water quality monitoring programs. Some models are used as internal guidance for beach managers and public health officials and others are publically available over the Internet for beachgoers to make more informed decisions.

The inherent inaccuracy of the persistence model for Beachway Park renders it an unacceptable approach for safeguarding public health from recreational water-borne illnesses. Based on the study performance evaluation results, the persistence model performs poorly in comparison to the predictive model. It is worth proposing that the predictive model be used to supplement the persistence model in order to accurately predict bacterial levels on a near real-time basis at Beachway Park.

8.0 Research Application and Initiatives

This research study clearly links the environmental sciences, policy and management disciplines. Currently, Halton Region posts public beaches as unsafe when the counts of *E. coli* exceed the provincial standard of 100 *E. coli* per 100 mL of water. The Halton Region Health Department is presently updating its Beach Water Quality Monitoring Policy and Procedures Manual. This update may incorporate predictive modelling to supplement Halton's current monitoring system (persistence model). Halton Region will continue to collect water samples for posting Beachway Park; however, the Region may also consider supplementing the persistence model with the predictive model in summer 2015.

This research study also provides recommendations for consideration by the Ministry of Health and Long-term Care to amend the *Beach Management Protocol* to include predictive modelling as an accepted approach for supplementing the persistence model. This amendment would help to determine bacterial levels at public beaches on a near real-time basis and better safeguard public health from water-borne illnesses related to recreational water use.

Furthermore, this research study could enhance the possibility of future career opportunities in Canada for environmental professionals, specializing in beach water quality monitoring. In Canada, not all agencies have either the technical expertise to develop and maintain predictive models or the management skills to make sure that these models are used effectively. The creation of the position of beach manager, currently non-existent in Canada, would provide such technical expertise. The career opportunity of beach water manager already exists in boards of health in the United States.

With the successful implementation of a predictive model, it is feasible that beach water quality "nowcasting" will become a desirable tool for near real-time predictions of bacterial levels in beach water at Beachway Park. Buoys installed on site, in the water, will measure and collect the required environmental variable data to allow for nowcasting. Nowcasting is a current practice in the United States, it is similar to a weather forecast, in that it provides the probability (in percent) that the bathing-water standard for *E. coli* will be exceeded based on environmental variables most significantly influencing beach water quality (USEPA, 2010).

9.0 Limitations and Recommendations

While one year of data were used for model development, redevelopment using three years of data (2013-2015 inclusive) is recommended for future research studies. Analysis of beach water quality data from the subsequent summer seasons will increase the sample size and allow for the development of a more accurate predictive model. According to the USGS (2013), predictive modelling is a dynamic process which requires refinement with newly available data to improve predictions. McPhedran *et al*. (2013) states that a greater dataset collected over a longer period of time will strengthen the accuracy of the predictive model.

Predictive modelling is an excellent precautionary approach for monitoring beach water quality in Ontario, an approach which triggers and guides policy-making deliberations in conditions of scientific uncertainty. The scientific uncertainty stemming from the persistence model renders it as an unacceptable approach for safeguarding public health from recreational water-borne illnesses; beachgoers require postings reflecting near real-time bacteriological concentrations in order to make informed decisions about swimming. The current 24-hour delay in obtaining laboratory results and posting public beaches, during which the concentrations of bacteria in the water may have changed, is problematic.

Vandenberg (2011) also speaks to the implementation of a precautionary approach when considering public health impacts of a known contaminant, in this case *E. coli*. Sly (2000) is also supportive of exercising the “precautionary principle” in order to protect both public health and the agency’s credibility. Predictive modelling is therefore worthy of consideration as a precautionary approach for monitoring beach water quality and addressing the scientific uncertainty stemming from the persistence model. A feasible solution for overcoming the above-mentioned limitations is to supplement the persistence model with a site-specific predictive model to accurately predict bacterial levels in the water on a near real-time basis.

According to Papadopoulos (2013), boards of health require an evidence-based recreational water quality monitoring program in a predictive model capacity, which includes a robust communication plan to better safeguard public health from recreational water-borne illnesses. Future research is required to establish a risk management framework for recreational water quality monitoring programs in a predictive model capacity that is more accurate and evidence-based.

10.0 Appendices

APPENDIX A.

Bacteriological Analysis of Water Form

Appendix A. Bacteriological Analysis of Water Form

Public Health Ontario | Santé publique Ontario

Public Health Laboratories

Barcode | Date/Time Received | PHL No.

Bacteriological Analysis of Water – Single Sample Requisition for Official Agencies

FOR DRINKING WATER: THE REGULATION STATUS OF THE SAMPLE MUST BE INDICATED. IF REGULATED, ALL NON-SHADED AREAS MUST BE COMPLETED OR THE SAMPLE WILL NOT BE ANALYZED BY THE LABORATORY AND ANOTHER SAMPLE WILL HAVE TO BE SUBMITTED.

A unique identifier (i.e. barcode) must be present on both the bottle and requisition when received at the laboratory or the sample will not be processed

Official Agency Address

Agency Name:

Bldg. No., Street, R.R., Box No.

City, Town

Province | Postal Code

Submitted By:

Submitted To: ____________ Public Health Lab

Comments/Additional Information:

Owner of the Water Supply

Facility:

Bldg. No., Street, R.R., Box No.

City, Town

Province | Postal Code

Contact Name(s):

Tel: *(Working hrs.)*: *(After Hours)*

Fax:

Waterworks No.: Not assigned ☐ Assigned ☐ if assigned, indicate number

Type of Drinking Water Systems

Mandatory: tick one box
- HPPA O. Reg 319/08 ☐
- HPPA Regulated Premises ☐
- Non Regulated ☐
- Private Residence ☐
- SDWA O. Reg 170/03 ☐

Reason for Sampling

- Control ☐
- Audit ☐
- Compliance ☐
- Resample ☐
- Complaint Investigation ☐
- Outbreak Investigation ☐

Outbreak Investigation

Outbreak Number: ____________

Etiological Agent if Known: ____________

Test for Etiological Agent* ☐ Or, Test for Potability ☐

*Call laboratory before sampling

Sample Information-Drinking Water

(Check all applicable boxes)

Date Collected: ____________

Time Collected: hh : mm AM PM (Circle one)

Collected By: ____________

Sampling Site: ____________

Free or combined chlorine residual (mg/L): ____________ HPC test Requested ☐

Source of Drinking Water

- Ground Water (i.e. well) ☐
- Cistern ☐
- Surface Water ☐
- Distribution ☐
- Bottled Water ☐
- Other: ________ ☐

Treatment
- Non-treated ☐
- Treated ☐

All potable samples must be <25°C when received at the lab. Samples must be received in the lab within 6 hours of collection if not refrigerated. Refrigerated non-potable samples must be received in the laboratory within 1 calendar day of collection and all drinking water must be received in the laboratory within 48 hours of collection (time of collection must be indicated).

Sample Information-Non-Potable

Date Collected: ____________

Time Collected: hh : mm AM PM (Circle one)

Collected By: ____________

Sampling Site: ____________

- Public Beach ☐
- Recreational Water Facility / Hydrotherapy Pool ☐
- Suspected Sewage Contamination ☐
- Other * (Please specify): ________ ☐

***Call laboratory before sampling**

For Laboratories Only

Tests Performed	Count	Reported By	Date Read
Total Coliforms (Cfu) per 100mL*V			
Escherichia coli (Cfu) per 100mL*V			
Background (Cfu) per 100mL*V			
Pseudomonas aeruginosa (Cfu) per 100mL*			
Presumptive Staphylococci (Cfu) per 100mL*			
Staphylococcus aureus (Cfu) per 100mL*			
Heterotrophic plate count (HPC) (Cfu) per mL**V			
Other per mL			
Date of Analysis:	Authorized By: (Technologist)		

For Regulated Drinking Water or Legal Samples:

Relinquished By: ____________ (Print Name) For Lab Use:

Relinquished By: ____________ (Signature) Received By: ____________

Date: ________ Time: ________ Date: ________ Time: ________

Laboratory Comments / Date Reported

4318-44 (12/11)

Ontario

Agency for Health Protection and Promotion

*Analysis by Membrane Filtration. **Analysis by Spread Plate. V = Accredited test (drinking water)

These results relate only to the sample tested.

This information is being collected in compliance with the requirements of the *Safe Drinking Act, 2002* and it's regulations, and it will only be used for the purposes for which it is collected. Public Health Ontario is subject to the *Freedom of Information and Protection of Privacy Act* and any information in its records may be subject to disclosure by the Ministry pursuant to the

APPENDIX B.

Routine Beach Surveillance−Field Data Report

Appendix B-Routine Beach Surveillance - Field Data Report

Beach Name	Posted at Time of Sampling ☐ Yes ☐ No
Beach ID Number	Surveyor Name
Day of Week: ☐ Mon ☐ Tues ☐ Wed ☐ Thurs ☐ Fri	
Date of Sampling:	
Time (24 hr clock):	

General Beach Conditions

Air Temperature _______°C Water Temperature ________°C Water Depth at Sample ________cm

Rainfall During Sampling: ☐ Light ☐ Medium ☐ Heavy ☐ None

Rainfall: ☐ <24 hours _____mm rainfall measured ☐ <48 hours _____mm rainfall measured

Wind Direction and Speed: Speed __________ UV Index __________
Direction ________

Wave Height (cm) ____________ Water Clarity (Turbidity) _____ NTUs

Algae Present ☐ Yes ☐ No

Potential Pollution Sources

Number of Bathers: ________ (count)

Presence of Wildlife and Domestic Animals & Feces (F)							
Type	Geese	Gulls	Dogs	F-Geese	F-Gulls	F-Dogs	Other (specify):
Number							
Location							
Samp. ID							

☐Other Pollution Sources at Time of Sampling (Describe)

Inspector's Signature ____

Inspector's Name ____

May 2013

11.0 References

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