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**for executing the 2010 beach sampling program**

## Highlights:

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- During the 2010 bathing season, 19 beaches were sampled by the North Bay Parry Sound District Health Unit (NBPSDHU).
- 3 beaches within the City of North Bay were sampled weekly, while all others were sampled monthly.
- 16 out of 19 (84%) of the beaches sampled did not return adverse geometric means in 2010.
- 5 Adverse sampling results were returned for 3 beaches and none of the re-sampling results were adverse. None of the public beaches in the NBPSDHU catchment area required closure due to adverse water test results.
- Rainfall, wind speed, wind direction, and daily average air temperature were explored as predictor variables.
- There appeared to be a positive correlation between geometric mean and rainfall during 48 hours preceding sampling. Rainfall during the 2010 bathing season was 90.8mm higher than average (ECNCA).
- Amelia Beach in North Bay was not sampled, and remained posted due to its history of adverse water quality.
- Based on the 2010 beach sampling program, recommendations for the 2011 beach sampling program include:
  1. Continue working to increase and strengthen relationships with Municipal partners. Any issues and obstacles limiting this goal should be identified.
  2. For ongoing consistency, the 2010 *Beach Pollution Surveys* and *Public Bathing Beach Schematic Diagrams* should be provided again to staff responsible for beach sampling in 2011.
  3. Consider weekly sampling of beaches that returned adverse results during 2010, as recommended in the 2008 Ontario Public Health Standards.
  4. Contact every Municipal office within the NBPSDHU catchment area to gather information about public beaches qualifying for inclusion in the 2011 beach sampling program.
  5. Conduct a physical inventory of signs during the first visit to each beach. Arrange to accompany Municipal or Swim Program Staff to locate all signs that are posted or held in storage.
  6. Collect signs provided to beaches that no longer qualify as, 'public beaches,' and re-distribute them as needed. Consider storing extra signs at NBPSDHU instead of in municipal storage.

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## Introduction

The purpose of the Beach Management Protocol is to assist in the prevention and reduction of water-borne illness and injury related to recreational water use at public beaches.

The 2010 Beach Sampling Program at the North Bay Parry Sound District Health Unit (NBPSDHU) was carried out in accordance with the 2008 Beach Management Protocol, as set out in the 2008 Ontario Public Health Standards (OPHS). The OPHS are structured to accommodate a process of ongoing review, support and enhancement so that the content may continually evolve. An evidence-based, scientific approach may lead to the development of additional criteria to address emerging public health hazards.

Because recreational water quality is influenced by various environmental and built factors, including rainfall, wave action, water and ambient air temperatures, waterfowl, industrial waste discharges, storm water outflows, septic system discharges and agricultural run-off, a comprehensive surveillance strategy is required to ensure public safety.

**Public Beach** is a beach area owned and/or operated by a municipality, which:

- ✓ The general public has direct access to;
- ✓ Allows supervised aquatics programs or is staffed by lifeguards; and
- ✓ Meets the requirements of the sampling protocol for sampling sites.

*OPHS, 2008, Beach Management Protocol*

## Beach Sampling Methodology

Similar to the 2009 Beach Sampling Program, the 2010 Program involved weekly sampling of the three beaches in the City of North Bay (Marathon, Birchaven Cove, and Olmsted), and monthly sampling was performed for those outside the City of North Bay (Callander Bay, Sturgeon Falls, Lake Nosbonsing, Mattawa, McManus, Magnetawan, Waubuno, McKellar, Bell Lake, Rosseau, Dunchurch, Fitzgerald, Foley Matheson Park, Nobel, Shebeshekong and 9-Mile Lake).

All municipalities in the NBPSDHU catchment area were contacted prior to the 2010 bathing season to determine whether they had beaches that met the criteria to define them as 'public beaches.' Those that no longer hired lifeguards or held swimming programs would have been excluded from the 2010 Beach Sampling Program. For those that met the definition of 'public beaches,' contact information for Municipal Recreational Coordinators and Swim Program Supervisors was obtained. An inventory

of beach status signs which NBPSDHU had previously provided to each municipality was also discussed.

A one-time *Beach Pollution Survey* (Appendix A) was conducted for each beach prior to sampling, using the survey data from the 2008 and 2009 bathing seasons. This survey was used to assess factors which could compromise the suitability of the beaches for public bathing. 'Posting' a beach means posting signs to notify the public that the beach is unsafe for bathing due to high levels of bacteria in the water. In the event that a public beach required posting or closure, further investigation into potential environmental and built factors affecting that beach location would be assessed. One-time *Public Bathing Beach Schematic Diagrams* (Appendix B) were also created during that time, using diagrams from 2008 and 2009 as a guide. The diagrams indicated the layout of the beaches and the sources of possible contaminants.

Sampling was conducted in accordance with the *Beach Management Protocol, 2008*. Since the overall lengths of the beaches, or the areas defined within their swimming boundaries measured less than 1000m, one sample from each of five sites was obtained at each beach. Water was collected in sterile, 3 or 4-barcode, 200 mL bottles containing sodium thiosulphate, provided by the Sudbury Public Health Laboratory.

*Public Bathing Beach Field Data Report* sheets (Appendix C) including information on date, time, air temperature, water temperature, rainfall, wind direction, sunlight, water clarity, bather density, presence and type of wild or domestic animals, wave action and signs posted were filled out each time water was sampled. *Bacteriological Analysis of Water* forms (Appendix D) were completed, and sterile water sample bottles were labelled, prior to each sampling. The sampler donned hip waders, a lifejacket, and carried a waterproof bag containing five sample bottles, a thermometer and a modified golf ball retriever. The sampler obtained water from 30 cm below the water surface at a depth of approximately 1.25 m at five sites named far-right (FR), right (R), center (C), left (L), and far-left (FL). The water temperature was recorded from the center sampling site at each beach.

Water samples were grouped and packaged on ice with respective *Bacteriological Analysis of Water* forms, and shipped to the Sudbury Public Health Laboratory at approximately 4:00 p.m. during the first business day of each week. Adverse water test results, constituting one sample exceeding 100 E.coli organisms per 100 mL water, were expedited to NBPSDHU via fax no later than two days following submission of samples. Where the geometric mean (Appendix E) of all five samples was determined to exceed 100 E.coli/100 mL, re-sampling was immediately performed. Where secondary results were adverse, beaches would be posted.

Data obtained from *Public Bathing Beach Field Data Reports*, *Bacteriological Analysis of Water* forms and online local weather from Environment Canada's National Climate Archive (ECNCA); [www.climate.weatheroffice.ec.gc.ca](http://www.climate.weatheroffice.ec.gc.ca) were entered into an Excel document that was shared throughout the Environmental Health Department at

NBPSDHU. Hard copies of all forms were stored in a beach-specific filing system at NBPSDHU.

In 2009, rainfall, daily temperature and wind speed were used as predictor variables to determine their impact on the geometric mean fluctuation. For consistency in reporting and comparison, these predictors were used in the 2010 data (Table 1).

**Table 1: Profile of Predictor Variables by Description**

Predictor Variable	Description
Air Temperature	Average values obtained from ECNCA website
Wind Speed	
Rainfall	The presence or absence of rain 48 hours prior to sampling was recorded as y=yes and n=no using the ECNCA website

Average Daily Air Temperature:

The average daily air temperature from ECNCA was plotted against geometric means, wind speeds, and presence or absence of rainfall in the preceding 48 hours for each sample date, for beaches that had results indicating at least one geometric mean exceeding 100 E.coli/100 mL of water.

Average Daily Wind Speed:

The wind speed was recorded using data from ECNCA. Information regarding wind speed was plotted against rainfall and geometric means.

Rainfall:

Data pertaining to rainfall were recorded under four questions for each sample date using observations recorded on *Public Bathing Beach Field Data Report* sheets and data from ECNCA, including:

- Did it rain at any time 48 hours prior to sampling? Yes or No.
- Did it rain during sampling? Yes or No.
- Was the rain a potential influence on the sample results? Yes or No.
- Amount of daily rainfall? Measured in millimetres.

Information regarding rainfall in the preceding 48 hours was used to compare against wind speed and geometric means for beaches that had results indicating at least one geometric mean exceeding 100 E.coli/100 mL of water.

## Results

Out of the 19 beaches sampled, 16 (84%) did not return adverse geometric means throughout the 2010 bathing season. These beaches are summarized below (Table 2):

**Table 2: Profile of Beaches by Township, Sampling Frequency and Average Geometric Mean**

Beach	Census Subdivision	Frequency of Sampling	Number of Times Sampled in 2010	Average Geometric Mean		
				2009	2010	Change
<b>9-Mile</b>	McDougall	Monthly	3	N/A	13.33	N/A
<b>Bell Lake</b>	McDougall	Monthly	3	10.00	34.27	Increase
<b>Birchaven Cove</b>	North Bay	Weekly	10	16.42	18.65	Increase
<b>Callander Bay</b>	Callander	Monthly	3	28.10	10.00	Decrease
<b>Dunchurch</b>	Whitestone	Monthly	3	20.44	13.33	Decrease
<b>Fitzgerald</b>	Carling	Monthly	3	19.73	15.50	Decrease
<b>Foley Matheson</b>	Seguin	Monthly	3	18.03	35.22	Increase
<b>Lake Nosbonsing</b>	Astorville	Monthly	3	41.49	23.83	Decrease
<b>Magnetawan</b>	Magnetawan	Monthly	3	11.56	24.54	Increase
<b>Mattawa</b>	Mattawa	Monthly	3	36.64	24.07	Decrease
<b>McKellar</b>	McKellar	Monthly	3	109.25	25.84	Decrease
<b>McManus</b>	Kearney	Monthly	4	258.52	24.54	Decrease
<b>Nobel</b>	McDougall	Monthly	3	12.50	10.00	Decrease
<b>Shebeshekong</b>	Magnetawan	Monthly	3	11.93	10.00	Decrease
<b>Sturgeon Falls</b>	Sturgeon Falls	Monthly	3	18.87	20.11	Increase
<b>Waubuno</b>	Parry Sound	Monthly	3	71.66	31.10	Decrease

There were three beaches that reported adverse geometric means throughout the 2010 bathing season, including Marathon, Olmsted and Rosseau. The variable that appears to be most frequently associated with adverse geometric means is rainfall that has occurred 48 hours prior to sampling. Rainfall warning signs are permanently posted at these beaches, and the summary information pertaining to them (Tables 3-5) and their respective graphs (Figures 1-3) appear below:

Table 3: Key Facts for Marathon Beach

Key Facts			
<b>Census Subdivision</b>		City of North Bay	
<b>Frequency of Beach Sampling</b>		Weekly	
<b>Number of Times Beach Was Sampled in 2010</b>		12	
<b>Average Geometric Mean</b>	<b>2010</b>	151.09	
	<b>2009</b>	73.65	
	<b>Change between 2009 and 2010</b>	Increase	
<b>Adverse Geometric Mean(s) Reported in 2010</b>		3	

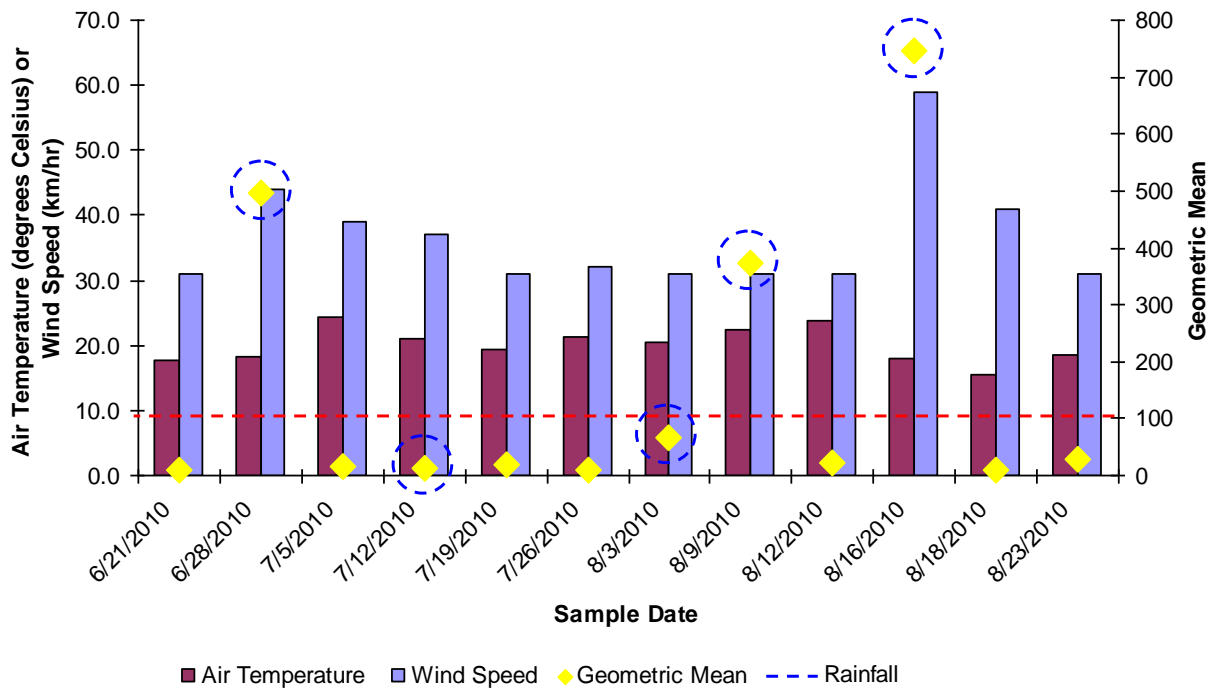


Figure 1: Marathon Beach Air Temperature, Wind Speed and Geometric Mean Comparison.

Table 4: Key Facts for Olmsted Beach

Key Facts			
Census Subdivision		City of North Bay	
Frequency of Beach Sampling		Weekly	
Number of Times Beach Was Sampled in 2010		11	
Average Geometric Mean	2010	39.91	
	2009	18.25	
	Change between 2009 and 2010	Increase	
Adverse Geometric Mean(s) Reported in 2010		1	

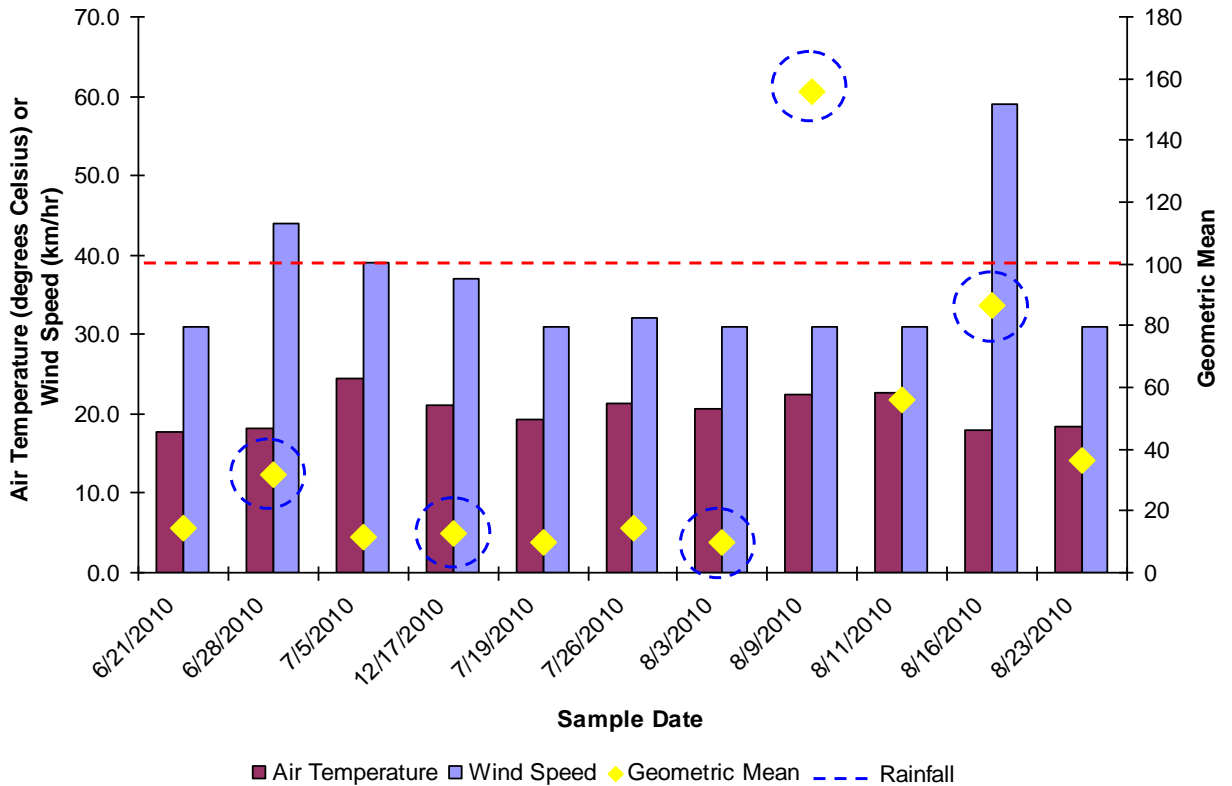


Figure 2: Olmsted Beach Air Temperature, Wind Speed and Geometric Mean Comparison.

Table 5: Key Facts for Rosseau Beach

Key Facts		
Census Subdivision		Rosseau Township
Frequency of Beach Sampling		Monthly
Number of Times Beach Was Sampled in 2010		4
Average Geometric Mean	2010	65.27
	2009	13.74
	Change between 2009 and 2010	Increase
Adverse Geometric Mean(s) Reported in 2010		1

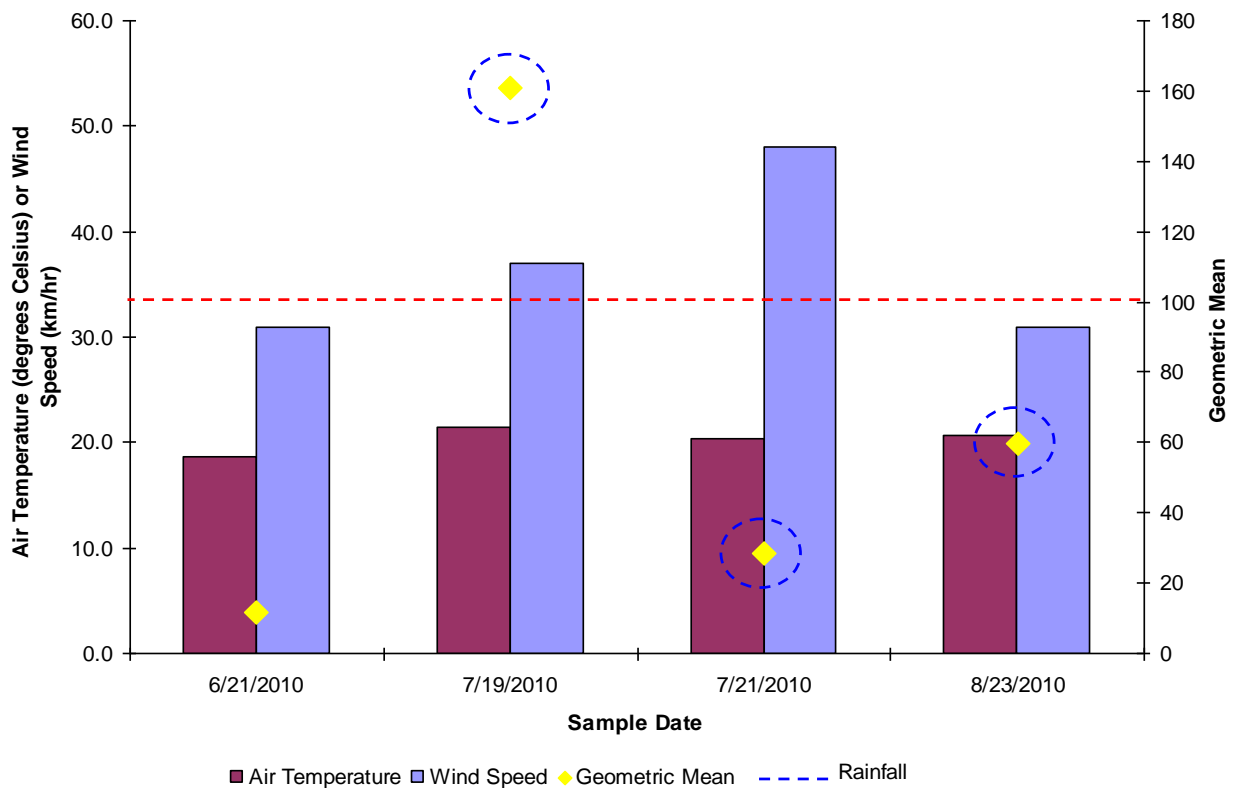


Figure 3: Rosseau Beach Air Temperature, Wind Speed and Geometric Mean Comparison.

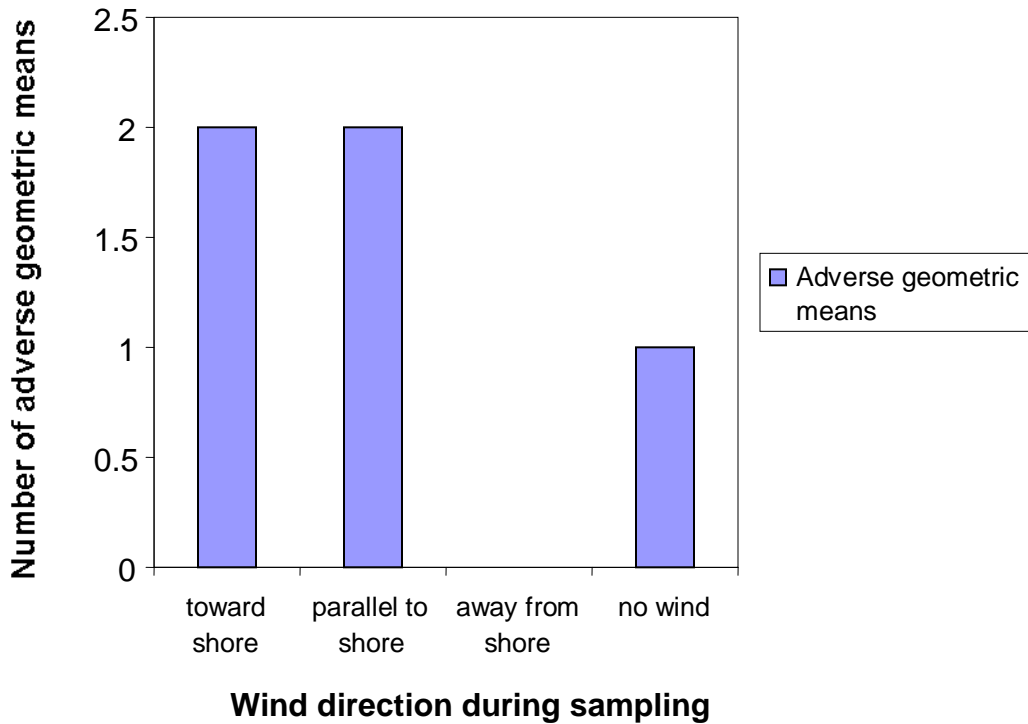


Figure 4: Number of adverse geometric means and wind direction comparison.

**Interpretation:**

Although it is likely that fluctuating geometric means at each of the beaches is due to interrelated variables, the graphic representation of the data appear to demonstrate a common trend among the beaches sampled. For this reason, the following interpretation applies to each of the 3 beaches reporting adverse geometric means:

- Five out of five (100%) of adverse geometric means occurred where rainfall was recorded in the preceding 48 hours. Rainfall appears to be positively correlated to the adverse results.
- Adverse geometric means occurred at wind speeds of 44, 31 and 59 km/hr at Marathon Beach, 31 km/hr at Olmsted Beach, and 37 km/hr at Rosseau Beach. There does not appear to be a strong correlation between wind speed and geometric mean.
- Adverse geometric means occurred within an average daily air temperature range of 20.1°C to 22.0°C. There does not appear to be a significant correlation between average daily air temperature and geometric mean.
- While there is no clear trend with regards to wind direction affecting geometric mean, two out of five (40%) of adverse geometric means occurred when wind direction was toward shore, and two out of five (40%) of adverse geometric

means occurred when wind direction was parallel to shore. One adverse result was returned when there was no wind, and no adverse results were returned when wind direction was away from shore.

## Discussion

The following recommendations were made in the 2009 report:

1. Expanding communication with community partners: It is essential to ensure that our municipal partners are fully aware and understand the goals and criteria for the beach sampling programs.
2. Alternative procedures for re-sampling: Due to the strong correlation between rainfall and adverse geometric means, re-sampling should only be considered when there is no potential influence of rainfall. Signs are currently posted advising the public to not swim if rainfall occurred during the previous 48 hours.

No additional sampling of Lake Nipissing's beaches within the NBPSDHU catchment area was conducted in the 2010 beach sampling program. Amelia Beach remained permanently posted and Marathon Beach was the only beach sampled on Lake Nipissing, as it was the only one classified under the 2008 *Beach Management Protocol* definition of 'public beach'.

The swimmer's itch reporting system during the 2010 bathing season involved discussions with lifeguard and swimming instruction staff as to their observations and the number of complaints received. In addition, the Environmental Health Department at NBPSDHU kept a record of phone inquiries pertaining to swimmer's itch with the intention of determining whether the call volume may warrant establishing a beach information hotline in the future. A link to the NBPSDHU website may be developed in the future to provide beach information to the public.

The staff responsible for beach sampling in the Parry Sound District used the same data collection and recording tools as staff in the North Bay District, and information for all areas within the NBPSDHU was complete by the end of the 2010 bathing season. An Excel spreadsheet located in a file that was shared by the Environmental Health Department was used as a standard data entry tool by staff responsible for beach sampling. *Public Bathing Beach Field Data Report* sheets, *Beach Pollution Survey* forms and *Public Bathing Beach Schematic Diagrams* forms were filled out for all beaches, and hard copies filed at respective branch offices.

Similar to the 2005-2009 beach sampling programs, the meteorological data used in 2010 was primarily obtained from the ECNCA website. While the data did not always reflect the actual conditions present at the beaches while they were sampled, it provided average daily values which were useful when considering the latent effects of weather

changes on water bodies. Water test results and meteorological information obtained through ECNCA are both retrospective data.

Adverse water sample results were promptly delivered to the staff member responsible for re-sampling as early as they were received by administrative staff in both North Bay and Parry Sound offices.

The understanding and intention to increase public knowledge and strengthen relationships with Municipal partners guided staff interactions with Municipalities and the public throughout the bathing season. Municipalities were provided with information packages, brochures, and signs to post at public beaches.

Although Municipalities were contacted prior to the 2010 bathing season, not all of the Municipalities were able to provide information regarding personnel contacts, sign inventory and sign locations. Obtaining a comprehensive inventory of all beach signs, their condition, location and contact information for key persons within Municipalities is an ongoing objective.

As a result of observations made and inefficiencies identified in 2010, the following recommendations should be considered for the 2011 beach sampling program:

1. Continue working to increase and strengthen relationships with Municipal partners. Any issues and obstacles limiting this goal should be identified.
2. For ongoing consistency, the 2010 *Beach Pollution Surveys* and *Public Bathing Beach Schematic Diagrams* should be provided again to staff responsible for beach sampling in 2011.
3. Consider weekly sampling of beaches that returned adverse results during 2010, as recommended in the 2008 Ontario Public Health Standards.
4. Contact every municipal office within the NBPSDHU catchment area to gather information about public beaches qualifying for inclusion in the 2011 beach sampling program.
5. Conduct a physical inventory of signs during the first visit to each beach. Arrange to accompany Municipal or Swim Program Staff to locate all signs that are posted or held in storage.
6. Collect signs provided to beaches that no longer qualify as, 'public beaches,' and re-distribute them as needed. Consider storing extra signs at NBPSDHU instead of in municipal storage.

A combination of environmental and built factors is likely to be the cause of the fluctuating geometric mean throughout the 2010 bathing season. Rainfall and wind direction, however, appear to have a significant influence on water quality. It is also worthwhile to note that there was a 90.8 mm greater than average rainfall recorded during the 2010 bathing season (ECNCA).

The 2010 beach sampling program investigated the effects of wind speed, wind direction, air temperature and rainfall on geometric means. Future consideration should be given to other predictor variables to determine their significance with regards to geometric mean. Historic data on additional variables are also available for retrospective study purposes. Data collected during 2010 showed that geometric means were consistently below 100 E.coli/100 mL in 84% of public beaches within the NBPSDHU catchment area. Due to the dynamic nature of these environmental systems, change can occur at any time which will necessitate continuous monitoring.

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Environment Canada National Climate Archive (ECNCA); [http://www.climate.weatheroffice.ec.gc.ca/climateData/canada\\_e.html](http://www.climate.weatheroffice.ec.gc.ca/climateData/canada_e.html)

# Appendix A:

**Appendix C**  
**Public Bathing Beach**  
**Beach Pollution Survey\* - Field Data Report**

HEALTH AGENCY: \_\_\_\_\_ DATE: \_\_\_\_\_ TIME: \_\_\_\_\_

BEACH NAME AND LOCATION: \_\_\_\_\_ SAMPLING SITE: \_\_\_\_\_

Potential Source of Contamination	Nature of Contaminant		Observations (Physical Characteristics)
	Bacteriological	Chemical	
			(For example: presence of oils, grease, algae deposits, dead fish, refuse accumulations, etc.)

\*Refer to Beach Pollution Survey data and Sampling Protocol as referred to in "Beach Management Protocol"

**Appendix B:**



**NORTH BAY PARRY SOUND DISTRICT HEALTH UNIT  
PUBLIC BATHING BEACH SCHEMATIC DIAGRAM**

Compass rose: N, E, S, W

Name of Beach: \_\_\_\_\_  
Municipality: \_\_\_\_\_  
Date: \_\_\_\_\_

1. Pollution Sources:  
(Description and Distance to bathing area)
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
2. Other areas of concern:
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_

Signature: \_\_\_\_\_, Environmental Health



# Appendix D:



Ministry of Health and Long-Term Care  
Public Health Laboratories

## Bacteriological Analysis of Water Multiple Sample Requirement for Official Agencies

**FOR DRINKING WATER: THE REGULATION STATUS OF THE SAMPLE(S) MUST BE INDICATED. IF REGULATED, ALL NON-SHADED AREAS MUST BE COMPLETED OR THE SAMPLE(S) WILL NOT BE ANALYZED BY THE LABORATORY AND ANOTHER SAMPLE / SAMPLE(S) WILL HAVE TO BE SUBMITTED. A UNIQUE IDENTIFIER (I.E. BARCODE) MUST BE PROVIDED ON BOTH THE BOTTLE AND REQUIREMENTS FOR THE LABORATORY OR THE SAMPLE(S) WILL NOT BE PROCESSED.**

- Sampling Instructions:**
- All samples must be kept at 4°C when received at the lab. Samples must be received in the lab within 6 hours of collection or must be refrigerated.
  - Refrigerated non-potable samples must be received in the laboratory within 1 calendar day of collection.
  - Regulated drinking water must be received in the laboratory within 48 hours of collection.
  - Non-regulated drinking water must be received in the laboratory within 2 calendar days of collection.

<b>Agency Name</b> 95020 MEDICAL OFFICER OF HEALTH 681 COMMERCIAL STREET NORTH BAY, ONTARIO P1B 4E7		<b>Date Collected:</b> _____ <b>Time Collected:</b> _____ <b>Collected By:</b> _____ <b>Sampling Site:</b> _____		<b>Source of Drinking Water</b> Municipal <input type="checkbox"/> Location Type Non-Municipal <input type="checkbox"/> Treated <input type="checkbox"/> Private Residence <input type="checkbox"/> Non-Treated <input type="checkbox"/> Other <input type="checkbox"/> Well (ground water) <input type="checkbox"/> Distribution <input type="checkbox"/>		<b>Reason For Sampling</b> Mandatory (select HPPA or SDWA): HPPA <input type="checkbox"/> SDWA <input type="checkbox"/> Indicate O Regulation #: _____ Optional: <input type="checkbox"/> Customer Complaint <input type="checkbox"/> HACCP Audit, Food Premises <input type="checkbox"/> Outbreak Investigation (complete section below) Outbreak Number: _____ Etiological Agent if Known: _____		<b>Identification of Collection Site &amp; Time Collected</b> Barcode HPC Requested <input checked="" type="checkbox"/>		<b>Bacterial Counts (CU) Based on 100mL Vol. By Membrane Filtration</b> E. coli <input type="checkbox"/> Presumptive S. aureus <input type="checkbox"/> Total Coliforms <input type="checkbox"/> Staphylococci <input type="checkbox"/>		<b>Lab. No. / Date &amp; Time Received</b>	
<b>Owner of the Water Supply</b> Facility Bldg. No. Street, R.R., Box No. City, Town Province Postal Code Contact Name(s): Tel: (Working hrs.): Tel: (After hrs.): Fax: MOE Waterworks No.: <input type="checkbox"/> Not assigned <input type="checkbox"/> if assigned, indicate number <input type="checkbox"/> Assigned <input type="checkbox"/>		<b>Relinquished By:</b> _____ For Lab Use: (Print Name) <b>Relinquished By:</b> _____ Received By: _____ (Signature) Date: _____ Time: _____ Date: _____ Time: _____		<b>For Regulated Drinking Water or Legal Samples:</b> Reported By: _____ Date Recd: _____		<b>Sample Information - Non-Potable</b> Date Collected: _____ Collected by: _____ Sampling site: _____ Recreational <input type="checkbox"/> Pool / Spa, swimming, whirlpool <input type="checkbox"/> Suspected Sewage Contamination <input type="checkbox"/> Other (Please specify) <input type="checkbox"/>		<b>Laboratory Comments:</b> Date Reported: _____		Date of Analysis: _____ Analyzed By: _____ (Technologist)			

452-144 (10/07) 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 its regulations, and it will only be used for the purposes for which it is collected. The Ministry of Health and Long-Term Care 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 Freedom of Information and Protection of Privacy Act.

## Appendix E:

### 2.2. Recreational Water Samples – Calculation of Geometric Mean

#### Definition of Geometric Mean:

**Mathematical Definition:** the  $n^{\text{th}}$  root of the product of  $n$  values.

**Practical Definition:** the average of the logarithmic values of a data set, converted back to a base 10 number.

#### Geometric Mean for Recreational Water Samples:

The BOH monitoring a public beach must test for and report *E. coli* bacteria concentrations. The data must be calculated as a geometric mean of all the test results obtained during the reporting period. The geometric mean, rather than the arithmetic average, is used in these calculations because it tends to minimize the effect of very high or low values on the average. For example, the arithmetic average of four counts of 10,000, 10,000, 10,000 and 1,000,000 is 257,500, while the geometric mean is about 31,600. The single high reading may indicate an error or sporadic occurrence, the cause of which should be investigated. However, use of the arithmetic average, when incorporating an uncommon high reading, results in an exaggerated or inaccurate estimate of average conditions.

The geometric mean is a log-transformation of data that permits meaningful statistical evaluations.

#### The Bacteria Count and the Geometric Mean

Assessment of the bacterial quality of bathing water requires more than a single result. Due to the uneven distribution of bacteria throughout a liquid medium, the count of microorganisms in a single "grab sample" does not necessarily represent the average concentration in a particular body of water. In fact, a random sample may demonstrate a concentration that is far above (or below) the average. In order to get an accurate estimate of the quality of recreational water, the results of a number of samples must be combined in such a way that a random, unrepresentative sample will not unduly influence the average. For this reason, scientific publications setting bacterial standards for water quality usually require either that a large proportion of the readings (e.g. 90-95%) fall below a certain maximum permissible value, or that the geometric mean of all samples falls below such maximum value. The *Beach Management Protocol* applies the latter approach with respect to bathing beaches in Ontario.

The geometric mean could be thought of as the average of the logarithmic values, converted back to a base 10 number.

The formula for the geometric mean is:

$$\text{Geometric Mean} = ((X_1)(X_2)(X_3)\dots(X_n))^{1/n}$$

where  $X_1$ ,  $X_2$ , etc. represent the individual data points and  $n$  is the total number of data points used in the calculation.

#### Calculating the Geometric Mean

To calculate a geometric mean:

1. Compute the natural logarithm (ln) of each sample result.
2. Add the logarithm of each sample result together.
3. Divide the result by the number of samples.
4. Convert this product (logarithm of the geometric mean) back to an arithmetic value by computing the antilog of the product.

The formula for the logarithm of the geometric mean is:

$$\text{Logarithm of Geometric Mean} = ((\ln X_1) + (\ln X_2) + (\ln X_3) + \dots + (\ln X_n))/n$$

The following example illustrates how this is done:

where 45, 120, 55, 35 and 75 are sample data results of colony-forming units (cfu) per 100 ml of water, calculate the geometric mean. This calculation can be performed on a scientific calculator using the "log" key. For example, enter "45" on the calculator and then press the "log" key.

Sample 1	45	ln(45) =	3.806
Sample 2	120	ln(120) =	4.787
Sample 3	55	ln(55) =	4.007
Sample 4	35	ln(35) =	3.555
Sample 5	75	ln(75) =	4.317

Average of logarithms = 4.094  
Antilog of average = 60.0

In this example, the geometric mean for the data is 60 cfu/100ml of water. Public health inspectors would use this value in addition to other public health factors to determine the necessity for posting or other advisory actions.