GUIDELINES FOR

CANADIAN
RECREATIONAL WATER QUALITY

UNDERSTANDING AND MANAGING RISKS IN RECREATIONAL WATERS

Guideline Technical Document

Health Canada
Santé Canada

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Health Canada is the federal department responsible for helping the people of Canada maintain and improve their health. Health Canada is committed to improving the lives of all of Canada's people and to making this country's population among the healthiest in the world as measured by longevity, lifestyle and effective use of the public health care system.

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UNDERSTANDING AND MANAGING RISKS IN RECREATIONAL WATERS

Foreword

The *Guidelines for Canadian Recreational Water Quality* comprise multiple guideline technical documents that consider the various factors that could interfere with the safety of recreational waters from a human health perspective. This includes technical documents on understanding and managing risks in recreational waters; fecal indicator organisms; microbiological sampling and analysis; cyanobacteria and their toxins; physical, aesthetic, and chemical characteristics; microbiological pathogens and other biological hazards. These documents provide guideline values for specific parameters used to monitor water quality hazards, and recommend science-based monitoring and risk management strategies.

Recreational waters are considered to be any natural fresh, marine or estuarine bodies of water that are used for recreational purposes; this includes lakes, rivers, and human-made systems (e.g., stormwater ponds, artificial lakes) that are filled with untreated natural waters. Jurisdictions may choose to apply these guidelines to other natural waters for which limited treatment is applied (e.g., short-term use of disinfection for an athletic event). Applying the guidelines in these scenarios should be done with caution. Some disease-causing microorganisms (e.g., protozoan pathogens) are more difficult to disinfect than fecal indicator organisms and may still be present even if disinfection has reduced the fecal indicators to acceptable levels.

Recreational activities that could present a human health risk through intentional or incidental immersion and ingestion include primary contact activities (e.g., swimming, bathing, wading, windsurfing and waterskiing) and secondary contact activities (e.g., canoeing, boating or fishing).

Each guideline technical document has been established based on current, published scientific research related to health effects, aesthetic effects, and beach management considerations. The responsibility for recreational water quality generally falls under provincial and territorial jurisdiction, and therefore the policies and approaches, as well as the resulting management decisions, may vary between jurisdictions. The guideline technical documents are intended to guide decisions by provincial, territorial, and local authorities that are responsible for the management of recreational waters. For a complete list of the guideline technical documents available, please refer to the *Guidelines for Canadian Recreational Water Quality* summary document available on the Canada.ca website (in publication).

Understanding and Managing Risks in Recreational Waters

The authority charged with the day-to-day oversight of the recreational water area generally has the most comprehensive knowledge of the recreational area and is therefore in the best position to take the actions necessary to ensure safe water recreation. The risk management information in this document is more pertinent to managed beaches (either public or private); however, the same risk management principles can be applied to any natural water area that has been designated as a recreational area. Effective recreational water management requires the cooperation of all stakeholders, including beach operators, service providers, governments, local businesses and industry, as well as users. All stakeholders are expected to become informed about their roles and responsibilities in the management of recreational waters.

The best strategy for protecting public health from risks associated with recreational waters is a preventive risk management approach that focuses on the identification and control of water quality hazards and their associated risks, combined with routine microbial water quality assessments. Reactive management strategies that rely on microbial water quality monitoring alone are not sufficient to protect the health of recreational water users.
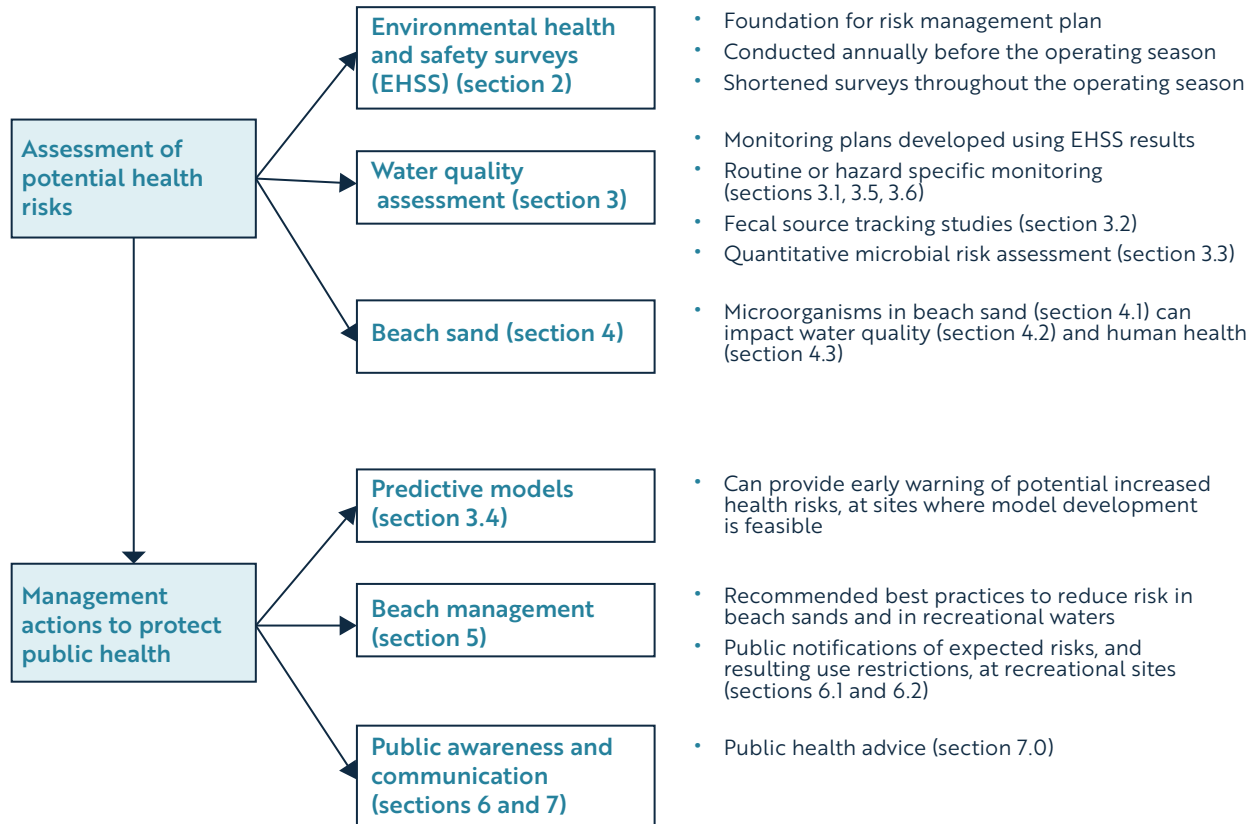
1.0 A RISK MANAGEMENT APPROACH

A preventive risk management approach that incorporates procedures, actions and tools to collectively reduce the risk of human exposure to recreational water quality hazards is recognized by water quality professionals worldwide as the preferred approach to protecting public health. This approach is based on concepts that mirror those found in drinking water frameworks, such as the source-to-tap approach (CCME, 2004), and in drinking water management plans, such as water safety plans (WHO, 2004). Engaging in recreational water activities, regardless of whether it is swimming, splashing, or other activities, will always involve some level of associated risk. The goal of a risk management approach is to make decisions that are based on an assessment of the possible health risks to recreational water users balanced against the significant benefits that recreational water activities provide in terms of health and enjoyment. The concepts of preventive risk management were at the heart of the recommendations for improved management of recreational waters proposed by an international panel of experts and published in the document that has come to be known as the "Annapolis Protocol" (WHO, 1999). Similarly, it is this approach that formed the basis for the management framework outlined in the *Guidelines for Safe Recreational Water Environments* (WHO, 2003).

A preventive risk management approach succeeds by incorporating multiple areas of management (e.g., source protection, hazard assessment and prioritization, monitoring, hazard control, communication, consultation, and training), rather than focusing all efforts in a single area. Specific benefits include:

» more effective public health protection;

» improved recreational water management, i.e., operational plans can be specifically tailored to address an area's individual needs and resources;

» improved public communication on how individuals can protect themselves while enjoying recreational waters (e.g., not swallowing water), and the public's role in ensuring recreational water safety;

» increased public confidence in the recreational water quality; and

» better management of emergencies, i.e., water quality hazards are understood and plans are in place to address the problems effectively.

Figure 1 summarizes the risk management approach included in this guideline document. This information can be applied to any natural fresh, marine or estuarine bodies of water that have been designated as recreational areas; this includes lakes, rivers, and human-made systems (e.g., stormwater ponds, artificial lakes).

Figure 1. Overview of the risk management approach described in this document

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Assessment of          →  Environmental health       •  Foundation for risk management plan
potential health          and safety surveys          •  Conducted annually before the operating season
risks                     (EHSS) (section 2)          •  Shortened surveys throughout the operating season

                       →  Water quality               •  Monitoring plans developed using EHSS results
                          assessment (section 3)       •  Routine or hazard specific monitoring
                                                          (sections 3.1, 3.5, 3.6)
                                                       •  Fecal source tracking studies (section 3.2)
                                                       •  Quantitative microbial risk assessment (section 3.3)

                       →  Beach sand (section 4)       •  Microorganisms in beach sand (section 4.1) can
                                                          impact water quality (section 4.2) and human health
                                                          (section 4.3)

Management             →  Predictive models           •  Can provide early warning of potential increased
actions to protect        (section 3.4)                  health risks, at sites where model development
public health                                             is feasible

                       →  Beach management            •  Recommended best practices to reduce risk in
                          (section 5)                     beach sands and in recreational waters
                                                       •  Public notifications of expected risks, and
                                                          resulting use restrictions, at recreational sites
                                                          (sections 6.1 and 6.2)

                       →  Public awareness and        •  Public health advice (section 7.0)
                          communication
                          (sections 6 and 7)
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2.0 ENVIRONMENTAL HEALTH AND SAFETY SURVEY

An environmental health and safety survey (EHSS) provides the foundation or "blueprint" for designing and implementing an effective risk management plan for recreational waters. It is a comprehensive search for, and assessment of, existing and potential water quality hazards (biological, chemical and physical) and their associated risks to the health and safety of the public at designated beach areas. The EHSS also represents a general review of all aspects of a beach's operation. Similar approaches, such as beach sanitary surveys or sanitary inspections, are used in other jurisdictions (NHMRC, 2008; U.S. EPA, 2008; U.S. EPA, 2013; Government of Alberta, 2019). The data collected during an EHSS provide beach operators, service providers and responsible authorities with the information necessary to make sound risk management decisions and to develop and maintain an effective beach monitoring program. The EHSS process consists of three basic steps: pre-survey preparations, the on-site visit and the assessment report.

An EHSS should be conducted on an annual basis, just before the start of the swimming season. This survey should:

» catalogue the recreational water area's basic characteristics;

» identify any potential sources of fecal contamination in the immediate recreational area as well as sources that may be impacting the area from the larger watershed;

» identify any other potential physical, chemical or biological water quality hazards that may present a risk to recreational water users; and

» evaluate the effectiveness of the monitoring programs and risk management measures (i.e., barriers) currently in place.

The authority with the most knowledge of the day-to-day operation of the beach is the best candidate to lead this process. Not all potential impacts may be known to the lead candidate and collaborations with other persons or groups may be necessary. This may include collaborations with:

» the appropriate provincial or territorial management or regulatory authority;

» beach managers;

» public and environmental health departments;

» wastewater infrastructure managers;

» local universities and water researchers;

» community members;

» watershed or lake management groups; and

» individuals representing local business and industry.

2.1 Pre-survey preparations

The pre-survey preparation step involves the collection and review of all information available on the beach and adjacent area, including reports of any previous surveys. It can provide valuable information on historical trends, problems and successes, which will help ensure a more thorough and efficient on-site visit. The type and quantity of information on any given beach will vary, but it is important to gather whatever information is available. Initial preparations may begin with a review of basic beach information, such as the beach's physical characteristics, the types of activities practised and estimates of beach attendance. The use of topographical maps, aerial photos and geographic information system (GIS) data (including delineation of any sanitary and stormwater infrastructure) can provide additional perspective and help in the identification of contamination sources, potential sampling sites and nearby land uses. The examination of historically accumulated data relating to microbiological results, cyanobacterial blooms, beach postings, and disease surveillance will provide information on the area's suitability for recreation and the potential risks to swimmers. Assessment of hydrological, meteorological and other information on rainfall, currents, tides, and prevailing winds can help identify their impact (either singly or collectively) on water quality. Information on potential point sources of contamination (e.g., waste discharges from sewage, storm drains) and, in wet weather, sources of non-point runoff (e.g., from surrounding urban, agricultural, or forested areas), should also be collected. Regular communication between beach managers and agencies with wastewater infrastructure responsibilities can be important for identifying changes to sanitary or stormwater systems that could have impacts on recreational water areas.

2.2   On-site visit

The purpose of the on-site visit is to visually identify and confirm any existing or potential water quality hazards and to identify any barriers currently in place. Information may be collected on the existence and adequacy of public facilities, safety provisions, and signage used for public awareness and communication. For the purposes of this EHSS, a hazard is an object or condition that may increase human health risk or pose a safety issue. A barrier is any risk management measure used to control hazards or reduce human exposure. For most swimming areas, contact with fecal contaminants in the environment is a significant health concern; thus, special attention should be paid to the potential sources of fecal contamination, both point sources (e.g., discharges or drainage that may contain sewage, stormwater or other fecal wastes including rivers/streams/creeks) and non-point sources (e.g., domestic and wild animals and birds, upstream livestock and crop operations, stormwater runoff from the beach and surrounding areas, septic wastes, contamination from swimmers themselves). The risk to human health is more significant and the relationship between the indicators of fecal contamination (*Escherichia coli (E. coli)* or enterococci concentrations) and impacts on human health is more reliable when the contamination sources have the potential for high concentrations of human pathogens (e.g., human and ruminant feces). Identifying these fecal sources is essential for understanding beach water quality. For beaches where information on fecal contamination sources is missing or incomplete, fecal pollution source tracking approaches can be considered (see Section 3.2). Alternatively, beach managers should take a conservative approach and assume that all fecal contamination is from high-risk human and ruminant fecal sources.

Additional hazards can include:

» chemical hazards (e.g., industrial discharges, contamination from marinas/watercraft);

» biological hazards (e.g., cyanobacterial blooms, schistosome cercariae responsible for swimmer's itch); and

» physical hazards (e.g., litter, poor visibility, submerged items, riptides and strong currents).

Other information collected may be useful in identifying hazards that are less apparent. For example, the presence of large amounts of floating debris may be indicative of sewage (e.g., condoms, tampon applicators) or stormwater discharges. An example of an EHSS checklist, which includes the type of information to be collected during an on-site visit, is provided in Appendix B.

Additionally, it is advisable to conduct site visits under both dry and wet weather conditions and, in the case of marine waters, under various tidal conditions. Certain contamination sources or events (e.g., runoff, stormwater discharges) may be visible only during rainfall periods, and discharge pipes may be visible only at low tides or dry periods. Representative water samples should also be collected and analyzed to confirm the presence of contamination and to help determine its variability and source (see Section 3.0). Shortened surveys may also be carried out throughout the swimming season at the time of microbiological monitoring; these can be used to collect more timely information about the recreational water area that can be helpful when interpreting the monitoring results. Such information has also been valuable in developing models aimed at predicting water quality (see Section 3.4).

2.3   Assessment report

Once the on-site visit is completed, priority water quality hazards need to be identified. Priorities should be based on the likelihood of exposure to a given hazard and the associated consequences. Factors that may contribute to a swimmer's exposure also need to be considered. These may include the proximity of the hazard to the swimming area, effects of the area's physical characteristics (depth, water circulation), potential weather influences, types and patterns of recreational activities practised in the area and impacts of any existing barriers. Particular attention should be directed towards identification and assessment of sources of human sewage and cattle fecal wastes. For example, in the case of a sewage cross-connection into a stormwater outfall or a combined sewer overflow, factors contributing to swimmer exposure include heavy rains causing a discharge of sewage material, currents or winds driving this material towards the swimming area and the absence of public communication methods to alert the public that contact with the water should be avoided for a period immediately following heavy rainfall. In some instances, the information collected may be used to help inform a quantitative assessment of potential health risks (see Section 3.3). The risk assessment may also be used to identify potential points at which additional barriers may be needed to reduce the degree of human exposure.

The process should culminate in an assessment report which should be used when developing further beach management or operational plans (i.e., risk management strategies). In addition to reporting on the pre-survey preparations and the survey findings, it should specify priorities for action, identify barriers that may be implemented to protect recreational users and provide recommendations for an appropriate beach monitoring program, which should include water quality sampling as well as routine actions (e.g., shortened beach surveys) that monitor the implemented barriers identified in the EHSS. The flowchart in Figure 2 (modified from Codd et al., 2005) shows a possible sequence of events when designing and implementing a plan to manage the risks for recreational waters. It may be used as a guide for beach operators, service providers or responsible authorities wishing to develop their own operational plans.

Figure 2. Sequence of events for designing and implementing a risk management strategy for recreational waters.
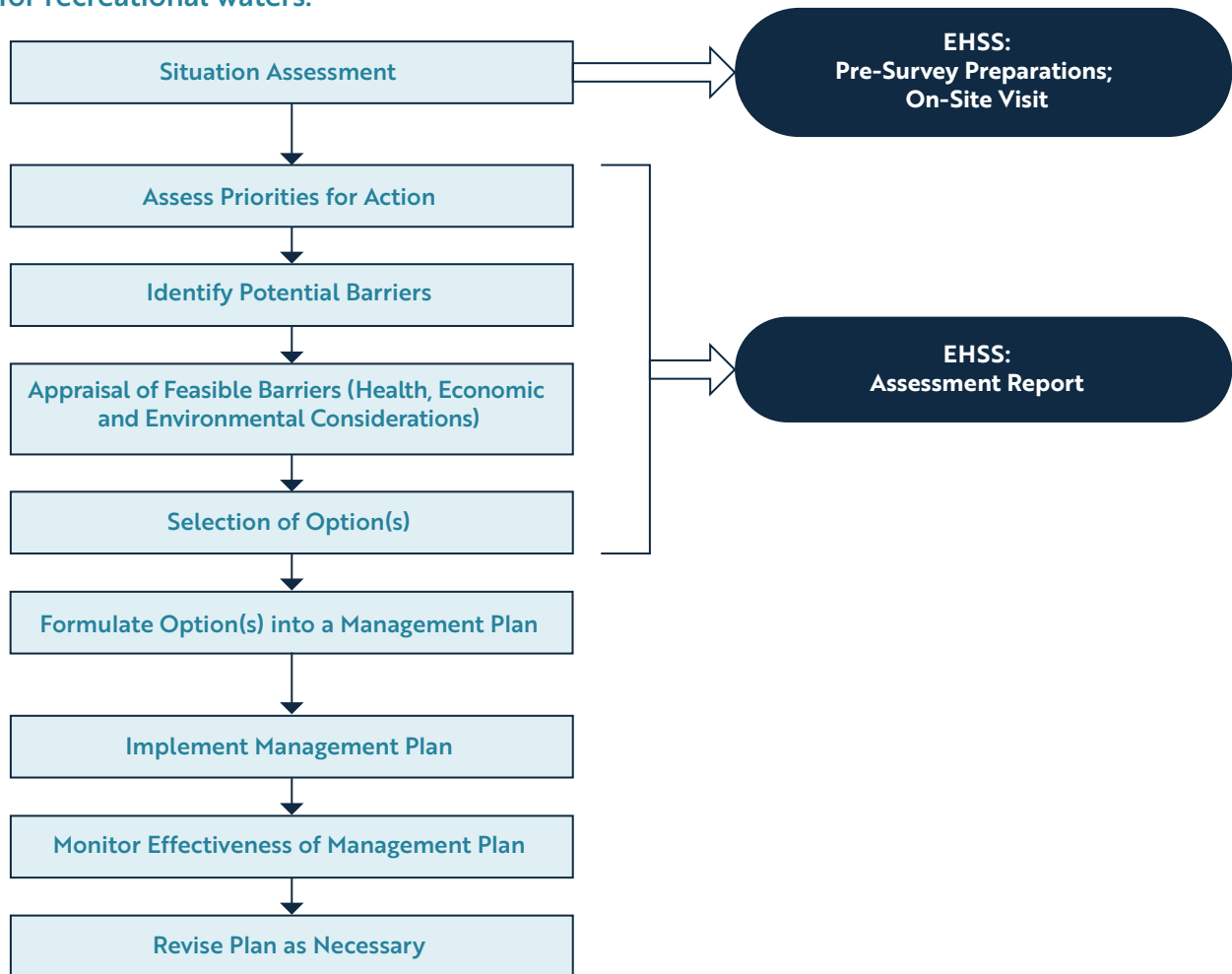
3.0 WATER QUALITY ASSESSMENT

Water quality assessment at recreational water areas can be included as part of a risk management strategy and may serve many functions. It can be used to:

» compare water quality to guideline values;

» identify the impacts of water quality events;

» demonstrate long-term water quality trends;

» support EHSS findings or identify gaps;

» verify that mitigation strategies (e.g., notifications, corrective actions) are put in place; and

» verify that these strategies are operating effectively.

Water quality monitoring may be conducted routinely or may be carried out for specific hazards (e.g., during a suspected outbreak or in response to an unusual wastewater discharge) when there is evidence of water quality issues or when further information is needed. The level and type of monitoring required will vary between recreational areas and should be determined by the appropriate regulatory and management authorities.

Routine monitoring usually includes indicators that inform beach managers about the potential impacts of fecal contamination, such as the fecal indicators *E. coli* or enterococci (see Section 3.1) as well as other types of parameters (i.e., cyanobacterial indicators or toxins, aesthetic quality, physical hazards, specific hazards) (see Sections 3.5 and 3.6).

Targeted water quality monitoring for specific hazards may be necessary in the following situations:

» identifying fecal sources to inform decision making on level of risk associated with a recreational area (see Sections 3.2 and 3.3);

» reports of a disease outbreak or illnesses of specific etiology;

» reports of a suspected illness of undetermined cause;

» reports of water-related injuries;

» levels of an indicator strongly suggesting the presence of a specific hazard;

» reports of a specific event such as a sewage or chemical spill;

» reports of suspected animal/bird illnesses or deaths associated with a recreational water area; or

» visual reports of the development of a cyanobacteria bloom.

Routine and targeted monitoring data can also be used in setting up predictive models for beach areas (see Section 3.4).

3.1   Monitoring for fecal indicators

Recreational waters are routinely monitored to characterize the level of fecal pollution. A monitoring program for a recreational area (when required) should be developed based on the information obtained as part of the recreational area's EHSS. A well-structured and planned monitoring program is essential for assessing and communicating information on the quality of recreational waters.

The primary fecal indicators used for routine monitoring are *E. coli* or enterococci. Guideline values have been developed for these fecal indicators to protect public health. Other fecal indicators may provide valuable supplemental information with respect to the fecal contamination of recreational waters. They may be included in a monitoring program or for fecal source tracking studies. A notable area of current research is the development of water quality risk-based thresholds for some of the other fecal indicators

(e.g., coliphages, HF183 and crAssphage microbial source tracking marker genes for human sewage). Further information can be found in Section 3.2 and in the *Indicators of Fecal Contamination* guideline technical document (Health Canada, 2023).

There are a number of factors that can influence the spatial and temporal microbiological quality of a recreational water body. For example, studies have reported higher concentrations of indicator bacteria in samples collected in the mornings, with concentrations decreasing later in the day (U.S. EPA, 2005a; U.S. EPA, 2010). In addition to the time of day, the type and periodicity of contamination events (both point and non-point sources), recent weather conditions, the number of users frequenting the swimming area and the physical characteristics of the area itself can impact water quality. Consequently, significant day-to-day (and within-day) variation in indicator organism densities has been well documented for recreational waters (Leecaster and Weisberg, 2001; Boehm et al., 2002; Whitman and Nevers, 2004; U.S. EPA, 2005a). As a result of this variation, it is important to have a well-designed monitoring program and to understand how the information obtained can be best used to inform public health decisions. Monitoring using polymerase chain reaction (PCR)-based methods has the advantage of providing more rapid results for decision-making purposes, sometimes within a few hours of the time of analysis. Development of predictive beach water quality models may also be beneficial where water quality is variable and sufficient data are available. All monitoring data collected, whether daily or less frequently, provide information that allow the responsible authorities to more easily observe water quality trends and to make more informed decisions regarding the area's overall suitability for recreation.

Decisions regarding the frequency of monitoring, the areas to be monitored, choice of indicators and methods, and monitoring program design (including the number of samples and the locations where they should be collected) will be made by the appropriate regulatory and management authorities. Further information on monitoring methods, including advantages and limitations, can be found in Health Canada (in publication). Monitoring programs should capture the spatial variability of beach areas and incorporate information derived from the EHSS, taking into account recommendations made about priority areas of concern.

There should be a documented monitoring plan for all monitored beaches, providing, at a minimum, instructions on:

» the parameters to be analyzed and the method of analysis;

» the locations (including GIS coordinates or fixed landmarks) at which samples are to be collected; and

» the sampling procedures, including the times, sample collection depth and frequencies of sample collection.

In general, waters regularly used for primary contact recreational activities should be monitored for fecal indicators at a minimum frequency of one sampling event per week during the swimming season. Each sampling event may require the collection of multiple samples. A weekly monitoring strategy allows comparison of the water quality results to the guideline values. It is also useful to alert managers and responsible authorities to more persistent contamination problems that may have developed and allows them to make the necessary decisions within a reasonable time frame. More frequent monitoring should be considered for high-use beaches. These recommendations are consistent with those published by the United States Environmental Protection Agency (U.S. EPA) in its 2012 *Recreational Water Quality Criteria* (U.S. EPA, 2012).

Beaches may also have classification systems that consider a number of factors in assigning an overall rating to the beach (see Section 6.2 for more information on beach classification). For such systems, it is suggested that a minimum of 60 samples should be used to characterize water quality, although a greater number of samples (e.g., closer to 100) provides a more precise estimate (WHO, 2009). As many beaches do not collect this number of samples yearly, water quality results from multiple bathing seasons (when no substantive change has occurred in the watershed) can be combined.

When developing sampling programs, defining the purpose of the monitoring program (e.g., to determine water quality trends, to investigate spatial distribution of pollutants, to detect specific hazards) will help determine the types and frequency of sampling that is needed. This may include collecting samples to characterize event-driven episodes of pollution that may affect recreational waters—for example, immediately following periods of heavy rainfall or at times of greatest swimmer activity. Information collected during an areas' EHSS will also aid in identifying key factors that should be considered during sampling program design. Detailed information on the design and implementation of recreational water monitoring programs are outside the scope of this document but are described elsewhere (Bartram and Rees, 2000; U.S. EPA, 2010).

Less frequent monitoring may be possible under certain circumstances, such as at beaches in remote locations or in areas where primary contact recreational activities are not a regular occurrence. Beaches that have historically demonstrated water quality results well below the guideline values through relatively intensive monitoring and the use of an EHSS may also be able to reduce their sampling frequency to help ease the burden of monitoring (Bartram and Rees, 2000; WHO, 2003, 2021). Thus, if it can be determined that a recreational water area is of consistently good microbiological quality, does not have any obvious sources of fecal contamination and is not considered to present a significant risk to the health and safety of its users, monitoring may be reduced to a frequency that is sufficient to verify that the conditions have not deteriorated (e.g., once a month). If the water quality

deteriorates, an investigation into the cause is recommended and it may be necessary to return to an increased sampling frequency. It may also be acceptable to reduce monitoring frequencies for recreational water areas that consistently demonstrate poor water quality results, but only where appropriate management actions are taken to discourage recreational use and the risks are clearly communicated to the public.

3.1.1   Location of microbiological sampling

Most bodies of water used for recreational purposes are not completely homogeneous with respect to their microbiological properties. In recreational water evaluations, the purpose of sampling is to obtain aliquots that are as representative as possible of microbiological quality of the area. A single water sample provides a quantitative estimate of the indicator bacteria present at a particular site and time. Multiple samples may be needed to provide a more accurate estimate of the water quality during each sampling event (Whitman and Nevers, 2004; U.S. EPA, 2005a, 2010). The number of discrete sampling locations included during a sampling event should be based on the beach characteristics as well as the fecal sources identified as part of the EHSS. However, as the total number of samples increases, the more representative the data will be of the overall water quality.

Sampling sites should be chosen to be representative of the water quality encountered throughout the entire swimming area. This should include points of greatest swimmer activity, as well as peripheral points subject to external fecal contamination. Stormwater, sewage or river outlets can give certain sections of a body of water microbiological qualities that are very different from those of the water body at large. If there are distinct areas that are highly influenced by a pollution source and they can be delineated from the rest of the beach area, it is possible to sample these areas separately. At some longer beaches, sources of fecal pollution can vary significantly along the length of the beach (Edge et al., 2010). The degree of heterogeneity in a water area can also be affected by rainfall, wind direction and velocity, currents and tides, or the presence of physical barriers, such as sandbars, natural or artificial wave breaks and piers. Further general guidance on microbiological sampling can be found in the *Microbiological Sampling and Analysis guideline technical document (Health Canada, in publication) and detailed sampling plan guidance has been published elsewhere (U.S. EPA, 2010).*

The depth at which samples are collected can have a significant effect on the resulting estimates of water quality. Where the water is very shallow, disturbances of the foreshore sand and sediment caused by wave swash and swimmer activity can result in the resuspension of fecal indicator microorganisms (Whitman and Nevers, 2003; Vogel

et al., 2016; Palmer et al., 2020). This resuspension may inflate microbiological estimates but not necessarily reflect an increase in bather risk if pathogens are not also present in the sediments. Where the water is deeper, this effect has less influence on water quality measurements. In contrast, deeper waters are relatively more exposed to offshore fecal sources than shallower waters (U.S. EPA, 2005a). Adult chest depth (approximately 1.2 to 1.5 m from the bottom) has historically been the most common sampling depth, although newer epidemiological studies have also used waist depth (approximately 1 m). Traditionally, this has been considered to represent the depth of greatest swimmer activity and the location nearest to the point of head immersion, which would be indicative of the risk associated with accidentally swallowing water. However, sampling at shallower depths (ankle or knee depth—approximately 0.15 to 0.5 m from the bottom) may be more representative of water quality encountered by young children playing at the water's edge. Epidemiological studies have typically found that only samples collected at depths greater then knee depth show a mathematical relationship between indicator organism density and swimmer illnesses (U.S. EPA, 2010). It is suggested that a reasonable but still conservative approach to monitoring may be to sample at waist depth (U.S. EPA, 2010). The sample depth (or depths) selected for an individual beach should be determined by the local or regional authority in order to obtain the best information for their particular recreational water area. However, if more than one sampling depth is included in the monitoring plan, all samples collected at a specific depth should be analyzed as a single group (e.g., for calculating the geometric mean) in order to improve the precision of the data.

3.1.2   Composite sampling

Composite sampling provides a way to increase the area covered under a beach monitoring program, while potentially minimizing the costs associated with analysis. Composite sampling involves the collection of multiple samples from across a stretch of beach, combining them into one large composite, and then analyzing a subsample of the resulting mixture. There are some challenges with the use of this technique. Increased sampling is required initially to validate whether composite sampling will be feasible at a given area. The area must be characterized to identify hot spots (sampling points having continuously poor water quality) that can disrupt the analysis. Some level of statistical knowledge is required to analyze the data. Nevertheless, investigations have suggested that, if properly conducted, composite sampling can be used to make water quality decisions with a degree of accuracy comparable to that achieved by analyzing the samples individually and averaging the results (Kinzelman et al., 2006; Bertke, 2007; Reicherts and Emerson, 2010). Further information on composite sampling can be found in the *Guidelines for Canadian Recreational Water Quality—Microbiological Sampling and Analysis* technical document (Health Canada, in publication).

3.2   Fecal pollution source tracking methods

Fecal source tracking can be used to supplement the monitoring and assessment tools that are already in place in recreational areas. Understanding the fecal sources can help to assess potential public health risks, as sources of human and ruminant fecal contamination have been shown to be of greater concern than other animal sources (see Section 3.3). It can also help target appropriate risk management barriers, which can both reduce beach notifications and help prevent waterborne disease outbreaks.

Fecal source tracking initiatives should be designed to answer a specific question and should be based on the analysis of the available data, including bacteriological sampling, EHSS results, and local knowledge. In order to conduct fecal source tracking, it is important to have a good understanding of the nature of the fecal pollution problem. The EHSS is a particularly useful tool for helping recreational water area operators, service providers and local authorities identify the potential sources of fecal contamination that are relevant to their recreational water area. It is also important to have the necessary expertise for designing and carrying out the study. This may include individuals from the public (e.g., government scientists) or private (e.g., university researchers) sectors with knowledge of fecal source tracking methodologies.

If fecal source tracking is being considered, there is a toolbox of methods available. Many of the available methods are not standardized; however, they are well described in the scientific literature. A number of methods have been used successfully in recreational water settings to identify unexpected fecal pollution sources, to verify information from other lines of evidence, to resolve local beach closure problems involving limited fecal sources, and to break down large source tracking problems into more manageable studies (Kinzelman and McLellan, 2009; Converse et al., 2012; Edge et al., 2018; Edge et al., 2021). Fecal source tracking is also being used to aid in beach management decisions (Government of Alberta, 2019).

The choice of methods will depend on the question that needs to be answered, the suspected fecal sources, and the expertise of the researchers involved. The methods selected may differ depending on whether the study only needs to differentiate human from non-human sources, or whether the fecal pollution attribution needs to be broken down into more categories (i.e., human, cattle, wildlife, birds, etc.) or linked to human illnesses.

Fecal source tracking in recreational water areas often focuses on identifying sources with known human-pathogen contributing potential (i.e., human and ruminant feces), as even minor contributions from human sewage (e.g., 10% to 20% of the *E. coli* concentration) is sufficient to drive bather risk (Schoen and Ashbolt, 2010). Other animal markers may aid in clarifying observed or expected fecal sources but their relationship to potential disease impacts has not been clearly established (Schoen and Ashbolt, 2010). It should be noted that fecal source tracking methods may not be able to identify all of the sources contributing fecal material to the watershed and the recreational water area. Also, although markers are considered host-specific, studies have reported some cross-reactivity with species other than the intended target, generally in fewer samples and at lower concentrations than found in the target species (Nguyen et al., 2018; Staley et al., 2018b).

When designing a fecal source tracking study, a tiered approach should be considered. A tiered approach utilizes the currently available information on the watershed and recreational area (e.g., fecal indicator bacteria data, land use information, sanitary infrastructure conditions) to help determine fecal sources before instituting more complex chemical and microbiological source tracking methods. Any fecal source tracking assessment should also use a toolbox approach based on multiple lines of evidence to identify fecal pollution sources. Additional information on the tiered approach is available elsewhere (Griffith et al., 2013). Further guidance on designing fecal source tracking studies can be found in publications from the U.S. EPA (2005b, 2019a,b), the Southern California Coastal Water Research Project (Griffith et al., 2013), and the US Geological Survey (Stoeckel, 2005).

If chemical and microbiological methods are needed in a recreational area, a variety of methods are available. These are described in the following sections.

3.2.1   Chemical methods

Chemical methods of analysis are based on the detection of chemical compounds known to be present in fecal material as a result of human activities—either through consumption and/or metabolism and the subsequent excretion in feces or via disposal as sewage wastes. Numerous chemical compounds have been investigated as potential markers for human sources of fecal pollution. Artificial sweeteners, caffeine, detergents, fluorescent whitening agents, fragrance materials, fecal sterols, fecal stanols, pharmaceuticals and personal care products have all been proposed as markers of fecal pollution from sewage treatment plants (Glassmeyer et al., 2005; Tran et al., 2015; Devane et al., 2019).

Chemical tracers such as smoke or dyes have been used to confirm suspected sources of contamination, such as wastewater outfalls and wastewater infrastructure cross-connection issues. Some advantages to using chemical markers include a shorter analysis time than for many microbial methods, low detection limits, and ease of analysis (Haack et al., 2009). Potential drawbacks may include differing fates in the environment for chemical markers compared to microorganisms (Glassmeyer et al., 2005), lack of any consistent relationship with illness for risk modelling (Napier et al., 2018), non-fecal sources of some chemical markers (Tran et al., 2015), and costs. However, chemical markers can be used as part of multiple lines of evidence and a toolbox approach to understanding fecal sources.

3.2.2   Microbial methods

Microbial source tracking (MST) methods are based on the premise that certain fecal microorganisms are strongly associated with specific hosts and that particular attributes of these host-associated microorganisms can be used to determine fecal sources (Harwood et al., 2014). MST methods can be divided into library-dependent and library-independent methods. Library-dependent methods were more widely used in early MST studies, whereas in recent investigations, library-independent methods are used almost exclusively.

Library-dependent methods establish a reference library of characteristics of individual fecal indicator bacteria isolates obtained from known fecal sources and then compare these characteristics to those from "unknown" water sample isolates. For example, a library could be a database of antibiotic resistance profiles or DNA fingerprints of *E. coli* isolates obtained from animal feces and municipal wastewater effluent (Wiggins, 1996; Dombek et al., 2000; Carson et al., 2001; Edge and Hill, 2007). The similarity of the profiles or fingerprints of *E. coli* isolates obtained from recreational waters ("unknowns") can then be compared with the profiles or fingerprints in the library ("knowns") to make statistical inferences about the source of the waterborne *E. coli* isolates. There are numerous drawbacks to this type of method. They require large reference libraries for comparison to unknowns (smaller libraries with fewer than 1 000 biotypes tend to mislead in associations), are prone to misclassification of fecal sources (especially when the library size is limited), and the libraries are not transferable between locations (Griffith et al., 2003; Stoeckel et al., 2004). They are also labour intensive and can have long wait times for results. These drawbacks have generally led to a discontinuation of library-dependent methods that are based on collecting isolates for fecal indicator bacteria. However, there has been some investigation into using high-throughput DNA sequence analyses such as high-density microarrays (Dubinsky et al., 2012, 2016) and next-generation sequencing results for MST (Staley et al., 2018a; Unno et al., 2018). These methods are considered library-dependent methods and are being investigated as part of the MST toolbox.

Library-independent methods are now more widely reported in the scientific literature. They involve detecting host-specific DNA markers or host-specific organisms (bacteria or viruses) to identify the sources of fecal contamination in the water. Most library-independent methods rely on PCR methods (quantitative PCR, digital PCR, or, in early studies, end-point PCR) to detect the markers or organisms of interest. Examples of host-specific markers include toxin genes (Khatib et al., 2002, 2003), genes for virulence factors (Scott et al., 2005) and highly conserved DNA sequences (Bernhard and Field, 2000a; Johnston et al., 2010). In particular, human-specific markers within the 16S rDNA of the genus *Bacteroides* are widely used (Bernhard and Field, 2000b; Layton et al., 2006; Kildare et al., 2007; Okabe et al., 2007; Ahmed et al., 2009; Shanks et al., 2009; Green et al., 2014; Mayer et al., 2018). Animal host-specific DNA markers have also been developed, including avian, ruminant, and various pet markers (Bernhard and Fields, 2000a; Kildare et al., 2007; Lu et al., 2008; Shanks et al., 2008; Weidhaas et al., 2010; Green et al., 2012). The host-specific viruses most commonly researched are human adenovirus, human polyomaviruses, pepper mild mottle viruses, and the phage crAssphage (McQuaig et al., 2009; Ahmed et al., 2010; Wong et al., 2012; Rusiñol et al., 2014; Symonds et al., 2016; Farkas et al., 2019). Although there can be some geographic variability in host-specific markers and host-specific organisms, these methods have been applied successfully to MST studies in recreational waters worldwide (Boehm et al., 2003; Bower et al., 2005; Noble et al., 2006; Hughes et al., 2017; Cao et al., 2018; Nguyen et al., 2018; Staley et al., 2018b).

There are advantages and drawbacks to library-independent methods. On the positive side, these methods are less labour intensive than library-dependent methods and therefore are easier and less expensive to conduct. Some of the best host-specific markers (e.g., HF183 for human sources) have been shown to be transferrable across regions (Mayer et al., 2018) and may be related to bather illness (Boehm et al., 2015; Cao et al., 2018; Boehm et al., 2018; Boehm and Soller, 2020), although this relationship has not been consistently reported (Napier et al., 2017). Some human-specific markers (e.g., crAssphage) also occur at high concentrations in raw sewage (Farkas et al., 2019; Korajkic et al., 2020) and decay more slowly than other genetic markers (Ahmed et al., 2019), which makes them useful for fecal source tracking. One of the main drawbacks of library-independent methods is the need to develop source specific markers that are applicable across watersheds and that have a minimal amount of cross-reactivity with non-target fecal materials.

3.3　Quantitative microbial risk assessment

Quantitative microbial risk assessment (QMRA) is used to estimate the potential health risks associated with a specific exposure scenario. Assessments use water quality information, assumptions on exposure conditions, and dose-response models for specific pathogens as inputs to provide risk estimates. In recreational settings, QMRA has been used to better understand the relative potential health impacts from human pathogens, as well as to support decisions about health risk in water quality management plans. QMRA studies require a significant amount of data on the recreational water area and a high level of technical expertise to conduct properly. These are considerable limitations to their more widespread use.

3.3.1　Estimating health risks at beach sites

QMRA has been used in research studies to investigate the estimated risks from various pathogens at beach sites (Boehm et al., 2018; Federigi et al., 2019; Sunger et al., 2019). The pathogens most often included are enteric viruses (e.g., noroviruses, human adenoviruses), enteric protozoa (e.g., *Cryptosporidium*, *Giardia*), and enteric bacteria (e.g., *Campylobacter*, *Salmonella*). QMRA studies are often conducted as an alternative to epidemiological studies. Although epidemiological studies can directly investigate health risks to the public, they are expensive and labour intensive. QMRA studies can also predict

risks to lower levels than can be identified using epidemiological studies. However, QMRA studies are only as good as the information that is used to support their development. They involve numerous assumptions that may need to be validated for the site of interest.

Some researchers have conducted QMRA studies in parallel with epidemiological studies to compare the health risk outcomes. For example, in a study investigating wet weather impacts on surfer health in southern California, similar gastrointestinal (GI) impacts were estimated when comparing the QMRA analysis to the epidemiological study results (15 GI per 1 000 recreation events vs 12 excess GI per 1 000 recreational events, respectively) (Soller et al., 2017). Another paired QMRA and epidemiological study in Chicago, investigating secondary contact activities, reported approximately an order of magnitude difference in the health risk from the two approaches (Rijal et al., 2011; Dorevitch et al., 2012). QMRA methods have also been used to reanalyze the epidemiological study data from Boquerón beach in Puerto Rico where no links to human health could be identified. The QMRA predicted 2 to 3 illnesses per 1 000 recreators, well below the level that would be detectable by the epidemiological study (Soller et al., 2016). Although conducting QMRA investigations requires a high degree of scientific expertise, these studies highlight the usefulness of QMRA for estimating human health risks in a recreational water quality setting.

3.3.2   Comparing health risks from various fecal sources

Using QMRA, researchers have also investigated the relative risks from different fecal sources, including human sewage sources, stormwater runoff, bird contamination issues, and agricultural fecal inputs. This research is the basis for recommending the development of alternative water quality guideline values when appropriate (e.g., based on site-specific risk assessments).

Human sources of fecal material (e.g., municipal wastewater, septic systems, other swimmers at the beach) pose the greatest risk to human health as they are the sources most likely to contain human pathogens. Most studies have reported that the enteric viruses, specifically norovirus, pose the greatest risk to swimmer's health in recreational waters (Schoen and Ashbolt, 2010; Soller et al., 2010a; Dufour et al., 2012; McBride et al., 2013; Eregno et al., 2016; Vergara et al., 2016). Other fecal sources (e.g., agricultural and wildlife) can contain pathogens of human health concern, but the impacts are more variable. A study of the potential risks from stormwater runoff containing only animal fecal sources estimated the risk to human health from cattle, pig, and chicken manure to range from 30 to 180, from 35 to 65, and from 25 to 6 000 times lower, respectively, than the potential risks from municipal wastewater at similar levels of *E. coli* and enterococci (Soller et al., 2015). Fresh fecal matter from cattle has been estimated to present a risk of

illness similar to municipal wastewater, but chicken, pig and gull feces were lower risk (Soller et al., 2010b). Researchers also estimated at least a 1 log lower health risk from gull feces than from sewage, assuming the same enterococci concentrations (Schoen and Ashbolt, 2010). In recreational sites, enterococci from waterfowl feces can predominate but may represent a significantly lower human health risk compared to sites that have sewage contamination (even at low levels) (Schoen and Ashbolt, 2010). Risk modelling has shown that when less than 10% to 30% of the enterococci present in recreational water is from human sources, the potential risk to human health may be significantly lower than indicated by the bacteriological indicator guideline value (Schoen and Ashbolt, 2010; Soller et al., 2014). Although non-human fecal sources are usually lower risk, there are times when animal fecal material can contain higher levels of human pathogens, for example, *E. coli* O157:H7 in calves (Soller et al., 2015).

In general, the predominant fecal source at a recreational site may not be the dominant health risk. Some studies have combined QMRA methods with data from human-specific fecal markers (e.g., HF183) to estimate health risks from specific pathogens, as well as to estimate threshold concentrations for the human-specific markers that correspond to the health risk levels associated with the 2012 U.S. EPA recreational water quality criteria for *E. coli* and enterococci (Brown et al., 2017; Boehm et al., 2018; Boehm and Soller, 2020). Other human-specific fecal source tracking markers could also potentially be used; however, further research is needed before guidelines could be developed.

3.3.3   QMRA in water quality management plans

Although implementation of QMRA requires a high degree of scientific knowledge, it has been used to support site-specific recreational water quality management plans. A pilot project at an Australian beach used sanitary survey information, combined with a QMRA approach, to design a site-specific recreational water quality management program (Ashbolt et al., 2010). In Canada, the Government of Alberta has used published QMRA data on comparative risks to implement fecal source tracking as part of their updated safe beach protocol (Government of Alberta, 2019). The *Guidelines for Canadian Recreational Water Quality – Indicators of Fecal Contamination* technical document uses QMRA study results as support for developing alternative recreational criteria on a site-specific basis (Health Canada, 2023). The U.S. EPA, in its most recent recreational water quality criteria, allows for the development of site-specific water quality objectives using QMRA models when non-sewage source(s) drive the health risk (U.S. EPA, 2012).

3.4   Predictive water quality models

Predictive water quality modelling uses mathematical approaches (e.g., linear regression equations, artificial intelligence tools) to predict whether a water quality target (e.g., *E. coli* or enterococci guideline values) may be exceeded. Approaches can range in complexity. The overall goal is to use the predictive modelling results as part of a recreational water quality management plan. The modelling informs public health decisions regarding the suitability of the water quality for recreational activities.

Using models to predict fecal indicator bacteria concentrations can overcome some of the limitations of current monitoring approaches, such as the lag times associated with obtaining culture-based fecal indicator bacteria results and less than daily bacteriological sampling frequencies (WHO, 2003; U.S. EPA, 2012, 2016). Predictive models are designed to make same-day predictions, including on weekends, when many recreational areas are not being monitored. Models can also be automated, so that predictions are generated daily and automatically sent to beach managers (Searcy et al., 2018). It should be noted that not all beaches are good candidates for the use of predictive modelling in their recreational water quality management plans (MOE, 2012; U.S. EPA, 2016). Beaches that hardly ever exceed guideline values or beaches where the water quality is known to remain constant over extended periods of time may not benefit from predictive tools. Also, in order for predictive tools to work, a set of variables must be available for use in modelling the water quality with a reasonable degree of accuracy. A list of common variables used for modelling can be found in U.S. EPA (2016). Recreational areas that are subject to a wide or frequently changing set of conditions and disturbances that are not predictable are not good candidates for modelling.

Predictive models have been developed and validated using data from various water- and weather-related parameters (e.g., rainfall, wave height, wind direction, turbidity, fecal indicator counts). Examples of such models include SwimCast (Olyphant and Pfister, 2005; Lake County Health Department, 2010), NowCast (Francy and Darner, 2007; Francy et al., 2013a; Francy et al., 2013b), and Virtual Beach (Frick et al., 2008; Mednick, 2012; Cyterski et al., 2013; Neet et al., 2015), although numerous other examples have also been published (Nevers et al., 2009; Lawrence, 2012; Chan et al., 2013; Francy et al., 2013b; Jones et al., 2013; Gonzalez and Noble, 2014; Brooks et al., 2016; He et al., 2016; U.S. EPA, 2016; Searcy et al., 2018). In many cases, predictive models have been shown to have a degree of accuracy comparable to, or greater than, traditional fecal bacteria beach monitoring for providing correct and timely beach management decisions. Models are not static, however, and on-going evaluation and improvements to the models are necessary (Searcy et al., 2018). U.S. EPA (2016) outlines a six-step process for developing and using predictive modelling at a beach site.

There are a number of challenges associated with using predictive tools. A significant level of technical expertise is required to develop the models, to analyze and interpret the data, and to maintain and re-evaluate the models. Moreover, as mentioned earlier, models may not work in all areas. Modellers use historical data to develop the mathematical equations that describe the relationships between different variables. Therefore, data on the recreational area must be available. Data from well-designed monitoring programs, representative of the range of conditions, will be most useful for developing predictive models. The models need to be validated against monitoring data to ensure they are providing accurate estimates. If these challenges can be addressed, beach operators, service providers or responsible authorities looking for an additional tool with which to potentially improve the timeliness of their water quality decisions may wish to investigate this approach.

3.5 Monitoring for cyanobacteria and their toxins

Appropriate monitoring programs for cyanobacteria blooms and their toxins provide early warning information to inform users of potential health risks. Both planktonic cyanobacteria and benthic cyanobacteria can cause illnesses in human and animals. Not all rivers and lakes used for recreational activities need to be monitored for cyanobacteria or their toxins. Instead, responsible authorities should use criteria to help evaluate the risk of bloom formation in order to identify the water bodies that are at greater risk. The types of recreational activities that are taking place in the area and the level of exposure of individuals in the event of a cyanobacteria bloom formation also need to be considered. This information can then be used to prioritize areas that should be monitored, to determine a monitoring approach (e.g., what to monitor, how often), and to develop an action plan for responding to a bloom event. Further guidance on cyanobacteria and their toxins can be found in the *Guidelines for Canadian Recreational Water Quality—Cyanobacteria and Their Toxins* technical document (Health Canada, 2022a).

3.6 Other monitoring

Other water quality parameters (e.g., colour, clarity, oil/grease film) related to the physical or aesthetic characteristics of a recreational water body and its surrounding environment have links to the health and safety of recreational water users and thus may be included in a monitoring program. Guideline values or aesthetic objectives have been specified for these parameters where necessary. Further information can be found in the *Guidelines for Canadian Recreational Water Quality—Physical, Aesthetic and Chemical Characteristics* technical document (Health Canada, 2022b).

4.0 BEACH SAND MANAGEMENT

Management of beach sand is important as beach users often spend more time on the beach than in the water, and children routinely play in the sand at the water's edge (DeFlorio-Barker et al., 2018). Beach sands can contain many types of microorganisms, including various human pathogens, deposited through numerous routes. This includes direct deposition of fecal materials from bird or animal droppings, human activities on beach sands, runoff from surrounding areas including from storm drains or combined sewer overflows, as well as from the adjacent waters. The concentrations of microorganisms in beach sand can be significantly greater than the adjacent water, but are highly variable over very small distances. Some studies have shown that contact with beach sand can increase the risk of GI illness (Heaney et al., 2009, 2012). Therefore, it is important for users to understand how to minimize this risk (e.g., washing hands before consuming food).

Some international organizations have recently included recommendations on how to assess the microbiological quality of sand in their guidelines. For example, WHO published updated guidelines for coastal and fresh waters which includes a recommended provisional guideline value for beach sand of 60 cfu of intestinal enterococci per gram of sand (WHO, 2021). This provisional value depends on a significant assumption: that the ratios and uptake of enterococci and human pathogens are the same for water and sand. The purpose of the provisional value is to help determine whether beach sand is in need of improved management actions to reduce the concentration of fecal indicator microorganisms.

The present document does not include a guideline value for beach sand as further research is needed to characterize the relationships between fecal indicator bacteria in sand and the potential implications to human health. Instead, protection of public health from beach sand risks should focus on management measures (e.g., beach grooming and cleaning, access restrictions), along with education and communication. Responsible authorities may choose to include sampling beach sands for fecal indicators as a management measure. Information on sampling sands can be found in the guideline technical document on *Microbiological Sampling and Analysis* (Health Canada, in publication). Certain circumstances may warrant testing of sand and sediment samples, such as during investigations of potential waterborne disease outbreaks, after sewage spills, or when conducting an environmental health and safety survey (see Section 2.0).

4.1   Microorganisms in beach sand

Beach sand can harbour microorganisms from fecal matter and other environmental sources. Gulls in particular are thought to be a significant source of fecal indicator bacteria for some beaches (Levesque et al., 1993; Fogarty et al., 2003; Williamson et al., 2004). Their contribution of human pathogenic microorganisms, however, is generally low but does vary depending on contamination sources in the surrounding environment where gulls may also occur (e.g., wastewater management facilities) (Quessy and Messier, 1992; Lu et al., 2011; Alm et al., 2018). Canada geese populations can also present a source of fecal material at areas adjacent to surface waters, and their feces have been found to contain and transport pathogenic viruses, protozoa and bacteria that may pose a human health risk (Moriarty et al., 2011; Gorham and Lee, 2016). Non-fecal sources can include microorganisms naturally found in the sand environment as well as those deposited on the sand through mechanisms such as land runoff and wave action. The numerous sources of microorganisms that may impact beach sands can lead to high concentrations of microbes in the sand, many of which will not be a concern to human health.

Beach sands can provide more favourable conditions for survival of microorganisms than adjacent waters. They can provide protection from sunlight, buffered temperatures, a degree of cover from predation, large surface areas for biofilm development and a replenishing supply of moisture and organic nutrients from wave swash (Whitman and Nevers, 2003; Whitman et al., 2014). When microorganisms are introduced to the beach environment, several outcomes are possible: they may die off within hours, they may persist for days to months without replicating, or some proportion of the bacterial members can become established and start growing in the environment.

The fecal indicators, *E. coli* and enterococci, have both exhibited a greater persistence in beach sands relative to natural waters. They have been isolated from numerous locations in the beach environment, including foreshore sands (i.e., the sand directly influenced by lake water, usually between the low and high water mark), nearshore waters (Alm et al., 2003; Whitman and Nevers, 2003; Edge and Hill, 2007; Yamahara et al., 2007, 2012; Staley et al., 2016) and backshore sands (Byappanahalli et al., 2006), as well as from subtropical and temperate stream sediments (Byappanahalli et al., 2003; Jamieson et al., 2003, 2004; Ferguson et al., 2005; Ishii et al., 2006a), temperate forest soils (Byappanahalli et al., 2006), and beach wrack (Whitman et al., 2003; Ishii et al., 2006b). Both E. coli and enterococci may also replicate in beach sands under favourable conditions (Ishii et al., 2006a; Hartz et al., 2008; Yamahara et al., 2009; Halliday and Gast, 2011; Byappanahalli et al., 2012; Whitman et al., 2014). They have also been shown to reach concentrations that are many fold higher than the adjacent swimming waters (Alm et al., 2003; Whitman and Nevers, 2003; Williamson et al., 2004; Bonilla et al., 2007; Edge and Hill, 2007; Halliday

and Gast, 2011). Of the beach areas studied, foreshore sands generally have the highest levels of fecal indicator bacteria, potentially resulting from the favourable survival conditions provided by the moist sand or from deposition of fecal droppings by shorebirds (Whitman and Nevers, 2003; Whitman et al., 2006; Whitman et al., 2014; Staley et al., 2016). This is the area where children tend to play in the sand. Although concentrations in beach sand can be significantly greater than the adjacent water, the concentrations are highly variable over very small distances, making beach sand monitoring difficult.

Beach sand can be a reservoir for pathogenic microorganisms that may be a risk to human health. Fecal and non-fecal pathogenic species of bacteria, viruses, parasites and fungi have been isolated from the sand environment (WHO, 2021; Shah et al., 2011). This includes *Aeromonas* spp., *Campylobacter* spp., pathogenic *E. coli*, *Pseudomonas aeruginosa*, *Salmonella spp.*, *Staphylococcus aureus*, *Vibrio* spp., *Cryptosporidium spp.*, Giardia spp., numerous fungal pathogens, and some viral pathogens (Whitman et al., 2014). Of the pathogens studied, *Salmonella* spp. and *Campylobacter* spp. are among the most frequently detected (Bolton et al., 1999; Obiri-Danso and Jones, 1999, 2000; Yamahara et al., 2012), with the source most often being related to contamination of the beach sand by bird feces. These pathogens are not expected to grow in beach sand but can survive for various lengths of time (Eichmiller et al., 2014). *S. aureus* and *P. aeruginosa* have also been detected in some studies (Mohammed et al., 2012; Thapaliya et al., 2017). Humans are the primary source of *S. aureus* as it is not considered a natural inhabitant of environmental waters, whereas *P. aeruginosa* is widely distributed in the aquatic environment. Both of these non-enteric pathogens may survive and replicate in beach sands (Mohammed et al., 2012). Pathogenic protozoa (Abdelzaher et al., 2010; Shah et al., 2011), enteroviruses (Shah et al., 2011), and other infectious viruses, including the influenza A virus (Poulson et al., 2017), have also been isolated from sands in various marine beaches, but a plausible pathway to human infection is probably limited to the enteric viruses. Multiple pathogenic fungal species have also been identified in sand samples at marine beaches (Sabino et al., 2011).

To date, there has been no consistent relationship between the concentrations of fecal indicator microorganisms and the occurrence of pathogens in beach sands (Whitman et al., 2014).

4.2   Effects of beach sand on microbiological water quality

There have been numerous studies showing that beach sand can present a significant non-point source of fecal indicator bacteria for swimming waters (Alm et al., 2003; Whitman and Nevers, 2003; Williamson et al., 2004; Yamahara et al., 2007; Edge and Hill, 2007; Heaney et al., 2014; Torres-Bejarano et al., 2018). Disturbances to foreshore and nearshore sands and sediments can affect the microbial quality of shallow waters (WHO, 2003; Skalbeck et al., 2010; Vogel et al., 2017). These disturbances can resuspend fecal indicator microorganisms, inflating microbiological counts. Edge and Hill (2007) applied microbial source tracking techniques and found that sand could be a source of *E. coli* out to 150 m off a beach in Hamilton Harbour. Mechanisms of transfer of sandborne contamination to the water environment include wave swash, sand erosion, rain-mediated runoff and direct transfer from swimmers (Boehm et al., 2004; Vogel et al., 2016). A study examining the movement of enterococci through sand showed that these microorganisms were not strongly bound to beach sand and can be easily transferred to the water environment (Yamahara et al., 2007). Resuspension of nearshore sediments can occur through a number of mechanisms, including wave action (including those artificially generated by commercial and recreational boating), storms and swimmer activities. Boehm et al. (2004) proposed that the wave- and tide-driven recirculation of water through the beach aquifer may also present a mechanism for transfer of microorganisms and nutrients from the sand environment to swimming waters. The potential health risks that may be associated with resuspension of microorganisms from beach sand is not currently known.

4.3   Relationship between beach sand and human illness

Several studies have been undertaken to determine whether exposure to beach sand (digging in sand, buried in sand) increases the risk of becoming ill. Whitman et al. (2009) looked at the transferability of *E. coli* and F+ coliphages from beach sand to hands to assess whether sufficient quantities of microorganisms could be transferred to make it a possible route of exposure to pathogens. They determined that if beach sands contain high levels of human pathogens, the quantities of microorganisms transferred on the fingertips and hands from playing in the sand could be sufficient to increase the risk of GI illness. This study also reaffirmed that hand washing is effective at removing these microorganisms (i.e., 92% to 98% reduction), supporting the recommendation to always wash your hands before consuming food.

Heaney et al. (2009) studied associations between sand exposure and illness at marine and freshwater beaches under the U.S. EPA's National Epidemiological and Environmental Assessment of Recreational (NEEAR) Water study. The authors observed that digging in sand was associated with a modest increase in the risk of GI illness (1.13; CI = 1.02–1.25) and diarrhea (1.20; CI = 1.05–1.36). Individuals who reported being buried in sand showed a slightly higher incidence of GI illness (1.23; CI = 1.05–1.43) and diarrhea (1.24; CI = 1.01–1.52), with children under 10 years old having the strongest association. The increased risks for sand exposure were found for both swimmers and non-swimmers. No associations were demonstrated for sand contact and non-enteric illness (Heaney et al., 2009). In a follow-up study at two recreational marine beaches, Heaney et al. (2012) determined that individuals who reported digging in sand, where enterococci concentrations were in the highest tertile (i.e., the highest third of the ordered distribution; >324 CCE/g of sand), had increased risks of GI illness (2.0: CI = 1.2–3.2) and diarrhea (2.4; CI = 1.4–4.2). Estimates were even higher for GI illness (3.3; CI = 1.3–7.9) and diarrhea (4.9; CI = 1.8–13) among individuals buried in sand. However, the study had very few participants who reported sand exposure but did not swim, so the risk from swimming could not be separated from the risk from beach sand. An earlier study by Marino et al. (1995) reported no evidence of a relationship between the incidence of skin symptoms and sand concentrations of any of the indicator organisms monitored (*E. coli,* fecal streptococci, *Candida albicans*, dermatophytic fungi) during a prospective epidemiological study at two beaches in Malaga, Spain. Using a QMRA approach, Shibata and Solo-Gabriele (2012) calculated the concentration of pathogens (*Cryptosporidium*, enteroviruses, *S. aureus*) in beach sand that would represent an equivalent level of risk to U.S. EPA water quality recreational limits. They determined that at a non-point source recreational beach in Florida, the concentration of pathogens in the beach sand generally presented a low infection risk.

Further research is needed to more fully characterize the relationships between fecal indicator bacteria and the possible presence of fecal pathogens in beach sand, as well as the potential implications to human health.

5.0 BEACH MANAGEMENT BEST PRACTICES

Combining management actions, procedures, and tools into beach best management practices can collectively reduce the risks in beach sands and recreational waters, thereby protecting the health of recreational water users. Enteric pathogens are of significant concern in recreational environments, and implementing barriers to reduce the extent of fecal contamination is therefore recommended. An environmental health and safety survey is an important tool for helping recreational water operators identify potential onshore sources of fecal contamination that are relevant to their beach area (see Section 2.0). Removal of litter that may attract animals to the area and the installation of physical barriers (e.g., animal-proof refuse containers, fences and gull nets) designed to discourage wildlife may be useful strategies. Restricting access of pets to public beaches during the operating season is another potential control mechanism as pets can be a significant source of fecal contamination in recreational areas.

Physical manipulation of the sand environment may also help minimize fecal contamination and reduce its transport to swimming waters (Kinzelman et al., 2004; Kinzelman and McLellan, 2009; Hernandez et al., 2014; Whitman et al., 2014; Kelly et al., 2018; Edge et al., 2018). This could include deep mechanical grooming to remove harmful materials, beach berm construction to prevent stormwater runoff onto a beach, and targeted beach grading to increase the steepness of the slope, which reduces the area vulnerable to wave swash and permits more rapid sand drying through improved drainage.

Some beaches may also implement pre-emptive beach postings or swimming advisories restricting recreational water activities for short periods immediately after rainfall events. These limit swimmer exposures to fecal contamination that may have been washed into the swimming or beach area. Not all beaches are negatively impacted by rainfall events, so beach managers should determine whether pre-emptive beach postings will be beneficial for the recreational area. The decision to use pre-emptive beach postings should be based on historical monitoring results and the EHSS. Larger-scale management options for beaches require a comprehensive review of the contamination inputs and watershed characteristics and the identification of specific options to minimize or control the sources of fecal contamination and to reduce the transfer of pollution to the swimming area.

Beach users can also do their part by properly disposing of their litter, refraining from feeding animals on or near the beach, using available facilities for hygiene practices (e.g., washing hands, changing diapers) and complying with any existing beach regulations or codes of conduct. They may also contribute by becoming informed of, and following, steps that can be taken to reduce their personal exposure (see Section 6.0).

Authorities may wish to consult the following types of resources for further information to help them address specific beach-related issues:

» Published texts: Texts are available that provide comprehensive discussion of broader topics like stormwater management, wastewater treatment, and coastal water management. Texts are also available for specific topics such as differentiating plants (like duckweed) from cyanobacteria.

» Searchable databases of published articles: Keyword searches can direct the user to specific scientific studies, related articles, bibliographical citations and topic review papers. Peer-reviewed publications are preferred to information published in non-refereed sources.

» Proceedings from international conferences: A review of proceedings can identify accounts of actions evaluated in other communities, providing an indication of results and potential contacts. Specific conferences include the Great Lakes Beach Association Conferences (www.greatlakesbeachassociation.org) (www.great-lakes.net/glba), and the U.S. EPA National Beach Conferences (www.epa.gov).

» Manuals or publications produced by stakeholder organizations.

Water quality issues can have impacts across multiple fields (e.g., health, environment, agriculture, municipal infrastructure) and require an approach (e.g., One Health approach) which aims to balance and optimize the health of people, animals and ecosystems by mobilizing multiple sectors, disciplines and communities to tackle threats to health and ecosystems (OHHLEP, 2021). Consultation with responsible authorities, other beach operators or service providers and recreational water quality professionals may help to identify actions that have proven to be successful in other communities.

6.0 PUBLIC AWARENESS AND COMMUNICATION

To participate in safe, enjoyable recreational water activities, the public needs access to information on the quality of the area and its facilities, as well as notification of any existing water quality hazards. Beach operators, service providers and responsible authorities have a responsibility to inform and educate the public and provide adequate warnings about any hazards relevant to their recreational water areas. The public can also do their part by taking actions to protect themselves and the recreational areas, such as;

» avoid swallowing water, regardless of the water quality;

» avoid swimming with open sores or wounds;

» stay out of the water if you have diarrhea or other gastrointestinal illnesses;

» wash hands before consuming food;

» use clean beach towels to reduce the degree of sand contact;

» towel dry after being in the water;

» shower as soon as practical after swimming;

» obey all posted signage (e.g., swimming advisories, warnings for specific hazards; restrictions regarding pets, motorized vehicles); and

» properly dispose of garbage.

The public should also be aware of where the water quality monitoring results are posted and should consult this information before going to the beach.

Efforts to improve the public's awareness and understanding of water quality can have numerous benefits (Bartram and Rees, 2000; Pendleton et al., 2001). Communication tools can be used to:

» reduce the potential risk of swimmer illness or injury;

» improve the quality of the water;

» correct public misconceptions regarding water quality;

» improve public confidence; and

» increase beach attendance.

6.1　Posting of information at recreational water areas

Information on the expected risks associated with the recreational area should be communicated to the user through the use of posted signs. Other means of communicating information to users is provided in Section 6.2. Signs should be posted in locations that are highly visible to the public. The information provided should be easily understood and not open to misinterpretation. Ideally, signs should be standardized to permit comparisons across different locations. Examples of informative beach signs are provided in Appendix C.

Signs and messaging should be used to warn users about the potential risks associated with a recreational area. Even in waters considered to be of good quality for swimming, there is always some risk that swimmers may experience adverse health effects. Warnings should be issued in a timely manner and promptly removed once the issuing authority has determined that the risk no longer exists.

The information provided on warning signs and in messaging should include, at a minimum:

» a statement identifying the health or safety risk;

» recommended actions to be taken;

» the name of the authority responsible for issuing the warning; and

» contact information for the issuing authority

Warning signs or messages may be posted to announce a swimming advisory, to announce a beach closure, or to provide cautionary information such as permanent signage at beaches with re-occurring cyanobacterial blooms. A swimming advisory or a beach closure should be issued by the responsible authority in accordance with the legislation in each province or territory. This decision should be based on a thorough assessment of the situation with information provided by recreational water monitoring, the EHSS and public health surveillance.

A swimming advisory can be issued if the responsible authority decides that there is an unacceptable level of risk associated with recreational use. Under this situation, users are advised to refrain from contact with the water. Contact with the beach is usually permissible, and access to the facilities is generally not restricted. Examples of scenarios that may trigger jurisdictions to issue a swimming advisory include:

» exceedance of the guideline values for the recommended fecal indicators, based on sampling or predicted based on modelling;

» exceedance of the guideline values for toxic cyanobacteria and their toxins, or in the event of the development of a cyanobacteria bloom;

» evidence of the risk of swimmer's itch for recreational water users; and

» periods of significant rainfall, which could trigger an advisory as a pre-emptive action (at applicable beaches).

A beach closure may be issued (where possible) if the responsible authority determines that a beach or body of water poses a serious risk to the health and safety of recreational water users and that it is necessary to further restrict individuals from coming in contact with the area. Under a closure, the area is considered closed to all recreational activity. Users are advised to avoid contact with the beach and recreational water area, and access to the facilities may be restricted. Examples of situations in which jurisdictions may deem it necessary to issue a beach closure include:

» suspicion that the area is responsible for a waterborne disease outbreak;

» a sewage or chemical spill that is expected to affect the recreational water area; and

» other conditions such that the area is judged to pose a significant risk to public health (e.g., persistently poor water quality).

Appropriate signs may also be posted at waters that have been deemed suitable for secondary contact activities (e.g., rowing, sailing, canoe touring, fishing), but not for primary contact uses (e.g., swimming, wading, windsurfing, waterskiing). In these instances, it may be necessary to expand the location of the signs beyond the beach area to improve their visibility. Suggested locations include relevant points of entry and launch areas. Responsible authorities should also routinely update the signage content, especially for signage in areas with chronic issues (e.g., cyanobacteria blooms) to avoid message fatigue among public users.

6.2   Other tools for public education and communication

In addition to posted signs, other tools can be used to promote public education and communicate information, including:

» printed materials (e.g., posters, information sheets, educational bulletins, pamphlets, brochures);

» media sources such as websites (e.g., Swim Guide; local government or beach management authorities), social media platforms, local newspapers, television and radio announcements;

» participation in beach certification or award programs (e.g., Blue Flag certification);

» educational events such as volunteer monitoring programs, drowning prevention initiatives, and beach cleanup days; and

» classification or grading systems for beaches.

Classification or grading systems for beaches can be used as a tool to promote communication and understanding of water quality information. They are also thought to help encourage a sense of shared accountability and responsibility among the beach authorities and beach users. A number of jurisdictions and multinational organizations have adopted grading systems as part of their recreational water management recommendations (WHO, 2021; NHMRC, 2008; MELCC, 2019). Both the WHO and the Australian Guidelines (WHO, 2021; NHMRC, 2008) make use of a grade-based format for fecal indicator density within their framework for assessing fecal pollution in recreational waters. These approaches use a microbiological assessment component along with a sanitary inspection categorization to produce a classification of an area's overall suitability for recreation. Under the Quebec framework for fecal pollution assessment (MDDEP, 2004; MELCC, 2019), water quality grades are assigned to recreational waters based on average yearly fecal indicator monitoring results. This grade is used as a public communication tool and also dictates the sampling frequency requirements for the recreational area.

There are advantages and disadvantages associated with the use of beach grading systems. Responsible authorities should be aware of the limitations of any system when investigating its use as a potential communication tool. For example, grading systems based on fecal indicator monitoring results provide information on only one aspect of recreational water quality. The accuracy of any such grading system would be strongly affected by the limitations known to be associated with fecal indicator monitoring. Ideally, a successful beach grading system would involve criteria from a number of categories, encompassing monitoring results, communication tools and water quality hazard control actions.

7.0 PUBLIC HEALTH ADVICE

Consultation with public health authorities is an essential component of risk management. In the event of an incident (microbiological, chemical or physical) that represents a risk to public health or safety, health officials can play a key role by providing advice to beach managers in determining what actions need to be taken. Local public health authorities should be promptly notified of any situation that threatens the health or safety of recreational water users. There is a particular need for good communication between public health agencies and organizations with responsibilities for managing wastewater infrastructure since changes to sanitary or stormwater systems can have immediate impacts on some beaches. As part of normal operations, local public health officials may be periodically consulted for information and advice on topics pertinent to safe recreational water use.

In assessing the risks associated with recreational water quality hazards, the local health authorities should, wherever possible, establish surveillance for swimmer illness or injuries. This can be established by consulting public health surveillance mechanisms currently in operation or by conducting specific investigations. Information sources include:

» federal, provincial/territorial or regional departments or agencies' surveillance programs or reporting systems;

» clinical reports from hospital emergency departments and local physicians;

» accident or incident reports held by recreational water area operators or service providers;

» formal epidemiological investigations; and

» other potential surveillance mechanisms (e.g., monitoring of over-the-counter medicine sales in pharmacies).

Procedures for the investigation of illness associated with recreational waters should adhere to the recommendations given in the third edition of *Procedures to Investigate Waterborne Illness (IAFP, 2016).*

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APPENDIX A: LIST OF ABBREVIATIONS

CCE/g	Calibrator cell equivalents per gram
EHSS	Environmental health and safety survey
GI	Gastrointestinal illness
GIS	Geographic information system
MST	Microbial source tracking
PCR	Polymerase chain reaction
QMRA	Quantitative microbial risk assessment
qPCR	Quantitative polymerase chain reaction
U.S. EPA	United States Environmental Protection Agency
WHO	World Health Organization

APPENDIX B:
RECREATIONAL SWIMMING AREA ENVIRONMENTAL HEALTH AND SAFETY

IDENTIFICATION

Beach Name: _____

Address: _____

_____

Responsible Authority: _____

Tel.: _____ Fax: _____ E-mail: _____

Person(s) Conducting Survey: _____

Date: _____ Time: _____

BACKGROUND INFORMATION

Water Body Type: _____

Dimensions of Beach: Length (m): _____ Width (m): _____

Dimensions of Swimming Area: Length (m): _____Width (m): _____

Number of Sampling Sites: _____

[Attach Map or Aerial Photo of Suitable Scale (including location of sample sites)]

Water Temperature High/Low (°C): _____Average (°C): _____

Prevailing Winds Direction: _____Avg. Speed (km/h): _____

Prevailing Currents Direction: _____Avg. Speed (km/h):_____

Seasonal Rainfall Total (mm): _____24-h High (mm):_____

Wave Height Average (m): _____Range (m): _____

Surrounding Land Uses (check all that apply):

Urban ☐	Rural ☐	Agricultural (specify): ☐
Residential ☐	Forest ☐	Commercial (specify): ☐
Field ☐	Hills/Uplands ☐	Industrial (specify): ☐
Marsh/Swamp ☐	Landfill ☐	River/Stream/Ditch: _____☐
Harbour ☐	Other: _____☐	Other: _____☐

MICROBIOLOGICAL HAZARDS

Potential Sources of Fecal Contamination

Municipal Sewage Discharges ☐   Combined Sewer Overflows (CSOs) ☐

Stormwater Drains/Discharges ☐   Septic Waste Systems ☐

Wastes from Animal Feeding Operations ☐

Other Discharges Containing Fecal Wastes (List):

_____ ☐   _____ ☐

Other Sewage Collection/Disposal/Treatment Systems (List):

_____ ☐   _____ ☐

Stormwater Runoff from:

Agricultural Areas ☐   Areas Receiving Sewage Sludge ☐

Beach and Surrounding Facilities (e.g., parking) ☐

Other:_____ ☐   Other: _____ ☐

Other Environmental Sources:

Discharging Rivers/Streams/Creeks   ☐

Birds (e.g., gulls, ducks, geese, other)   ☐   (#'s: None Low Med High [circle one])

Other wild animals   ☐   (#'s: None Low Med High [circle one])

Pets   ☐   (#'s: None Low Med High [circle one])

Swimmers   ☐   (#'s: None Low Med High [circle one])

Other: _____   ☐

Other: _____   ☐

ITEMS FOR CONSIDERATION DURING THE RISK ASSESSMENT

- Proximity of potential contamination sources to the swimming area.
- Potential for contamination sources to have an impact on the swimming area (including an indication of their risk priority: Low, Medium, High).
- Evaluation of water quality according to historical microbiological data (e.g., frequency of exceedances of the guideline values for the recommended indicators of fecal contamination [e.g., continuous/periodic/sporadic]).
- Discharges: Assessment of such factors as volume, flow rate, treatment type, applicable indicator standards, periodicity (continuous, sporadic) and predictability.
- Effects of rainfall: Levels triggering contamination events and typical event duration.
- Assessment of swimming area circulation: Effect of onshore winds, tides, currents, flow patterns in transporting fecal contamination to and entrapping it within the swimming area.
- Animals and birds: Assessment of their types, numbers and droppings.
- Impact of swimmers on water quality—numbers, ages.
- Assessment of potential barriers: Barrier types and points at which they may be applied to reduce impact of the contamination source and/or swimmer exposure (e.g., riparian zones, barriers to limit livestock access to water).

CHEMICAL HAZARDS

Potential Sources of Chemical Contamination

Commercial/Industrial Discharges ☐   Marinas ☐

Motorized Watercraft ☐   Other: _____ ☐

Other: _____ ☐

Stormwater Runoff From:

Areas subject to Pesticide Application ☐   Urban Areas ☐

Areas subject to Fertilizer Application ☐   Other: _____ ☐

ITEMS FOR CONSIDERATION DURING THE RISK ASSESSMENT

- Proximity of potential contamination sources to the bathing area.
- Potential for contamination sources to have an impact on the swimming area (including an indication of their risk priority: Low, Medium, High).
- Discharges: Assessment of such factors as volume, flow rate, treatment type, periodicity (continuous, sporadic) and predictability.
- Effects of rainfall: Levels triggering contamination events and typical event duration.
- Assessment of swimming area circulation: Effect of onshore winds, tides, currents, flow patterns in potentially transporting chemical contamination to and entrapping it within the swimming area.
- Motorized watercraft: Assessment of their types and numbers.
- Assessment of potential barriers: Barrier types and points at which they may be applied to reduce impact of the contamination source and/or swimmer exposure.

OTHER BIOLOGICAL HAZARDS KNOWN TO AFFECT THE RECREATIONAL WATER AREA

(Presence may be continuous, seasonal or sporadic.)

Cyanobacterial Blooms ☐   Schistosomes (Swimmer's Itch) ☐

Large Numbers of Aquatic Plants ☐   Other (specify): _____ ☐

Other (specify): _____ ☐

ITEMS FOR CONSIDERATION DURING THE RISK ASSESSMENT

- Seasonal nature of the hazard: continuous, annual, sporadic.

- Presence of contributing factors (as applicable): water conditions, local geography, temperatures, nutrient levels, presence of appropriate host species.

- Assessment of potential barriers to control hazard and/or reduce human exposure in areas/during times of increased risk.

PHYSICAL HAZARDS AND AESTHETIC CONSIDERATIONS

Subsurface Hazards:

Steep Slopes or Drop-offs ☐   Depths Greater than 4.5 m ☐

Large Rocks ☐   Slippery or Uneven Bottom ☐

Other: _____ ☐

Other: _____ ☐

Water Conditions:

Strong Currents or Riptides ☐   Undertows ☐

Other:

Litter on Beach ☐   (None   Low   Med   High [circle one])

Floating Debris ☐   (None   Low   Med   High [circle one])

Broken Glass or Other Sharp Objects ☐   (None   Low   Med   High [circle one])

Medical Wastes ☐   (None   Low   Med   High [circle one])

Seaweed/Algae on Beach ☐   (None   Low   Med   High [circle one])

Vehicles Permitted on Beach or Near Bathing Area:

Automobiles Y / N   Boats/Watercraft Y / N

Specify: _____

ITEMS FOR CONSIDERATION DURING THE RISK ASSESSMENT

- Assessment of the physical characteristics of the beach and their potential impacts on safe enjoyable use of the area; includes evaluation of physical layout (geography, topography), composition of shoreline and bottom material, influence of existing structures.

- Assessment of potential risks posed by specific hazards/factors in causing injury or illness or otherwise interfering with the enjoyable use of the area.

- Shoreline and water free from obstructions and of sufficient clarity to permit viewing of persons who may be in distress.

- Assessment of the nature and origin of litter and floating debris.

- Applicable physical and aesthetic parameters (pH, temperature, turbidity, colour, clarity, litter) in agreement with recommendations given in the *Guidelines for Canadian Recreational Water Quality*.

- Assessment of potential barriers to control hazard and/or reduce human exposure in areas/during times of increased risk.

FACILITIES AND SAFETY PROVISIONS

Facilities:

Toilets	#:_____ ☐	Showers	#:_____ ☐
Drinking Water Fountains	#:_____ ☐	Litter Bins	#:_____ ☐
Other:	#:_____ ☐	Other	#:_____ ☐

Access for Persons with Disabilities ☐

Safety Provisions:

Lifeguard Stations	#:_____ ☐	Lifesaving Equipment	#:_____ ☐
Emergency Telephone	#:_____ ☐	First Aid Stations	#:_____ ☐

Signs/Communication Materials:

Beach Posting/Suitability for Swimming ☐   Emergency Contact Information ☐

Life Guard On-Duty Hours ☐   Other: _____ ☐

Other Hazards (list):

_____ ☐   _____ ☐

Formal Procedures or Reporting Mechanisms in Place to Deal with:

Municipal or Industrial Spills/Discharges/Treatment Bypasses _____ ☐

Waterborne Disease Outbreaks _____ ☐

Swimmer Injuries _____ ☐

ITEMS FOR CONSIDERATION DURING THE RISK ASSESSMENT

- Assessment of the adequacy of facilities and safety provisions.
- Evaluation of signs and other materials for public communication: Message clear and concise, signs placed in locations highly visible to the public.

APPENDIX C: INFORMATIVE BEACH SIGNS

C.1 BEACH POSTING: EXAMPLE OF AN INFORMATIVE SWIMMING ADVISORY SIGN

WARNING
WATER NOT SUITABLE
FOR SWIMMING

Clear communication that a risk exists.

Instructions for users regarding the suitability of the water.

Accompanying graphic that is easy to understand.

Statement regarding the reason for the posting.

BACTERIA LEVELS ARE ABOVE RECOMMENDED LIMITS

CONTACT WITH THESE WATERS MAY INCREASE YOUR RISK OF ILLNESS

POOR WATER QUALITY CAN BE CAUSED BY HEAVY RAINS, HIGH WINDS AND WAVES, AND HIGH NUMBERS OF SWIMMERS

Additional information beneficial to the public's understanding of the situation.

FOR MORE INFORMATION, PLEASE CONTACT:
[Department – Telephone No.]

Contact for more information on the details of the monitoring program.

[NAME OF ISSUING AUTHORITY]

[CONTACT INFORMATION]

Contact information for authority responsible for issuing posting.

C.2 BEACH POSTING: EXAMPLE OF AN INFORMATIVE WATER SUITABLE FOR SWIMMING SIGN

WATER OPEN

SUITABLE FOR SWIMMING ———— Clear communication that the beach is open.

———— Instructions for users regarding the suitability of the water.

———— Accompanying graphic that is easy to understand.

THE MOST RECENTLY MEASURED BACTERIA LEVELS MEET THE RECOMMENDED LIMITS

———— Statement regarding the reason for the decision.

WE ALWAYS RECOMMEND THAT YOU:
- DO NOT SWALLOW THE WATER
- DO NOT PUT OPEN SORES OR WOUNDS IN THE WATER
- WASH YOUR HANDS BEFORE EATING

FOR MORE INFORMATION ON THE MONITORING OF THIS BEACH, PLEASE CONTACT:
[Department – Telephone No.]

———— Contact for more information on the details of the monitoring program.

[NAME OF ISSUING AUTHORITY]
[CONTACT INFORMATION]

———— Contact information for authority responsible for issuing posting.