Water Quality Assessment and Proposed Objectives for Burrard Inlet: Microbiological Indicators Technical Report

September 2021

Tsleil-Waututh Nation
səlilwətaɬ

BRITISH COLUMBIA

This Technical Report forms part of a series of water quality parameter reports whose purpose is to inform updates to the 1990 Provincial Water Quality Objectives for Burrard Inlet. This report and others in the series assess the current state and impacts of contamination in Burrard Inlet; incorporate new scientific research and monitoring of water quality; and reflect a broader understanding of goals and values, including those of First Nations, to improve the health of the marine waters of Burrard Inlet. Updating the 1990 Provincial Water Quality Objectives is a priority action identified in the Tsleil-Waututh Nation's Burrard Inlet Action Plan which has been an impetus for this work.

ISBN: 978-0-7726-8020-4

Citation:
LeNoble, J.L., Lilley, P. and A. Rao. 2021. Water Quality Assessment and Proposed Objectives for Burrard Inlet: Microbiological Indicators Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C.

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Cover Photograph:
Underwater monitoring equipment is installed from the Tsleil-Waututh Nation boat in Burrard Inlet.

Acknowledgements

Work to update the Burrard Inlet Water Quality Objectives is being led by the Tsleil-Waututh Nation (TWN), in collaboration with the BC Ministry of Environment and Climate Change Strategy (BC ENV). Progress on this work and production of this Technical Report have been supported by the following:

The project Coordination Team including: Anuradha Rao (project manager, consultant to TWN), Diane Sutherland (ENV), Patrick Lilley (Kerr Wood Leidal, consultant to TWN), Sarah Dal Santo (TWN).

Multi-agency advisory bodies: Burrard Inlet Water Quality Technical Working Group and Roundtable (representatives of First Nations; local, provincial and federal governments; health authorities; industry; academics and NGOs).

Staff, specialists and consultants including:

- Adrienne Hembree, Andrew George, Bridget Doyle, Carleen Thomas, Ernie George, Gabriel George, Graham Nicholas, John Konovsky, Stormy MacKay (TWN) and Allison Hunt (Inlailawatash)
- Deb Epps, Liz Freyman, Kevin Rieberger and Melany Sanchez (ENV), and Dan Stein (BC MOH)
- Daniel Brown, Jack Lau, Karin Björklund, Larissa Low (Kerr Wood Leidal)

We would also like to acknowledge financial support from: BC Ministry of Environment and Climate Change Strategy, City of Vancouver, Government of Canada, Sitka Foundation and Vancity Credit Union, and in-kind contributions from Roundtable members.

CHAPTER SUMMARY

The following chapter presents the proposed water quality objectives (WQOs) for microbiological indicators in Burrard Inlet. It includes relevant background information, a water quality assessment of potential pollution sources and available data on the status and trends in microbiological indicator levels in water in Burrard Inlet, a review of applicable water quality guidelines and standards, and a rationale for the proposed objectives. Recommendations for future monitoring as well as management options to help achieve these proposed objectives are also included.

Microbiological indicators are microscopic organisms used to indicate the presence of pathogens that present a risk to human health. Because direct monitoring of pathogens may be slow or uneconomical, indicator species or groups of species (i.e., microbiological indicators) are commonly used as a surrogate for microbiological water quality. The indicators of microbiological water quality preferred by relevant health authorities are fecal coliforms, *E. coli*, and enterococci.

The 1990 objectives for microbiological indicators were provisional and utilized fecal coliform and enterococci as indicators. The objectives were set to protect primary contact recreation (e.g., swimming, bathing, and wading) as this was considered the most sensitive water use at the time. The objectives were the same across all the Burrard Inlet sub-basins.

Based on the values and goals articulated through this process to update the WQOs for Burrard Inlet (Rao *et al.* 2019), the values most sensitive to microbiological contamination in Burrard Inlet include shellfish harvesting for human consumption and primary contact activities, including recreation and First Nation cultural practices. Although shellfish harvesting is not currently possible within most of the Inlet due to the current water quality and existing sources of pollution, Tsleil-Waututh Nation has a goal to expand harvesting opportunities within Burrard Inlet over time.

Potential sources of microbiological pollution in Burrard Inlet include provincially authorized waste discharges, effluent from the Lions Gate Wastewater Treatment Plant (WWTP), combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs), cross-connections between storm and sanitary systems, on-site sewage disposal systems, stormwater runoff, marinas and recreational boating, and domestic and wild animals.

Water Quality Assessment

Data used to assess status and trends in microbiological water quality in Burrard Inlet primarily came from four monitoring programs: provincial water quality objectives attainment monitoring, the Canadian Shellfish Sanitation Program, Metro Vancouver's Recreational Water Quality Monitoring Program and the Burrard Inlet Ambient Monitoring Program, also run by Metro Vancouver.

The following points summarize the key patterns and trends in microbiological water quality across all sub-basins of Burrard Inlet from the early 1970s to present:

- Among the sub-basins of Burrard Inlet, False Creek consistently has the highest microbiological indicator levels. Levels are highest in the eastern portion of False Creek where levels are consistently above guidelines for primary and secondary contact activities, usually during the summer months. Levels decline towards the western end of False Creek.
- Outside of False Creek, exceedances of water quality benchmarks for primary contact activities occur at times but tend to be localized and tied to specific sites. Exceedances are commonly associated with the locations of potential pollution sources, although specific cause-and-effect relationships have generally not been determined. Areas with frequent exceedances of water quality benchmarks for primary contact activities include Jericho Beach near the Balaclava CSO,

Ambleside, Eagle Harbour near the mouth of Eagle Creek, Inner Brockton Point near the Brockton CSO, Deep Cove near the marina, and the Indian River estuary at the mouth of the Indian River, among others.

- Swimming beaches near CSOs and emergency sanitary sewer overflows (SSOs) have higher rates of exceedances. Monitoring sites near the CSOs or SSOs at Jericho Beach, Central False Creek, East False Creek, and Clark Drive showed higher microbiological indicator levels and have had increases in the last five years, compared to sites in the same areas but farther from the CSOs. There is some concern that dry weather overflows from both the CSOs and emergency SSOs may occur and this can have an impact on primary contact activities during the summer months (e.g. Metro Vancouver 2019).
- Indian Arm and Port Moody Arm have better microbiological water quality than other sub-basins, although elevated *E. coli* levels have been detected in the area around Deep Cove.
- Throughout Burrard Inlet, prior to 2005, water quality at some swimming beaches appears to be above benchmarks for primary contact activities more often during the summer than during the rest of the year.
- There is a lack of recent data on seasonal changes in microbiological indicator levels as no year-round monitoring program has been conducted since 2005.

Key knowledge gaps and research needs in Burrard Inlet include:

- A lack of monitoring and information on the relative contributions of specific sources of microbiological pollution.
- A lack of regular, year-round monitoring, which limits our understanding of seasonality and responses to rainfall, discharges, and other patterns.
- Relatively little enterococci monitoring data, although Health Canada (2012) recommends enterococci as the preferred indicator for recreational water quality monitoring in marine waters.
- A lack of data on actual pathogen levels in shellfish tissue.

Proposed Objectives for Microbiological Indicators in Burrard Inlet

Proposed short-term, medium-term and long-term WQOs were derived from current health guidelines (CFIA 2020; ENV 2001, 2019; Health Canada 2012), are summarized in the following three tables, and reflect current microbiological sources, water uses, aspirational goals for Burrard Inlet as outlined in Rao et al. (2019) and the likely availability of management options to address major pollution sources over time. These goals were adapted from TWN's Burrard Inlet Action Plan (KWL 2017) through discussions with the multi-sector Burrard Inlet Water Quality Roundtable. They include the following of particular relevance to microbiological indicators:

- *Healthy, wild shellfish can be harvested safely by present and future generations*
- *Water and sediment are safe and clean for cultural, spiritual, and recreational activities*

The proposed short-term WQOs are based on existing guidelines for the protection of primary or secondary contact recreation and shellfish harvesting, where existing microbiological water quality has the potential to support shellfish harvesting. The long-term WQOs for Burrard Inlet are based on current health authority guidelines for the protection of shellfish harvesting, since it is the aspiration of TWN to restore water quality in Burrard Inlet to a level that would support shellfish harvesting across all sub-basins. Medium-term WQOs allow for a transition period between the short and long term. Proposed objectives are included for fecal coliforms, *E. coli*, and enterococci. The proposed objectives are set for the water column and are applicable only in the ambient environment. The appropriate ambient benchmarks for each indicator and value are presented in Table 2 of the full report.

Proposed Water Quality Objectives for Microbiological Indicators in Burrard Inlet – Short-term (2020 to 2025)

Parameter	Value	Sub-basin					
		False Creek	**Outer Harbour**	**Inner Harbour**	**Central Harbour**	**Port Moody Arm**	**Indian Arm**
Fecal coliform	*Shellfish consumption*	Not applicable					14 median and not more than 10% of samples > 43[7]
E. coli	*Recreation and cultural practices*	1000 geometric mean[1,4]	200 geometric mean[1,5] 400 max[3,5]				
Enterococci	*Shellfish consumption*	Not applicable					4 median[1] 11 90th percentile[2,6]
	Recreation and cultural practices	175 geometric mean[1]	35 geometric mean[1,5] 70 max[3,5]				

All units are bacteria/100 mL in CFU or MPN
[1]Using at least 5 weekly samples collected in a 30-day period
[2]Maximum allowable concentration for 90% of results within a sampling period. Sampling periods require a minimum of 10 results.
[3]Single sample allowable concentration
[4]Intended to protect secondary contact activities only; from Health Canada (2012)
[5]Intended to protect both primary and secondary contact activities; from ENV (2019)
[6]From ENV (2001)
[7]For a five-tube decimal dilution test. From CFIA (2020)

Proposed Water Quality Objectives for Microbiological Indicators in Burrard Inlet – Medium-term (2025 to 2050)

Parameter	Value	Sub-basin					
		False Creek	**Outer Harbour**	**Inner Harbour**	**Central Harbour**	**Port Moody Arm**	**Indian Arm**
Fecal coliform	*Shellfish consumption*	Not applicable	14 median and not more than 10% of samples > 43[7]	Not applicable	14 median and not more than 10% of samples > 43[7]		
E. coli	*Recreation and cultural practices*	200 geometric mean[1,5] 400 max[3,5]					
Enterococci	*Shellfish consumption*	Not applicable	4 median[1] 11 90th percentile[2,6]	Not applicable	4 median[1] 11 90th percentile[2,6]		
	Recreation and cultural practices	35 geometric mean[1,5] 70 max[3,5]					

All units are bacteria/100 mL in CFU or MPN
[1]Using at least 5 weekly samples collected in a 30-day period
[2]Maximum allowable concentration for 90% of results within a sampling period. Sampling periods require a minimum of 10 results.
[3]Single sample allowable concentration
[4]Intended to protect secondary contact activities only; from Health Canada (2012)
[5]Intended to protect both primary and secondary contact activities; from ENV (2019)
[6]From ENV (2001)
[7]For a five-tube decimal dilution test. From CFIA (2020)

Proposed Water Quality Objectives for Microbiological Indicators – Long-term (2050 onwards)

Parameter	Value	Sub-basin					
		False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Fecal coliform	*Shellfish consumption*	14 median and not more than 10% of samples > 43[6]					
E. coli	*Recreation and cultural practices*	200 geometric mean[1,4] 400 max[3,4]					
Enterococci	*Shellfish consumption*	4 median[1] 11 90th percentile[2,5]					
	Recreation and cultural practices	35 geometric mean[1,4] 70 max[3,5]					

All units are bacteria/100 mL in CFU or MPN
[1]Using at least 5 weekly samples collected in a 30-day period
[2]Maximum allowable concentration for 90% of results within a sampling period. Sampling periods require a minimum of 10 results.
[3]Single sample allowable concentration
[4]Intended to protect both primary and secondary contact activities; from ENV (2019)
[5]From ENV (2001)
[6]For a five-tube decimal dilution test. From CFIA (2020)

Updated WQOs for microbiological indicators are proposed to reflect current B.C. and Health Canada guidelines for recreational water quality, and B.C. and Canadian Shellfish Sanitation Program guidelines for shellfish consumption. The proposed objectives would apply year-round to protect shellfish harvesting, recreation, and cultural practices.

Monitoring and Reporting Recommendations

Key recommendations for future monitoring of microbiological indicators in Burrard Inlet include:

- Consider adopting both *E. coli* and enterococci as preferred indicators for ambient and recreational water quality monitoring and sample for both indicators wherever possible. Once several years of simultaneous monitoring has occurred using both indicators, use these data to re-visit whether there is a preferred indicator for Burrard Inlet.
- Continue to use fecal coliform as the preferred indicator for monitoring of shellfish harvesting areas because of its long-term use by the Canadian Shellfish Sanitation Program and use in current regulations. Monitor enterococci simultaneously to establish a basis for comparison of these indicators where resources allow.
- Evaluate whether it may be beneficial to combine monitoring by Metro Vancouver, the Canadian Shellfish Sanitation Program, and the provincial government into a single, integrated program to increase efficiency and reduce duplication of effort.
- Consider re-establishing year-round ambient water quality monitoring of microbiological indicators under Metro Vancouver's monitoring program on at least a monthly basis.
- Ensure all monitoring data becomes open data and is made available to First Nations, regulatory agencies, municipalities, and the public on timely basis.
- Improve the public availability of monitoring results using near real-time and web-based reporting tools. This is especially relevant for monitoring of CSOs which could impact recreational or cultural use areas.

Management Options

Attainment of the proposed objectives within the specified timeframes is expected to be challenging and will require concerted action among the various jurisdictions responsible for water quality management in the Inlet. The following initiatives are planned or underway that will have benefits to microbiological water quality in Burrard Inlet:

- Upgrading the Lions Gate WWTP from primary to tertiary treatment, with anticipated completion in 2024;
- Separating all remaining combined sewers within the City of Vancouver by 2050 and the City of Burnaby by 2075;
- Municipal sanitary-storm sewer cross-connection detection and control programs;
- Inflow and infiltration reduction programs to reduce groundwater and stormwater into sanitary sewer pipes, thereby reducing SSOs and CSOs;
- Development and implementation of Integrated Stormwater Management Plans (ISMPs) for all developed watersheds that flow into Burrard Inlet;
- The development, in process, by the City of Vancouver of a Sewage and Rainwater Management Plan alongside a broad, integrated Vancouver Plan); and
- Bacterial source tracking by the BC Centre for Disease Control and other health authorities.

Based on the assessment of sources above, and in recognition of the limitations of the analyses in this report (see Section 3.3.3) the following broad management options are presented for consideration:

- Implementing year-round disinfection of effluent at the current and future Lions Gate WWTP;
- Considering specific interim actions to reduce the frequency, duration, and magnitude of CSOs and SSOs (such as green stormwater infrastructure/stormwater source controls, attenuation tanks, inflow and infiltration reduction measures, and other sanitary and/or stormwater volume reduction measures);
- Accelerating the rate of connection by individual landowners to new separated sewers through incentives and other measures;
- Increased adoption of green stormwater infrastructure/stormwater source controls and design criteria that provide water quality treatment for stormwater runoff prior to discharge to Burrard Inlet;
- Working with the federal government to designate and keep Burrard Inlet as a no-discharge zone for boats;
- Assessing pump-out facilities and other discharge alternatives for recreational vessels in Burrard Inlet;
- Advocating for municipal, regional, or provincial development standards that protect watershed health and the health of receiving environments such as Burrard Inlet.
- Regulation of urban stormwater discharges by senior regulatory agencies;
- Creating specific education and awareness campaigns to target individual sources of microbiological pollution (e.g., pet waste) ; and
- Cooperative work by multiple agencies for public engagement and awareness to reduce boat discharges.

In addition, the following location-specific management options are recommended as high priorities:

- Separation of the combined sewer areas that connect to the Heather Street, Balaclava, Brockton Point, and Clark Drive CSOs;
- Prevention of other overflows that occur close to recreational beaches;

- Prevention of discharges from the Lynn Drive siphon;
- Investigation of the sources of microbiological water quality issues in Eagle Creek (West Vancouver) and the Indian River (north end of Indian Arm); and
- Priority implementation of source controls to reduce stormwater discharges to False Creek, Outer Harbour, Inner Harbour, and Central Harbour.

Feasibility analyses, integration of ongoing programs (e.g., Integrated Stormwater Management Plans, the City of Vancouver's Sewage and Rainwater Management Plan) and coordination with pollution reduction efforts related to other water quality parameters are necessary to develop response and management actions.

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ACRONYMS

BIAMP	Burrard Inlet Ambient Monitoring Program
BOD	Biochemical oxygen demand
CCME	Canadian Council of Ministers of the Environment
CFIA	Canadian Food Inspection Agency
CFU	Colony forming unit
CRWQG	Canadian Recreational Water Quality Guideline
CSO	Combined sewer overflow
CSSP	Canadian Shellfish Sanitation Program
ECCC	Environment and Climate Change Canada
E. coli	*Escherichia coli*
ENV	British Columbia Ministry of Environment & Climate Change Strategy
FSC	Food, social and ceremonial
ILWRMP	Integrated Liquid Waste and Resource Management Plan
MF	Membrane filtration
MPN	Most probable number
MTF	Multiple tube fermentation
QA/QC	Quality Assurance/Quality Control
RWQC	Recreational Water Quality Criteria
SSO	Sanitary sewer overflow
TSS	Total suspended solids
TWN	Tsleil-Waututh Nation
US EPA	United States Environmental Protection Agency
WQO	Water quality objective
WWTP	Wastewater treatment plant

1. INTRODUCTION

This chapter proposes updated water quality objectives (WQOs) for microbiological indicators in Burrard Inlet. It includes relevant background information, discussion of potential pollution sources and assessment of available data on the status and trends in microbiological indicator levels in water in Burrard Inlet, a review of applicable water quality guidelines and standards, and a scientific rationale for the proposed objectives. Recommendations for future monitoring as well as management considerations to help achieve these proposed objectives are also provided.

2. BACKGROUND

Microbiological indicators are microscopic organisms used to indicate the presence of pathogens that present a risk to human health. The presence of pathogens in the Inlet is specified as a high priority for management in Tsleil-Waututh Nation's (TWN's) Burrard Inlet Action Plan (KWL 2017).

Waterborne pathogens are a common source of a wide variety of diseases which can infect humans either through skin contact or ingestion. Common waterborne pathogens of concern to humans include *Campylobacter, Cryptosporidium, Escherichia coli (E. coli) O157:H7*, *Giardia, Leptospira*, *Salmonella*, *Shigella, Yersinia* and enteric viruses. Current analytical methods do not allow for fast or economical monitoring of all potential human pathogens. For this reason, several indicator species or groups of species (i.e., microbiological indicators) are commonly used as a surrogate for microbiological water quality. Many waterborne pathogens originate from poor management of human waste. Thus, monitoring programs typically target microbiological indicators of human feces. Animal waste is also a source of fecal indicators, however. Microbiological indicators serve as a proxy for the level of fecal contamination, and thus the probability of associated pathogenic bacteria, viruses and protozoa, in the water.

2.1 Values and Potential Effects

Water values to be protected in Burrard Inlet are articulated in Rao et al. (2019); they were adapted from Tsleil-Waututh Nation's Burrard Inlet Action Plan (KWL 2017) through discussion with the multi-sector Burrard Inlet Water Quality Roundtable. Of these, the most sensitive values to be protected from microbial pathogens in Burrard Inlet include shellfish harvesting for human consumption and primary contact activities, including recreation and First Nation cultural practices.

2.1.1 Shellfish Harvesting for Human Consumption

Generations of Tsleil-Waututh people were brought up with the teaching, "When the tide went out, the table was set". About 90% of the Tsleil-Waututh diet was once derived from Burrard Inlet and the Fraser River; however, by 1972 sanitation and contamination concerns resulting from uninvited development led to the closure of the Inlet to bivalve harvesting. TWN has a goal to be able to obtain 10% of their protein from the Inlet. In the Burrard Inlet Action Plan (KWL 2017), TWN set re-opening more of Burrard Inlet to shellfish harvesting as a long-term goal. This is contingent on the broader goal of improving water quality and reducing contamination.

Microbiological indicators are relevant to shellfish harvesting due to the dangers of ingesting pathogen-laden shellfish and contracting diseases following contact with pathogen-laden water while shellfish harvesting. Harvesting of contaminated shellfish for consumption can cause disease outbreaks because shellfish filter out and concentrate pathogens found in the water at relatively low levels (ENV 2001). Shellfish of interest in Burrard Inlet include bivalve molluscs such as clams, mussels, and oysters.

Due to sanitation concerns and microbiological contamination, Burrard Inlet has been closed to bivalve shellfish harvesting since 1972. A limited opening for food, social, and ceremonial (FSC) purposes occurs in a portion of Indian Arm, though this is a closely monitored and managed harvest.

2.1.2 Primary Contact Activities

Health Canada considers primary contact to be immersive activities such as swimming, bathing and wading, when it is likely some water will be swallowed, and defines secondary contact as activities in which only the limbs are regularly wetted and in which greater contact, including swallowing water, is unusual (Health Canada 2012). Both primary and secondary contact activities can include recreation and Indigenous cultural practices. Exposure to water containing elevated levels of pathogens during primary contact activities may cause gastrointestinal diseases and skin diseases (ENV 2001, Health Canada 2012). Primary contact activities have typically been the most sensitive value for setting water quality objectives for microbiological indicators in many BC water bodies to date. Primary or secondary contact may also occur during shellfish harvesting activities.

2.2 Potential Sources of Microbiological Pollution

There are several potential sources of microbiological pollution in Burrard Inlet, some which are specific to each sub-basin and some of which apply to Burrard Inlet as a whole. An overview of some of these sources is provided here; detailed descriptions of potential sources of microbiological pollution, broken down by sub-basin, are provided in Appendix B. Further details about these sources are provided in Rao et al. (2019), and supplementary maps associated with that report illustrate point and non-point sources of microbiological pollution in Burrard Inlet, specifically Maps 3, 3a and 4. Maps 3 and 4 are copied into Appendix B of this report as Figure 2 and Figure 3, respectively.

Provincially-Authorized Waste Discharges

Provincially authorized discharges relevant to microbiological water quality include sanitary discharges from resorts, summer camps, and food processing facilities, and the Lions Gate Wastewater Treatment Plant (WWTP).

The Lions Gate WWTP operated by Metro Vancouver, is located at First Narrows between the Outer Harbour and the Inner Harbour and discharges over 32 million m^3 of treated effluent annually into the Outer Harbour near the Lions Gate Bridge. The Lions Gate WWTP currently provides primary treatment only, meaning that it removes materials that settle or float and achieves removal of 50% to 60% of total suspended solids (TSS) and 30% to 50% of the biochemical oxygen demand (BOD) in the wastewater. A new Lions Gate WWTP that will provide tertiary treatment is currently under construction approximately 2 km east of the existing location. Treatment of wastewater does not necessarily remove all potential pathogens. During the main swimming season in Burrard Inlet (May to September), WWTP effluent is chlorinated to further reduce the risk of human exposure to pathogens.

Combined Sewer Overflows

While Combined Sewer Overflows (CSOs) are in the process of being phased out of the City of Vancouver's existing sewerage system by 2050, 23 CSO outfall locations existed as of 2017 with a combined annual overflow volume of over 18 million m^3 (Metro Vancouver, 2017). The largest CSOs by annual volume are located at: Heather Street in False Creek; Balaclava Street in Outer Harbour; Cassiar Street East, Clark Drive 1, and Victoria Drive in the Inner Harbour; and Westridge and Willingdon 1 in the Central Harbour. While CSOs occur seasonally to infrequently depending on the outfall, they typically carry a higher pathogen load than stormwater. Due to the frequency and volume of discharges from some outfalls, CSOs present a significant risk to microbiological water quality in Burrard Inlet.

Sanitary Sewer Overflows

Raw sanitary sewage carries a very high pathogen load. As of 2019, there were 25 lift station emergency overflow outfalls and one Sanitary Sewer Overflow (SSO) outfall that had the potential to discharge into Burrard Inlet. A priority emergency lift station for upgrades to address chronic overflows is the Lynn Branch Siphon in the Inner Harbour. The only remaining SSO is the Mackay Avenue Outfall in the Inner Harbour.

On-site Sewage Disposal Systems

There are a number of on-site sewage disposal systems in Burrard Inlet, primarily concentrated in Indian Arm. In 2006, there were 64 on-site sewage disposal systems, though the number has likely increased since that time (WorleyParsons Komex and Lorax Environmental, 2006). There are three types of on-site sewage systems approved for the disposal of domestic sewage, which are classified based the level of treatment (B.C. Public Health Act, Reg. 209/2010, ss. 1 and 2).

Stormwater Runoff

There are 320 stormwater outfalls that discharge runoff collected by storm sewer systems from urban and industrial areas. Stormwater is also discharged from outfalls into rivers and streams that flow into Burrard Inlet. Stormwater is a known source of pathogens, as runoff can pick up contaminants as it travels over land and encounters waste or animal feces.

Marinas and Recreational Boating

Waste discharges from boats are thought to contribute to elevated pathogen levels in Burrard Inlet, especially when recreational boating is more popular in summer. Current federal regulations do not allow for recreational boats to directly discharge sanitary waste within 3 km of a shoreline. It is suspected that some recreational boaters may be ignoring this requirement, however, and there is little enforcement at this time. Marina residents on liveaboard boats may also improperly connect to the sanitary system. The City of Vancouver provides free pump-out stations to reduce the direct dumping of human waste into parts of Burrard Inlet (City of Vancouver 2021a).

Domestic and Wild Animals

Domestic animals and local wildlife (e.g., marine mammals, waterfowl, gulls, deer, bears, coyotes, rodents) can contribute pathogens by defecating directly into marine waters, or in nearshore areas, from where fecal contaminants can be carried by storm runoff into Burrard Inlet. The contribution of animals to pathogen loads can be of more concern where large numbers of domestic and wild species directly share beaches with humans, such as near bird grazing areas or dog beaches. Except for Maplewood Farm in North Vancouver, there are no farm animals, livestock operations or significant agricultural land use in the Burrard Inlet catchment.

Infrastructure Failures and Cross-Connections

Other potential sources of microbiological pollution include cross-connected storm and sanitary pipes on private property as well as leaking sanitary pipes and sewer mains.

2.3 Factors Influencing Microbiological Indicator Levels in Burrard Inlet

Three microbiological indicators are commonly used to assess the risk of contaminated waters to human health in Canada (not including indicators specific to drinking water assessment):

1. **Fecal coliforms** have and continue to be used as an indicator of microbiological contamination but are no longer a preferred microbiological indicator for most Canadian monitoring programs (Health

Canada, 2012). Though overly-wide abundance and a potential to include species that are not specific to fecal contamination make this indicator less preferable than other indicators (Tallon et al., 2005; Scott et al., 2002), for historic reasons, fecal coliforms are still the microbiological indicator used by the CSSP.

2. ***Escherichia coli* (*E. coli*)** is considered a good indicator of fecal contamination but is recommended by Health Canada (2012) and BC recreational water quality guidelines for monitoring of freshwater only. In marine waters, monitoring *E. coli* is recommended to be monitored in conjunction with enterococci (Edberg et al., 2000).
3. **Enterococci** is a currently considered to be the preferred microbiological indicator for marine waters (Health Canada, 2012). In recreational marine waters, enterococci are known to survive longer than *E. coli* due to a stronger resistance to UV radiation (Health Canada, 2012).

Microbiological indicators are associated with the gut and fecal material of warm-blooded animals and cannot survive for long durations outside of that environment. Factors such as climate (e.g., temperature, precipitation), water type, starting concentration, magnitude of contributing sources, UV exposure, pH, and chemical stress can impact the entry and persistence of microbiological indicators in the marine environment, and therefore detection during routine monitoring. Climate change impacts including higher water temperatures and increased frequency and intensity of storm events are additional factors that can influence microbiological indicator levels in Burrard Inlet.

2.4 1990 Provisional Water Quality Objectives for Microbiological Indicators

The 1990 objectives for microbiological indicators were provisional and used fecal coliform and enterococci as indicators (Nijman, 1990). They are summarized in Table 1. The objectives were set to protect primary contact recreation as this was considered the most sensitive value at the time. The objectives were the same across all Burrard Inlet sub-basins, except for False Creek where the primary contact recreation objective only applied to bathing beaches near its mouth.

Table 1: 1990 Provisional Water Quality Objectives for Microbiological Indicators.

Microbiological Indicator[1]	Value	Sub-Basin					
		False Creek[3]	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Fecal coliform	Primary Contact Recreation	≤ 200/100 mL geometric mean[2]					
Enterococci		≤ 20/100 mL geometric mean[2]					

[1] All units are bacteria/100 mL in CFU or MPN, since units were not reported in 1990.
[2] For microbiological indicators, the geometric mean is calculated from at least five weekly samples taken in a period of 30 days during the recreation season.
[3] The objective for microbiological indicators in False Creek applies only to bathing beaches at the mouth of False Creek.

3. WATER QUALITY ASSESSMENT

3.1 Benchmarks Used in this Assessment

Benchmarks for microbiological indicators were used in this data assessment to screen available data to identify exceedances and trends in Burrard Inlet, to inform the proposal of WQOs for microbiological indicators in Burrard Inlet towards the protection of values that are sensitive to the presence of pathogens, and to recommend management actions to improve water quality. The values most sensitive to pathogens are shellfish harvesting and primary contact activities such as cultural practices and recreation.

With respect to shellfish harvesting, Environment and Climate Change Canada (ECCC), the Canadian Food Inspection Agency (CFIA), and Fisheries and Oceans Canada work together to deliver the Canadian Shellfish Sanitation Program (CSSP), which ensures that only shellfish that are safe for human consumption are harvested. In Burrard Inlet, this involves applying the classification guidelines in CFIA's Manual of Operations (2020) and delivering a monitoring program in Indian Arm to test water quality for the safe harvesting of shellfish. ENV also has approved guidelines for shellfish harvesting (ENV 2001), derived from several sources and essentially consistent with the guidance of the CFIA (2020).

With respect to primary contact activities in British Columbia, ENV is responsible for setting recreational water quality guidelines for microbiological levels. ENV has adopted Health Canada's Recreational Water Quality Guidelines (2012) for this purpose. Vancouver Coastal Health determines whether "no swimming" advisories are required based on comparison of the microbiological levels reported via Metro Vancouver monitoring programs to the Health Canada (2012) guidelines. The First Nations Health Authority is responsible for monitoring water quality on Reserve Lands, in collaboration with federal and provincial health authorities (FNHA 2021).

Existing monitoring programs were designed to identify potential health risks to either primary contact activities or to shellfish harvesting for human consumption. Therefore, in this data assessment, benchmarks and data sets relevant to primary contact activities were considered separately from those relevant to shellfish harvesting.

The details of these benchmarks are presented in Appendix A. The benchmarks chosen for the purpose of this data assessment were the Approved British Columbia Water Quality Guidelines (ENV 2001, 2019) and Health Canada Guidelines for Canadian Recreational Water Quality (Health Canada 2012), as they were the most relevant, the most recently updated and the most protective of the sensitive values at the time of writing. More up to date CSSP guidelines (CFIA 2020) became available after the data assessment had been completed, but it is not anticipated that they would significantly change the results.

The BC recreation guidelines (ENV 2019) are based on Health Canada guidelines from 2012, which were derived from analysis of epidemiological evidence relating microbiological indicator levels to the incidence of swimming-associated gastrointestinal illness observed among swimmers. "The [guidelines] represent risk management decisions based on the assessment of possible health risks for the recreational water user and the recognition of the significant benefits that recreational water activities provide in terms of health and enjoyment" (ENV 2019: 9). These standards are based on an acceptable level of risk (10-20 illnesses per 1000 swimmers) compared against the benefits of recreational water use (ENV 2019). These guidelines were set to balance health risks vs. health benefits, and do not necessarily protect water users from potential illness following primary contact activities.

The BC guidelines were last updated in 2017 for primary contact recreation (and re-evaluated in 2019 with no changes made). Changes to the primary contact recreation guidelines in 2017 included archiving of the guideline for fecal coliforms in recognition that it is no longer preferred for monitoring over *E. coli*. The fecal coliform guideline is retained as a benchmark in this assessment to allow for screening of long-term monitoring programs that have historically used fecal coliforms as a microbiological indicator.

The BC shellfish harvesting guidelines (ENV 2001) were last updated in 2001 for shellfish harvesting. They had originally been derived following a review of Health Canada, Environment Canada, US EPA, Washington State and BC Ministry of Health guidelines (BC Ministry of Environment and Parks 1988).

Table 2 outlines the benchmarks that were used for screening of microbiological indicator levels in this assessment and represents the benchmarks from relevant authorities for each relevant sensitive value or water use (ENV 2001, 2019; Health Canada 2012). All values are for total microbiological indicator levels. Although attainment of secondary contact benchmarks were not assessed under the scope of this study, secondary contact benchmarks are included in Table 2 and were used to inform the timeline for transitioning proposed WQOs from short-term to long-term in locations where the primary contact benchmarks are frequently not attained. Health Canada (2012: 42) advises that "where a water area is intended to be used specifically for secondary contact recreation (i.e., where primary contact is not an existing use), the application of a factor of 5 to the geometric mean faecal indicator concentration used to protect primary contact recreation users may be used as an approach to establish faecal indicator limits."

Table 2: Benchmarks for Microbiological Indicator Levels in Water Used in this Assessment[1,2]

Shellfish Harvesting[3]	
Fecal coliform	≤ 14/100 mL median ≤ 43/100 mL 90th percentile
E. coli	≤ 14/100 mL median ≤ 43/100 mL 90th percentile
Enterococci	≤ 4/100 mL median ≤ 11/100 mL 90th percentile
Primary Contact Activities	
Fecal coliform[4]	≤ 200/100 mL geometric mean
E. coli[5]	≤ 200/100 mL geometric mean ≤ 400/100 mL maximum
Enterococci[5]	≤ 35/100 mL geometric mean ≤ 70/100 mL maximum
Secondary Contact Activities[6]	
E. coli	1000/100 mL geometric mean
Enterococci	175/100 mL geometric mean

[1] All units are CFU/100 mL or MPN/100 mL, depending on the analytical method that is used
[2] In minimum 5 samples collected over a 30-day period
[3] BC Approved Water Quality Guidelines (last updated for shellfish harvesting in 2001)
[4] Archived in the 2017 BC Approved Water Guidelines (ENV 2019)
[5] BC Approved Water Quality Guidelines (ENV 2019)
[6] From Health Canada (2012), which recommends using enterococci in marine waters and *E. coli* in fresh waters. *E. coli* is retained here because of its use in Metro Vancouver's Recreational Water Quality Monitoring Program.

3.2 Data Sources

3.2.1 Key Monitoring Programs

Monitoring to protect physical contact activities is typically performed using water samples since sediments are known to prolong the survival of microbiological indicators in marine environments (Health Canada, 2012). Monitoring for shellfish harvesting is performed on water samples since humans can be exposed to pathogens during both the harvest and consumption of the shellfish and it is easier and less expensive to monitor water samples than tissue samples.

Data on microbiological indicator levels in Burrard Inlet were gathered from four monitoring programs with recent data. Although other datasets containing microbiological indicator sampling data may exist, these datasets were found to be the best available data for assessing the status of microbiological indicators within Burrard Inlet within the constraints of the project. A summary of the datasets used for this assessment is presented in Table 3.

A map showing the distribution of sampling sites for each monitoring program is provided as Figure 1.

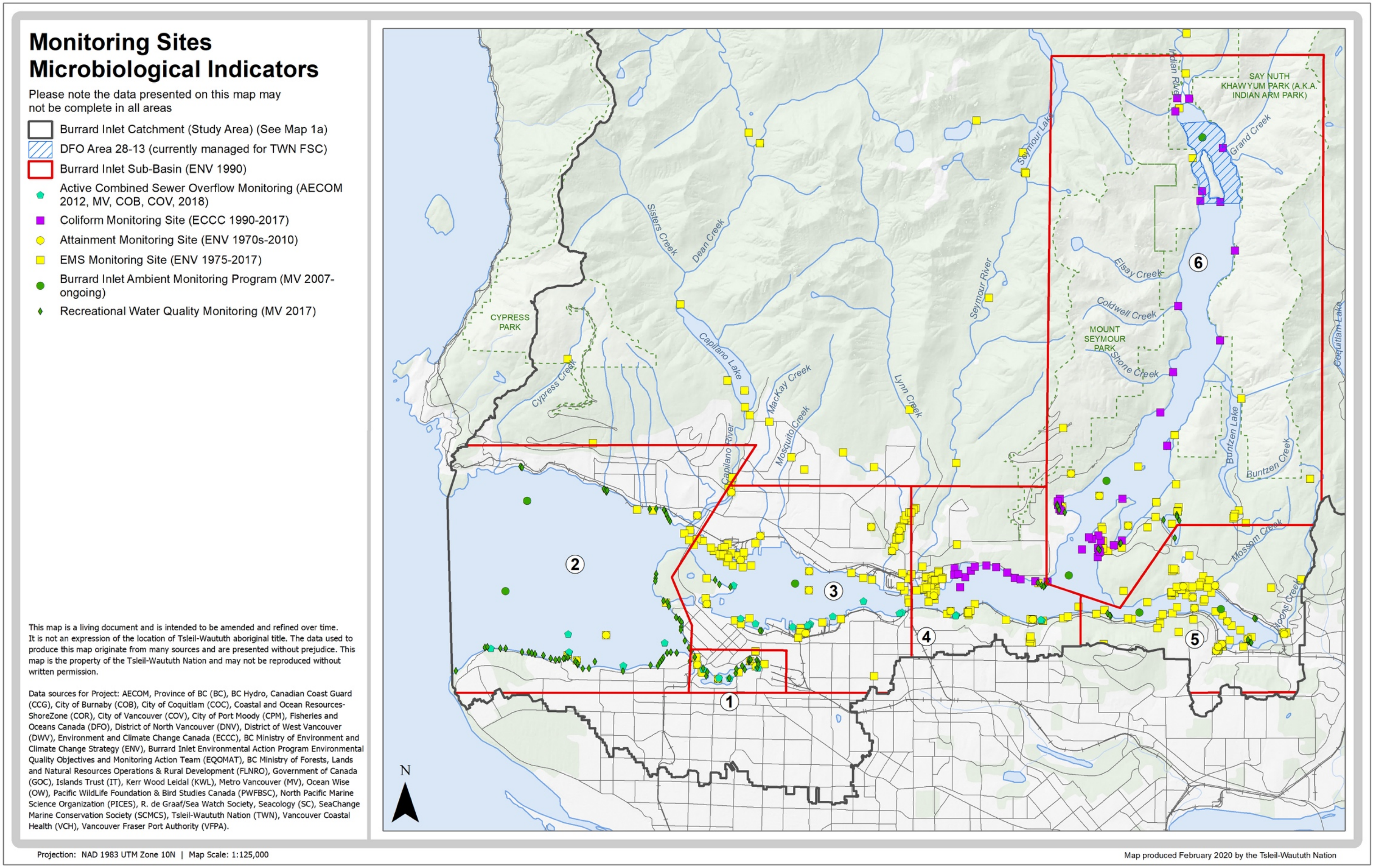

Figure 1. Monitoring sites for microbiological indicators in Burrard Inlet

- **Provincial WQOs Attainment Monitoring:** ENV monitors water quality to assess whether WQOs are attained, including monitoring of fecal coliforms, *E. coli*, and enterococci. In general, parameters have been sampled inconsistently with differing sample counts, frequency, and locations sampled between years.
- **Canadian Shellfish Sanitation Program:** CSSP monitors water quality to assess whether water quality is adequate for shellfish harvesting and consumption and to assess changes in water quality from year to year. Monitoring locations have been inconsistent and based on program needs. The CSSP may close sites for shellfish harvesting if there is evidence of pollution sources, regardless of whether there is monitoring data to indicate potentially harmful microbiological indicator levels.
- **Metro Vancouver's Recreational Water Quality Monitoring Program:** On behalf of Vancouver Coastal Health, Metro Vancouver monitors microbiological indicator levels at Metro Vancouver swimming beaches, including 26 beaches in Burrard Inlet to protect human health by determining if beach water quality complies with the Canadian Recreational Water Quality Guidelines (CRWQGs; 2012). Sampling was conducted weekly throughout the year from 1993 to 2004 and weekly from May to September since 2004 which allows for calculation of rolling 30-day geometric means and regression fitting. Comparison of winter microbiological indicator levels with other seasons is not possible after 2004.
- **Metro Vancouver's Burrard Inlet Ambient Monitoring Program (BIAMP)**: Metro Vancouver monitors ambient water quality to assess the impact of wastewater and stormwater discharges on water quality in Burrard Inlet. Metro Vancouver ambient water samples are collected within 1 m of the water surface to capture stormwater runoff effects and 3 m from the bottom of the water column to capture mixing and marine water effects. Samples are taken five times over a 30-day period.

Table 3: Monitoring Programs for Microbiological Indicators Included in this Assessment

Owner	Monitoring Program	Date Range	No. Observa-tions	No. Sites	Frequency at Each Site (Recent)	Parameters Sampled
Ministry of Environment	Provincial WQOs attainment monitoring	1973–2009	569	26	2–10 samples/year, irregular	Fecal coliform, enterococci (2002 onward)
Environment and Climate Change Canada	Canadian Shellfish Sanitation Program	1990–2017	1,540	45	3–15 samples/year, variable	Fecal coliform
Metro Vancouver	Recreational Water Quality Monitoring Program	1993–2016	79,218	95	Up to 5 samples/month, regular	Fecal coliform (1993–2012), *E. coli (2013 onward)*
Metro Vancouver	Burrard Inlet Ambient Monitoring Program	2007–2016	2,336	16	5–10 samples/year, regular	Fecal coliform, *E. coli* enterococci

3.2.2 Additional Monitoring Programs and Data

Several datasets representing monitoring of specific sources of microbiological pollution in Burrard Inlet were also used as part of the assessment but were not analyzed for trends. When abnormally elevated microbiological indicator levels were measured as part of the major monitoring programs, these datasets were reviewed to determine potential microbiological indicator sources. Other monitoring datasets that were reviewed include:

- Metro Vancouver monitoring of fecal coliforms at the Lions Gate WWTP;
- Metro Vancouver and municipal government monitoring at stormwater outfalls and CSO locations;
- Effluent monitoring by holders of various provincial waste discharge authorizations; and
- Other studies which were also reviewed include Phippen and Sutherland (2006) and Worley Parsons (2012).

3.3 Assessment Methods

Data from each of the major monitoring programs were reviewed and analyzed. Due to differences in the methods of each monitoring program and parameters monitored, each data source was analyzed independently.

3.3.1 Summary Statistics

To assist with comparison to benchmarks, the following statistics were calculated for each monitoring location:

- For monitoring programs that target primary contact activities such as recreation and cultural practices:
  - Rolling 30-day geometric mean and maximum levels using a minimum of five samples collected over 30 days when adequate data is available; or
  - Geometric mean and single sample maximum levels, annually, if there is no period with five samples collected over 30 days.
- For monitoring programs that target shellfish consumption:
  - Median and 90th percentile levels, using a minimum of five samples collected over 30 days, where available; or
  - Median and 90th percentile levels, annually, if there is no period with five samples collected over 30 days.

The geometric mean is calculated using the n^{th} root of the product of n samples, where n represents the total sample count. Geometric means are used to summarize microbiological indicator data. Bacteria can grow at an exponential rate if given the right conditions and are therefore quite variable. Use of the geometric means ensures that mean values are not overly influenced by large fluctuations in numbers.

The median is the value at which 50% of the samples in the dataset are smaller. It is calculated by extracting the middle value in a ranked dataset. Likewise, the 90th percentile is the value at which 90% of samples in the dataset are smaller. Medians and 90th percentiles are often used to account for datasets that include infrequent outlier values.

3.3.2 Comparison to Benchmarks

Each data set and microbiological indicator was compared to benchmarks (see Section 3.1). The benchmarks were selected based on the objective of the monitoring program that generated the data. The Canadian Shellfish Sanitation Program data were compared to benchmarks for shellfish consumption. ENV Attainment Monitoring and Metro Vancouver Recreational and Ambient Water Quality Monitoring data were compared to both primary contact recreation and shellfish harvesting benchmarks. More focus was given to comparing Metro Vancouver's data with primary contact recreation benchmarks because these benchmarks align with the intents of the monitoring programs. Some comparisons and discussion against shellfish harvesting benchmarks are provided using the Metro Vancouver data because there was a limited amount of high quality data available to assess against shellfish harvesting benchmarks at most locations within Burrard Inlet. Discussion of exceedances refers to whether a summary statistic exceeds the relevant benchmark.

3.4 Limitations

Analysis of a large dataset comprised of data from numerous monitoring programs generated the following limitations for the analysis:

- No detailed analysis of Quality Assurance/Quality Control (QA/QC) for each dataset was performed. However, all laboratory analyses for the key monitoring programs were conducted by CALA-accredited laboratories, and the monitoring programs conduct their own internal QA/QC.
- Detection limits varied between data sources, parameters, and years. In this analysis, non-detects were treated as their detection limit when calculating geometric mean, maximum, median, and 90th percentile (e.g., <10 was treated as 10). These methods were sufficient to determine high-level patterns and trends in the data, including the extent of exceedances in space and time.
- Programs had different laboratory methods and units: either Most Probable Number (MPN) or Colony Forming Units (CFU). Units are identified in all figures and the outcomes from the assessment were not impacted by the choice of laboratory method.
- There are limitations when comparing monitoring programs that were designed to track human health during recreation to benchmarks for shellfish harvesting, because the monitoring programs were not designed to assess against risks associated with human consumption of shellfish. Monitoring program elements that could be inadequate include the sampling method, precise location, number of samples, detection limits or time of year, among others. Given the limited monitoring data for shellfish harvesting, however, comparisons to recreational monitoring program data were deemed to be useful for recommending short-term objectives, management options, and future monitoring.
- There are inherent limitations associated with the use of indicators, in lieu of data on the presence and abundance of actual pathogenic bacteria, viruses, and parasites. There is a lack of data on the presence and abundance of actual pathogenic bacteria, viruses, and parasites. Microbiological indicators are selected to balance accuracy with monitoring simplicity and resources. While microbiological indicators have traditionally been used for water quality monitoring and assessing compliance with WQOs, there is evidence to suggest that these indicators provide imperfect determinations of abundance, or in some cases even presence/absence of all pathogenic organisms (Meals, Harcum and Dressing, 2013), for example viruses.

3.5 Assessment Results

A summary of the results of the water quality assessment is presented below, with further details provided in Appendix C. Monitoring data were analyzed and are presented by sub-basin. Because of variation in the methods, distribution of sites, and microbiological indicators used, results from each monitoring program are discussed separately.

3.5.1 False Creek

Monitoring Programs

Provincial water quality attainment monitoring and Metro Vancouver's Recreational Water Quality Monitoring Program cover False Creek. False Creek is not designated for primary contact activities at this time but is currently used for secondary contact activities. While a detailed analysis against secondary contact benchmarks was not completed as part of this study's scope, comments are provided on the general extent of secondary contact exceedances that were observed for each monitoring program conducted in False Creek.

ENV has been monitoring False Creek for attainment since 1973. ENV did not collect samples in False Creek from 1979 to 2002 but the program was intermittently reinstated for a period between 2002 to 2009. From 2002 to 2009, both fecal coliforms and enterococci were monitored in False Creek between Granville Street and Cambie Street to the West (Site E207815), False Creek Cambie Street (Site 300082), and at East End (Site E216034).

Metro Vancouver's Recreational Water Quality Monitoring Program has 25 sample collection locations in False Creek which can be broadly classified into four sites: (1) Sunset Beach (4 locations); (2) West False Creek (4 locations); (3) Central False Creek (3 locations); and (4) East False Creek (10 locations).

False Creek has not been monitored as part of the Canadian Shellfish Sanitation Program or Metro Vancouver's Burrard Inlet Ambient Monitoring Program.

Refer to Appendix D1 for figures illustrating monitoring results in False Creek.

Provincial WQOs Attainment Monitoring

ENV has monitored microbiological indicators at 4 locations. Table 4 provides a summary of ENV's monitoring results for False Creek.

Table 4: Summary of ENV Provincial Water Quality Attainment Monitoring Results for Microbiological Indicators in False Creek

Location Name	Owner Site ID	Indicator	Year	Sample Count	Annual Geometric Mean	Annual Single Sample Maximum	Annual Median	Annual 90th Percentile
FALSE CREEK BURRARD ST BR	300081	Fecal Coliform	1973	2	77	180	107	
FALSE CREEK BURRARD ST BR	300081	Fecal Coliform	1974	4	59	490	130	
FALSE CREEK BURRARD ST BR	300081	Fecal Coliform	1975	8	532	24,000	410	
FALSE CREEK BURRARD ST BR	300081	Fecal Coliform	1976	4	320	1,600	295	
FALSE CREEK BURRARD ST BR	300081	Fecal Coliform	1977	5	86	540	110	
FALSE CREEK BURRARD ST BR	300081	Fecal Coliform	1978	6	61	540	50	
FALSE CREEK BETWEEN GRANVILLE AND CAMBIE	E207815	Fecal Coliform	1975	8	532	24,000	410	
FALSE CREEK BETWEEN GRANVILLE AND CAMBIE	E207815	Fecal Coliform	1976	4	320	1,600	295	
FALSE CREEK BETWEEN GRANVILLE AND CAMBIE	E207815	Fecal Coliform	1977	5	86	540	110	
FALSE CREEK BETWEEN GRANVILLE AND CAMBIE	E207815	Fecal Coliform	2002	10	56	780	18	780
FALSE CREEK BETWEEN GRANVILLE AND CAMBIE	E207815	Fecal Coliform	2003	2	469	1080	642	
FALSE CREEK BETWEEN GRANVILLE AND CAMBIE	E207815	Fecal Coliform	2009	4	12	79	19	
FALSE CREEK BETWEEN GRANVILLE AND CAMBIE	E207815	Enterococci	2002	10	23	880	17	880
FALSE CREEK BETWEEN GRANVILLE AND CAMBIE	E207815	Enterococci	2003	2	4	19	10	
FALSE CREEK BETWEEN GRANVILLE AND CAMBIE	E207815	Enterococci	2009	4	12	64	34	
FALSE CREEK CAMBIE ST	300082	Fecal Coliform	1973	2	135	230	155	
FALSE CREEK CAMBIE ST	300082	Fecal Coliform	1978	6	61	540	50	
FALSE CREEK EAST END	E207814	Fecal Coliform	1974	5	335	2,400	350	
FALSE CREEK EAST END	E207814	Fecal Coliform	1975	6	1150	5,400	1980	
FALSE CREEK EAST END	E207814	Fecal Coliform	1976	5	715	2,400	920	
FALSE CREEK EAST END	E207814	Fecal Coliform	2002	10	239	680	170	680

Location Name	Owner Site ID	Indicator	Year	Sample Count	Annual Geometric Mean	Annual Single Sample Maximum	Annual Median	Annual 90th Percentile
FALSE CREEK EAST END	E207814	Fecal Coliform	2003	2	1956	2090	1960	
FALSE CREEK EAST END	E207814	Fecal Coliform	2009	4	18	130	18	
FALSE CREEK EAST END	E207814	Enterococci	2002	10	40	370	34	370
FALSE CREEK EAST END	E207814	Enterococci	2003	2	18	20	19	
FALSE CREEK EAST END	E207814	Enterococci	2009	4	6	59	4.5	

Key observations include:

- Monitoring by ENV in False Creek has been infrequent and sporadic with few years achieving the minimum 5 samples in 30 days criteria. For this reason, annual values were calculated.
- Recorded values frequently exceed recreation and shellfish harvesting benchmarks.
- The highest values were recorded in the 1970s. No samples were collected in the 1980s and 1990s.

Metro Vancouver's Recreational Water Quality Monitoring

Metro Vancouver has monitored microbiological indicators at 4 locations. Table 5 provides a summary of Metro Vancouver's recreational monitoring results for False Creek.

Table 5: Summary of Metro Vancouver Burrard Inlet Recreational Water Quality Monitoring Results for Microbiological Indicators in False Creek

Location Name	Indicator	Years	Total No. of Samples	Range of Rolling Geometric Mean Values	No. of Primary Contact Geometric Mean Benchmark Exceedances	Range of Rolling Maximum Values	No. of Primary Contact Maximum Benchmark Exceedances
Sunset Beach	*E. coli*	2013 – 2016	555	10 – 1,817	75	10 – 21,000	37
Sunset Beach	Fecal Coliform	1993 – 2012	5695	10 – 1,423	393	10 – 40,170	NA[1]
West False Creek	*E. coli*	2013 – 2016	372	11 – 2,002	57	20 – 17,329	30
West False Creek	Fecal Coliform	1993 – 2012	2833	13 – 1,748	363	20 – 16,000	NA
Central False Creek	*E. coli*	2013 – 2016	375	12 – 3,013	113	30 – 24,196	61
Central False Creek	Fecal Coliform	2003 – 2012	1098	20 – 3,380	247	20 – 35,000	NA[1]
East False Creek	*E. coli*	2013 – 2016	701	10 – 16,323	500	10 – 24,196	375
East False Creek	Fecal Coliform	1993 – 2012	3817	20 – 7,728	2327	20 – 21,000	NA
[1] Not applicable – no primary contact single sample maximum benchmark for fecal coliform							

Key observations include:

- Microbiological indicator levels have been highest in East False Creek compared to the other monitoring locations.
- In the period since *E. coli* has been monitored, there is evidence that indicator levels are the highest in the summer season, which is of concern since this is the period of highest recreational use.
- An unusually high year for microbiological indicators occurred in 2014.
- Both the primary contact and secondary contact recreation benchmarks have frequently been exceeded in False Creek.

3.5.2 Outer Harbour

Monitoring Programs

Provincial water quality attainment monitoring, and Metro Vancouver's Burrard Inlet Ambient Monitoring Program include ambient monitoring sites within the Outer Harbour. ENV collected samples from one ambient monitoring site at English Bay Centre in 2002 and 2009. Fecal coliforms and enterococci were measured. Metro Vancouver has collected samples from two sites (Outer Harbour North and Outer Harbour South) since 2007.

Both provincial attainment monitoring and Metro Vancouver's Recreational Water Quality Monitoring Program cover shoreline areas around the Outer Harbour. ENV collected samples from the English Bay shoreline at one location from 1973 to 1979 and from Jericho Beach, Ambleside Beach, and Second Beach, each at one location, in 2003. Fecal coliforms were measured from 1973 to 1979 and fecal coliforms and enterococci were monitored in 2003. Metro Vancouver has 52 sample collection locations in the Outer Harbour which can be broadly classified into eleven sites:

1. Sandy Cove (2 locations);
2. Dundarave (5 locations);
3. Ambleside (6 locations);
4. Spanish Banks (5 locations);
5. Locarno Beach (6 locations);
6. Jericho Beach (7 locations);
7. Kitsilano Beach (5 locations);
8. Kitsilano Point (5 locations);
9. English Bay Beach (5 locations);
10. Second Beach (3 locations); and
11. Third Beach (3 locations).

The Outer Harbour has not been monitored under the Canadian Shellfish Sanitation Program to date; however, shellfish were historically gathered off the shores of Vancouver from Spanish Banks extending to Jericho Beach and from Sunset beach extending to Prospect Point in Stanley Park and off the shores of West Vancouver near Lighthouse Park (Tsleil-Waututh Nation, unpublished data). Refer to Appendix D2 for figures illustrating monitoring results in the Outer Harbour.

Metro Vancouver's Burrard Inlet Ambient Monitoring Program

Metro Vancouver has two ambient monitoring locations in Outer Harbour, identified as Outer Harbour North and Outer Harbour South. Table 6 provides a summary of monitoring results for the Outer Harbour.

Table 6: Summary of Metro Vancouver Burrard Inlet Ambient Monitoring Results for Microbiological Indicators in the Outer Harbour for Samples Collected at the Top of the Water Column

Location Name	Indicator	Years	Total No. of Samples	Range of Annual Geometric Mean Values	No. of Primary Contact Geometric Mean Benchmark Exceedances	Range of Annual Median Values	No. of Shellfish Harvesting Median Benchmark Exceedances	Range of Annual Single Sample Maximum Values	No. of Primary Contact Maximum Benchmark Exceedances
OUTER HARBOUR NORTH	*E. coli*	2007 – 2016	55	49 – 233	1	40 – 380	10	93 – 1,300	5
OUTER HARBOUR NORTH	Enterococci	2007 – 2016	55	22 – 92	7	14 – 130	10	52 – 340	8
OUTER HARBOUR NORTH	Fecal Coliform	2007 – 2016	55	49 – 325	1	40 – 380	10	93 – 1,300	NA[1]
OUTER HARBOUR SOUTH	*E. coli*	2007 – 2016	55	25 – 91	0	20 – 100	10	45 – 590	1
OUTER HARBOUR SOUTH	Enterococci	2007 – 2016	55	11 – 139	3	10 – 170	10	20 – 510	6
OUTER HARBOUR SOUTH	Fecal Coliform	2007 – 2016	55	27 – 136	0	20 – 110	10	45 – 590	NA

[1] Not applicable – no primary contact single sample maximum benchmark for fecal coliform

Key observations include:

- The wider range of measured values and more frequent benchmark exceedances suggest that microbiological indicator levels are higher in the north of the Outer Harbour than the south of the Outer Harbour.

Provincial WQOs Attainment Monitoring

ENV has monitored microbiological indicators at 4 locations. Table 7 provides a summary of ENV's monitoring results for the Outer Harbour.

Table 7: Summary of ENV Provincial Water Quality Attainment Monitoring Results for Microbiological Indicators in the Outer Harbour

Location Name	Owner Site ID	Indicator	Year	Sample Count	Annual Geometric Mean	Annual Single Sample Maximum	Annual Median	Annual 90th Percentile
ENGLISH BAY	300076	Fecal Coliform	1973	1	79	79	79	
ENGLISH BAY	300076	Fecal Coliform	1974	5	34	490	17	
ENGLISH BAY	300076	Fecal Coliform	1975	7	75	790	70	
ENGLISH BAY	300076	Fecal Coliform	1976	7	71	700	80	
ENGLISH BAY	300076	Fecal Coliform	1977	5	52	240	79	
ENGLISH BAY	300076	Fecal Coliform	1978	5	20	920	20	
ENGLISH BAY CENTRE	300076	Fecal Coliform	2002	11	10	110	6	110
ENGLISH BAY CENTRE	300076	Fecal Coliform	2009	4	8	79	8	
ENGLISH BAY CENTRE	300076	Enterococci	2002	11	6	55	2	55
ENGLISH BAY CENTRE	300076	Enterococci	2009	4	4	13	6	
AMBLESIDE BEACH	E253270	Fecal Coliform	2003	2	15	39	23	
AMBLESIDE BEACH	E253270	Enterococci	2003	2	3	7	4	
SECOND BEACH	E253276	Fecal Coliform	2003	2	12	16	13	
SECOND BEACH	E253276	Enterococci	2003	2	3	9	5	

Key observations include:

- The lower mean, maximum, and median values calculated for 2002 to 2009 compared to 1973 to 1978 provide some evidence to suggest that fecal coliform levels have fallen between 1970 and 2002; however, there is too little data and there are too many differences in the sampling efforts to confirm trends.

Metro Vancouver's Recreational Water Quality Monitoring Program

Metro Vancouver has measured fecal coliforms from 1993 to 2012 and *E. coli* from 2012 to present at 11 stations, as listed in the description of monitoring programs for the Outer Harbour. Sampling was performed weekly on a year-round basis from 1993 to 2004 and weekly from May to September after 2004. Table 8 provides a summary of Metro Vancouver's recreational monitoring results for the Outer Harbour.

Table 8: Summary of Metro Vancouver Burrard Inlet Recreational Water Quality Monitoring Results for Microbiological Indicators in the Outer Harbour

Location Name	Indicator	Years	Total No. of Samples	Range of Rolling Geometric Mean Values	No. of Primary Contact Geometric Mean Benchmark Exceedances	Range of Rolling Maximum Values	No. of Primary Contact Maximum Benchmark Exceedances
Ambleside	*E. coli*	2013 – 2016	494	10 – 782	41	10 – 21,000	13
Ambleside	Fecal Coliform	1993 – 2012	4294	11 – 642	428	20 – 16,000	NA[1]
Dundarave	*E. coli*	2013 – 2016	328	10 – 1363	43	10 – 21,000	25
Dundarave	Fecal Coliform	1994 – 2012	1347	10 – 492	43	10 – 3,000	NA
English Bay Beach	*E. coli*	2013 – 2016	396	10 – 259	2	10 – 1,900	0
English Bay Beach	Fecal Coliform	1993 – 2012	5471	10 – 1,028	162	10 – 16,000	NA
Jericho Beach	*E. coli*	2013 – 2016	684	10 – 599	35	10 – 21,000	9
Jericho Beach	Fecal Coliform	1993 – 2012	5026	10 – 3,280	249	10 – 240,000	NA
Kitsilano Beach	*E. coli*	2013 – 2016	458	10 – 131	0	10 – 4,200	0
Kitsilano Beach	Fecal Coliform	1993 – 2012	4015	10 – 833	62	10 – 16,000	NA
Kitsilano Point	*E. coli*	2013 – 2016	242	10 – 330	6	10 – 8,000	0
Kitsilano Point	Fecal Coliform	2003 – 2012	670	10 – 464	13	10 – 16,000	NA
Locarno Beach	*E. coli*	2013 – 2016	542	10 – 86	0	10 – 6,867	0
Locarno Beach	Fecal Coliform	1993 – 2012	4641	10 – 483	98	10 – 16,000	NA
Sandy Cove	*E. coli*	2014 – 2016	193	10 – 476	13	10 – 3,654	3
Second Beach	*E. coli*	2013 – 2016	258	10 – 285	8	10 – 1,800	0
Second Beach	Fecal Coliform	1993 – 2012	3055	10 – 313	26	10 – 16,000	NA
Spanish Banks	*E. coli*	2013 – 2016	357	10 – 43	0	10 – 350	0
Spanish Banks	Fecal Coliform	1993 – 2012	3930	10 – 296	41	10 – 16,000	NA
Third Beach	*E. coli*	2013 – 2016	366	10 – 148	0	10 – 2,400	0
Third Beach	Fecal Coliform	1993 – 2012	3414	10 – 287	15	10 – 9,000	NA

[1] Not applicable – no primary contact single sample maximum benchmark for fecal coliform

Key observations include:

- Earlier data in the series suggest that there are commonly two periods with data spikes, in the winter from November to February and in the summer from July to September.
- At the east end of the south shore of the Outer Harbour, results are different at Sunset Beach and English Bay Beach compared to Second Beach and Third Beach. At Sunset Beach and English Bay Beach, microbiological indicator levels are generally consistent and high with exceedances of the primary contact benchmark throughout the year, though more frequently in the summer season. In contrast, since 1993, microbiological indicator levels appear to have decreased at both Second Beach and Third Beach; however, peaks in summer levels were evident in 2013 and 2014.
- Along the west end of the south shore of the Outer Harbour, there are similar patterns for microbiological indicator levels at the beaches between Spanish Banks and Kitsilano Point. For example, there are sporadic primary contact benchmark exceedances over this period, which are consistent at all three sample collection locations.
- Dundarave and Ambleside exhibit similar seasonal changes in microbiological indicator levels across the years. There are alternating periods of several years with high summer values, then lower summer values. From 2013 to 2016, summer levels were consistently high and in exceedance of the primary contact benchmark.
- There are summer peaks and evidence of increased microbiological pollution associated with the Balaclava CSO, located in proximity to Jericho Beach. The Balaclava CSO has the highest overflow frequency of any of the three CSOs in the Outer Harbour. Location BEB-06-647 (closest to the CSO) is consistently higher than all other monitoring locations over the entire year and rolling 30-day geometric mean values have exceeded the primary contact benchmark for at least some duration of most monitoring years.

3.5.3 Inner Harbour

Monitoring Programs

Provincial water quality attainment monitoring and Metro Vancouver's Burrard Inlet Ambient Water Quality Monitoring Program include ambient monitoring sites within the Inner Harbour. ENV collected samples from the Inner Harbour at one ambient site at Loch Katrine Bank in 2002. Fecal coliforms and enterococci were measured. Metro Vancouver's Burrard Inlet Ambient Monitoring Program has collected samples from one site since 2007. The Metro Vancouver site is located in the centre of the sub-basin, approximately 500 m west of the ENV site.

Both provincial attainment monitoring and Metro Vancouver's Recreational Water Quality Monitoring Program cover shoreline areas around the Inner Harbour. ENV collected samples from Burrard Inlet at Lions Gate (Site 300077) and from Burrard Inlet at Second Narrows (Site 300078) between 1973 to 1979 and from Coal Harbour (Site E207698), Clark Drive (Site E207818), and Vancouver Wharves (Site E207816) in 2002 and 2009. Fecal coliforms were measured from 1973 to 1979 and both fecal coliforms and enterococci were measured in 2002 and 2009. Metro Vancouver's Recreational Water Quality Monitoring Program has three sample collection locations at Brockton Point and two sample collection locations at Crab Park.

The Inner Harbour has not been monitored under the Canadian Shellfish Sanitation Program and there are no active shellfish gathering sites in the Inner Harbour; however, shellfish were historically gathered off the north and east sides of Stanley Park.

Refer to Appendix D3 for figures illustrating monitoring results in the Inner Harbour.

Metro Vancouver's Burrard Inlet Ambient Monitoring Program

Table 9 provides a summary of Metro Vancouver ambient monitoring results for the Inner Harbour.

Table 9: Summary of Metro Vancouver Burrard Inlet Ambient Monitoring Results for Microbiological Indicators in the Inner Harbour for Samples Collected at the Top of the Water Column

Location Name	Indicator	Years	Total No. of Samples	Range of Annual Geometric Mean Values	No. of Primary Contact Geometric Mean Benchmark Exceedances	Range of Annual Median Values	No. of Shellfish Harvesting Median Benchmark Exceedances	Range of Annual Single Sample Maximum Values	No. of Primary Contact Maximum Benchmark Exceedances
INNER HARBOUR	*E. coli*	2007 – 2016	55	65 – 383	3	55 – 330	10	130 – 860	7
INNER HARBOUR	Enterococci	2007 – 2016	55	24 – 143	9	20 – 180	10	51 – 390	8
INNER HARBOUR	Fecal Coliform	2007 – 2016	55	93 – 436	5	62 – 390	10	380 – 1,200	NA[1]

[1] Not applicable – no primary contact single sample maximum benchmark for fecal coliform

Key observations include:

- Microbiological indicator levels in the Inner Harbour are lower than in False Creek but are higher than in the Outer Harbour and Central Harbour.
- Other than microbiological water quality potentially appearing better from 2013 to 2015, there is no discernable temporal pattern in the data.

Provincial WQOs Attainment Monitoring

ENV has monitored microbiological indicators at 6 locations. Table 10 provides a summary of ENV's monitoring results for Inner Harbour.

Table 10: Summary of ENV Provincial Water Quality Attainment Monitoring Results for Microbiological Indicators in the Inner Harbour

Location Name	Owner Site ID	Indicator	Year	Sample Count	Annual Geometric Mean	Annual Single Sample Maximum	Annual Median	Annual 90th Percentile
BURRARD INLET LIONS GATE	300077	Fecal Coliform	1973	1	7	7	7	
BURRARD INLET LIONS GATE	300077	Fecal Coliform	1974	5	40	240	79	
BURRARD INLET LIONS GATE	300077	Fecal Coliform	1975	6	62	790	50	
BURRARD INLET LIONS GATE	300077	Fecal Coliform	1976	5	99	490	120	
BURRARD INLET LIONS GATE	300077	Fecal Coliform	1977	5	22	240	49	
BURRARD INLET LIONS GATE	300077	Fecal Coliform	1978	6	34	138	45	
COAL HARBOUR - SOUTH SHORE NEAR BAYSHORE HOTEL	E207813	Fecal Coliform	2002	11	141	870	120	870
COAL HARBOUR - SOUTH SHORE NEAR BAYSHORE HOTEL	E207813	Fecal Coliform	2003	2	22	28	23	
COAL HARBOUR - SOUTH SHORE NEAR BAYSHORE HOTEL	E207813	Fecal Coliform	2009	4	43	230	127	
COAL HARBOUR - SOUTH SHORE NEAR BAYSHORE HOTEL	E207813	Enterococci	2002	11	103	290	84	290
COAL HARBOUR - SOUTH SHORE NEAR BAYSHORE HOTEL	E207813	Enterococci	2003	2	7	9	7	
COAL HARBOUR - SOUTH SHORE NEAR BAYSHORE HOTEL	E207813	Enterococci	2009	4	15	62	32	
VANCOUVER HARBOUR VANCOUVER WHARVES	E207816	Fecal Coliform	2002	14	78	230	115	221

Location Name	Owner Site ID	Indicator	Year	Sample Count	Annual Geometric Mean	Annual Single Sample Maximum	Annual Median	Annual 90th Percentile
VANCOUVER HARBOUR VANCOUVER WHARVES	E207816	Fecal Coliform	2009	4	155	16,000	100	
VANCOUVER HARBOUR VANCOUVER WHARVES	E207816	Enterococci	2002	14	26	94	35	92
VANCOUVER HARBOUR VANCOUVER WHARVES	E207816	Enterococci	2009	4	30	67	38	
VANCOUVER HARBOUR CLARKE DRIVE	E207818	Fecal Coliform	2002	5	112	660	120	
VANCOUVER HARBOUR CLARKE DRIVE	E207818	Enterococci	2002	5	41	290	45	
VANCOUVER HARBOUR LOCH KATRINE BANK	E207819	Fecal Coliform	2002	5	32	330	63	
VANCOUVER HARBOUR LOCH KATRINE BANK	E207819	Enterococci	2002	5	38	260	140	
BURRARD INLET 2ND NARROWS	300078	Fecal Coliform	1973	1	130	130	130	
BURRARD INLET 2ND NARROWS	300078	Fecal Coliform	1974	5	97	350	79	
BURRARD INLET 2ND NARROWS	300078	Fecal Coliform	1975	6	73	790	50	
BURRARD INLET 2ND NARROWS	300078	Fecal Coliform	1976	5	77	240	110	
BURRARD INLET 2ND NARROWS	300078	Fecal Coliform	1977	5	102	920	49	
BURRARD INLET 2ND NARROWS	300078	Fecal Coliform	1978	6	29	540	20	

Key observations include:

- Because there are no overlaps in monitoring sites between data collected in the 1970s and 2000s, it is not possible to compare recent and historic microbiological indicator levels.

Metro Vancouver's Recreational Water Quality Monitoring Program

Table 11 provides a summary of Metro Vancouver's recreational monitoring results for the Inner Harbour.

Table 11: Summary of Metro Vancouver Burrard Inlet Recreational Water Quality Monitoring Results for Microbiological Indicators in the Inner Harbour

Location Name	Indicator	Years	Total No. of Samples	Range of Rolling Geometric Mean Values	No. of Primary Contact Geometric Mean Benchmark Exceedances	Range of Rolling Maximum Values	No. of Primary Contact Maximum Benchmark Exceedances
Brockton Point	*E. coli*	2013 - 2016	375	10 - 431	6	10 – 3,600	2
Brockton Point	Fecal Coliform	1993 - 2012	2186	10 – 4,461	349	10 – 160,000	NA[1]
C R A B Park	*E. coli*	2014 - 2016	180	15 - 117	0	30 – 1,500	0
[1] Not applicable – no primary contact single sample maximum benchmark for fecal coliform							

Key observations include:

- Earlier data in the series from Brockton Point suggests that there are two common periods with data spikes, in the winter from November to February and in the summer from July to September.
- Summer increases in microbiological indicator levels have become increasingly common and discernable in recent years.
- All sample collection locations at Brockton Point including BBR-01-07, which is closest to the Brockton Point CSO, have had frequent primary contact benchmark exceedances since 1993.

3.5.4 Central Harbour

Monitoring Programs

Provincial water quality attainment monitoring, Metro Vancouver's Recreational Water Quality Monitoring Program, and the Canadian Shellfish Sanitation Program all include sampling sites along shoreline areas of the Central Harbour. ENV monitoring sites are focused on areas with some proximity to provincially-authorized discharges or specific sites of importance. There were four monitoring sites where samples were collected in 2002/2003 and/or 2009 (from west to east): (1) Second Narrows at Hooker Chemical on the north shore; (2) Chevron Parkland Refinery on the south shore (3) Shellburn Distribution Terminal on the south shore, and (4) Cates Park/Whey-ah-Wichen on the north shore. The Canadian Shellfish Sanitation Program intermittently monitored 14 sites between Maplewood Flats and Cates Park/Whey-ah-Wichen from 1992 to 2014. Metro Vancouver's Recreational Water Quality Monitoring Program has sampled intermittently at six locations within Cates Park since 1993.

Metro Vancouver's Burrard Inlet Ambient Monitoring Program monitors one site at the centre of the sub-basin.

Due to the shellfish harvesting closure throughout most of Burrard Inlet, there are no currently active shellfish gathering sites in the Central Harbour; however, shellfish were historically gathered across nearly the entire shoreline.

Refer to Appendix D4 for figures illustrating monitoring results in the Central Harbour.

Metro Vancouver's Burrard Inlet Ambient Monitoring Program

Table 12 provides a summary of Metro Vancouver ambient monitoring results for the Central Harbour.

Table 12: Summary of Metro Vancouver Burrard Inlet Ambient Monitoring Results for Microbiological Indicators in the Central Harbour for Samples Collected at the Top of the Water Column

Location Name	Indicator	Years	Total No. of Samples	Range of Annual Geometric Mean Values	No. of Primary Contact Geometric Mean Benchmark Exceedances	Range of Annual Median Values	No. of Shellfish Harvesting Median Benchmark Exceedances	Range of Annual Single Sample Maximum Values	No. of Primary Contact Maximum Benchmark Exceedances
CENTRAL HARBOUR	E. *coli*	2007 – 2016	55	5 – 44	0	2 – 59	8	33 – 170	0
CENTRAL HARBOUR	Enterococci	2007 – 2016	55	10 – 22	0	10 – 20	10	10 – 56	0
CENTRAL HARBOUR	Fecal Coliform	2007 – 2016	55	8 – 63	0	5 – 68	8	34 – 330	NA[1]
[1] Not applicable – no primary contact single sample maximum benchmark for fecal coliform									

Key observations include:

- Microbiological water quality is generally better in the Central Harbour than the Inner Harbour, Outer Harbour, and False Creek with no exceedances of the primary contact recreation benchmark observed.
- There is no discernable temporal pattern in the data.

Provincial WQOs Attainment Monitoring

ENV has monitored microbiological indicators at 4 locations. Table 13 provides a summary of ENV's monitoring results for the Central Harbour.

Table 13: Summary of ENV Provincial Water Quality Attainment Monitoring Results for Microbiological Indicators in the Central Harbour

Location Name	Owner Site ID	Indicator	Year	Sample Count	Annual Geometric Mean	Annual Single Sample Maximum	Annual Median	Annual 90th Percentile
SECOND NARROWS HOOKER CHEMICAL	E207820	Fecal Coliform	2009	2	56	79	60	
SECOND NARROWS HOOKER CHEMICAL	E207820	Enterococci	2009	2	23	40	27	
VANCOUVER HARBOUR SHELLBURN	E207822	Fecal Coliform	2002	8	6	30	13	
VANCOUVER HARBOUR SHELLBURN	E207822	Fecal Coliform	2009	4	6	22	10	
VANCOUVER HARBOUR SHELLBURN	E207822	Enterococci	2002	8	5	14	9	
VANCOUVER HARBOUR SHELLBURN	E207822	Enterococci	2009	4	5	12	9	
SECOND NARROWS CHEVRON	E207821	Fecal Coliform	2009	4	21	330	21	
SECOND NARROWS CHEVRON	E207821	Enterococci	2009	4	10	38	17	
CATES PARK DOCK	E253271	Fecal Coliform	2003	2	3	4	3	
CATES PARK DOCK	E253271	Enterococci	2003	2	2	4	3	

Key observations include:

- There is a general trend of higher fecal coliforms and enterococci in the western portion of the Central Harbour compared to the eastern portion of the Central Harbour.
- There is not enough data in this series to determine temporal trends or patterns, although levels between 2002 to 2009 appear to be stable.

Metro Vancouver's Recreational Water Quality Monitoring Program

Table 14 provides a summary of Metro Vancouver's recreational monitoring results for the Central Harbour.

Table 14: Summary of Metro Vancouver Burrard Inlet Recreational Water Quality Monitoring Results for Microbiological Indicators in the Central Harbour

Location Name	Indicator	Years	Total No. of Samples	Range of Rolling Geometric Mean Values	No. of Primary Contact Geometric Mean Benchmark Exceedances	Range of Rolling Maximum Values	No. of Primary Contact Maximum Benchmark Exceedances
Cates Park	*E. coli*	2013 – 2016	511	10 – 77	0	10 – 720	0
Cates Park	Fecal Coliform	1993 – 2012	1706	10 – 561	80	10 – 16,000	NA[1]
[1] Not applicable – no primary contact single sample maximum benchmark for fecal coliform							

Key observations include:

- Earlier data in the series suggests that there were periods with data spikes in the winter between November to February.
- There is also some evidence of summer spikes in microbiological indicator levels beginning in 2004.

Canadian Shellfish Sanitation Program

The CSSP conducted monitoring for fecal coliforms at 10 locations at Maplewood Flats between 1992 and 2014 and two locations at Cates Park/Whey-ah-Wichen between 2006 and 2008. Monitoring under the CSSP is conducted specifically to determine whether sites are safe for shellfish harvesting. For this reason, CSSP monitoring data has only been compared to the shellfish harvesting benchmarks. Table 15 provides a summary of the CSSP results for the Central Harbour.

Table 15: Summary of CSSP Provincial Monitoring Results for Microbiological Indicators in the Central Harbour

Location Name	Indicator	Year	Total No. of Samples	Annual Geometric Mean	Annual 90th Percentile
Beach W of Cates Park dock	Fecal Coliform	2006	13	24	110
Beach W of Cates Park dock	Fecal Coliform	2007	15	23	79
Beach W of Cates Park dock	Fecal Coliform	2008	2	48	
Maplewood - Lagoon beside PESC parking lot	Fecal Coliform	1997	11	34	140
Maplewood - next to bridge on SW portion of PESC trails	Fecal Coliform	1997	10	15	51.7
Maplewood - off bench at SE portion of PESC trails	Fecal Coliform	1997	23	59	314
Maplewood Flats - off S end of dolphins at Western end of mudflats	Fecal Coliform	2006	13	17	73
Maplewood Flats - off S end of dolphins at Western end of mudflats	Fecal Coliform	2007	4	34	
MAPLEWOOD FLATS EAST-OFF CREEK NEXT TO ISOLATED HOME	Fecal Coliform	1992	4	636	
MAPLEWOOD FLATS EAST-OFF OLD LOGGING PLATFORM	Fecal Coliform	1992	5	80	
MAPLEWOOD FLATS EAST-OFF POINT WEST OF SHIPYARD	Fecal Coliform	1992	5	181	
MAPLEWOOD FLATS EAST-OFF SMALL SHACK BY ROW OF SMALL SHACKS	Fecal Coliform	1992	5	70	
MAPLEWOOD FLATS-BETWEEN 1ST & 2ND PILING LINES	Fecal Coliform	1992	5	124	
MAPLEWOOD FLATS-OFF CEMENT RETAINING WALL WITH CULVERT	Fecal Coliform	1992	5	110	
MAPLEWOOD FLATS-OFF CEMENT RETAINING WALL WITH CULVERT	Fecal Coliform	2006	12	116	863
MAPLEWOOD FLATS-OFF CEMENT RETAINING WALL WITH CULVERT	Fecal Coliform	2007	15	32	196
MAPLEWOOD FLATS-OFF CEMENT RETAINING WALL WITH CULVERT	Fecal Coliform	2008	15	17	94
MAPLEWOOD FLATS-OFF CEMENT RETAINING WALL WITH CULVERT	Fecal Coliform	2009	6	48	
MAPLEWOOD FLATS-OFF CEMENT RETAINING WALL WITH CULVERT	Fecal Coliform	2010	6	62	
MAPLEWOOD FLATS-OFF CEMENT RETAINING WALL WITH CULVERT	Fecal Coliform	2011	5	74	
MAPLEWOOD FLATS-OFF CEMENT RETAINING WALL WITH CULVERT	Fecal Coliform	2012	5	33	
MAPLEWOOD FLATS-OFF CEMENT RETAINING WALL WITH CULVERT	Fecal Coliform	2013	5	22	
MAPLEWOOD FLATS-OFF CEMENT RETAINING WALL WITH CULVERT	Fecal Coliform	2014	2	80	
MAPLEWOOD FLATS-OFF CEMETARY POINT OFF CREEK	Fecal Coliform	1992	5	164	
MAPLEWOOD FLATS-OUTSIDE OUTERMOST PILING LINE	Fecal Coliform	1992	5	78	
MAPLEWOOD FLATS-OUTSIDE OUTERMOST PILING LINE	Fecal Coliform	2006	13	16	126
MAPLEWOOD FLATS-OUTSIDE OUTERMOST PILING LINE	Fecal Coliform	2007	15	15	79
MAPLEWOOD FLATS-OUTSIDE OUTERMOST PILING LINE	Fecal Coliform	2008	2	75	

Key observations include:

- There is no clear evidence of an increasing or decreasing trend from west to east or between 1992 to 2014. However, data collection has been inconsistent under the CSSP.
- The monitoring program around Maplewood Flats was abandoned in 2014 due to the high number of exceedances of the microbiological indicator levels required for shellfish harvesting.

3.5.5 Port Moody Arm

Monitoring Programs

Ambient water quality monitoring for microbiological indicators in Port Moody Arm has included two sites monitored under Metro Vancouver's Burrard Inlet Ambient Monitoring Program and two sites monitored periodically as part of provincial WQOs attainment monitoring. One of Metro Vancouver's sites is located near the outlet of Port Moody Arm while the other Metro Vancouver site and the two ENV sites are located closer to Rocky Point Park. Metro Vancouver has monitored Outer Port Moody Arm since 2007 while Inner Port Moody Arm was only monitored in 2008. ENV has collected historical samples in Inner Port Moody Arm dating back to 1973.

Some provincial WQOs attainment monitoring sites and Metro Vancouver's Recreational Water Quality Monitoring Program cover shoreline areas around Port Moody Arm. ENV collected samples from Barnet Marine Park, IOCO between Carraholly and Pleasantside, and Rocky Point Park in 2002 and at IOCO between Carraholly and Pleasantside in 2009. Metro Vancouver monitors three recreational beach sites in Port Moody Arm: Barnet Marine Park (3 locations); Rocky Point Park (3 locations); and Old Orchard (2 locations).

Port Moody Arm has not been monitored under the Canadian Shellfish Sanitation Program and there are no active shellfish gathering sites in this part of the inlet; however, shellfish were historically gathered off the shores of most of Port Moody Arm.

Refer to Appendix D5 for figures illustrating monitoring results in Port Moody Arm.

Metro Vancouver's Burrard Inlet Ambient Monitoring Program

Metro Vancouver has monitored microbiological indicators at two ambient locations in Port Moody Arm. Table 16 provides a summary of Metro Vancouver ambient monitoring results for Port Moody Arm.

Table 16: Summary of Metro Vancouver Burrard Inlet Ambient Monitoring Results for Microbiological Indicators in Port Moody Arm for Samples Collected at the Top of the Water Column

Location Name	Indicator	Years	Total No. of Samples	Range of Annual Geometric Mean Values	No. of Primary Contact Geometric Mean Benchmark Exceedances	Range of Annual Median Values	No. of Shellfish Harvesting Median Benchmark Exceedances	Range of Annual Single Sample Maximum Values	No. of Primary Contact Maximum Benchmark Exceedances
INNER PORT MOODY ARM	*E. coli*	2008	5	30	0	20	1	68 – 68	0
INNER PORT MOODY ARM	Enterococci	2008	5	13	0	20	1	41 – 41	0
INNER PORT MOODY ARM	Fecal Coliform	2008	5	30	0	20	1	68 – 68	NA[1]
PORT MOODY ARM	*E. coli*	2007 – 2016	55	10 – 53	0	7 – 45	8	20 – 100	0
PORT MOODY ARM	Enterococci	2007 – 2016	55	10 – 28	0	10 – 30	10	10 – 80	2
PORT MOODY ARM	Fecal Coliform	2007 – 2016	55	12 – 61	0	7 – 59	9	20 – 100	NA

[1] Not applicable – no primary contact single sample maximum benchmark for fecal coliform

Key observations include:

- There appears to be a pattern of increasing levels of *E. coli* and enterococci at the Outer Port Moody Arm monitoring site since 2013.

Provincial WQOs Attainment Monitoring

ENV has monitored microbiological indicators at 3 locations. Table 17 provides a summary of ENV's monitoring results for Port Moody Arm.

Table 17: Summary of ENV Provincial Water Quality Attainment Monitoring Results for Microbiological Indicators in Port Moody Arm

Location Name	Owner Site ID	Indicator	Year	Sample Count	Annual Geometric Mean	Annual Single Sample Maximum	Annual Median	Annual 90th Percentile
BURRARD INLET	300079	Fecal Coliform	1973	1	2	2	2	
BURRARD INLET	300079	Fecal Coliform	1974	5	11	23	20	
BURRARD INLET	300079	Fecal Coliform	1975	6	29	80	20	
BURRARD INLET	300079	Fecal Coliform	1976	5	14	33	20	
BURRARD INLET	300079	Fecal Coliform	1977	5	5	23	5	
BURRARD INLET	300079	Fecal Coliform	1978	6	29	1,600	20	
PORT MOODY IOCO	E207823	Fecal Coliform	2002	5	18	160	13	
PORT MOODY IOCO	E207823	Enterococci	2002	5	9	210	5	
PACIFIC COAST # 11 75 METERS NORTHEAST	E207698	Fecal Coliform	2002	10	23	180	17	180
PACIFIC COAST # 11 75 METERS NORTHEAST	E207698	Fecal Coliform	2009	4	11	79	13	
PACIFIC COAST # 11 75 METERS NORTHEAST	E207698	Enterococci	2002	10	24	190	12	190
PACIFIC COAST # 11 75 METERS NORTHEAST	E207698	Enterococci	2009	4	9	64	8	

Key observations include:

- The lowest fecal coliform and enterococci levels were measured at the western side of Port Moody Arm while microbiological indicator levels increase as the sites progress east. This suggests there is some evidence of a spatial trend of increasing microbiological levels from west to east.

Metro Vancouver's Recreational Water Quality Monitoring Program

Table 18 provides a summary of Metro Vancouver's recreational monitoring results for Port Moody Arm.

Table 18: Summary of Metro Vancouver Burrard Inlet Recreational Water Quality Monitoring Results for Microbiological Indicators in Port Moody Arm

Location Name	Indicator	Years	Total No. of Samples	Range of Rolling Geometric Mean Values	No. of Primary Contact Geometric Mean Benchmark Exceedances	Range of Rolling Maximum Values	No. of Primary Contact Maximum Benchmark Exceedances
Barnet Marine Park	*E. coli*	2013 – 2016	340	10 - 253	3	10 – 2,400	0
Barnet Marine Park	Fecal Coliform	1993 – 2012	707	10 - 498	32	10 – 16,000	NA[1]
Old Orchard	*E. coli*	2013 – 2016	246	10 - 251	3	10 – 7,500	0
Old Orchard	Fecal Coliform	2004 – 2012	403	10 - 256	5	10 – 3,500	NA
Rocky Point Park	E. *coli*	2013 – 2014	58	10 - 740	6	10 – 13,000	5
Rocky Point Park	Fecal Coliform	2009 – 2012	122	15 - 369	3	30 – 1,100	NA

[1] Not applicable – no primary contact single sample maximum benchmark for fecal coliform

Key observations include:

- There appear to be consistent results in a specific year across the different monitoring sites. For example, there were elevated levels at all sites in 2014.
- In general, levels of microbiological indicators tended to increase during the summer.

3.5.6 Indian Arm

Monitoring Programs

Ambient water quality monitoring for microbiological indicators in Indian Arm consists of two sites monitored under Metro Vancouver's Burrard Inlet Ambient Monitoring Program and two sites monitored as part of provincial WQOs attainment monitoring. Metro Vancouver has one station at the north end of Indian Arm and one station to the south close to the boundary with the Central Harbour. Samples have been collected at these sites since 2007. ENV has monitored one monitoring site at Bedwell Bay and one site that is close to Metro Vancouver's southern Indian Arm site. ENV collected samples from Bedwell Bay in 2003 and 2009 and at the south Indian Arm site from 1973 to 1978, in 1991, and in 2002.

Metro Vancouver's Recreational Water Quality Monitoring Program, provincial WQOs attainment monitoring, and the Canadian Shellfish Sanitation Program cover shoreline areas around Indian Arm. Metro Vancouver's monitoring is focused on beach and park areas where recreation is most popular. Metro Vancouver has collected samples from Deep Cove at four locations since 1993, from Bedwell Bay at two locations since 2004, and at Belcarra Park at two locations since 2004. ENV collected samples from Deep Cove in 2003 and 2009. Shoreline sampling by the Canadian Shellfish Sanitation Program is focused on areas where shellfish are harvested and on areas where shellfish may one day be harvested again. Starting at Deep Cove and moving counterclockwise, CSSP collects samples from:

- Deep Cove (5 locations);
- Belcarra (10 locations);
- Bedwell Bay (2 locations);
- Jug Island (1 location);
- Twin Island (1 location);
- Buntzen Bay (1 location);
- Johnson Bay (1 location);
- South Croker Island (1 location);
- Iron Bay (1 location);
- Indian River Estuary (2 locations);
- Bishop Creek (2 locations);
- Coldwell Beach (1 location);
- Orlomah Beach (1 location); and
- Brighton Beach (1 location).

Indian Arm supports a small annual shellfish harvest for food, social, and ceremonial (FSC) purposes by Tsleil-Waututh Nation (TWN).

Refer to Appendix D6 for figures illustrating monitoring results in Indian Arm.

Metro Vancouver's Burrard Inlet Ambient Monitoring Program

Metro Vancouver has monitored microbiological indicators at two ambient locations in Indian Arm. Table 19 provides a summary of Metro Vancouver ambient monitoring results for Indian Arm.

Table 19: Summary of Metro Vancouver Burrard Inlet Ambient Monitoring Results for Microbiological Indicators in Indian Arm for Samples Collected at the Top of the Water Column

Location Name	Indicator	Years	Total No. of Samples	Range of Annual Geometric Mean Values	No. of Primary Contact Geometric Mean Benchmark Exceedances	Range of Annual Median Values	No. of Shellfish Harvesting Median Benchmark Exceedances	Range of Annual Single Sample Maximum Values	No. of Primary Contact Maximum Benchmark Exceedances
INDIAN ARM NORTH	*E. coli*	2007 – 2016	55	2 – 24	0	2 – 20	4	2 – 33	0
INDIAN ARM NORTH	Enterococci	2007 – 2016	55	6 – 11	0	10	10	10 – 20	0
INDIAN ARM NORTH	Fecal Coliform	2007 – 2016	55	2 – 24	0	2 – 20	4	2 – 33	NA[1]
INDIAN ARM SOUTH	*E. coli*	2007 – 2016	55	3 – 29	0	2 – 20	4	17 – 59	0
INDIAN ARM SOUTH	Enterococci	2007 – 2016	55	6 – 14	0	9 – 10	10	10 – 41	0
INDIAN ARM SOUTH	Fecal Coliform	2007 – 2016	55	3 – 35	0	2 – 40	5	19 – 73	NA

[1] Not applicable – no primary contact single sample maximum benchmark for fecal coliform

Key observations include:

- No exceedances of the primary contact benchmarks were identified. However, frequent exceedances of the shellfish harvesting benchmark were identified.

Provincial WQOs Attainment Monitoring

ENV has monitored microbiological indicators at three locations. Table 20 provides a summary of ENV's monitoring results for Indian Arm.

Table 20: Summary of ENV Provincial Water Quality Attainment Monitoring Results for Microbiological Indicators in Indian Arm

Location Name	Owner Site ID	Indicator	Year	Sample Count	Annual Geometric Mean	Annual Single Sample Maximum	Annual Median	Annual 90th Percentile
INDIAN ARM	300080	Fecal Coliform	1973	2	3	5	4	
INDIAN ARM	300080	Fecal Coliform	1974	5	3	13	2	
INDIAN ARM	300080	Fecal Coliform	1975	7	40	2,400	20	
INDIAN ARM	300080	Fecal Coliform	1976	5	13	23	20	
INDIAN ARM	300080	Fecal Coliform	1977	5	5	23	2	
INDIAN ARM	300080	Fecal Coliform	1978	6	3	23	2	
INDIAN ARM AT CABLE CROSSING	300080	Fecal Coliform	1991	1	7	7	7	
INDIAN ARM AT CABLE CROSSING	300080	Fecal Coliform	2002	10	4	34	2	34
INDIAN ARM AT CABLE CROSSING	300080	Enterococci	2002	10	3	18	2	18

Key observations include:

- The screening benchmarks were met in all cases for both fecal coliforms and enterococci except for one outlier in 1976 when a maximum fecal coliform level of 2400 MPN/100 mL was recorded at the south monitoring station.

- There is not enough data to determine whether microbiological indicator levels have increased or decreased over time, though recent results are below the benchmarks used for this assessment.

Metro Vancouver's Recreational Water Quality Monitoring Program

Table 21 provides a summary of Metro Vancouver's recreational monitoring results for Indian Arm.

Table 21: Summary of Metro Vancouver Burrard Inlet Recreational Water Quality Monitoring Results for Microbiological Indicators in Port Moody Arm

Location Name	Indicator	Years	Total No. of Samples	Range of Rolling Geometric Mean Values	No. of Primary Contact Geometric Mean Benchmark Exceedances	Range of Rolling Maximum Values	No. of Primary Contact Maximum Benchmark Exceedances
Bedwell Bay	*E. coli*	2013 – 2016	240	10 – 199	0	10 – 2,300	0
Bedwell Bay	Fecal Coliform	2004 – 2012	476	10 – 64	0	10 – 1,100	NA[1]
Belcarra Park	*E. coli*	2013 – 2016	238	10 – 62	0	10 – 1,400	0
Belcarra Park	Fecal Coliform	2004 – 2012	476	10 – 133	0	10 – 2,400	NA
Deep Cove	*E. coli*	2013 – 2016	444	10 – 202	3	10 – 4,500	0
Deep Cove	Fecal Coliform	1993 – 2012	3130	10 – 905	440	10 – 16,000	NA

[1] Not applicable – no primary contact single sample maximum benchmark for fecal coliform

Key observations include:

- Weekly sampling was performed from January to December from 1993 to 2004 and from May to September after 2004. Earlier data in the series suggests that there are common data spikes in the summer and sometimes in the winter though there is not a clear seasonal pattern.
- Of all the sampling sites in Indian Arm, mean fecal coliform and *E. coli* levels are the highest in Deep Cove. Seasonally, there is some evidence that *E. coli* levels are higher in the summer at present than in past summers.
- Rolling 30 day maximum summer microbiological indicator levels at Belcarra Park have been trending higher every year since 2012.
- Generally, microbiological water quality improves from west to east at the south end of Indian Arm.

Canadian Shellfish Sanitation Program

Because of concerted effort by the TWN and ECCC to reopen a portion of Indian Arm for shellfish harvesting, a large amount of monitoring for fecal coliforms has been conducted in Indian Arm. Monitoring under the CSSP is conducted specifically to determine whether sites are safe for shellfish harvesting. For this reason, CSSP monitoring data has only been compared to the shellfish harvesting benchmarks. CSSP has conducted monitoring at numerous locations as described under the monitoring programs section for Indian Arm. More recent data are summarized here, with details on these, as well as summaries of older and more limited data, provided in Appendix C.

Table 22 provides a summary of the range of median and 90th percentile values for the last three years of available data for each monitoring site. Five samples were not collected over 30-day periods for all sites, and some years and sites have had more sampling efforts than others.

Table 22: Summary of CSSP Monitoring Results for Indian Arm (details in Appendix C)

Location Name	3 Latest Monitoring Years	Range of Median Values	Range of 90th Percentile Values
Beach NE of Roche Pt at Cates Park	2006 – 2008	8 – 57	62 – 114
Indian Arm – Boulder Island – Beach on NE side	2012 – 2014	2 – 8	
Beach S of Belcarra Dock	2006 – 2008	11 – 27	43 – 146
Head of Bedwell Bay	2012 – 2014	2 – 5	
Bedwell Bay – on E side, S of last house	2012 – 2014	2 – 4	
Beach inside Jug Is	2012 – 2014	2 - 5	
Indian Arm – Brighton Beach – off creekmouth in front of brown house with a bridge	2015 – 2017	2 – 21	
Beach at Twin Islands b/w islets	2012 – 2014	2 – 13	
Indian Arm – Orlomah Beach – North of Shone Creek	2015 – 2017	2 – 7	
Beach S of Wigwam Inn	2015 – 2017	5 – 9	
Indian River Estuary – West side	2015 – 2017	8 – 13	
Indian Arm – Coldwell Beach – off creek mouth S of Lou's Landing dock, in front of brown house tucked behind trees with solar panel	2015 – 2017	2 – 5	
Indian River Estuary – East Side	2015 – 2017	2 – 13	
Bishop Creek – beach at SW end	2015 – 2017	2 – 9	
Bishop Creek – beach at N end S of breakwater	2015 – 2017	2 – 3.5	
Indian Arm – Buntzen Bay – at beach between two large docks	2015 – 2017	2 – 11	
Indian Arm – Southern tip of Croker Island	2015 – 2017	2	
Indian Arm – Granite Falls – South side at beach east of navigational light	2015 – 2017	2 – 17	
Indian Arm – Johnson Bay – off creekmouth S of brown house with white trim	2015 – 2017	2 – 4	

Key observations include:

- In southwest Indian Arm, Cates Park/Whey-ah-wichen, Deep Cove, and Belcarra Park have higher microbiological indicator levels than nearby Boulder Island.
- The southwest side of Indian Arm has lower microbiological indicator levels than the southeast side of Indian Arm.
- The north end of Indian Arm has lower microbiological indicator levels than the south end of Indian Arm, with the exception of the northernmost section near the Indian River.
- In the northernmost section of Indian Arm, fecal coliform levels frequently exceed shellfish harvesting benchmarks.
- Fecal coliform levels measured at Brighton Beach exceeded shellfish harvest benchmarks in two of the four monitoring years whereas samples collected from Orlamah Beach and Coldwell Beach met benchmarks in all years.
- The north middle section of Indian Arm is the only area that consistently meets benchmarks for shellfish harvesting. Fecal coliform levels met shellfish harvesting benchmarks in all instances near Bishop Creek, Iron Bay, and South Croker Island.
- Fecal coliform levels are too low and sampling is generally too inconsistent to establish temporal patterns.

3.6 Key Findings

The following points summarize the key findings for the observations made for microbiological indicator levels across all sub-basins of Burrard Inlet from the early 1970s to present:

- Among the sub-basins of Burrard Inlet, False Creek consistently has the highest levels of microbiological indicators. Levels are highest in the eastern portion of False Creek where they are consistently above primary contact benchmarks, usually during the summer months. Levels decline towards the western end of False Creek.
- Outside of False Creek, exceedances of primary contact and/or shellfish harvest benchmarks occur at times but tend to be localized and tied to specific sites. Exceedances are commonly associated with the locations of potential pollution sources, although specific cause-and-effect relationships have not been confirmed. Areas with frequent exceedances of primary contact benchmarks include Jericho Beach near the Balaclava CSO, Ambleside, Dundarave, Eagle Harbour near the mouth of Eagle Creek, Inner Brockton Point near the Brockton CSO, Deep Cove near the marina, and the Indian River estuary at the mouth of the Indian River.
- Swimming beaches near CSOs and emergency SSOs have higher rates of primary contact benchmark exceedances. Monitoring sites near the CSOs or SSOs at Jericho Beach, Central False Creek, East False Creek, and Clark Drive showed higher microbiological indicator levels and have had increases in the last five years, compared to sites in the same areas but farther from the CSOs. There is some concern of dry weather overflows from both the CSOs and emergency SSOs and the impact this can have on recreational and cultural values during the summer months.
- In general, Indian Arm and Port Moody Arm have better microbiological water quality than other sub-basins.
- Throughout Burrard Inlet, at some monitoring stations prior to 2005, water quality at swimming beaches appeared to have been above primary contact benchmarks more frequently during the summer than during the rest of the year. There is a lack of recent data on seasonal changes in microbiological indicator levels as no monitoring program has sampled on a year-round basis since 2005. An example of this observation is illustrated in Figure 2 showing the rolling geometric mean of the Metro Vancouver Recreational Water Quality Monitoring fecal coliform observations for Deep Cove in Indian Arm plotted alongside the primary contact recreation benchmark (200 MPN of CFU/100 mL).

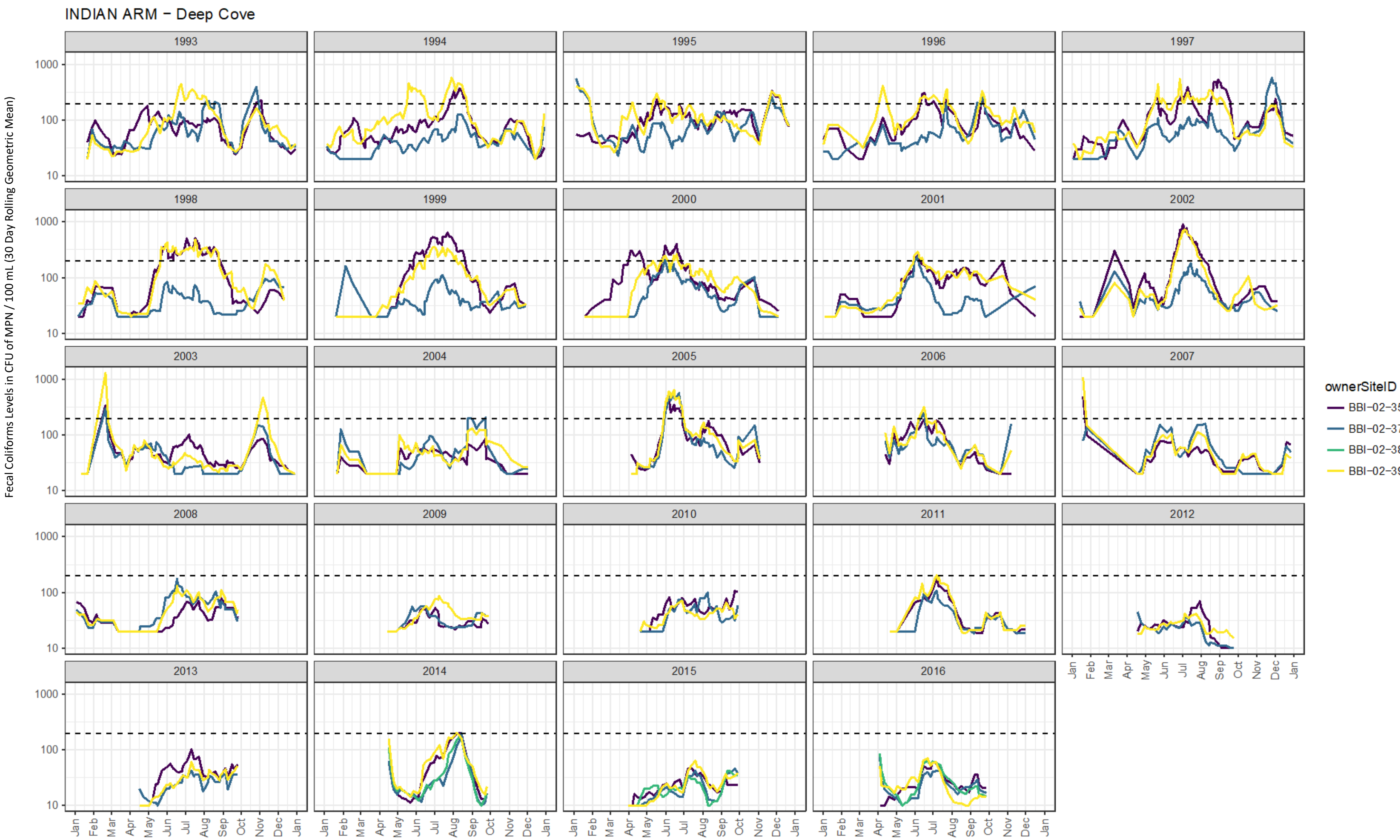

Figure 2. Metro Vancouver Recreational Water Quality Monitoring Data 30 Day Rolling Geometric Mean for Fecal Coliforms at the Four Deep Cove Monitoring Stations in Indian Arm Showing Frequent Exceedances of the Benchmark (dashed line) Occur in the Summer Season Prior to 2005

3.7 Knowledge Gaps and Research Needs

Knowledge gaps and research needs that were identified during the data assessment are detailed below, in decreasing order of priority. It is acknowledged that filling these gaps would be resource intensive and difficult to accomplish. Knowledge gaps and research needs in Burrard Inlet include:

- There is little information on the relative contributions of specific sources of microbiological pollution. For example, CSOs, discharges from boats, and stormwater runoff all contribute pathogens to False Creek, but the relative contributions from each of these sources is not well known. In addition to monitoring of ambient concentrations of microbiological indicator levels, increased monitoring of sources, including the timing, duration, and volumes of discharges, is needed. A microbial source tracking program has been initiated in and around False Creek, involving the BC Centre for Disease Control, Vancouver Coastal Health, Metro Vancouver, Edgewater Research & Consulting and the City of Vancouver. This information can help in setting and acting on priorities for remediation.
- Since 2014, there has been little to no monitoring of swimming beaches during the fall and winter months (October to March). Also, many programs only sample a small number of times per year, often within the 30-day period. The lack of regular, year-round monitoring limits our understanding of seasonality, responses to rainfall, discharges, and other patterns and remediation priorities.
- Health Canada (2012) recommends enterococci as the preferred indicator for recreational water quality monitoring in marine waters; however, there has been relatively little enterococci monitoring data collected for Burrard Inlet. As a result, it is difficult to assess the suitability of enterococci as an indicator against some of the indicators currently in use.
- There is a lack of data on actual pathogen levels in shellfish tissue. With shellfish ingestion being a risk exposure pathway, a mechanism to trigger comprehensive sampling in high risk areas or direct tissue or food sampling could be helpful.
- Where multiple depths in the water column are monitored, microbiological pollution appears to be consistently higher at depth than at the surface. A thorough assessment of differences between the upper and lower fractions of the water column in each sub-basin would require more detailed analysis of the data than was possible within the scope of this report.

4. PROPOSED OBJECTIVES FOR MICROBIOLOGICAL INDICATORS IN BURRARD INLET

4.1 Proposed Objectives

Proposed short-term, medium-term, and long-term WQOs for microbiological indicators for Burrard Inlet are presented in Table 23, Table 24, and Table 25. WQOs were derived from current health guidelines (CFIA 2020; ENV 2001, 2019; Health Canada 2012), and reflect aspirational goals for Burrard Inlet as outlined in Rao et al. (2019), combined with the likely availability of management options over time. The aspirational goals were adapted from TWN’s Burrard Inlet Action Plan (KWL 2017) through discussions with the multi-sector Burrard Inlet Water Quality Roundtable. They include the following of particular relevance to microbiological indicators:

- *Healthy, wild shellfish can be harvested safely by present and future generations*
- *Water and sediment are safe and clean for cultural, spiritual, and recreational activities*

Changes from the 1990 objectives include:

- Reducing the short-term objective for Indian Arm in order to protect and potentially expand the existing shellfish harvesting in this sub-basin;

- Adding short-term *E. coli* objectives, including objectives for 30-day geometric means and single sample maximums, for sub-basins where primary contact (for cultural or recreational activities) is currently the most sensitive water use (i.e., all sub-basins of Burrard Inlet except Indian Arm);
- Adding a short-term objective for False Creek to protect secondary contact activities;
- Incorporating medium-term objectives to achieve microbiological water quality suitable for shellfish harvesting in the Outer Harbour, Central Harbour, and Port Moody Arm and primary contact activities in the Inner Harbour and False Creek; and
- Incorporating a long-term goal to achieve microbiological water quality suitable for shellfish harvesting in all sub-basins.

Table 23: Proposed WQOs for Microbiological Indicators – Short-term (2020-2025)

Parameter	Value	Sub-basin					
		False Creek	**Outer Harbour**	**Inner Harbour**	**Central Harbour**	**Port Moody Arm**	**Indian Arm**
Fecal coliform	*Shellfish consumption*	Not applicable					14 median and not more than 10% of samples > 43[7]
E. coli	*Recreation and cultural practices*	1000 geometric mean[1,4]	200 geometric mean[1,5] 400 max[3,5]				
Enterococci	*Shellfish consumption*	Not applicable					4 median[1] 11 90th percentile[2,6]
	Recreation and cultural practices	175 geometric mean[1]	35 geometric mean[1,5] 70 max[3,5]				

All units are bacteria/100 mL in CFU or MPN
[1]Using at least 5 weekly samples collected in a 30-day period
[2]Maximum allowable concentration for 90% of results within a sampling period. Sampling periods require a minimum of 10 results.
[3]Single sample allowable concentration
[4]Intended to protect secondary contact activities only; from Health Canada (2012)
[5]Intended to protect both primary and secondary contact activities; from ENV (2019)
[6]From ENV (2001)
[7]For a five-tube decimal dilution test. From CFIA (2020)

Table 24: Proposed WQOs for Microbiological Indicators – Medium-term (2025-2050)

Parameter	Value	Sub-basin					
		False Creek	**Outer Harbour**	**Inner Harbour**	**Central Harbour**	**Port Moody Arm**	**Indian Arm**
Fecal coliform	*Shellfish consumption*	Not applicable	14 median and not more than 10% of samples > 43[7]	Not applicable	14 median and not more than 10% of samples > 43[7]		
E. coli	*Recreation and cultural practices*	200 geometric mean[1,5] 400 max[3,5]					
Enterococci	*Shellfish consumption*	Not applicable	4 median[1] 11 90th percentile[2,6]	Not applicable	4 median[1] 11 90th percentile[2,6]		
	Recreation and cultural practices	35 geometric mean[1,5] 70 max[3,5]					

All units are bacteria/100 mL in CFU or MPN
[1]Using at least 5 weekly samples collected in a 30-day period
[2]Maximum allowable concentration for 90% of results within a sampling period. Sampling periods require a minimum of 10 results.
[3]Single sample allowable concentration
[4]Intended to protect secondary contact activities only; from Health Canada (2012)
[5]Intended to protect both primary and secondary contact activities; from ENV (2019)
[6]From ENV (2001)
[7]For a five-tube decimal dilution test. From CFIA (2020)

Table 25: Proposed WQOs for Microbiological Indicators – Long-term (2050 onwards)

Parameter	Value	Sub-basin					
		False Creek	**Outer Harbour**	**Inner Harbour**	**Central Harbour**	**Port Moody Arm**	**Indian Arm**
Fecal coliform	*Shellfish consumption*	14 median and not more than 10% of samples > 43[6]					
E. coli	*Recreation and cultural practices*	200 geometric mean[1,4] 400 max[3,4]					
Enterococci	*Shellfish consumption*	4 median[1] 11 90th percentile[2,5]					
	Recreation and cultural practices	35 geometric mean[1,4] 70 max[3,5]					

All units are bacteria/100 mL in CFU or MPN
[1]Using at least 5 weekly samples collected in a 30-day period
[2]Maximum allowable concentration for 90% of results within a sampling period. Sampling periods require a minimum of 10 results.
[3]Single sample allowable concentration
[4]Intended to protect both primary and secondary contact activities; from ENV (2019)
[5]From ENV (2001)
[6]For a five-tube decimal dilution test. From CFIA (2020)

4.2 Rationale

The 1990 provisional objectives for microbiological indicator levels in Burrard Inlet do not reflect the most recent scientific consensus. Proposed updates reflect more recent changes to sampling of *E. coli* over fecal coliforms, the latest study consensus on safe enterococci levels, and consideration of shellfish harvesting as a value in Burrard Inlet, particularly for Tsleil-Waututh Nation.

Updated WQOs for microbiological indicators are proposed to reflect current B.C. and Health Canada guidelines for recreational water quality (ENV 2019, Health Canada 2012), and B.C. and Canadian Shellfish Sanitation Program guidelines for shellfish consumption (ENV 2001, CFIA 2020). Updated CSSP guidelines for fecal coliforms are proposed as objectives; these had not been used in the data assessment, as they became available after the data assessment had been completed. Resources were insufficient to enable the data assessment to be redone; however, the two benchmarks are similar enough that the assessment results are also expected to be similar.

The proposed objectives apply year-round to protect shellfish harvesting, other cultural practices and recreational use. While previous objectives applied only during the summer recreation season from May through September (Nijman and Swain, 1990), there has been a shift in attitudes and use since this time. Protecting values throughout the year will produce a wide host of economic, environmental, and social benefits. The appropriate ambient WQOs for each indicator and each use are presented in Table 2. WQOs are proposed for short-term, medium-term and long-term time frames in consideration of current impacts and uses, anticipated availability of management options, as well as Tsleil-Waututh Nation's recovery goals.

The data assessment revealed that current microbiological indicator levels in all sub-basins except for Indian Arm are frequently and significantly above benchmarks that would protect shellfish harvesting. For example, in False Creek, calculated annual median levels for fecal coliforms have exceeded the shellfish harvesting median benchmark under every monitoring program and at every location for 100% of the years with available data. This indicates that extensive changes to water quality management will be needed before all sub-basins would frequently meet TWN's aspirational goals for shellfish harvesting in Burrard Inlet.

The data assessment also revealed that primary contact benchmarks are achieved more often than not in all sub-basins. False Creek is an exception with large fluctuations in microbiological indicator levels and exceedances of the primary contact benchmarks in most years and most monitoring locations. For this reason, a phased approach was developed with short-term objectives proposed to be protective of secondary contact only for False Creek.

The proposed short-term objectives aim to achieve microbiological indicator levels suitable for primary contact in all sub-basins except for False Creek where short-term objectives are proposed to achieve microbiological indicator levels suitable for secondary contact. In Indian Arm, the proposed short-term objective aims to protect the FSC shellfish harvest already occurring in a portion of this sub-basin and to possibly expand areas in Indian Arm available for harvest. This proposed objective also recognizes that Indian Arm could potentially be used to depurate bivalve shellfish harvested in other sub-basins prior to consumption. Revising the short-term objective upwards for False Creek recognizes that the current condition of False Creek falls well short of achieving water quality conditions suitable for primary contact and that the current management objective of the City of Vancouver and Vancouver Coastal Health is to protect non-immersive uses.

The proposed medium-term objectives aim to achieve water quality suitable for shellfish harvesting in four of the six sub-basins—the Outer Harbour, Central Harbour, Port Moody Arm, and Indian Arm—and for primary contact activities in False Creek and the Inner Harbour. The split of sub-basins for the medium-term objectives was informed by the range of microbiological indicator levels measured, the extent of shellfish harvesting benchmark exceedances that were observed since 2007, and the frequency of microbiological indicator levels that are an order of magnitude or more above the shellfish harvesting benchmarks.

The proposed long-term objectives are based on a long-term recovery goal to reopen shellfish harvesting in all sub-basins of Burrard Inlet, which is aspirational in nature. Any future expansion of shellfish harvesting areas will be dependent on the success of measures taken to reduce microbiological pollution. The data assessment showed that benchmark exceedances occur more frequently in the winter when the region receives the most rainfall (see appended figures and detailed monitoring assessment). This suggests that timelines for CSO elimination and wet weather planning will be a key component for achieving desired water quality improvements. The timeline for meeting the long-term WQOs was set to align with Metro Vancouver's commitment to eliminate CSOs by 2050.

Proposed objectives are included for fecal coliforms, *E. coli*, and enterococci. The addition of *E. coli* as an indicator recognizes that *E. coli* was selected as the preferred indicator by Metro Vancouver and health authorities for recreational water quality monitoring. However, enterococci has also been retained as it is the indicator recommended by both ENV and Health Canada for marine waters. A proposed objective for fecal coliform has also been retained as a "legacy objective" and because of its continued use in some jurisdictions and monitoring programs, including the Canadian Shellfish Sanitation Program.

The proposed objectives are set for the water column only. Objectives for sediment are not typically set for microbiological indicators and objectives for tissue, while they could be adopted in the future, are not proposed for use at present because of a lack of widely accepted guidelines, although CFIA has export guidelines for *E. coli* in tissue.

Note that these proposed WQOs are set for the ambient environment only and attainment of these objectives alone may not be sufficient to protect human health. Decisions on swimming and shellfish harvesting openings and closures are made by the relevant health authorities and the Canadian Shellfish Sanitation Program, respectively, considering microbiological indicator monitoring results, other potential pollutants, information on pollution sources, and other factors.

Pathogenic risk assessments may require additional monitoring beyond the microbiological indicators outlined in these WQOs; however, the proposed WQOs consider the best available science and data for health outcomes and provide a relevant measure of microbiological water quality for the marine environment and designated values in Burrard Inlet.

5. MONITORING RECOMMENDATIONS

Monitoring recommendations are made to help in refining the existing monitoring programs and to inform future assessments to determine whether the WQOs for microbiological indicators are being met. Monitoring data contribute to prioritizing source control efforts and mitigation, and tracking improvements over time. The following recommendations are made regarding the future monitoring of microbiological indicators in Burrard Inlet:

- Consider adopting both *E. coli* and enterococci as preferred indicators for ambient and recreational water quality monitoring and sample for both indicators wherever possible. Once several years of simultaneous monitoring has occurred using both indicators, use these data to re-visit which is the preferred indicator for Burrard Inlet.
- Carry out more detailed sampling when elevated counts are detected to establish the applicability of indicator organisms.
- Continue to use fecal coliforms as the preferred indicator for monitoring of shellfish harvesting areas because of its long-term use by the Canadian Shellfish Sanitation Program and use in current regulations. Monitor enterococci simultaneously to establish a basis for comparison of these indicators where resources allow.

- Carry out shellfish tissue sampling from current FSC harvesting locations with co-located water column samples for microbial indicators.
- Expand microbial source monitoring programs, including monitoring microbial parameters potentially found in stormwater, and integrate with local government work related to Integrated Stormwater Management Plans (ISMPs).
- Evaluate whether it may be beneficial to combine monitoring by Metro Vancouver, the Canadian Shellfish Sanitation Program, the provincial government and municipalities into a single, integrated program in order to increase efficiency and reduce duplication of effort.
- Establish or adopt Standard Operating Procedures to ensure that all agencies are collecting samples similarly (e.g. with respect to depth, distance from shoreline, distance from discharge points)
- Consider re-establishing year-round ambient water quality monitoring of microbiological indicators under Metro Vancouver's monitoring program on at least a monthly basis.
- Ensure all monitoring data becomes open data and is made available to First Nations, regulatory agencies, municipalities, and the public on timely basis.
- Improve the public availability of monitoring results using near real-time and web-based reporting tools. This is especially relevant for monitoring of CSOs which could impact recreational or cultural use areas. Expand CSO real-time alerts for all CSOs.
- Investigate the causes of dry weather overflows from CSOs and emergency SSOs.
- Restart the Maplewood Flats monitoring program once measures are taken to address microbiological pollution sources.

6. MANAGEMENT OPTIONS

Attainment of the proposed objectives within the specified timeframes is expected to be challenging, and will require concerted action among the various jurisdictions responsible for water quality management in the Inlet. The following initiatives are planned or underway that will have benefits to microbiological water quality in Burrard Inlet:

- Upgrading the Lions Gate WWTP from primary to tertiary treatment, with anticipated completion in 2024;
- Separating all of the remaining combined sewers within the City of Vancouver by 2050 and the City of Burnaby by 2075;
- Municipal sanitary-storm sewer cross connection detection and control programs;
- Inflow & infiltration reduction programs to reduce groundwater and stormwater into sanitary sewer pipes, thereby reducing sanitary and CSO overflows;
- Development and implementation of ISMPs for all developed watersheds that flow into Burrard Inlet; stormwater is an area of growing concern for microbiological water quality and municipalities are developing a variety of infrastructure strategies and source controls to decrease the quantity and improve the quality of stormwater discharges;
- Updating of Metro Vancouver's Integrated Liquid Waste and Resource Management Plan;
- The development, in process, by the City of Vancouver of a Sewage and Rainwater Management Plan to address pollution from sewage and urban run-off along with risks presented by climate change, aging infrastructure and urban growth (City of Vancouver 2020), alongside a broad, integrated Vancouver Plan (City of Vancouver 2021b); and
- Bacterial source tracking initiatives by the BC Centre for Disease Control and other health authorities.

Based on the known sources of microbiological pollution as described above and in Appendix B, and in recognition of the limitations of the analyses in this report (see Section 3.3.3), the following broad management options are presented for consideration:

- Implementing year-round disinfection of effluent at the current and future Lions Gate WWTP to protect primary contact activities year-round;
- Considering specific interim actions to reduce the frequency, duration, and magnitude of CSOs and SSOs (such as green stormwater infrastructure/stormwater source controls, attenuation tanks, inflow & infiltration reduction measures, and other sanitary and/or stormwater volume reduction measures);
- Accelerating the rate of connection by individual landowners to new separated sewers through incentives and other measures;
- Increased adoption of green stormwater infrastructure/stormwater source controls and design criteria that provide water quality treatment for stormwater runoff prior to discharge to Burrard Inlet, for example regular clean-out of catch basins, implementation of green infrastructure, and requirement for stormwater mitigations for new projects;
- Working with the federal government to designate and keep Burrard Inlet as a no-discharge zone for boats;
- Assessing pump-out facilities and other discharge alternatives for recreational vessels in Burrard Inlet;
- Advocating for municipal, regional, or provincial development standards that protect watershed health and the health of receiving environments such as Burrard Inlet, with consideration of the predicted and observed effects of climate change;
- Regulation of urban stormwater discharges by senior regulatory agencies;
- Creating specific education and awareness campaigns to target individual sources of microbiological pollution (e.g., pet waste); and
- Cooperative work by multiple agencies for public engagement and awareness to reduce boat discharges.

In addition, the following location-specific management options are recommended as high priorities, based on the benchmark exceedances observed in their vicinities:

- Separation of the combined sewers that connect to the Heather Street, Balaclava, Brockton Point, and Clark Drive CSOs;
- Prevention of other overflows that occur close to recreational beaches (e.g. Port Moody);
- Prevention of discharges from the Lynn Drive siphon;
- Investigation of the sources of microbiological water quality pollution in Eagle Creek (West Vancouver) and the Indian River (north end of Indian Arm); and
- Priority implementation of source controls to reduce stormwater discharges to False Creek, Outer Harbour, Inner Harbour, and Central Harbour.

A more in-depth feasibility analysis of each option may be required prior to decisions about implementation. Expansion of bacterial source tracking efforts could help to prioritize actions that would have the most effect on reducing microbiological pollution in the Inlet. Further analyses, integration of ongoing programs (e.g., Integrated Stormwater Management Plans, the City of Vancouver's Sewage and Rainwater Management Plan) and coordination with pollution reduction efforts related to other water quality parameters will also be useful to develop response and management actions.

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APPENDIX A: REVIEW OF RELEVANT WATER QUALITY GUIDELINES AND STANDARDS FOR MICROBIOLOGICAL INDICATORS

The following water quality guidelines and standards have potential relevance to microbiological water quality in Burrard Inlet. These guidelines and standards were used to guide the development of the screening benchmarks and proposed objectives for Burrard Inlet.

A.1 Provincial (ENV) Water Quality Guidelines

The BC criteria for microbiological indicators were first developed in 1988 and last updated in 2001. These criteria include *Escherichia coli* (*E. coli*), enterococci, *Pseudomonas aeruginosa* (no longer considered to be associated with fecal contamination), and fecal coliforms (Warrington, 1988; ENV, 2001). The purpose of these criteria is to protect source drinking water, shellfish harvesting, primary and secondary contact recreational use, and irrigation. These criteria are summarized in Table 26.

Table 26: B.C. Approved Water Quality Guidelines – Water Quality Criteria for Microbiological Indicator Levels for Protection of Shellfish Harvesting (ENV, 2001)

Microbiological Indicator	Guideline
Fecal coliform	≤ 14/100 mL median MPN over 30 days ≤ 43/100 mL 90th percentile MPN over 30 days
E. coli	≤ 14/100 mL median MPN over 30 days ≤ 43/100 mL 90th percentile MPN over 30 days
Enterococci	≤ 4/100 mL median MPN over 30 days ≤ 11/100 mL 90th percentile MPN over 30 days

Current provincial water quality guidelines for microbiological indicators for the protection of primary contact recreation were last updated in 2017 and re-evaluated in 2019 with no changes made. The current guidelines were adopted from Health Canada (2012) and are designed to protect people who swallow water. Changes to the primary contact recreation guidelines in 2017 included archiving of the guideline for fecal coliforms (in recognition that it is no longer preferred for monitoring over *E. coli*) and increasing the allowable geometric mean microbiological levels for *E. coli* from 77 *E. coli*/100 mL to 200 *E. coli*/100 mL and for enterococci from 20 enterococci/ 100 mL to 35 Enterococci/100 mL. There are no provincial guidelines for secondary contact activities because Health Canada criteria for secondary contact are considered tentative, since complete epidemiological studies have not provided statistically defensible and permanent criteria. The provincial water quality guidelines for recreation are outlined in Table 27.

Table 27: B.C. Water Quality Guidelines for Microbiological Indicators for the Protection of Primary Contact Recreation (ENV, 2019)

Microbiological Indicator	Guideline
E. coli	≤ 200/100 mL geometric mean[1, 2] ≤ 400/100 mL single-sample maximum[, 2]
Enterococci	≤ 35/100 mL geometric mean[1, 2] ≤ 70/100 mL single-sample maximum[1, 2]
[1] All units are MPN/100 mL [2] In 5 samples taken in a 30-day period.	

A.2 Health Canada Recreational Water Quality Guidelines

The primary goal of the *Guidelines for Canadian Recreational Water Quality* published by Health Canada (2012) is to protect public health and safety. The guideline considers human health risks associated with both primary and secondary contact activities.

Currently, Health Canada does not have a guideline for secondary contact as there is insufficient epidemiological data available to derive precise health-based microbiological indicator limit values. Instead, Health Canada proposes applying a factor of 5 to the existing primary contact geometric mean microbiological indicator concentration as an approach for setting fecal indicator limits in areas where water is intended to be used specifically for secondary contact activities. Applying a factor of 5 represents a risk management decision based on the assessment of the expected exposure scenarios. Health Canada guidelines for microbiological water quality for recreation are summarized in Table 28.

Table 28: Canadian Recreational Water Quality Guidelines (Health Canada, 2012)

Microbiological Indicator	Recreation Type	Guideline
E. coli (fresh water)	Primary	≤ 200/100 mL geometric mean[1] ≤ 400/100 mL single-sample maximum
Enterococci (marine)	Primary	≤ 35/100 mL geometric mean[1] ≤ 70/100 mL single-sample maximum
Enterococci (marine)	Secondary	≤ 175/100 mL geometric mean[1]

[1] Geometric mean concentration based on a minimum of five samples, collected at times and sites that are representative of the water quality likely to be encountered by users.
Note: Health Canada guidelines state that, 'Consideration should be given to the type of water being analysed when selecting the most appropriate method for analysis' (2012) but does not state a preference between multiple tube fermentation (results reported in MPN) or membrane filtration (results reported in CFU).

A.3 Canadian Shellfish Sanitation Program (CSSP) Standards

The CSSP is a federal food safety program administered by the Canadian Food Inspection Agency (CFIA), Environment and Climate Change Canada, and Fisheries and Oceans Canada. The goal of the program is to protect Canadians from the health risks associated with the consumption of contaminated shellfish. Meeting microbiological indicator levels in water quality is one condition for approval but, due to the health risks for eating contaminated shellfish, the CSSP may also close sites for shellfish harvesting if there is evidence of pollution sources, regardless of measured microbiological indicator levels. The CSSP specifies that, "A shellfish harvest area may be classified as approved if the area is not contaminated with pathogenic micro-organisms to the extent that consuming the shellfish might be hazardous, and if the national shellfish growing area water quality standard is met" (CFIA 2020, Section 4.1.3.1). The criteria that define this standard are outlined in Table 29; the first criterion is applicable to Burrard Inlet, as pollution sources have not been clearly identified. There may be circumstances under which areas in closed status can be harvested for depuration. TWN has been working collaboratively with ECCC and CFIA on water quality monitoring to identify areas suitable for opening limited FSC shellfish harvests.

Table 29: CSSP Shellfish Harvesting Microbiological Indicator Level Requirements for Approved Classification (CFIA, 2020), also referred to as the National Shellfish Growing Area Water Quality Standard

Microbiological Indicator	Guideline
Fecal Coliform	<14/100 mL median MPN, and no more than 10% of the samples > 43/100 mL MPN for a five-tube decimal dilution test OR <14/100 mL MPN and estimated 90^{th} percentile <43/100 mL, for a five-tube decimal dilution test and actual and potential sources of pollution have been identified, and these have been determined not to impact the shellfish harvest area AND the shellfish harvest area is not otherwise contaminated by harmful substances

APPENDIX B: POTENTIAL SOURCES OF MICROBIOLOGICAL POLLUTION BY SUB-BASIN

Maps of potential point- and non-point sources of pollution into Burrard Inlet are provided in Figure 2 and Figure 3.

B.1 False Creek

Presently in False Creek, there are no provincially-authorized industrial discharges that are likely to impact microbiological indicator levels. False Creek is not designated for primary contact activities at the time of writing, but is used for secondary contact recreation.

There is one CSO that discharges to False Creek at Heather Street. In 2016, this CSO discharged over 400,000 m^3 of combined effluent (Metro Vancouver, 2017). The ranges for measured microbiological indicator levels from the Heather Street CSO were:

- *E. coli* – 70,000 – 410,000 MPN/100 mL
- Enterococci – 50,000 – 490,000 MPN/100 mL
- Fecal coliforms – 120,000 – 730,000 MPN/100 mL (Metro Vancouver, 2017)

Historic CSOs were likely a significant source of microbiological pollution during peak rainfall events given that historic average[1] fecal coliform levels measured at the CSOs in False Creek were 1.7×10^6 MPN/100 mL and this was approximately 70 times greater than the concentration estimated for stormwater alone (Nijman and Swain, 1990).

There are 13 stormwater outfalls that discharge an unquantified volume of stormwater to False Creek annually. Because urban runoff picks up contaminants during overland flow, fecal coliforms in stormwater are expected to be in the range of 20–24,000 MPN/100 mL. Fecal coliform loading was estimated historically to be on the order of 10^{15} MPN fecal coliforms annually (Stanley Associates, 1992).

During a sanitary sewer emergency overflow event in 2016, Metro Vancouver's Jervis Pump Station discharged 4,313 m^3 of effluent during a dry weather event. This is of concern for microbiological water quality given the high volume of sewage discharged and given the dry weather event, which would not have allowed for much dilution of the microbiological loading in the sanitary sewage prior to its discharge to False Creek.

Stormwater/sanitary cross-connections also contribute to pollution in False Creek.

No natural tributaries or streams currently flow into False Creek. Previously existing streams that would have discharged to False Creek have been turned into storm sewers or culverts (Haggarty, 1997). The shoreline is heavily developed with at least 80% being anthropogenically modified and/or altered with riprap and landscaping. While highly modified, existing public park space provides habitat for birds and animals as well as space for domestic pets. Animal feces from the parks and boardwalk areas may contribute to microbiological pollution as fecal material is transported into False Creek during rain events.

With 13 marinas in False Creek, microbiological pollution is a risk if boat owners do not properly dispose of human waste. There is anecdotal evidence that during City events, such as the Celebration of Light, increased boat traffic contributes to microbiological pollutant spikes in False Creek (Cummings, 2016). The City of Vancouver has enacted by-laws requiring all marinas to provide operational pump-out facilities; as of 2020, all marinas in False Creek have met this requirement (Margot Davis, City of

[1] Nijman and Swain (1990) referred to 'average'.

Vancouver, *pers. comm.*, December 2020). The City of Vancouver also launched a mobile pump-out service in 2019.

Inadequate circulation and flushing in False Creek contribute to elevated microbiological indicator levels and prevent the dilution of outfall discharges, particularly in eastern False Creek (ENV, 2006).

B.2 Outer Harbour

The Lions Gate WWTP is located near First Narrows just east from the Capilano River, and discharges effluent to the Outer Harbour through a 200 m outfall pipe to the centre of the channel under the Lions Gate Bridge. The plant provides primary treatment to just over 30 billion litres of wastewater annually, accounting for 7% of the total municipal wastewater flow in Metro Vancouver. Operating since 1961, the plant has undergone several upgrades since it was first built. In 2016, the WWTP achieved 46% BOD reduction and 67% TSS reduction using a combination of screening, aeration, sedimentation and chlorination/dichlorination (Metro Vancouver, 2017). New federal and provincial regulations require that all wastewater treatment plants be upgraded to secondary treatment. The existing Lions Gate WWTP is slated for decommissioning as a new WWTP with tertiary treatment is scheduled for completion in 2024.

The existing Lions Gate WWTP has operated under operational certificate ME 00030 since April 23, 2004. Since 2011, there have been no recorded exceedances of maximum daily discharge allowances or BOD and TSS allowances. The maximum flow recorded in 2016 was 184 million litres per day. There have been two disinfection interruptions since 2011, one in 2012 and one in 2016, though no exceedances of fecal coliform discharge requirements have occurred.

In summer 2016, the rolling 30-day geometric mean for fecal coliforms in the effluent from the plant ranged from 57 to 79 CFU/100 mL. This is five orders of magnitude lower than the fecal coliform levels measured at nearby CSOs. Dilution dispersion modelling has been performed for the outfall on several occasions and has concluded that the dilution available to the wastewater is sufficient to minimize any concern with respect to the microbiological loading from this discharge (Nijman and Swain, 1990; Metro Vancouver, 2017). Metro Vancouver applies a minimum dilution ratio of 250:1 for the Lions Gate outfall modelling. Historically, sewage sludge from the Lions Gate WWTP was also discharged into the Outer Harbour though this sludge is now transported to other local WWTPs.

Presently, there is one provincially-authorized industrial discharge permit that allows discharge to the Outer Harbour. This permit is for the former West Vancouver landfill located at Third Street, which was decommissioned in 1969. As this is a closed facility, there should be minimal risk of pathogenic microbiological pollution from this effluent.

There are four CSO outfalls that discharge to the Outer Harbour. The four CSOs are Alma-Discovery, Balaclava Street, English Bay, and Park Lane, all of which are on the south shore. In 2016, the English Bay and Alma-Discovery outfalls discharged a combined volume of 280,000 m^3, the Balaclava Street outfall discharged 780,000 m^3, and Park Lane discharged an unmeasured quantity of combined sewage (Metro Vancouver, 2017). Historic mean fecal coliform levels measured at the CSOs in the Outer Harbour are 3.2×10^6 MPN/100 mL (Nijman and Swain, 1990).

Since 1990, some CSOs that had input into the Outer Harbour were decommissioned. In 1990, the CSOs were estimated to contribute $1.5 \text{ X } 10^{16}$ MPN fecal coliforms during the summer season.

There are 30 stormwater outfalls that discharge an estimated 46 million m^3 of runoff to the Outer Harbour annually. Estimates of the stormwater contribution to microbiological loading are in the order of $16 \text{ X } 10^{15}$ MPN of fecal coliforms annually (Stanley Associates, 1992).

In 2015, there was one overflow of 3 m^3 from the Glen Eagles Lift Station and one overflow of 36 m^3 from the Locarno combined trunk sewer. These volumes may have had localized impacts on microbiological pollution within the vicinity of the outfalls. The District of West Vancouver has fully separated stormwater and sanitary sewer systems, though as of 2017, the District operated 11 lift station emergency overflow outfalls that discharged into the Outer Harbour. These tend to overflow infrequently.

There are 19 tributary streams that feed into the Outer Harbour from West Vancouver. The Capilano River is the largest tributary to this sub-basin. The Capilano watershed has restricted access as it is a drinking water source. With the exception of two small creeks that have been restored (Spanish Bank Creek and Salish Creek), all historic streams that flowed onto the City of Vancouver portion of the Outer Harbour shoreline have been converted into culverts or storm sewers. Tributary streams are generally a lower risk for microbiological pollution, although this may be influenced by the amount of impervious area within their catchments.

There has been little industrial development in the Outer Harbour, but much of the shoreline has been hardened with sea walls or filled for residential development. Much of the south shore is sand beaches, and historically, the eastern beaches in English Bay were augmented with sand placements. Beaches in West Vancouver are mostly cobble and gravel, though some were also augmented with sand in the past (BIEAP, 2011). Residential and beach areas can be a source of microbiological pollution due to improper disposal of human waste, and impacts from use by wild and domestic animals.

B.3 Inner Harbour

Of the provincially-authorized discharges to the Inner Harbour, the discharges from West Coast Reduction Ltd., an animal and fish processing plant, and the Lantic Inc. sugar refinery may be relevant to microbiological water quality. The West Coast Reduction facility was authorized by the Province of BC to discharge 1,850 m^3 of combined stormwater and process water per day as of 1994 (Georgia Straight Alliance, 2003).

In addition to the provincially-authorized discharges, there are nine CSO outfalls and 125 stormwater outfalls that discharge to the Inner Harbour. Significant operational improvements were implemented in the Vancouver Sewerage Area (VSA) in 1996, resulting in a reduction of CSO discharge volume by 30% in an average year. Clark Drive CSO volumes were reduced by about 40% (City of Vancouver, 1999).

Despite the above reductions, CSOs are still a significant source of microbiological pollution to the Inner Harbour. Impacts of these overflows on water quality in the Inner Harbour cannot be predicted without knowledge of the water exchange rate and localized conditions near each of the outfalls. The most recent annual CSO overflow volumes from 2016 were:

- Brockton Point – 86,000 m^3
- Cassiar – 3,879,000 m^3
- Clark Drive 1 – 2,791,000 m^3
- Clark Drive 2 – 9,064,000 m^3
- Vernon Relief Outfall – 957,000 m^3 (Metro Vancouver, 2017)

In 2016, ranges for measured levels of microbiological indicators from the Brockton Point CSO included:

- *E. coli* – 18–7,980,000 MPN/100 mL
- Enterococci – 100–2,400,000 MPN/100 mL
- Fecal coliforms – 18–13,000,000 MPN/100 mL (Metro Vancouver, 2017)

Likewise, in 2016, measured levels of microbiological indicators from the Clark Drive 2 CSO included:

- *E. coli* – 2,400,000 MPN/100 mL
- Enterococci – 580,000 MPN/100 mL
- Fecal coliforms – 3,600,000 MPN/100 mL (Metro Vancouver, 2017)

The volume of discharge at the Clark Drive 2 CSO is considerably higher than at the Brockton Point CSO. Given the high volume of discharge from the Clark Drive 2 CSO and the high density of microbiological indicators, this outfall is considered to be a significant contributor to microbiological pollution in the Inner Harbour, and to Burrard Inlet generally.

Because of the very high number of stormwater outfalls and lack of consistent monitoring of stormwater discharges, it is challenging to quantify the contribution of these outfalls to microbiological pollution in the Inner Harbour. Fecal coliform concentrations in stormwater were expected to be in the range of 20–24,000 MPN/100 mL in 1992 (Stanley Associates, 1992). In 1990, it was estimated that 4.92 X 10^{14} fecal coliforms were discharged annually with stormwater runoff into the Inner Harbour (Nijman and Swain, 1990). Comparatively, in 1992, Stanley Associates (1992) estimated that 6.7 X 10^{15} fecal coliforms were discharged annually with stormwater runoff into the Inner Harbour. Both estimation methods were crude due to a lack of flow monitoring data.

During three emergency sanitary sewer overflows into the Inner Harbour recorded in 2015, the Mackay overflow discharged 11,416 m^3 and 127 m^3 during two events, the Lynn Branch overflow discharged a total of 30,128 m^3 during five events, and the Chilco Pump Station discharged 1409 m^3 over two summer events (Metro Vancouver, 2016). The Chilco Pump Station overflows took place near areas commonly frequented by the public.

The only remaining SSO in Burrard Inlet is located at Mackay Avenue in North Vancouver. As an illustration of its activity, it released 11,416 m^3 of discharge in between 2012 to 2015. The peak hourly flow was 0.529 m^3/s for up to eight hours (Metro Vancouver, 2017).

There are seven tributary streams that feed into the Inner Harbour with Lynn Creek being a major tributary. All of these are located on the North Shore as all the natural streams on the City of Vancouver side of Burrard Inlet have been converted into culverts or storm sewers. Tributary streams are generally a lower risk for microbiological pollution loadings though pollutants can be picked up from stream shorelines or as a result of stormwater inputs.

There are seven marinas in the Inner Harbour with three pump-out stations (Georgia Strait Alliance, 2019). Recreational and commercial boats that use the Inner Harbour have the potential to impact microbiological water quality if human waste is improperly disposed of. Many cruise ships visit the Inner Harbour each year though it is no longer legal to dump bilge water near the shore.

Over 90% of the shoreline of the Inner Harbour has been altered, which may prevent natural processes from filtering and remediating potential microbiological pollutants from human, wildlife, and domestic animal sources.

B.4 Central Harbour

Of the provincially-authorized discharges into the Central Harbour, the discharge from Great Northern Packaging Ltd., a fish processing plant, may be relevant to microbiological water quality. This facility discharged no effluent in 2005 or 2010 (BIEAP, 2010; BIEAP, 2011).

There are four CSOs and 71 stormwater outfalls that discharge to the Central Harbour. All CSOs in this sub-basin are within the boundaries of the City of Burnaby. The District of North Vancouver has a separated sewer system. Microbiological loadings during CSOs are of concern due to the high microbiological concentration in combined sewage. A summary of 2016 CSO overflow volumes are:

- Gilmore – 0 m^3
- Westridge – 45,000 m^3
- Willingdon 1 and 2 – 758,000 m^3 (Metro Vancouver, 2017)

In 2013, ranges for measured levels of microbiological indicators from the Westridge CSO include:

- Enterococci – 19,000 – 160,000 MPN/100 mL
- Fecal coliforms – 190,000 – 480,000 MPN/100 mL (Metro Vancouver, 2015)

In 2013, ranges for measured levels of microbiological indicators from the Willingdon 1/2 CSO include:

- *E. coli* – 210 MPN/100 mL
- Enterococci – 1,000 – 1,300 MPN/100 mL
- Fecal coliforms – 93 – 720 MPN/100 mL (Metro Vancouver, 2014)

As in the Inner Harbour, because of the high number of stormwater outfalls, it is challenging to quantify the impact on microbiological pollution; however, fecal coliform concentrations in stormwater runoff were estimated to be in the range of 20–24,000 MPN/100 mL in 1992 (Stanley and Associates, 1992). In 1990, it was estimated that 4×10^{13} fecal coliforms are discharged annually into the Inner Harbour (Nijman and Swain, 1990). In 1992, the fecal coliform load was re-evaluated to be 2×10^{14} discharged annually (Stanley and Associates, 1992). This level of microbiological loading is expected to lead to guideline exceedances near public beaches.

There are 14 tributary streams that feed into Burrard Inlet. Nine of these streams are on the North Shore and the remainder are within the City of Burnaby.

Shoreline hardening in the Central Harbour may prevent natural filtration and degradation of pathogens in the environment.

B.5 Port Moody Arm

Historically, there was one provincially-authorized discharge for leachate from the closed Port Moody refuse site, which may have been relevant to microbiological indicators. The site has since been capped and decommissioned since at least 1990, and no other relevant provincially-authorized discharges remain. Remediation in the area has included the creation of a creek, ditches for runoff and a stormwater detention pond. Its marine discharge was likely located at what is now the Reed Point Marina (A. Crampton, City of Port Moody, *pers. comm.*, January 2021).

There are currently no CSO outfalls that discharge to Port Moody Arm but there are 54 stormwater outfalls. In 1990, two CSOs had been identified–one located at the southeastern end of Port Moody Arm and one located on the south shore near Reed Point though the magnitude of overflow was low compared to other CSOs around Burrard Inlet (Nijman and Swain, 1990). It is likely that those had been mis-identified in 1990 as CSOs; they are more likely locations of surcharges from Metro Vancouver sanitary pipes (A. Crampton, City of Port Moody, *pers. comm.* January 2021). The surrounding catchment has seen a high degree of development in the past two decades, though in 1990, the fecal coliform loading from stormwater was estimated to be 1.4×10^{14} annually (Stanley Associates, 1992).

There are three emergency SSOs that discharge into Port Moody Arm or its tributaries. As an illustration of their activity, in 2015 the Albert Street Sanitary Trunk Extension discharged 107 m^3 and 14 m^3 of sanitary sewage into Schoolhouse Creek during wet weather events in 2015 (Metro Vancouver, 2017). These events have the potential to have localized impacts on microbiological water quality. Metro Vancouver is upgrading the Albert Street trunk (A. Crampton, City of Port Moody, *pers. comm.* April 2020).

There are two marinas located within Port Moody Arm. Marinas and boats can be a source of microbiological pollution near public beaches if owners do not adequately dispose of their sanitary waste.

There are 26 tributary streams that feed into Port Moody Arm. As discussed previously, tributary streams are generally a lower risk for microbiological pollution, but this is influenced by the amount of impervious area within their watersheds. Higher impervious area is typically correlated with higher levels of microbiological pollution.

Some shoreline has also been hardened with sea walls and filled for residential development, which would impede the natural filtration and degradation of pathogens in the environment. Residential and beach areas can be a source of microbiological pollution due to human waste and wild and domestic animals.

B.6 Indian Arm

There are four provincial waste discharge authorizations that have been approved in Indian Arm; all are for sanitary waste. These provincially-authorized discharge sites could be a source of microbiological pollution if there is inadequate treatment for microbiological pollution. Mount Seymour Resorts discharges from its secondary treatment plant into a creek near the Mount Seymour ski facility, which then leads to Indian Arm; this facility discharged 77,600 m^3 of treated effluent in 2010. Camp Howdy, owned by the Evangelical Laymen's Church of Canada (Vancouver), discharged 11,700 m^3 of treated effluent from its secondary wastewater treatment plant and sand filter into Burrard Inlet in 2010. The other two provincial authorizations are also for discharges following secondary wastewater treatment (Rao et al. 2019: Appendices).

There are no CSO outfalls that discharge to Indian Arm but there are 23 stormwater outfalls. All of these are concentrated at the south end of Indian Arm. In 1990, the fecal coliform loading from stormwater was estimated to be 3.6×10^{13} MPN annually (Stanley Associates, 1992).

There are six emergency sanitary sewage outfalls that discharge into Indian Arm, all of which are in the south end of Indian Arm. There were no emergency overflows into Indian Arm in 2016.

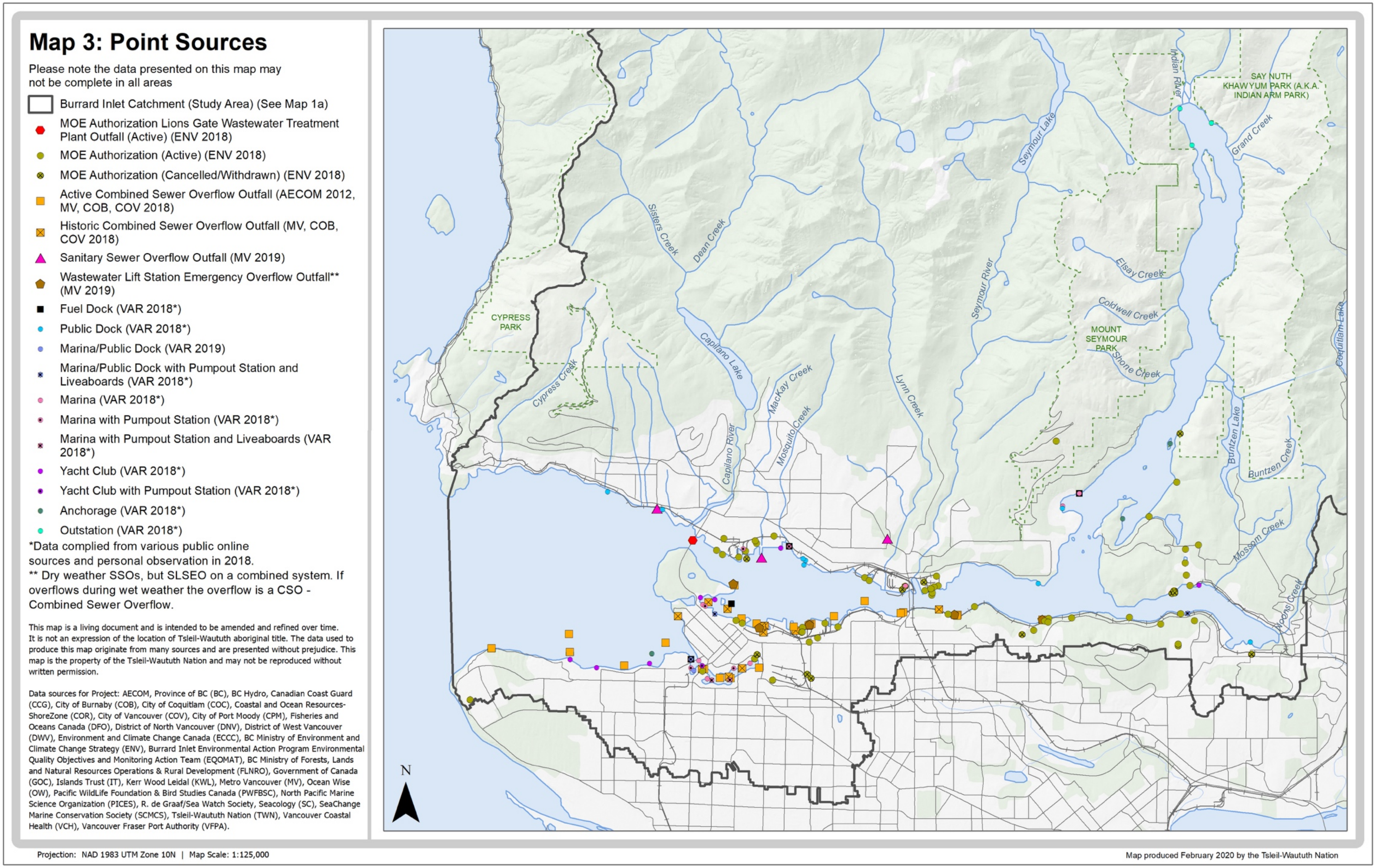
There are four marinas and two campsites located within Indian Arm. These can be a source of microbiological pollution near public beaches if owners or visitors do not adequately dispose of their human waste.

There has been little industrial development in Indian Arm but a few sections of shoreline have been hardened with sea walls and filled for residential development. Residential and beach areas can be a source of microbiological pollution due to human waste and wild and domestic animals. Canada geese regularly graze and nest at the Indian River estuary and in Belcarra Regional Park, among other areas and their scat can contribute to microbiological pollution.

There are 43 tributary streams that feed into Indian Arm. Because many of these tributary streams have largely undeveloped catchments, they are likely to have a smaller contribution to microbiological pollution than in the other sub-basins.

In 2006, WorleyParsons Komex and Lorax Environmental identified 64 outfalls from on-site sewage disposal systems in Indian Arm. This number has likely increased and is predicted to increase in the future. Many of the residential homes and cabins located along Indian Arm are unable to access municipal sewage systems, therefore wastewater disposal at these properties is often achieved through land-based disposal systems such as septic fields or by discharge to the marine environment via outfalls (Vancouver Port Authority, 2004). A survey conducted by the Vancouver Port Authority, the Fraser

Health Authority, and the Vancouver Coastal Health Authority in 2004 identified that many homes located along Indian Arm are likely using outfalls, as many are built on rock outcrops or where soil is unsuitable for land-based disposal systems. New homes located within the Belcarra area are expected to use land-based wastewater disposal systems as the area is not connected to a municipal sewage system and the village does not support the use of outfalls to Indian Arm. Septic systems on properties in the Village of Anmore may also seep into creeks (A. Crampton, City of Port Moody, *pers. comm.* April 2020).



Map 3: Point Sources
Please note the data presented on this map may not be complete in all areas
Burrard Inlet Catchment (Study Area) (See Map 1a)
MOE Authorization Lions Gate Wastewater Treatment Plant Outfall (Active) (ENV 2018)
MOE Authorization (Active) (ENV 2018)
MOE Authorization (Cancelled/Withdrawn) (ENV 2018)
Active Combined Sewer Overflow Outfall (AECOM 2012, MV, COB, COV 2018)
Historic Combined Sewer Overflow Outfall (MV, COB, COV 2018)
Sanitary Sewer Overflow Outfall (MV 2019)
Wastewater Lift Station Emergency Overflow Outfall** (MV 2019)
Fuel Dock (VAR 2018*)
Public Dock (VAR 2018*)
Marina/Public Dock (VAR 2019)
Marina/Public Dock with Pumpout Station and Liveaboards (VAR 2018*)
Marina (VAR 2018*)
Marina with Pumpout Station (VAR 2018*)
Marina with Pumpout Station and Liveaboards (VAR 2018*)
Yacht Club (VAR 2018*)
Yacht Club with Pumpout Station (VAR 2018*)
Anchorage (VAR 2018*)
Outstation (VAR 2018*)
*Data complied from various public online sources and personal observation in 2018.
** Dry weather SSOs, but SLSEO on a combined system. If overflows during wet weather the overflow is a CSO - Combined Sewer Overflow.
This map is a living document and is intended to be amended and refined over time. It is not an expression of the location of Tsleil-Waututh aboriginal title. The data used to produce this map originate from many sources and are presented without prejudice. This map is the property of the Tsleil-Waututh Nation and may not be reproduced without written permission.
Data sources for Project: AECOM, Province of BC (BC), BC Hydro, Canadian Coast Guard (CCG), City of Burnaby (COB), City of Coquitlam (COC), Coastal and Ocean Resources-ShoreZone (COR), City of Vancouver (COV), City of Port Moody (CPM), Fisheries and Oceans Canada (DFO), District of North Vancouver (DNV), District of West Vancouver (DWV), Environment and Climate Change Canada (ECCC), BC Ministry of Environment and Climate Change Strategy (ENV), Burrard Inlet Environmental Action Program Environmental Quality Objectives and Monitoring Action Team (EQOMAT), BC Ministry of Forests, Lands and Natural Resources Operations & Rural Development (FLNRO), Government of Canada (GOC), Islands Trust (IT), Kerr Wood Leidal (KWL), Metro Vancouver (MV), Ocean Wise (OW), Pacific WildLife Foundation & Bird Studies Canada (PWFBSC), North Pacific Marine Science Organization (PICES), R. de Graaf/Sea Watch Society, Seacology (SC), SeaChange Marine Conservation Society (SCMCS), Tsleil-Waututh Nation (TWN), Vancouver Coastal Health (VCH), Vancouver Fraser Port Authority (VFPA).
CYPRESS PARK
Cypress Creek
Sisters Creek
Dean Creek
Capilano Lake
Capilano River
MacKay Creek
Mosquito Creek
Lynn Creek
Seymour River
Seymour Lake
Indian River
SAY NUTH KHAWYUM PARK (A.K.A. INDIAN ARM PARK)
Grand Creek
Elsay Creek
Coldwell Creek
MOUNT SEYMOUR PARK
Shone Creek
Buntzen Lake
Buntzen Creek
Coquitlam Lake
Mossom Creek
Noons Creek
N
Projection: NAD 1983 UTM Zone 10N | Map Scale: 1:125,000
Map produced February 2020 by the Tsleil-Waututh Nation

1

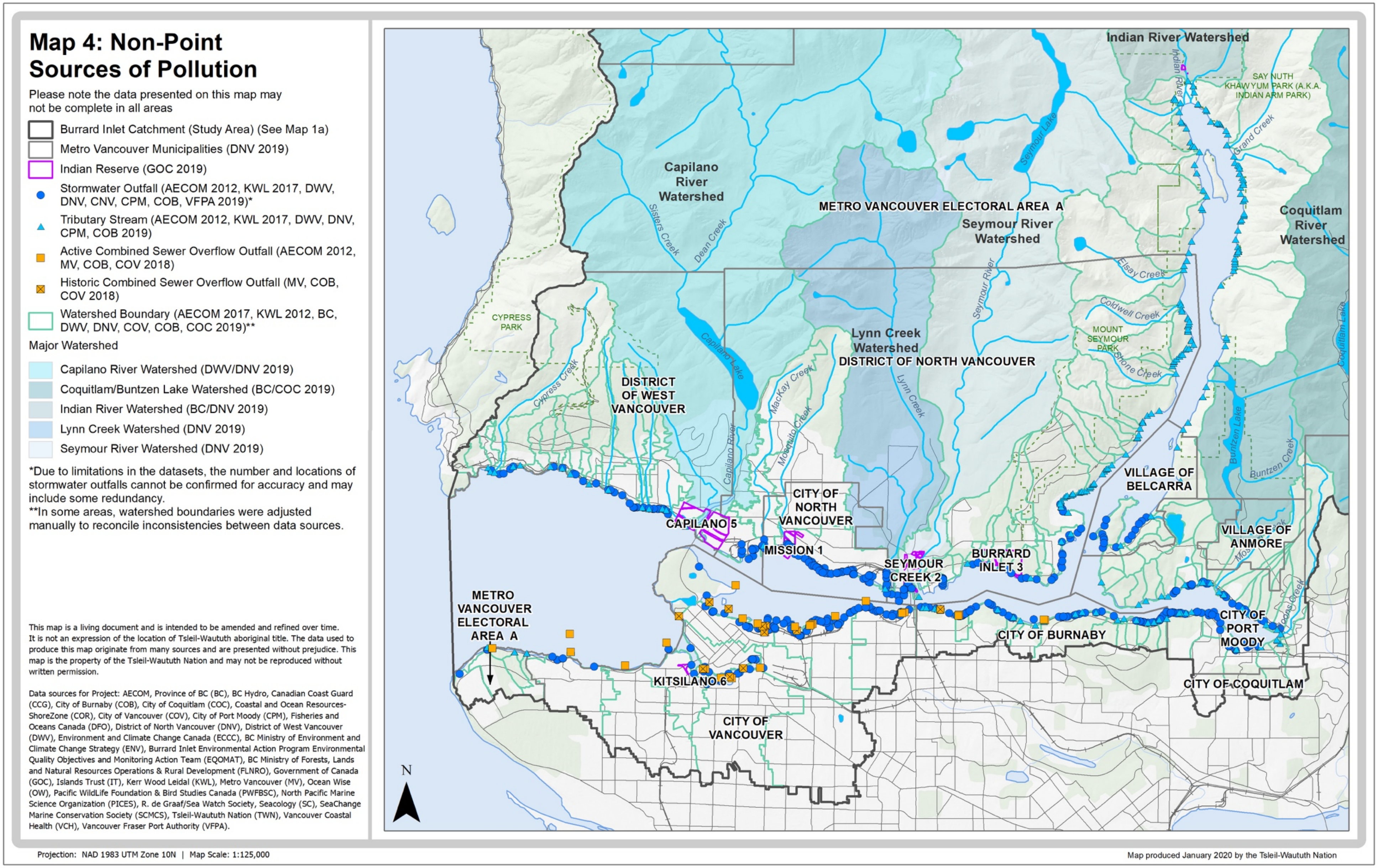


Figure 4. Point sources in Burrard Inlet, including likely contributors of microbiological indicators

APPENDIX C: DETAILED RESULTS SUMMARY

The information presented in this appendix supplements the summaries provided in Section 3.4 with additional details.

C.1 False Creek

Provincial WQOs Attainment Monitoring

Early provincial attainment monitoring data from 1973 to 1978 indicates that False Creek historically had elevated levels of fecal coliforms. During this period, there were three monitoring locations—False Creek Burrard Street Bridge (Site 300081), False Creek Between Granville and Cambie (Site E207815) and False Creek Cambie Street (Site 300082). Multiple samples were not collected over a 30-day period so summary statistics could not be calculated. Since single or duplicate samples were collected independently, only individual data points were compared to the benchmarks for primary contact activities and shellfish harvesting. All data was for fecal coliforms only. Fourteen of 28 samples collected in False Creek at Burrard Street between 1973 and 1978 exceeded the primary contact benchmark (200 MPN/100 mL) while only one sample was less than the median shellfish harvesting benchmark (14 MPN/100 mL). Likewise, 16 of 22 samples collected in False Creek at Cambie Street between 1973 and 1977 exceeded the primary contact benchmark (200 MPN/100mL) and no samples were lower than the median shellfish harvesting benchmark (14 MPN/100mL). Individual fecal coliform values for this period ranged from 5 MPN/100 mL in July 1974 at Burrard Street to over 24,000 MPN/100 mL in December 1974 at Burrard Street. The large range of results is expected given that four CSOs discharged to False Creek and given the lack of stormwater source controls during this period. Enterococci was not monitored during this early period.

Monitoring results from 2002, 2003, and/or 2009 indicate that fecal coliform and enterococci levels in False Creek exceeded benchmark values during the period. There were two sample locations during this period—False Creek Between Granville and Cambie (Site E207815), and False Creek East End (Site E207814). Summary statistics were calculated for these sites; however, sampling was conducted over 50 days rather than 30 days. The following is a summary of the fecal coliform results for the False Creek monitoring locations in 2002:

- False Creek Between Granville and Cambie (Site E207815)
    - Geometric Mean: 56 CFU/100 mL
    - Median: 18 CFU/100 mL
    - Single-sample Maximum: 780 CFU/100 mL
- False Creek East End (Site E207814)
    - Geometric Mean: 239 CFU/100 mL
    - Median: 170 CFU/100 mL
    - Single-sample Maximum: 680 CFU/100 mL

In most cases, the fecal coliform summary data from 2002 exceeds the shellfish harvest benchmarks (14 fecal coliform/100mL median, 43 fecal coliform/100mL 90th percentile) by approximately one order of magnitude. The Granville and Cambie location meets the primary contact benchmark for fecal coliforms (200/100 mL geometric mean) but the East End monitoring location exceeds this benchmark.

Summary statistics are not accurate for 2003 or 2009 since only 2 samples were collected at each monitoring location in August 2003 and only 4 samples were collected in February 2009. Fecal coliform values in 2003 exceeded the primary contact benchmark (200/100 mL geometric mean) at both monitoring locations whereas values in 2009 ranged from 4 MPN/100 mL to 130 MPN/100 mL.

Measurements of enterococci further corroborate the fecal coliform results. The following is a summary of the enterococci results for the False Creek monitoring locations in 2002:

- False Creek Between Granville and Cambie (Site E207815)
  - Geometric Mean: 23 CFU/100 mL
  - Median: 17 CFU/100 mL
  - Single-sample Maximum: 880 CFU/100 mL
- False Creek East End (Site E207814)
  - Geometric Mean: 40 CFU/100 mL
  - Median: 34 CFU/100 mL
  - Single-sample Maximum: 370 CFU/100 mL

Enterococci levels in 2002 exceeded the maximum benchmark for primary contact activities at both monitoring locations and exceeded both shellfish harvest benchmarks at both monitoring locations.

In this dataset, there is some evidence to suggest that maximum fecal coliform levels have fallen between 1970 and 2009; however, there are too little data and too many differences in the sampling efforts to confirm trends.

Metro Vancouver's Recreational Water Quality Monitoring

Metro Vancouver measured fecal coliforms from 1993 to 2012 and *E. coli* from 2012 to present at four stations from west to east: (1) Sunset Beach; (2) West False Creek; (3) Central False Creek; and (4) East False Creek.

Sunset Beach

From 1993 to 2012, rolling 30-day geometric means for fecal coliforms ranged from <10 MPN/100 mL to over 1000 MPN/100 mL. Mean fecal coliform levels exceeded the primary contact benchmark in every summer between 1993 to 2002, 2004, 2013, and 2014. Median levels exceeded the shellfish harvest benchmark in nearly all cases with median levels ranging between <20 MPN/100 mL to over 1000 MPN/100 mL. Maximum and 90^{th} percentile levels exceeded 5000 MPN/100 mL.

From 2012 to 2016, rolling 30-day geometric means for *E. coli* ranged from <10 MPN/100 mL to over 1,800 MPN/ 100 mL. Mean *E. coli* levels exceeded the primary contact benchmark for three weeks in 2013 and for much of the summer season in 2014. Maximum *E. coli* levels also exceeded primary contact single-sample maximum benchmarks in all years. *E. coli* levels are above shellfish harvesting benchmarks in a large majority of cases.

West False Creek

From 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 2000 MPN/100 mL. Mean fecal coliform levels exceeded the primary contact benchmark in every summer except for 2009. Median levels exceeded shellfish harvest benchmarks in a large majority of cases with median levels ranging from <20 MPN/100 mL to over 1000 MPN/100 mL. Maximum and 90^{th} percentile levels exceeded 10,000 MPN/100 mL.

From 2012 to 2016, 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to 2,500 MPN/ 100 mL. Geometric mean *E. coli* levels exceeded the primary contact benchmark for much of the summer season in 2013 to 2015. Maximum *E. coli* levels also exceeded the primary contact single-sample maximum benchmark in all years. *E. coli* levels were above shellfish harvesting benchmarks in a large majority of cases.

Central False Creek

From 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 5000 MPN/100 mL. Fecal coliform levels exceeded the primary contact benchmark in every summer except for 2009. Median levels exceed shellfish harvest benchmarks in a large majority of cases with median levels ranging between <20 MPN/100 mL to over 5000 MPN/100 mL. Maximum and 90th percentile levels exceed 10,000 MPN/100 mL.

From 2012 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to 5000 MPN/ 100 mL. Geometric mean *E. coli* levels exceeded the primary contact benchmark for much of the summer season in 2013 and 2014. Maximum *E. coli* levels also exceeded the primary contact single-sample maximum benchmark in all years. *E. coli* levels were above shellfish harvesting benchmarks in a large majority of cases.

East False Creek

From 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 9000 MPN/100 mL. Fecal coliform levels exceeded the primary contact benchmark in every summer. Median levels exceeded shellfish harvest benchmarks in a large majority of cases with median levels ranging between <20 MPN/100 mL to over 10,000 MPN/100 mL. Maximum and 90th percentile levels exceeded 10,000 MPN/100 mL.

From 2013 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to over 10,000 MPN/ 100 mL. Geometric mean *E. coli* levels exceeded the primary contact benchmark for much of the summer season in 2013 to 2016. Maximum *E. coli* levels also exceeded the primary contact single-sample maximum benchmark in all years. *E. coli* levels are above shellfish harvesting benchmarks in a large majority of cases.

C.2 Outer Harbour

Metro Vancouver's Burrard Inlet Ambient Monitoring Program

Metro Vancouver has two ambient monitoring locations in Outer Harbour, identified as Outer Harbour North and Outer Harbour South.

Outer Harbour North

From 2007 to 2016, there were elevated levels of fecal coliforms, *E. coli*, and enterococci at Outer Harbour North. For samples collected at the top of the water column, geometric means of five samples collected over 30 days did not exceed the primary contact benchmarks for either *E. coli* or fecal coliforms, though the benchmarks were exceeded at the bottom of the water column in 2010, 2011, 2013, and 2014. 30-day geometric mean values exceeded the primary contact benchmark in 2008, 2010, and 2016 for enterococci at the top of the water column and in all years at the bottom of the water column. Similarly, single-sample maximum levels exceeded the primary contact benchmark in the majority of monitoring years for *E. coli* and in all but three years for enterococci. Median and 90th percentile values are well above shellfish harvesting benchmarks for all microbiological indicators in all years.

Outer Harbour South

Like Outer Harbour North, from 2007 to 2016, there were elevated levels of fecal coliforms, *E. coli,* and enterococci at Outer Harbour South. For samples collected at the top of the water column, geometric means of five samples collected over 30 days did not exceed the primary contact benchmarks for either *E. coli* or fecal coliforms, though the benchmark was exceeded at the bottom of the water column in 2010 and 2013. 30-day geometric mean values exceeded the primary contact benchmark in 2009 and 2016 for enterococci at the top of the water column and in all years at the bottom of the water column. Single-sample maximum levels exceeded the primary contact benchmark in 2008 to 2016 for *E. coli* and in all years for enterococci. Median and 90th percentile values are above shellfish harvesting benchmarks for all microbiological indicators in most monitoring years.

Provincial WQOs Attainment Monitoring

Early provincial attainment monitoring data from 1973 to 1978 at ENV's English Bay monitoring site (Site 300076) indicates that the Outer Harbour had historically high levels of fecal coliforms, though not as high as False Creek. Multiple samples were not collected over a 30-day period so summary statistics could not be calculated. Since single or duplicate samples were collected independently, only individual data points were compared to the benchmarks for recreation and shellfish harvesting. Four of 29 samples collected in English Bay between 1973 and 1978 exceeded the primary contact benchmark (200 MPN/100 mL) while four other samples were less than the median shellfish harvesting benchmark (14 MPN/100 mL). Individual fecal coliform values for this period ranged from 4 MPN/100 mL in May 1978 to over 790 MPN/100 mL in December 1975. Enterococci was not monitored during this early period.

Monitoring results from 2002 indicate that fecal coliform levels in the Outer Harbour at English Bay generally did not exceed benchmarks for primary contact activities but did exceed benchmarks for shellfish harvesting. Summary statistics were calculated; however, sampling was conducted over 50 days rather than 30 days. The following is a summary of the fecal coliform results for the English Bay Centre in 2002:

- English Bay Centre (Site 300076)
    - Geometric Mean: 13 CFU/100 mL
    - Median: 17.5 CFU/100 mL
    - Single-sample Maximum: 110 CFU/100 mL

Measurements of enterococci further corroborate the fecal coliform results. The following is a summary of the enterococci results for the False Creek monitoring locations in 2002:

- English Bay Centre (Site 300076)
    - Geometric Mean: 7 CFU/100 mL
    - Median: 14 CFU/100 mL
    - Single-sample Maximum: 55 CFU/100 mL

Metro Vancouver's Recreational Water Quality Monitoring Program

Metro Vancouver has measured fecal coliforms from 1993 to 2012 and *E. coli* from 2012 to present at 11 stations, as listed in the description of monitoring programs for the Outer Harbour. Sampling was performed weekly on a year-round basis from 1993 to 2004 and weekly from May to September after 2004.

Sandy Cove

Monitoring of Sandy Cove has only occurred from 2014 to present. From 2014 to 2016, 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to over 5000 MPN/100 mL. Geometric mean *E. coli* levels exceeded the primary contact benchmark for most of the summer in 2013. Maximum *E. coli* levels also exceeded the primary contact maximum benchmark in all years. *E. coli* levels were above shellfish harvesting benchmarks.

Dundarave

From 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 500 MPN/100 mL. Fecal coliform levels exceeded the primary contact benchmark in every winter between 1993 to 1998, and 2011 but not in any summer season. Median levels have exceeded the shellfish harvest benchmarks in nearly all cases with median levels ranging between <20 MPN/100 mL to over 500 MPN/100 mL. Maximum and 90^{th} percentile levels have sometimes exceeded 1000 MPN/100 mL.

From 2013 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to over 1000 MPN/ 100 mL. Geometric mean *E. coli* levels exceeded the primary contact benchmark for the duration of the summer of 2014 and sporadically on three occasions in the summer of 2015. Maximum *E. coli* levels exceeded the primary contact single-sample maximum benchmark in 2014 to 2015. *E. coli* levels were above shellfish harvesting benchmarks in a large majority of cases.

Ambleside

From 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 500 MPN/100 mL. Fecal coliform levels exceeded the primary contact benchmark in the summers of 1998 to 2002, 2005, 2006, and 2008. Median levels exceeded the shellfish harvest benchmark in nearly all cases with median levels ranging between <20 MPN/100 mL to over 500 MPN/100 mL. Single-sample maximum and 90^{th} percentile levels exceeded 5000 MPN/100 mL.

From 2013 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to 500 MPN/ 100 mL. *E. coli* levels exceeded the primary contact benchmark for much of the summer season in 2014 and sporadically throughout the summers in 2013, 2015, and 2016. Maximum *E. coli* levels also exceeded the primary contact single-sample maximum benchmarks in all years. *E. coli* levels are above the shellfish harvesting benchmarks in a large majority of cases.

Spanish Banks

From 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 400 MPN/100 mL. Fecal coliform levels exceeded the primary contact benchmark in the summer of 2006. Median levels exceeded the shellfish harvest benchmark with median levels ranging between <20 MPN/100 mL to over 400 MPN/100 mL. Single-sample maximum and 90^{th} percentile levels exceeded 1000 MPN/100 mL.

From 2013 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to 40 MPN/ 100 mL. Geometric mean *E. coli* levels did not exceed the primary contact benchmark. However, median *E. coli* levels exceeded the shellfish harvesting benchmark.

Locarno Beach

From 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 500 MPN/100 mL. Fecal coliform levels exceeded the primary contact benchmark in the summers of 1999 and 2007. Median levels exceeded the shellfish harvest benchmark in nearly all cases with median levels ranging between <20 MPN/100 mL to over 500 MPN/100 mL. Single-sample maximum and 90^{th} percentile levels exceeded 5000 MPN/100 mL.

From 2013 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to 90 MPN/ 100 mL. Geometric mean *E. coli* levels have not exceeded the primary contact benchmark though single-sample maximum *E. coli* levels have exceeded the primary contact maximum benchmark. *E. coli* levels are above shellfish harvesting benchmarks.

Jericho Beach

From 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 5000 MPN/100 mL. Fecal coliform levels exceeded the primary contact benchmark in every summer except for 1996, 2003, 2004, and 2010. Median levels exceeded the shellfish harvest benchmark with median levels ranging between <20 MPN/100 mL to over 9000 MPN/100 mL. Single-sample maximum and 90th percentile levels exceeded 10,000 MPN/100 mL.

From 2013 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to 700 MPN/ 100 mL. Geometric mean *E. coli* levels exceeded the primary contact benchmark for three weeks in 2013 and four weeks in in 2014. Maximum *E. coli* levels also exceeded the primary contact maximum benchmark in all years. *E. coli* levels were above the shellfish harvesting benchmarks.

Kitsilano Beach

From 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to 900 MPN/100 mL. Fecal coliform levels exceeded the primary contact benchmark in the summers of 1997 and 2006. Median levels exceeded the shellfish harvest benchmark with median levels ranging between <20 MPN/100 mL to over 500 MPN/100 mL. Single-sample maximum and 90th percentile levels exceeded 5000 MPN/100 mL.

From 2012 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to 200 MPN/ 100 mL. Geometric mean *E. coli* levels have not exceeded the primary contact benchmark. Single-sample maximum *E. coli* levels exceed the primary contact maximum benchmarks in all years. *E. coli* levels were above the shellfish harvesting benchmarks.

Kitsilano Point

Monitoring of Kitsilano has only occurred from 2003 to present. From 2003 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 300 MPN/100 mL. Fecal coliform levels exceeded the primary contact benchmark in the summer of 2006 and for one week in the summer of 2008. Median levels exceeded shellfish harvest benchmarks with median levels ranging between <20 MPN/100 mL to over 300 MPN/100 mL. Single-sample maximum and 90th percentile levels exceeded 1000 MPN/100 mL and exceeded 5000 MPN/100 mL in 2006 and 2008.

From 2013 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to 900 MPN/ 100 mL. Mean *E. coli* levels have not exceeded the primary contact benchmark. Single-sample maximum *E. coli* levels occasionally exceeded the primary contact benchmark in 2013, 2014, and 2016. *E. coli* levels are above shellfish harvesting benchmarks though this is less frequent compared to other monitoring sites in the Outer Harbour.

English Bay Beach

From 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 1000 MPN/100 mL. Mean fecal coliform levels exceeded the primary contact benchmark in the summers of 1996, 2001, and 2011. Median levels exceeded the shellfish harvest benchmarks with median levels ranging between <20 MPN/100 mL to 900 MPN/100 mL. Single-sample maximum and 90th percentile levels exceeded 5000 MPN/100 mL prior to 2001 and exceeded 1000 MPN/100 mL after 2001.

From 2012 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to 300 MPN/ 100 mL. Mean *E. coli* levels exceeded the primary contact benchmark for two weeks in 2014. Maximum *E. coli* levels also exceeded the single-sample maximum primary contact benchmark in all years, except for 2015. *E. coli* levels were above the shellfish harvesting benchmarks.

Second Beach

From 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 200 MPN/100 mL. Mean fecal coliform levels exceeded the primary contact benchmark in the summer of 2002. Median levels exceeded the shellfish harvest benchmarks with median levels ranging between <20 MPN/100 mL to over 500 MPN/100 mL. Single-sample maximum and 90th percentile levels exceeded 1000 MPN/100 mL.

From 2013 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to 1000 MPN/ 100 mL. Mean *E. coli* levels exceeded the primary contact benchmark for three weeks of the summer in both 2013 and 2014. Maximum *E. coli* levels occasionally exceeded the single-sample maximum primary contact benchmark in 2013, 2014, and 2016. *E. coli* levels were above shellfish harvesting benchmarks.

Third Beach

From 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to 400 MPN/100 mL. Fecal coliform levels have not exceeded the primary contact benchmark in any summer season. Median levels exceeded the shellfish harvest benchmarks with median levels ranging between <20 MPN/100 mL to 400 MPN/100 mL. Single-sample maximum and 90th percentile levels exceeded 1000 MPN/100 mL in 1998, 1999, and 2004.

From 2013 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to 150 MPN/ 100 mL. Mean *E. coli* levels have not exceeded the primary contact benchmark in any summers. Maximum *E. coli* levels exceeded the single-sample maximum primary contact benchmark in 2013 and 2014. *E. coli* levels were above shellfish harvesting benchmarks though this is less frequent compared to other monitoring sites in Outer Harbour.

C.3 Inner Harbour

Metro Vancouver's Burrard Inlet Ambient Monitoring Program

From 2007 to 2016, there were elevated levels of fecal coliforms, *E. coli*, and enterococci at the Inner Harbour monitoring site. For samples collected at the top of the water column, mean *E. coli* levels (five samples collected over 30 days) exceeded the primary contact benchmark in 2009, 2011, and 2016 for samples collected at the top of the water column and in 2008, 2009, 2011, 2012, and 2016 for samples collected at the bottom of the water column. Geometric means exceeded the primary contact benchmark in all years except for 2014 and 2015 for both *E. coli* and fecal coliforms. Geometric mean values exceeded the primary contact benchmark in 2009, 2010, and 2016 for enterococci at the top of the water column and in all years at the bottom of the water column. Single-sample maximum levels among 5 samples collected over 30 days exceeded the primary contact benchmark all years but 2013 and 2015 for *E. coli* and in all years for enterococci. Median and 90th percentile values are well above shellfish harvesting benchmarks for all microbiological indicators in all years.

Provincial WQOs Attainment Monitoring

Early provincial attainment monitoring data collected from 1973 to 1978 in the Inner Harbour indicates that the Inner Harbour historically had elevated levels of fecal coliforms, though was less elevated in comparison to levels in False Creek and the Outer Harbour as measured by the same program in the same time period. During this period, there were two monitoring locations – Burrard Inlet Lions Gate and at Burrard Inlet Second Narrows. Multiple samples were not collected over a 30-day period so summary statistics could not be calculated. Since single or duplicate samples were collected independently, only individual data points were compared to the benchmarks for primary contact and shellfish harvesting. Five of 28 samples collected from the Burrard Inlet Lions Gate site between 1973 and 1978 exceeded the primary contact benchmark (200 MPN/100 mL) while 22 of 28 samples exceeded the median shellfish harvesting benchmark (14 MPN/100 mL). Likewise, eight of 28 samples collected from the Burrard Inlet Second Narrows site between 1973 and 1978 exceeded the primary contact benchmark and two samples were lower than the median shellfish harvesting benchmark. Individual fecal coliform values for this period ranged from 2 MPN/100 mL in August 1977 at Lions Gate to 920 MPN/100 mL in January 1977 at Second Narrows. This is a considerably lower range than False Creek, where maximum fecal coliform levels sometimes exceeded 24,000 MPN/100 mL during the same period.

In 2002, ENV conducted monitoring at four locations in the Inner Harbour: (1) Coal Harbour – South Shore near Bayshore Hotel (Site E207813); (2) Vancouver Harbour Vancouver Wharves (Site E207816); (3) Vancouver Harbour Clark Drive (Site E207818); and (4) Vancouver Harbour Lock Katrine Bank (Site E207819. Monitoring results from 2002 indicated that fecal coliform and enterococci levels in the Inner Harbour frequently exceeded the shellfish harvesting benchmarks and occasionally exceeded the primary contact benchmark. Summary statistics were calculated for these sites; however, except for the Vancouver Harbour Vancouver Wharves site, sampling was conducted over 50 days rather than 30 days. The following is a summary of the fecal coliform results for the Inner Harbour monitoring locations in 2002:

- Coal Harbour – South Shore near Bayshore Hotel (Site E207813)
  - Geometric Mean: 140 CFU/100 mL
  - Median: 125 CFU/100 mL
  - Single-sample Maximum: 870 CFU/100 mL
- Vancouver Harbour Vancouver Wharves (Site E207816)
  - Geometric Mean: 70 CFU/100 mL
  - Median: 110 CFU/100 mL
  - Single-sample Maximum: 230 CFU/100 mL
- Vancouver Harbour Clarke Drive (Site E207818)
  - Geometric Mean: 112 CFU/100 mL
  - Median: 120 CFU/100 mL
  - Single-sample Maximum: 660 CFU/100 mL
- Vancouver Harbour Loch Katrine Bank (Site E207819)
  - Geometric Mean: 32 CFU/100 mL
  - Median: 63 CFU/100 mL
  - Single-sample Maximum: 330 CFU/100 mL

In most cases, the summary data from 2002 exceeds the shellfish harvest benchmarks (14 bacteria/100mL median, 43 bacteria/100mL 90th percentile) by approximately one order of magnitude.

Measurements of enterococci further corroborate the fecal coliform results. The following is a summary of the enterococci results for the Inner Harbour monitoring locations in 2002:

- Coal Harbour – South Shore near Bayshore Hotel (Site E207813)
  - Geometric Mean: 102 CFU/100 mL
  - Median: 86.5 CFU/100 mL
  - Single-sample Maximum: 290 CFU/100 mL
- Vancouver Harbour Vancouver Wharves (Site E207816)
  - Geometric Mean: 24 CFU/100 mL
  - Median: 33 CFU/100 mL

    - Single-sample Maximum: 94 CFU/100 mL
- Vancouver Harbour Clarke Drive (Site E207818)
    - Geometric Mean: 41 CFU/100 mL
    - Median: 45 CFU/100 mL
    - Single-sample Maximum: 290 CFU/100 mL
- Vancouver Harbour Loch Katrine Bank (Site E207819)
    - Geometric Mean: 38 CFU/100 mL
    - Median: 140 CFU/100 mL
    - Single-sample Maximum: 330 CFU/100 mL

Metro Vancouver's Recreational Water Quality Monitoring Program

Metro Vancouver has measured fecal coliforms from 1993 to 2012 and *E. coli* from 2012 to present at two stations: (1) Brockton Point; and (2) Crab Park. Sampling was performed weekly on a year-round basis from 1993 to 2004 and weekly from May to September after 2004.

Brockton Point

From 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 5000 MPN/100 mL. Mean fecal coliform levels exceeded the primary contact benchmark in every summer except for 1999, 2005, 2008 2010 and 2012. Median levels exceeded shellfish harvest benchmarks in nearly the majority of cases with median levels ranging between <20 MPN/100 mL to over 10,000 MPN/100 mL. Single-sample maximum and 90th percentile levels have exceeded 10,000 MPN/100 mL prior to 2004 and exceeded 1000 MPN/100 mL after 2003.

From 2013 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to over 1000 MPN/ 100 mL. Geometric mean *E. coli* levels exceeded primary contact benchmarks for the duration of the summer of 2013 and sporadically on four occasions in the summer of 2014 and on two occasions in the summer of 2015. Maximum *E. coli* levels exceeded the primary contact maximum benchmarks in 2013 to 2015. *E. coli* levels are above shellfish harvesting benchmarks.

Crab Park

Monitoring of Crab Park has only occurred from 2014 to present. From 2014 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to 120 MPN/100 mL. Mean *E. coli* levels have not exceeded the primary contact benchmark to date. Single-sample maximum *E. coli* levels occasionally exceeded the primary contact benchmarks in all years. *E. coli* levels were above shellfish harvesting benchmarks.

C.4 Central Harbour

Metro Vancouver's Burrard Inlet Ambient Monitoring Program

From 2007 to 2016, there were some elevated levels of fecal coliforms, *E. coli*, and enterococci at the Central Harbour monitoring site. For samples separated based on collection at the top or bottom of the water column, geometric means of five samples collected over 30 days did not exceed the primary contact benchmark for *E. coli* or fecal coliforms in any program year. Geometric mean values did not exceed the primary contact benchmark for enterococci sampled at the top of the water column but did exceed the primary contact benchmark in 2010 to 2013 and 2016 at the bottom of the water column. Single-sample maximum levels among the five samples did not exceed the maximum primary contact benchmark for *E. coli* but did exceed the maximum primary contact benchmark for enterococci in 2016. Median and 90th percentile values were well above shellfish harvesting benchmarks for all microbiological indicators in all years, though there were some minor exceptions.

Provincial WQOs Attainment Monitoring

Monitoring results from 2002 indicate that fecal coliform levels in the Central Harbour at the Vancouver Harbour Shellburn (Site E207822) monitoring site generally did not exceed benchmarks for primary contact but did exceed enterococci shellfish harvesting benchmarks. Summary statistics were calculated; however, sampling was conducted over 50 days rather than 30 days and only 4 samples were collected. The following is a summary of the fecal coliform results for the Vancouver Harbour Shellburn site in 2002:

- Vancouver Harbour Shellburn (Site E207822)
    - Geometric Mean: 6 CFU/100 mL
    - Median: 12.5 CFU/100 mL
    - Single-sample Maximum: 30 CFU/100 mL

Measurements of enterococci further corroborate the fecal coliform results. The following is a summary of the enterococci results for the Vancouver Harbour Shellburn site in 2002:

- Vancouver Harbour Shellburn (Site E207822)
    - Geometric Mean: 5 CFU/100 mL
    - Median: 8.5 CFU/100 mL
    - Single-sample Maximum: 14 CFU/100 mL

Metro Vancouver's Recreational Water Quality Monitoring Program

Metro Vancouver has measured fecal coliforms from 1993 to 2012 and *E. coli* from 2012 to present at the Cates Park/Whey-ah-Wichen station. Sampling was performed weekly on a year-round basis from 1993 to 2004 and weekly from May to September after 2004.

Cates Park/Whey-ah-Wichen

From 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 700 MPN/100 mL. Mean fecal coliform levels exceeded the primary contact benchmark in the summers of 1996 to 2000 and 2005. Median levels exceeded the shellfish harvest benchmarks with median levels ranging between <20 MPN/100 mL to over 900 MPN/100 mL. Single-sample maximum and 90th percentile levels have exceeded 1000 MPN/100 mL.

From 2013 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to over 80 MPN/ 100 mL. Mean *E. coli* levels have not exceeded the primary contact benchmark. Single-sample maximum *E. coli* levels frequently exceeded the single-sample maximum primary contact benchmark in 2014 and occasionally exceeded the benchmark in 2015. *E. coli* levels are frequently above shellfish harvesting benchmarks, though less frequently than in the sub-basins to the west.

Canadian Shellfish Sanitation Program

The CSSP conducted monitoring at 10 locations at Maplewood Flats between 1992 and 2014 and two locations at Cates Park/Whey-ah-Wichen between 2006 and 2008. Monitoring under the CSSP is conducted specifically to determine whether sites are safe for shellfish harvesting. For this reason, CSSP monitoring data has only been compared to the shellfish harvesting benchmarks. Between 1992 and 2014, the median for fecal coliforms only met the shellfish harvesting benchmark. Because the sites are in close proximity to one another, the data has been summarized for the sites. Sampling was conducted with a minimum of five samples over 30 days so all median and 90th percentile values are reported using five samples over 30 days. The following is a summary of each site:

Maplewood Flats

- **Maplewood – Lagoon beside PESC Parking Lot** - This site was only monitored in 1997. Rolling median levels over the monitoring season ranged from 16 to 22 MPN/100 mL and the 90th percentile level was 28 MPN/100 mL. These ranges are in excess of the median shellfish harvesting benchmark but not in excess of the 90th percentile shellfish harvesting benchmark.
- **Maplewood – next to bridge on SW portion of PESC trails** - This site was only monitored in 1997. Rolling median levels ranged from 16 to 22 MPN/100 mL and the 90th percentile level was 28 MPN/100 mL. These ranges are in excess of the median shellfish harvesting benchmark but not in excess of the 90th percentile shellfish harvesting benchmark.
- **Maplewood – off bench at SE portion of PESC trails** - This site was only monitored in 1997. Rolling median levels ranged from <2 to 16 MPN/100 mL and the 90th percentile levels were 28 to 30 MPN/100 mL. These ranges are in excess of the median shellfish harvesting benchmark but not in excess of the 90th percentile shellfish harvesting benchmark.
- **Maplewood Flats East – Off old logging platform** - This site was only monitored in 1992. Rolling median levels ranged from 17 to 75 MPN/100 mL and the 90th percentile levels were 55 to 300 MPN/100 mL. These ranges are in excess of the median shellfish harvesting benchmark and 90th percentile shellfish harvesting benchmark.
- **Maplewood Flats East – Off point west of shipyard** - This site was only monitored in 1992. The median level was 80 MPN/100 mL and the 90th percentile level was 200 MPN/100 ML. These values are in excess of the median shellfish harvesting benchmark and the 90th percentile shellfish harvesting benchmark.
- **Maplewood Flats East – Off small shack by row of small shacks** - This site was only monitored in 1992. The median level was over 150 MPN/100 mL and the 90th percentile level was over 250 MPN/100 ML. These values are in excess of the median shellfish harvesting benchmark and the 90th percentile shellfish harvesting benchmark.
- **Maplewood Flats – Between 1st and 2nd piling lines** - This site was only monitored in 1992. The median level was 50 MPN/100 mL and the 90th percentile level was over 200 MPN/100 mL. These values are in excess of the median shellfish harvesting benchmark and the 90th percentile shellfish harvesting benchmark.
- **Maplewood Flats – Off cement retaining wall with culvert** - This site was monitored in 1992, and 2006 to 2014, though sampling was too infrequent in 2006 to 2014 to calculate summary statistics. In 1992, rolling median levels ranged from 49 to 125 MPN/100 mL and the 90th percentile levels were 49 to 429 MPN/100 mL. Single-sample values from later periods range from 2 to 920 MPN/100 mL. These ranges are in excess of the median shellfish harvesting benchmark and the 90th percentile shellfish harvesting benchmark.
- **Maplewood Flats – Off cemetery point off creek** - This site was only monitored in 1992. The median level was 163 MPN/100 mL and the 90th percentile level was 337 MPN/100 mL. These values are in excess of the median shellfish harvesting benchmark and the 90th percentile shellfish harvesting benchmark.
- **Maplewood Flats – Outside outermost piling line** - This site was monitored in 1992, and 2006 to 2014, though sampling was too infrequent in 2006 to 2014 to calculate summary statistics. In 1992, the median level was 79 MPN/100 mL and 90th percentile level was 154 MPN/100 mL. Single-sample values from later periods range from 2 to 170 MPN/100 mL. These ranges are in excess of the median shellfish harvesting benchmark and the 90th percentile shellfish harvesting benchmark.

Whey-ah-Wichen/Cates Park

- **Beach W of Cates Park dock** – This site was monitored from 2006 to 2008, though sampling was too infrequent to calculate summary statistics. Single-sample values ranged from 2 MPN/100 mL in August 2007 to 130 MPN/100 mL in December 2006 and October 2007. Where there were two or more samples collected over 30 days, geometric mean values ranged from 2 MPN/100 mL to 80 MPN/100 mL. Measured values exceeded the shellfish harvesting benchmarks.

Beach NE of Roche Pt at Cates Park - This site was monitored from 2006 to 2007, though sampling was too infrequent to calculate summary statistics. Single-sample values ranged from 2 MPN/100 mL in September 2006 and September 2007 to 130 MPN/100 mL in June 2006, December 2006, and January 2007. Where there are two or more samples collected over 30 days, geometric mean values ranged from 3 to 130 MPN/100 mL. Measured values exceeded the shellfish harvesting benchmarks.

C.5 Port Moody Arm

Metro Vancouver's Burrard Inlet Ambient Monitoring Program

From 2007 to 2016, there were some elevated levels of fecal coliforms, *E. coli*, and enterococci at the Outer Port Moody Arm monitoring site in comparison to the shellfish harvesting benchmarks. There were no exceedances of the primary contact benchmarks during this period. At both the top and bottom of the water column, medians of five samples collected over 30 days exceeded the shellfish harvesting benchmark in all years except 2011 and 2013 for *E. coli*, in all years except 2011 for fecal coliforms and in all years for enterococci. Median *E. coli* and fecal coliform values from samples collected at the bottom of the water column exceeded the benchmark in all years. The 90th percentile values of five samples collected over 30 days from the top of the water column exceeded the shellfish harvesting benchmark in all years except for 2011 for *E. coli*, in all years for enterococci, and in all years except 2011 for fecal coliforms. The 90th percentile values of samples collected at the bottom of the water column consistently exceeded the shellfish harvesting benchmark.

Provincial WQOs Attainment Monitoring

Early provincial attainment monitoring data from 1973 to 1978 at ENV's 'Burrard Inlet' (Site 300079) monitoring site indicates that Port Moody historically had some of the lowest fecal coliform levels in Burrard Inlet. Multiple samples were not collected over a 30-day period so summary statistics could not be calculated. Since single or duplicate samples were collected independently, only individual data points were compared to the benchmarks for primary contact activities and shellfish harvesting. One of 28 samples collected at the Burrard Inlet monitoring site (Port Moody Arm) between 1973 and 1978 exceeded the primary contact benchmark (200 MPN/100 mL) while 18 of 28 samples exceeded the median shellfish harvesting benchmark (14 MPN/100 mL), though detection limits were frequently 20 MPN/100 mL so at least eight of the 18 samples may have actually been below 14 MPN/100 mL. Individual fecal coliform values for this period ranged from 2 MPN/100 mL on several occasions to 1,600 MPN/100 mL in May 1978. Enterococci was not monitored during this early period.

In 2002, ENV conducted monitoring at two locations in Port Moody Arm: (1) Port Moody IOCO (Site E207823); and (2) Pacific Coast #11 75 meters northeast (Site E207698). Monitoring results from 2002 indicate that fecal coliform and enterococci levels in Port Moody Arm occasionally exceeded shellfish harvesting benchmarks but did not exceed the primary contact benchmarks. Summary statistics were calculated for these sites; however, sampling was conducted over 50 days rather than 30 days. The following is a summary of the fecal coliform results for the Port Moody Arm monitoring locations in 2002:

- Port Moody IOCO (Site E207823)
  - Geometric Mean: 18 CFU/100 mL
  - Median: 13 CFU/100 mL
  - Single-sample Maximum: 160 CFU/100 mL
- Pacific Coast #11 75 meters northeast (Site E207698)
  - Geometric Mean: 23 CFU/100 mL
  - Median: 17 CFU/100 mL
  - Single-sample Maximum: 180 CFU/100 mL

Measurements of enterococci further corroborate the fecal coliform results. The following is a summary of the enterococci results for the Port Moody Arm monitoring locations in 2002:

- Port Moody IOCO (Site E207823)
  - Geometric Mean: 9 CFU/100 mL
  - Median: 5 CFU/100 mL
  - Single-sample Maximum: 210 CFU/100 mL
- Pacific Coast #11 75 meters northeast (Site E207698)
  - Geometric Mean: 24 CFU/100 mL
  - Median: 12 CFU/100 mL
  - Single-sample Maximum: 190 CFU/100 mL

Metro Vancouver's Recreational Water Quality Monitoring Program

Metro Vancouver measured fecal coliforms from 1993 to 2012 and *E. coli* from 2012 to 2016 at three stations: (1) Barnet Marine Park; (2) Old Orchard; and (3) Rocky Point Park. Sampling was performed weekly on a year-round basis from 1993 to 2004 and weekly from May to September after 2004.

Barnet Marine Park

Monitoring was infrequent prior to 2003; however, from 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 500 MPN/100 mL. Fecal coliform levels exceeded the primary contact benchmark in the summers of 2005 and 2006. Median levels exceeded the shellfish harvest benchmark with median levels ranging between <20 MPN/100 mL to over 500 MPN/100 mL. Single-sample maximum and 90^{th} percentile levels exceeded 1000 MPN/100 mL in 2001, 2004, 2006, 2008, 2010, and 2011.

From 2013 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to over 200 MPN/ 100 mL. Mean *E. coli* levels exceeded the primary contact benchmark for three weeks of the summer in 2014. The single-sample maximum *E. coli* level exceeded the single-sample maximum primary contact benchmark in all monitoring years. *E. coli* levels are frequently above the shellfish harvesting benchmarks, though less frequently than in the sub-basins to the west.

Old Orchard

From 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 200 MPN/100 mL. Fecal coliform levels exceeded the primary contact benchmark for four weeks of the summer in 2006. Median levels exceeded the shellfish harvest benchmark with median levels ranging between <20 MPN/100 mL to over 500 MPN/100 mL. Single-sample maximum and 90^{th} percentile levels have occasionally exceeded 1000 MPN/100 mL.

From 2013 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to over 200 MPN/ 100 mL. Mean *E. coli* levels exceeded the primary contact benchmark for four weeks in the summer in 2014. Maximum *E. coli* levels exceeded the single-sample maximum primary contact benchmark in 2014 and occasionally exceeded this benchmark in 2013 and 2016. *E. coli* levels are above the shellfish harvesting benchmarks.

Rocky Point Park

Monitoring at Rocky Point Park began in 2009. From 2009 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 200 MPN/100 mL. Mean fecal coliform levels exceeded the primary contact benchmark for three weeks in the summer of 2011. Median levels exceeded the shellfish harvest benchmarks with median levels ranging between <20 MPN/100 mL to over 300 MPN/100 mL, though there were no exceedances in 2012. Single-sample maximum and 90th percentile levels have occasionally exceeded 500 MPN/100 mL but also exceeded 1000 MPN/100 mL in 2011.

Monitoring of *E. coli* in Rocky Point was only conducted in 2013 and 2014. From 2013 to 2014, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to over 800 MPN/ 100 mL. Mean *E. coli* levels exceeded the primary contact benchmark for six weeks in 2014. Maximum *E. coli* levels exceeded the single-sample maximum primary contact benchmark in 2014 but did not exceed the primary contact benchmark in 2013. *E. coli* levels are above shellfish harvesting benchmarks.

C.6 Indian Arm

Metro Vancouver's Burrard Inlet Ambient Monitoring Program

Metro Vancouver has two ambient monitoring locations in Indian Arm, identified as Indian Arm North and Indian Arm South.

Indian Arm North

From 2007 to 2016, there were some elevated levels of fecal coliforms, *E. coli*, and enterococci at the Indian Arm North monitoring site in comparison to the shellfish harvesting benchmarks. There were no exceedances of the primary contact benchmarks during this period. Medians of five samples collected over 30 days at the top of the water column exceeded the shellfish harvesting benchmark in 2007 to 2010 for both *E. coli* and fecal coliforms and in all years except 2016 for enterococci. The 90th percentile values from the top of the water column exceeded the 90th percentile shellfish harvesting benchmark in 2009, 2010, 2016 for enterococci and in no years for *E. coli* or fecal coliforms. The 90th percentile values of samples collected at the bottom of the water column exceeded the benchmark only for enterococci in 2016. However, there was no data for the bottom of the water column from 2007 to 2013 for *E. coli* and fecal coliforms and from 2007 to 2015 for enterococci.

Indian Arm South

From 2007 to 2016, there were some elevated levels of fecal coliforms, *E. coli*, and enterococci at the Indian Arm South monitoring site compared to benchmarks. Maximum values of five samples over 30 days collected at the bottom of the water column exceeded the primary contact benchmark in 2010 and 2012 for fecal coliforms, and in 2012 for enterococci. There were no exceedances of the primary contact benchmarks for samples collected at the top of the water column. Median values for samples collected from the top of the water column exceeded the shellfish harvesting benchmark from 2007 to 2010 for *E. coli*, in all years for enterococci, and from 2007 to 2010 and in 2012 for fecal coliforms. However, the exceedances that occurred from 2007 to 2010 were influenced by detection limits that were frequently in the range of 10 to 20 MPN/100 mL. The 90th percentile values for samples collected at the top of the water column exceeded the shellfish benchmark in 2010 for *E. coli* and inall years except for 2008 and 2016 for enterococci. Fecal coliform levels did not exceed the 90th percentile shellfish harvesting benchmark. The 90th percentile values for samples collected at the bottom of the water column were above the shellfish harvesting benchmark.

Provincial WQOs Attainment Monitoring

Early provincial attainment monitoring data from 1973 to 1978 at ENV's Indian Arm monitoring site indicates that Indian Arm has historically had low fecal coliform levels (<23 MPN/100 mL), other than one outlier sample that measured 2,400 MPN/100 mL in December 1975. Multiple samples were not collected over a 30-day period so summary statistics could not be calculated. Since single or duplicate samples were collected independently, only individual data points were compared to the benchmarks for primary contact activities and shellfish harvesting. Only one of the 29 samples collected at the Indian Arm monitoring site between 1973 and 1978 exceeded the mean primary contact benchmark (200 MPN/100 mL) while 13 of 28 samples exceeded the median shellfish harvesting benchmark (14 MPN/100 mL). Detection limits were frequently 20 MPN/100 mL, however, so at least some of the eight samples may have actually been below 14 MPN/100 mL. Individual fecal coliform values for this period ranged from 2 MPN/100 mL on several occasions to 2,400 MPN/100 mL in December 1975. Enterococci was not monitored during this early period.

Monitoring results from 2002 indicate that fecal coliform levels in Indian Arm at Cable Crossing did not exceed benchmarks for primary contact activities or shellfish harvesting. Summary statistics were calculated; however, sampling was conducted over 50 days rather than 30 days. The following is a summary of the fecal coliform results for the Indian Arm at Cable Crossing monitoring site in 2002:

- Indian Arm at Cable Crossing (Site 300080)
  - Geometric Mean: 4 CFU/100 mL
  - Median: 2 CFU/100 mL
  - Single-sample Maximum: 34 CFU/100 mL

Measurements of enterococci further corroborate the fecal coliform results. The following is a summary of the enterococci results for the Indian Arm at Cable Crossing monitoring site in 2002:

- Indian Arm at Cable Crossing (Site 300080)
  - Geometric Mean: 3 CFU/100 mL
  - Median: 2 CFU/100 mL
  - Single-sample Maximum: 18 CFU/100 mL

Metro Vancouver's Recreational Water Quality Monitoring Program

Metro Vancouver has measured fecal coliforms from 1993 to 2012 and *E. coli* from 2012 to present at 3 stations: (1) Bedwell Bay; (2) Belcarra Park; and (3) Deep Cove. Sampling was performed weekly on a year-round basis from 1993 to 2004 and weekly from May to September after 2004.

Bedwell Bay

Monitoring at Bedwell Bay began in 2004. From 2004 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 50 MPN/100 mL. Mean fecal coliform levels have not exceeded the primary contact benchmark. Median levels occasionally exceeded shellfish harvest benchmarks with median levels ranging between <20 MPN/100 mL to over 50 MPN/100 mL. Single-sample maximum and 90th percentile levels have occasionally exceeded 1000 MPN/100 mL and frequently exceed 300 MPN/100 mL.

From 2013 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to 200 MPN/ 100 mL. Mean *E. coli* levels exceeded the primary contact benchmark for one week in the summer of 2014. Single-sample maximum *E. coli* levels occasionally exceeded the primary contact maximum benchmark in 2014 and 2015. *E. coli* levels are frequently above shellfish harvesting benchmarks, though less frequently than in the western sub-basins.

Belcarra Park

Monitoring at Belcarra Park began in 2004. From 2004 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 100 MPN/100 mL. Mean fecal coliform levels have not exceeded the primary contact benchmark. Median levels occasionally exceeded shellfish harvest benchmarks with median levels ranging between <20 MPN/100 mL to over 100 MPN/100 mL. Single-sample maximum and 90th percentile levels have occasionally exceeded 1000 MPN/100 mL.

From 2013 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to over 70 MPN/ 100 mL. Mean *E. coli* levels have not exceeded the primary contact benchmark. Maximum *E. coli* levels occasionally exceeded the single-sample maximum primary contact benchmark in 2014, 2015, and 2016. *E. coli* levels are frequently above shellfish harvesting benchmarks, though less frequently than in the western sub-basins.

Deep Cove

From 1993 to 2012, rolling 30-day geometric mean levels for fecal coliforms ranged from <10 MPN/100 mL to over 900 MPN/100 mL. Mean fecal coliform levels exceeded the primary contact benchmark in all summers except for 2003, 2007 to 2010, and 2012. Median levels exceeded shellfish harvest benchmarks with median levels ranging between <20 MPN/100 mL to over 800 MPN/100 mL. Single-sample maximum and 90th percentile levels frequently exceeded 1000 MPN/100 mL and occasionally exceeded 10,000 MPN/100 mL.

From 2013 to 2016, rolling 30-day geometric mean levels for *E. coli* ranged from <10 MPN/100 mL to over 200 MPN/ 100 mL. Mean *E. coli* levels exceeded the primary contact benchmark for one week in the summer of 2014. Maximum *E. coli* levels exceeded the single-sample maximum primary contact benchmark in 2014 and occasionally exceeded the primary contact benchmark in 2013 and 2015. *E. coli* levels are frequently above shellfish harvesting benchmarks.

Canadian Shellfish Sanitation Program

Because the sites are in close proximity to one another, the data has been summarized for each of Belcarra Bay and Deep Cove. Sampling was conducted for fecal coliform only with a minimum of five samples over 30 days so all median and 90th percentile values are reported using five samples over 30 days. The following is a summary of each site.

Belcarra Bay

- **Belcarra – off beach between Hamber Is, and Turtle Head** – This site was only monitored in 1991. The median level was 33 MPN/100 mL and 90th percentile level was 86 MPN/100 mL. These values exceed the shellfish harvesting benchmarks.
- **Belcarra Bay – off grey house with 3-tiered retaining wall** – This site was only monitored in 1991. The median level was 18 MPN/100 mL and 90th percentile level was 92 MPN/100 mL. These values exceed the shellfish harvesting benchmarks.
- **Belcarra Bay – off large brown house on bluff** – This site was only monitored in 1991. The median level was 8 MPN/100 mL and 90th percentile level was 15 MPN/100 mL. These values meet the shellfish harvesting benchmarks.

- **Belcarra Bay – off large rock on beach near 2 leaning trees** – This site was only monitored in 1991. The median level was 5 MPN/100 mL and 90th percentile level was 35 MPN/100 mL. These values meet the shellfish harvesting benchmarks.
- **Belcarra Bay – off maple tree between 2 large wharves** – This site was only monitored in 1991. The median level was 33 MPN/100 mL and 90th percentile level was 106 MPN/100 mL. These values exceed the shellfish harvesting benchmarks.
- **Belcarra Bay – off small stream at head of bay** – This site was only monitored in 1991. The median level was 33 MPN/100 mL and 90th percentile level was 95 MPN/100 mL. These values exceed the shellfish harvesting benchmarks.
- **Belcarra Bay – off stairs beside wharf on pebble beach** – This site was only monitored in 1991. The median level was 16 MPN/100 mL and 90th percentile level was 31 MPN/100 mL. The median value exceeds the median shellfish harvest benchmark but the 90th percentile values meet the 90th percentile shellfish harvesting benchmarks.
- **Belcarra Bay – off trail between 2 houses in from buoy** - This site was only monitored in 1991. The median level was 10 MPN/100 mL and 90th percentile level was 25 MPN/100 mL. These values meet the shellfish harvesting benchmarks.

Deep Cove

- **Between LMOO2&004 off Panorama Park-Deep Cove** – This site was monitored in 1991 and 1992. In 1991, the median level was 10 MPN/100 mL and the 90th percentile level was 17 MPN/100 mL and the 1992 values were very similar. These values meet the shellfish harvesting benchmarks.
- **E of boat house off drainpipe-Deep Cove** – This site was monitored in 1990 and 1991. In 1990, the median level was 15 MPN/100 mL and the 90th percentile level was 115 MPN/100 mL and the 1991 values are roughly 10% higher. These values exceed the shellfish harvesting benchmarks.
- **Off Ck at N end of Deep Cove by houses** – This site was monitored in 1990 and 1991. In 1990, the median level was 37 MPN/100 mL and the 90th percentile level was 110 MPN/100 mL and the 1991 values are roughly 25% higher. These values exceed the shellfish harvesting benchmarks.
- **Off creek beside Deep Cove Yacht Club** – This site was monitored in 1990 and 1991. In 1990, the median level was 19 MPN/100 mL and the 90th percentile level was 223 MPN/100 mL and the 1991 values are roughly 50% higher for the median and 50% lower for the 90th percentile. These values are in excess of the shellfish harvesting benchmarks.

Since 2006, monitoring has occurred at numerous additional sites around Indian Arm. Table 30 provides a summary of the results for each monitoring site by year. Median values are provided for data from each year, however five samples were not collected over 30-day periods and some years and sites have had more sampling efforts than others.

Table 30: Summary of CSSP Monitoring Results for Indian Arm from 2006 to 2017

Location Name	Year	Sample Count	Median	90th Percentile
Beach NE of Roche Pt at Cates Park	2006	13	8	113.8
	2007	15	17	61.6
	2008	2	56.5	NA
Indian Arm – Boulder Island – Beach on NE side	2007	13	5	69.8
	2008	15	2	5
	2009	6	3	NA
	2010	7	2	NA
	2011	5	5	NA
	2012	5	2	NA
	2013	5	5	NA
	2014	2	7.5	NA
Beach S of Belcarra Dock	2006	13	11	145.8
	2007	15	14	42.6
	2008	2	26.5	NA
Head of Bedwell Bay	2006	13	5	21.8
	2007	15	2	19
	2008	15	2	7.6
	2009	6	9	NA
	2010	7	5	NA
	2011	5	2	NA
	2012	5	2	NA
	2013	5	5	NA
	2014	2	5	NA
Bedwell Bay – on E side, S of last house	2006	13	2	21
	2007	15	2	10.4
	2008	15	2	7.6
	2009	6	8	NA
	2010	7	11	NA
	2011	5	8	NA
	2012	5	2	NA
	2013	5	2	NA
	2014	2	3.5	NA
Beach inside Jug Is	2006	13	2	4.4
	2007	15	5	25
	2008	15	2	3.2
	2009	6	2	NA
	2010	7	2	NA
	2011	5	7	NA
	2012	5	2	NA
	2013	5	2	NA
	2014	2	5	NA
Indian Arm – Brighton Beach – off creekmouth in front of brown house with a bridge	2014	3	5	NA
	2015	6	20.5	NA
	2016	5	17	NA

Location Name	Year	Sample Count	Median	90th Percentile
	2017	3	2	NA
Beach at Twin Islands b/w islets	2006	13	5	11
	2007	15	7	17
	2008	15	2	12.8
	2009	6	3.5	NA
	2010	7	11	NA
	2011	5	23	NA
	2012	5	13	NA
	2013	5	2	NA
	2014	2	3.5	NA
Indian Arm – Orlomah Beach – North of Shone Creek	2007	13	2	12
	2008	15	2	11
	2009	6	2	NA
	2010	7	5	NA
	2011	5	8	NA
	2012	5	5	NA
	2013	5	2	NA
	2014	5	2	NA
	2015	6	3.5	NA
	2016	5	7	NA
	2017	3	2	NA
Beach S of Wigwam Inn	2006	13	11	45.8
	2007	15	8	42.6
	2008	15	2	25
	2009	6	17.5	NA
	2010	7	2	NA
	2011	5	8	NA
	2012	5	8	NA
	2013	5	5	NA
	2014	5	11	NA
	2015	6	9	NA
	2016	5	8	NA
	2017	3	5	NA
Indian River Estuary – West side	2006	13	23	162
	2007	14	12	48.1
	2008	2	4.5	NA
	2014	3	17	NA
	2015	6	8	NA
	2016	5	13	NA
	2017	3	11	NA
Indian Arm – Coldwell Beach – off creek mouth S of Lou's Landing dock, in front of brown house tucked behind trees with solar panel	2014	3	2	NA
	2015	6	5	NA
	2016	5	2	NA
	2017	3	2	NA

Location Name	Year	Sample Count	Median	90th Percentile
Indian River Estuary – East Side	2006	13	8	30.6
	2007	15	5	50.6
	2008	15	2	5
	2009	6	19	NA
	2010	7	8	NA
	2011	5	8	NA
	2012	5	4	NA
	2013	5	2	NA
	2014	5	5	NA
	2015	6	12.5	NA
	2016	5	2	NA
	2017	3	2	NA
Bishop Creek – beach at SW end	2006	13	5	11
	2007	15	2	9.8
	2008	15	2	11
	2009	6	6.5	NA
	2010	7	5	NA
	2011	5	2	NA
	2012	5	2	NA
	2013	5	2	NA
	2014	5	4	NA
	2015	6	9	NA
	2016	5	2	NA
	2017	3	2	NA
Bishop Creek – beach at N end S of breakwater	2006	13	5	21.8
	2007	15	5	24.4
	2008	15	2	13
	2009	6	3.5	NA
	2010	7	8	NA
	2011	5	8	NA
	2012	5	5	NA
	2013	5	2	NA
	2014	5	2	NA
	2015	6	3.5	NA
	2016	5	2	NA
	2017	3	2	NA
Indian Arm – Buntzen Bay – at beach between two large docks	2007	13	2	29
	2008	15	2	18.8
	2009	6	5	NA
	2010	7	2	NA
	2011	5	23	NA
	2012	5	2	NA
	2013	5	2	NA
	2014	5	5	NA
	2015	6	10.5	NA
	2016	5	2	NA

Location Name	Year	Sample Count	Median	90th Percentile
	2017	3	2	NA
Indian Arm – Southern tip of Croker Island	2007	13	2	11.4
	2008	15	2	8
	2009	6	2	NA
	2010	7	8	NA
	2011	5	5	NA
	2012	5	2	NA
	2013	5	2	NA
	2014	5	2	NA
	2015	6	2	NA
	2016	5	2	NA
	2017	3	2	NA
Indian Arm – Granite Falls – South side at beach east of navigational light	2007	13	2	7.6
	2008	15	2	9.2
	2009	6	2	NA
	2010	7	8	NA
	2011	5	8	NA
	2012	5	2	NA
	2013	5	2	NA
	2014	5	2	NA
	2015	6	10.5	NA
	2016	5	17	NA
	2017	3	2	NA
Indian Arm – Johnson Bay – off creekmouth S of brown house with white trim	2007	13	2	8
	2008	15	2	11
	2009	6	2	NA
	2010	7	2	NA
	2011	5	5	NA
	2012	5	2	NA
	2013	5	2	NA
	2014	5	2	NA
	2015	6	3.5	NA
	2016	5	2	NA
	2017	3	2	NA

APPENDIX D: DETAILED RESULTS SUMMARY FIGURES

(See supplementary document)