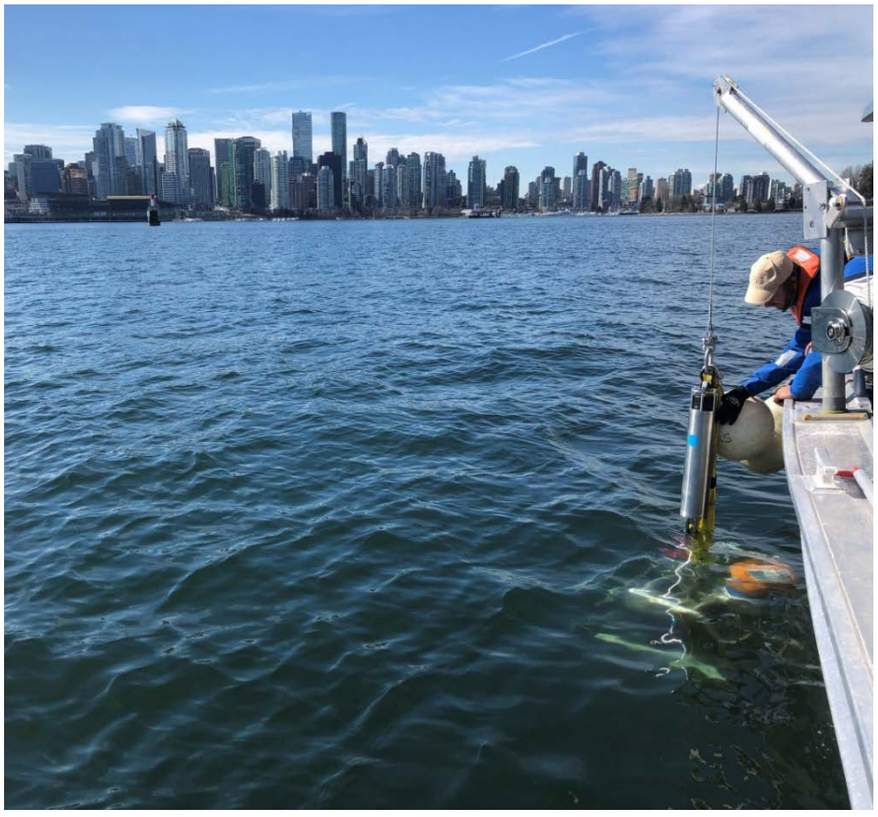
Water Quality Assessment and Proposed Objectives for Burrard Inlet: Introduction



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Tsleil-Waututh Nation
səlilwətaɬ

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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.

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Cover Photograph:

Underwater monitoring equipment is installed from the Tsleil-Waututh Nation boat in Burrard Inlet. Photo credit; Tsleil-Waututh Nation.

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ACRONYMS

BC: British Columbia
BCCSN: BC Cetacean Sightings Network
BOD_5: biological oxygen demand test (measure of dissolved oxygen at the beginning and end of a 5-day incubation period)
BIEAP: Burrard Inlet Environmental Action Program
$CBOD_5$: carbonaceous BOD_5
CCME: Canadian Council for Ministers of the Environment
Cl res: Residual chlorine
COP: BC Code of Practice
CPOs: chlorine-produced oxidants
CSO: combined sewer overflow
CSSP: Canadian Shellfish Sanitation Program
CWS-MMWE: Canada-Wide Strategy for the Management of Municipal Wastewater Effluent
DFO: Fisheries and Oceans Canada
EMA: BC *Environmental Management Act*
ENV: British Columbia Ministry of Environment and Climate Change Strategy
FSC: food, social and ceremonial
GVRD: Greater Vancouver Regional District
GVSDD: Greater Vancouver Sewerage and Drainage District
HBCD: hexabromocyclododecane (a flame retardant)
HWR: BC Hazardous Waste Regulation
HPAHs: high molecular weight polycyclic aromatic hydrocarbons
ILWRMP: Integrated Liquid Waste and Resource Management Plan
LPAHs: low molecular weight polycyclic aromatic hydrocarbons
LWMP: Liquid Waste Management Plan
MCA: Maplewood Conservation Area
MWR: BC Municipal Waste Regulation
O&G: oil and grease
PSDFSWR: BC Petroleum Storage and Distribution Facilities Storm Water Regulation
PAHs: polycyclic aromatic hydrocarbons
PBDEs: polybrominated diphenyl ethers (flame retardants)
PCBs: polychlorinated biphenyls
PFCs: perfluorinated compounds
PPCPs: pharmaceuticals and personal care products
SPES: Stanley Park Ecology Society
STP: sewage treatment plant
TBT: tributyl tin
TEH: total extractable hydrocarbons
TOC: total organic carbon
TSS: total suspended solids
TWN: Tsleil-Waututh Nation
UBC: University of British Columbia
VFPA: Vancouver Fraser Port Authority
WQOs: water quality objectives
WWTP: wastewater treatment plant

WEAVING TOGETHER INDIGENOUS AND WESTERN SCIENCE FOR A HEALTHY INLET

Tsleil-Waututh means “People of the Inlet”, refering directly to the Burrard Inlet up to the Indian River and including Indian Arm. We were born with a sacred obligation to protect the waters. Our first grandfather was transformed from a wolf into a human being. When it was time for him to have a mate, the Creator gave him a vision that he was to dive off one of the tallest cliffs in Indian Arm, grab two handfuls of sediment from the floor of the Inlet and bring them back to the beach. Our first grandmother was transformed from that sediment – our first grandmother comes from the Inlet. Our ties to this Inlet run deep. It’s important that we hold that responsibility, that as a Nation we gather people around who see our vision, and that our work resonates with their own spirit. Our projects are all related to restoring the habitat, and creating space for the Inlet to heal.

When I was a kid we would pack a lunch on hot summer days and go down to the beach. My dad would tell us sometimes, “Don’t go swimming in the Inlet today because of red tide.” I asked him, “What’s a red tide?” and he told me, “It’s just the Inlet cleansing herself.” So we stayed out of the Inlet until there wasn’t red tide anymore. As we had children it seemed like there was red tide all the time in the Inlet. So we didn’t spend a lot of time on the Inlet with my kids. Hopefully with my grandchildren, now we can spend more time down there than we have in the past.

Generations of Tsleil-Waututh people were brought up with the teachings, “When the tide went out, the table was set”. It is unfortunate that for the last couple of generations we haven’t been able to experience going to the Inlet to sustain ourselves. We haven’t been able to harvest shellfish from the Inlet since the 1970s. I remember spending a lot of time with my grandmother and cousins on the mudflats. My grandmother taught us how to dig clams and find crabs. Our goal is to bring back the harvest.

It’s really important to weave together western science and Indigenous science. My dad has been on the Inlet his entire life. He can tell you how to read the tide, and how to know when things are coming into harvesting season. The Inlet is coming back, but we need more. We have to do this work together. You’re not going anywhere. We’re not going anywhere. We have to find a way to co-exist. We have that shared responsibility. That’s what Tsleil-Waututh has done from the very beginning. We know we have to build those relationships around us because we can’t do the work alone. We’re looking in the same direction. We have to weave all our knowledge together so that our grandchildren will be able to grow up on the mudflats like we did as kids.

Carleen Thomas, Special Projects Manager

Treaty Lands and Resources, Tsleil-Waututh Nation

1. INTRODUCTION

1.1 səlilwət

Tsleil-Waututh, which means “People of the Inlet”, have used and occupied the lands and waters of səlilwət and surrounding watersheds since time out of mind. Burrard Inlet lies within the traditional and unceded territories of the səl̓ilwətaʔɬ (Tsleil-Waututh), xʷməθkʷəy̓əm (Musqueam) and Sḵwx̱wú7mesh Coast Salish Nations. While the English name is used throughout this document, Tsleil-Waututh’s name for Burrard Inlet in the həńq̓əmiṅəṁ language is səlilwət.

The Tsleil-Waututh people occupied, governed, and acted as stewards of their territory since time out of mind and continue to do so today. Tsleil-Waututh holds a sacred, legal obligation and responsibility to protect, defend and steward the lands and waters of their territory in accordance with Tsleil-Waututh law. This stewardship responsibility includes restoring conditions that provide the environmental, cultural, spiritual, and economic foundation for their communities to thrive.

According to Tsleil-Waututh oral history, knowledge and archaeological records, approximately 90% of the Tsleil-Waututh diet was derived from sal̓ ilw̓ət marine resources and Fraser River salmon. Today, the inlet is largely unable to support Tsleil-Waututh’s needs.

Adverse cumulative effects of colonial settlement, and subsequent industrialization and urbanization, have eroded the ecological health, integrity and diversity of səlilwət. Its herring population was extirpated by 1898 (Mathews 1955, Morin 2015), and by 1972 sanitation and contamination concerns were so great the federal government closed the inlet to bivalve shellfish harvesting (Jamieson and Lessard 2000, KWL 2017).

Much of its shorelines have been modified or armoured to enable industrial and municipal development, and estuaries have been lost or channelized. The inlet was estimated in 2015 to receive 25 times the volume of permitted industrial discharges than it did in 1957 (TWN 2015). Alongside increased inputs into the inlet has been the replacement of a large portion of the surrounding forested watersheds and vegetated marine riparian areas, and their natural filtration capacity, with impermeable infrastructure. Together, these activities have impacted water quality.

Tsleil-Waututh Nation (TWN) has a goal to restore the health of səlilwət, so the community can once again harvest healthy, sustainable wild marine resources and practice spiritual, cultural, ceremonial and recreational activities in clean water free of risk from contamination and harmful pathogens. Doing so upholds Tsleil-Waututh’s obligations to past, present, and future generations of Tsleil-Waututh people in accordance with Tsleil-Waututh law. Updating the water quality objectives is a key priority in the TWN Burrard Inlet Action Plan, and TWN has played an active role in initiating collaboration on exploration of environmental issues and strategic solutions to advance the ecological integrity and health of Burrard Inlet.

1.2 The need to update Water Quality Objectives for Burrard Inlet

WQOs were initially developed for Burrard Inlet upon request of the regional office of the BC Ministry of Environment (now referred to as the Ministry of Environment and Climate Change Strategy [ENV]) when the Greater Vancouver Regional District (now known as Metro Vancouver) was preparing a liquid waste management plan in 1985. Burrard Inlet WQOs were required to complement provisional objectives for the Fraser River (Nijman and Swain 1990).

The original WQOs for Burrard Inlet (provided in Appendix E) were provisional and were developed in 1990. Recognizing the water contamination in Burrard Inlet, these provisional objectives were set to protect aquatic life, wildlife and primary-contact recreation in Burrard Inlet, Lynn Creek and School House Brook; aquatic life and wildlife in False Creek; and aquatic life, wildlife, primary-contact recreation and drinking water supplies in the Capilano River (Nijman 1990).

Since 1990, ongoing research in Burrard Inlet has provided new monitoring data, a more complete list of contaminants of concern, and documentation of discharges into the Inlet. At the same time, knowledge of the biological thresholds and pathways of contaminants has improved. This body of research, along with the knowledge that the health of the inlet has deteriorated over time, provides an important opportunity and need to update the WQOs for Burrard Inlet. The proposed objectives must include consideration of sensitive water uses and values, changes in inputs and activities in Burrard Inlet, future goals for the health of the Inlet, as well as Indigenous traditional knowledge and perspectives.

Updating the provincial WQOs for Burrard Inlet has been identified as a priority by the BC ENV, Metro Vancouver and the Tsleil-Waututh Nation (TWN). It is the first strategy under the first goal identified by TWN in its Burrard Inlet Action Plan. Updating the WQOs will lay the groundwork for further efforts and coordination to reduce pollution in Burrard Inlet and attain the objectives.

The purpose of this initiative is to assess the present state of water quality in Burrard Inlet in relation to the original (1990) objectives, and to provide recommendations to update these WQOs to reflect current knowledge and updated future goals for the health of these waters. It draws upon the 1990 WQOs, the TWN Burrard Inlet Action Plan, the work of the Burrard Inlet Environmental Action Program[1], discharge authorization and monitoring records, current science, Indigenous knowledge and stewardship values, and more.

The following key documents provide important background information to this initiative:

- Ambient Water Quality Objectives for Burrard Inlet (BC Ministry of Environment), 1990
- Burrard Inlet Water Quality Assessment and Objectives – Technical Appendix (BC Ministry of Environment), 1990
- Burrard Inlet Action Plan (Tsleil-Waututh Nation), 2017

1.3 The process of establishing and updating Water Quality Objectives in BC

Water quality objectives (WQO) are used by the Ministry of Environment and Climate Change Strategy (ENV) for specific waterbodies to promote the protection and stewardship of B.C.'s water resources. WQOs define conditions that represent levels of low risk to water values. They formalize expectations with respect to water quality for a given waterbody and are used to inform resource management decisions in the natural resource sector.

WQOs are established on a priority basis for waterbodies (fresh, estuarine, marine) of regional, provincial, inter-provincial, and international significance as part of ENV's mandate to protect, manage, and conserve B.C.'s water resources. WQOs are set with the goal of protecting water values by

[1] The Burrard Inlet Environmental Action Program and the Fraser River Estuary Management Program (BIEAP-FREMP) were intergovernmental programs that coordinated environmental management review and interagency communications for projects and coastal developments in Burrard Inlet and the Fraser River estuary. The programs were closed in 2013.

maintaining existing water quality, improving existing water quality, or protecting water quality for a specific use.

WQOs are based on water quality guidelines, or similar information, and water quality assessments which consider the characteristics of the waterbody. These characteristics include: the ambient water quality and its assimilative capacity; the aquatic life and wildlife, and its habitat; the hydrology; the sediments; the potential contaminant loadings from point and non-point source waste discharges; and the cultural and social values associated with a waterbody.

Once approved, WQOs constitute formal ENV policy and must be considered in any decision affecting water quality made within ENV. WQOs have no legal standing at this time and are not directly enforced; however, they do provide policy direction for resource managers for the protection of values in specific waterbodies. Objectives guide the evaluation of water quality, the issuing of permits, licences and orders by provincial statutory decision-makers, and the management of fisheries and the province's land base. They also provide a reference against which the state of water quality in a particular water body can be checked, and help to determine whether basin-wide water quality studies should be initiated. WQOs are also a standard for assessing the Ministry's performance in protecting values.

By setting WQOs to protect the most sensitive water use in a given body of water, all the values for that water body (i.e. also those that are less sensitive) are also protected.

Water quality objectives provide policy direction for resource managers for the protection of water uses in Burrard Inlet. They do not indicate which activities are permissible in which areas or replace existing jurisdictions' authorities in making decisions about the permissibility of certain activities.

ENV undertakes monitoring to determine if the WQOs are being attained. In Burrard Inlet, several additional organizations have carried out water quality monitoring (see Map 5). These organizations are among those engaged as part of a Burrard Inlet Water Quality Roundtable (Appendix B). Water quality monitoring in Burrard Inlet will benefit from coordination of the many existing monitoring programs.

1.4 Multi-sectoral input

Work to update the WQOs for Burrard Inlet has been led by TWN, as guided by the Nation's Burrard Inlet Action Plan and traditional stewardship obligations. BC ENV has been an essential partner, providing staff resources and funding, and working to ensure that the analyses of pollutants and recommended guidelines meet a level of scientific rigour that can be used to inform provincial environmental policy updates and decision-making.

This work has been undertaken with input and recommendations from a multi-sectoral Roundtable and Technical Working Group, with membership from First Nations, federal, provincial, regional and local governments, industries, health authorities, non-governmental organizations and academia. The terms of reference for these bodies are provided in Appendix A, and their members are listed in Appendix B. Roundtable membership fluctuated over the period of the development of the proposed updated objectives with increased engagement of various sectors over time, and changes in representation within member organizations. Technical Working Group membership fluctuated depending on the nature of the technical subjects being discussed and the expertise required at the table at any given time during the course of the work.

1.5 Report structure

To address the complexity of water quality in Burrard Inlet, this report will consist of multiple phases and sections, to be produced and approved sequentially, although not necessarily in this order:

- Phase 1: Marine

- Introduction

1. Alkylphenols
2. Biotoxins and harmful algal blooms
3. Chlorates
4. Chlorinated ethanes
5. Chlorine
6. Chlorophenols
7. Cyanide
8. Dioxins and furans
9. Endocrine-disrupting chemicals
10. Flame retardants
    - 10.1 HBCD
    - 10.2 PBDEs
11. Hormones
12. Hydrocarbons
    - 12.1 Oil and grease
    - 12.2 Polycyclic aromatic hydrocarbons
13. Metals
    - 13.1 Aluminum
    - 13.2 Arsenic
    - 13.3 Barium
    - 13.4 Cadmium
    - 13.5 Chromium
    - 13.6 Copper
    - 13.7 Iron
    - 13.8 Lead
    - 13.9 Mercury
    - 13.10 Nickel
    - 13.11 Zinc
    - 13.12 others
14. Microbiological indicators[2]
15. Microplastics and marine debris
    - 15.1 Microplastics
16. Nutrients – nitrogen
17. Organotin – tributyl tin
18. Perfluorinated compounds
19. Pesticides (current use):
    - 19.1 Alachlor
    - 19.2 Octachlorostyrene
    - 19.3 Pendimethalin
    - 19.4 Permethrin
    - 19.5 Trifluralin
20. Pesticides (legacy)
    - 20.1 Aldrin

[2] Choice of microbiological indicator is discussed in depth in the technical report for microbiological indicators

    - 20.2 Chlordane
    - 20.3 DDT
    - 20.4 Dieldrin
    - 20.5 Endosulphan
    - 20.6 Endrin
    - 20.7 Heptachlor
    - 20.8 Hexachlorobenzene
    - 20.9 Hexachlorocyclohexane
    - 20.10 Methoxychlor
    - 20.11 Mirex
  21. Pharmaceuticals and personal care products
  22. Physical
    - 22.1 Dissolved oxygen
    - 22.2 pH
    - 22.3 Salinity/ Conductivity
    - 22.4 Suspended solids
    - 22.5 Temperature
    - 22.6 Total gas pressure
    - 22.7 Turbidity
  23. Polychlorinated biphenyls
  24. Styrene
  25. Sulphide
  26. Underwater noise
  27. Plan for attainment monitoring and filling data gaps
  28. Management plan and recommendations for improving water quality
- Phase 2: Freshwater tributaries

Phase 1 focuses on the marine environment (including the intertidal zone and estuaries). This first report presents Phase 1, Chapter 1: an introduction to Burrard Inlet and its six marine sub-basins. This chapter contains information about Burrard Inlet's location and context, drainage area, climate, oceanography and sensitive life stages, vision and values guiding this initiative, and factors influencing water quality. Parameters of concern in the inlet are summarized by sub-basin. This is followed by descriptions of each of the six sub-basins with respect to their characteristics, relevant values, provincial authorizations, other point and non-point sources of pollution, and parameters of concern. Emphasis is placed on notable changes since 1990.

Subsequent chapters will present water quality assessments, proposed water quality objectives (WQOs), monitoring recommendations and management considerations for individual parameters. WQOs will be proposed in consideration of the most sensitive value and/or species life stage affected by each parameter.

The Phase 2 reports will present proposed updated WQOs for freshwater tributaries to Burrard Inlet. These tributaries contain important habitats requiring protection from contamination. Their water quality also affects the marine water quality of Burrard Inlet. In 1990, WQOs were developed for three of these tributaries, namely Capilano River, Lynn Creek and Schoolhouse Brook, as being representative at that time. A change in approach for freshwater WQOs may be required, based on changes in land use patterns and inputs since 1990.

1.6 Site description

1.6.1 Location and context

Burrard Inlet is a marine area within the Pacific Ocean and Salish Sea that branches off the Strait of Georgia and winds its way through to Port Moody and the head of Indian Arm. The inlet can be divided into six sub-basins: False Creek, Outer Harbour, Inner Harbour, Central Harbour, Port Moody Arm and Indian Arm (see Map 2). The inlet's outer boundary, closest to its mouth, is defined here as the line connecting Point Atkinson (West Vancouver) and Point Grey (Vancouver).

The six sub-basins were delineated in the 1990 WQOs for ease of presentation (Nijman and Swain 1990). That delineation is maintained for this update, as each sub-basin has distinct oceanographic and usage characteristics, enabling meaningful subdivision of analyses and visualizations related to the inlet. Analyses will also be undertaken for the inlet as a whole, because circulation occurs throughout the inlet and from areas external to the inlet, and First Nations have a holistic understanding of the area.

Coast Salish First Nations have occupied the area and depended on the health of Burrard Inlet for their sustenance for thousands of years. Broader settlement and industrial development over the last 150 years have impaired the health of the inlet, including its water quality; this development is expected to increase. Currently, approximately 1.1 million people live in the seven municipalities bordering Burrard Inlet (see Map 10), using it for food, culture, transport, recreation, spiritual, aesthetic, work and other values. The area is part of Canada's largest port and is a major transportation hub (KWL 2017).

1.6.2 Drainage area and size

Burrard Inlet is 113 km^2 in size, extending 46 km from its outer boundary to the head of Indian Arm (with Port Moody Arm adding 7 km) and including 190 km of shoreline (BIEAP 2011, Haggerty 2001, Stantec 2009).

The Burrard Inlet catchment area is 1288 km^2 and is presented in Map 1. Defining this catchment area required the compilation of watershed and stormwater drainage data held by several jurisdictions. The Burrard Inlet catchment area is defined as follows (see Map 1a):

- Starts at Point Atkinson and follows a straight line[3] north through Lighthouse Park to join with District of West Vancouver data to include the Caulfeild Cove Catchment;
- Continues north using District of West Vancouver data to its northern edge separating the Montizambert Creek and Capilano River catchments;
- Follows District of North Vancouver watershed boundaries to the northern edge of the Seymour River watershed;
- Follows Province of B.C. watershed boundaries to the southeast edge of the Coquitlam River catchment;
- Follows the Coquitlam Dam southwest to the northern edge of the City of Coquitlam municipal boundary (BC Hydro 2005);
- Follows City of Coquitlam stormwater drainage area boundaries through Coquitlam to the School House Brook watershed; some areas in Coquitlam at the scale of a few properties may also drain into Burrard Inlet, but the spatial data has not been presented at that level of detail;

[3] A straight line was used in this area due to lack of reliable watershed data.

- Divides the City of Port Moody at Glenayre Drive and along a developed area, based on spatial data and imagery from the City of Port Moody;
- Follows stormwater drainage area boundaries from the City of Burnaby and AECOM (2016) west through Burnaby and Simon Fraser University to the boundary with the City of Vancouver;
- Follows City of Vancouver stormwater drainage area boundaries until the area of Blanca Street and West 12th Avenue;
- Continues through the University Endowment Lands until Acadia Road, following a report by AECOM (2017);
- Continues through the University of British Columbia campus based on data from Kerr Wood Leidal (2012) to Point Grey;
- Connects Point Grey and Point Atkinson with a straight line to form the western boundary.

In some areas, watershed boundaries were adjusted manually to reconcile inconsistencies between data sources.

1.6.3 Climate

The biogeoclimatic classification of the lowland areas around Burrard Inlet are Coastal Douglas-fir and Coastal Western Hemlock, and the alpine areas are Mountain Hemlock and Coastal Mountain-heather Alpine (Government of BC 2016). Weather patterns on the South Coast of British Columbia include a flow dominated by westerlies, meaning that most weather comes from the Pacific Ocean onto the coast. Heat from the ocean moderates coastal temperatures. In winter, the interaction of warm and cold air results in falling pressure and increased winds. The Coast Mountains divide this coastal area from the drier B.C. interior. Storms heading toward the coast are lifted up the windward slopes of these mountains, resulting in increased precipitation. These mountains are also a barrier to arctic air (Klock and Mullock 2001).

1.6.4 Oceanography

Most of Burrard Inlet's sub-basins are relatively shallow, although the northern portion of Indian Arm is a fjord, characterized by deep water (mean depth of 120 m and a maximum depth of 218 m) and bounded by steep-sided mountains (KWL 2017). Burrard Inlet lacks a sill at its seaward edge (Thompson 1981). Instead, the bulk of Burrard Inlet acts as a sill to the Indian Arm fjord (Figures 1 and 2). As a result of the constriction in shallow areas, tidal flow causes strong mixing and reduces estuarine flow in Burrard Inlet (Allen 2017).

Diurnal and semi-diurnal tides entering and exiting the inlet flush the Inner and Central Harbours (Li and Hodgins 2004), with tides averaging 3.1 m daily, with a maximum of 4.9 m (BIEAP 2011, Levings et al. 2004). Maximum currents are 11 km/h through First and Second Narrows (BIEAP 2011), creating eddies and upwellings in the Inner and Central Harbours as the water slows down, attracting seabirds and marine mammals (Haggarty 2001, Stone et al 2013). Easterly winds tend to drive surface water to the mouth (Nijman and Swain 1990).

Freshwater from the Fraser River, particularly during the spring freshet of May and June, influences circulation, chemistry, salinity, physical attributes (e.g. temperature, turbidity) and ecology (e.g. reduction of primary production, entry of juvenile salmonids) in Burrard Inlet (Levings et al. 2004, MacDonald and Chang 1993, Stockner and Cliff 1979, Stone et al., 2013, Thompson 1981). The inlet is also fed by approximately 112 streams (Balanced Environmental Services 2010), of which 17 are currently known to be salmon-bearing (Haggarty 2001). Development has led to the loss of approximately 40 additional streams within its catchment (DFO 1995, Lesack and Proctor 2019). The major streams entering Burrard Inlet are Capilano River, Seymour River, Indian River and water from the

Upper Coquitlam River via the Buntzen Lake diversion from the Coquitlam Reservoir. Metro Vancouver regulates Capilano and Seymour River with reservoirs containing the regional district's water supply. Other important creeks are Lynn, Mosquito, Mackay, McCartney, Noons, Schoolhouse and Mossom (Haggarty 2001). Due to the quantity of freshwater input, Burrard Inlet is considered estuarine (Davidson 1979). Surface waters of the inlet are less saline than deeper waters (Nijman and Swain 1990). Fresher water flows outward to the inlet's mouth, over more saline water entering from the Strait of Georgia (Haggarty 2001; see Figure 3).

Water temperature is influenced by water from the Strait of Georgia, the Fraser River, tributaries and runoff, tides and wind. The thermocline is located at 5 m depth. Shallow water in the Outer Harbour and Port Moody Arm can reach a temperature of 20°C; other areas reach 15°C. Winter temperatures range from 6-8°C (Haggerty 2001). Average monthly air temperatures in the Vancouver area range from 3.6°C in December to 18.0°C in July and August. Average monthly precipitation ranges from 35.6 mm in July to 188.9 mm in November (Government of Canada 2017). Turbulent mixing of fresh and tidal waters through the First and Second Narrows, most notably during spring tide, can result in lower summer and higher winter surface temperatures than in simpler estuaries (Nijman and Swain 1990), plus reduced salinity (Figure 3, Thompson 1981) and increased dissolved oxygen at depth in the Inner and Central harbours.

Deep water in Indian Arm is renewed on average every three years. In Burrard Inlet, freshwater is retained for about 6 months (Allen 2017).

1.6.5 Species and their sensitive life stages

More than 1200 wildlife species have been recorded in Burrard Inlet (Stone et al 2013). An extensive species list has been developed for Burrard Inlet as a whole (Appendix C). Spatial information is available for birds and marine mammals (BCMCA 2011, Butler *et al.* 2015), some fish and shellfish (BCMCA 2011, Haggarty 2001, R. deGraaf unpublished data, Cook 2018), plants and algae (BCMCA 2011), selected invertebrates (BCMCA 2011), eelgrass and kelp (SeaChange Marine Conservation Society and TWN, unpublished data). These are displayed on Map 13 but represent only a small fraction of species in the inlet and do not necessarily include the most sensitive species and life stages with respect to individual water quality parameters. The series of maps presented as Maps 6A and 6B show sensitive habitats that support wildlife species in the Inlet as well as other ecosystem services; the habitats surveyed to date include kelp and other algae, eelgrass and surfgrass, rockfish conservation areas, shellfish beds, forage fish spawning beaches, salt marshes and dune grass.

Several species on which BC or Canadian Council for Ministers of the Environment (CCME) water quality guidelines were based are found in Burrard Inlet. These include Dungeness crab, *Fucus vesiculosus*, *Daphnia* spp., rock crab larvae, Pacific oyster embryos, blue mussel embryos, salmonids and Pacific herring[4] (Appendix D).

[4] Although herring had been extirpated, herring spawn has recently been observed at various locations in the inlet and efforts are being made to create herring spawning habitat. Water quality will affect spawning success.

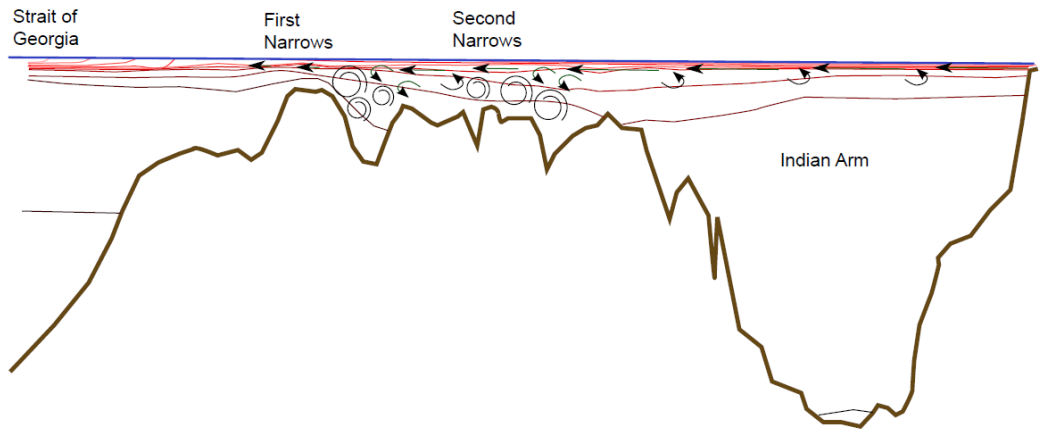

Figure 1. Burrard Inlet estuarine circulation (Allen 2017)

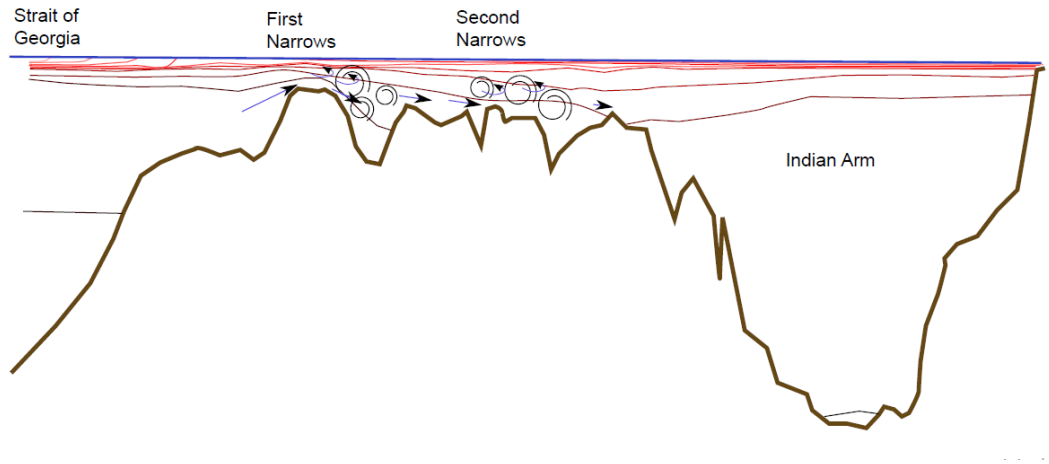

Figure 2. Burrard Inlet inflow circulation (Allen 2017)

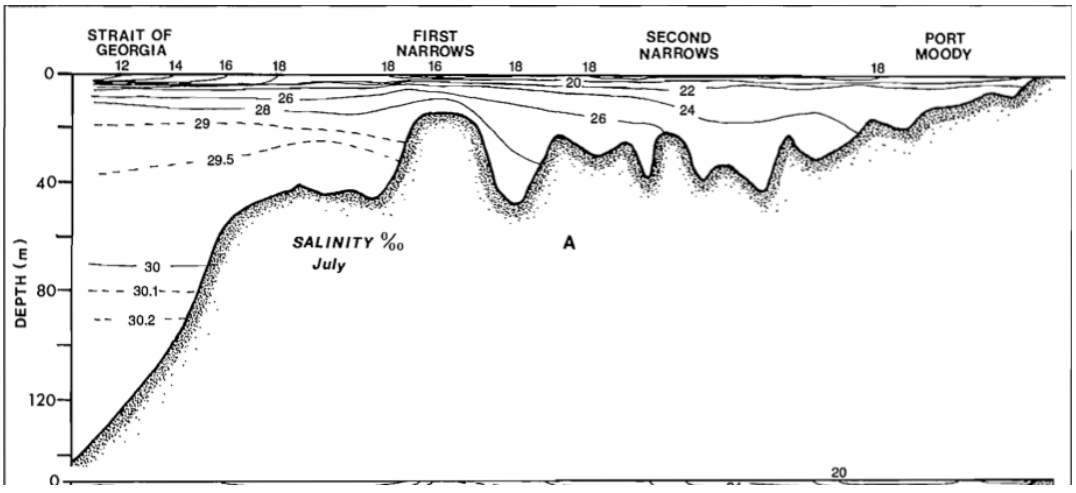

Figure 3. Stratification in Burrard Inlet (Thompson 1981)

1.7 Updated vision and values

The level of urbanization, industrialization and other uses in Burrard Inlet preclude these waters from returning to their original, pre-contact state[5]. It is possible, however, to expect that through collaborative and coordinated efforts to improve water quality, key sensitive water uses and values that have been lost to environmental degradation may be recovered over time. Tsleil-Waututh Nation and other governmental and non-governmental organizations have conducted restoration projects over many years with the aim of recovering these values.

The aim of the proposed WQOs is to consider the competing ecological, social, economic and cultural values in Burrard Inlet, and develop updated and achievable WQOs that will lead to a reduction in the overall stress on the system and improve the environmental health of Burrard Inlet.

What have historically been referred to as 'designated water uses' or 'beneficial uses' to guide the development of provincial WQOs are now referred to as 'values' with relevance to water quality. The provincial approach to WQOs has shifted to a system based on clarifying the level of protection of particular values and minimizing the use of a water body's assimilative capacity.

These values, and the short- and long-term goals associated with each of them, are ascribed by sub-basin (Table 1), in consideration of the different inputs and water quality characteristics in each sub-basin. In particular, water quality in False Creek and the Inner Harbour has been heavily impacted, limiting the extent to which they can be realistically improved in the short term. Conversely, the water quality in certain areas of Indian Arm can potentially support values such as shellfish consumption in the short term. These values, and the overall vision guiding this work, are described in more detail in the following sections.

Long-term goals reflect TWN's aspiration to improve overall water quality and restore values and traditional uses throughout the inlet. Short-term goals reflect what may be attainable in a shorter time frame. Short- and long-term WQOs will be set for each water quality parameter based on the short- and long-term goals for the value that is most sensitive to that parameter.

Although drinking water is a value that is often included among WQOs, it is not included here because drinking water sources among Burrard Inlet's tributaries are already managed through Metro Vancouver's Drinking Water Management Plan and Drinking Water Conservation Plan.

It is important to note that WQOs are set for the ambient environment. Although in some instances they are set in consideration of the requirements to enable certain activities (e.g. swimming, shellfish consumption), they are not in themselves a decision or statement about which activities are possible in which areas. Decisions about the permissibility of certain activities in specific areas of the inlet remain the jurisdiction of the authorities responsible for regulating those activities (e.g. health authorities, Canadian Shellfish Sanitation Program, DFO).

[5] Waters that are free from industrial contaminants and large-scale industrial modifications of the landscape, but which have sustained a population prior to European contact and colonization of the region.

Table 1. Values and goals by sub-basin in Burrard Inlet

S = updated short-term WQO goal (by 2025); L = updated long-term WQO goal (by 2050); 2° = secondary contact; rec = recreation

[1] The goal of shellfish consumption could potentially be reached via medium-term goals of enabling harvest from marginally affected areas according to recommended Canadian Shellfish Sanitation Program procedures

[2] Cultural practices and recreational uses refer by default to primary contact activities such as bathing and swimming. Secondary contact activities could include Coast Salish traditional canoe pulling, recreational canoeing and kayaking, fishing and boating. There are also limitations to watersports in the Outer, Inner and Central Harbours due to Port activities [VFPA 2018])

Values to Protect in Burrard Inlet	**False Creek**			**Outer Harbour**			**Inner Harbour**			**Central Harbour**			**Port Moody Arm**			**Indian Arm**		
	1990	**S**	**L**	**1990**	**S**	**L**	**1990**	**S**	**L**	**1990**	**S**	**L**	**1990**	**S**	**L**	**1990**	**S**	**L**
Shellfish Consumption[1]			✓			✓			✓			✓			✓		✓ bivalves	✓
Finfish Consumption		✓	✓		✓	✓			✓		✓	✓		✓	✓		✓	✓
Aquatic Life (including reproduction)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Wildlife (including reproduction)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cultural practices and recreational uses[2]		2°	✓	✓ rec	✓	✓	✓ rec	✓	✓	✓ rec	✓	✓	✓ rec	✓	✓	✓ rec	✓	✓
Institutional Water Uses	Depends on use																	

1.7.1 Vision for Burrard Inlet Water Quality Objectives

The following overall vision was developed with the Burrard Inlet Water Quality Roundtable:

*The **overall vision** of the Burrard Inlet Water Quality Objectives is to increase the benefits of Burrard Inlet to all in the region by reducing stressors and improving water quality while balancing ecological, social, economic, health and First Nation cultural values.*

1.7.2 Values and water quality goals in Burrard Inlet

Water uses in 1990 were outlined for marine sub-basins as follows (Nijman and Swain 1990):

- False Creek: Licensed water use, recreation, fisheries and other biological resources
- Outer Burrard Inlet (Outer Harbour): Licensed water use, recreation, fisheries and other biological resources, marine shipping
- Inner Burrard Inlet-Port Moody (Inner Harbour, Central Harbour, Port Moody Arm): Licensed water use, recreation, fisheries and other biological resources, marine shipping
- Indian Arm: Licensed water use, recreation, fisheries and other biological resources

The most sensitive water uses for the development of marine WQOs in 1990 were considered to be aquatic life and wildlife in all sub-basins, and primary contact recreation in all sub-basins except False Creek.

Several statements identified in the Burrard Inlet Action Plan (KWL 2017) were consulted to develop the values for the proposed updated WQOs:

> TWN envisions a productive, resilient, and diverse Burrard Inlet ecosystem where:
>
> • Healthy, wild foods can be harvested safely and sustainably;
>
> • Water and sediment are safe and clean for cultural, spiritual, ceremonial, and recreational activities;
>
> • High levels of biodiversity and healthy populations of key species are viable and will continue to persist in the long term. (p.66)

and

> …a healthy Burrard Inlet ecosystem in its current context should also have the following attributes: …
>
> • *Redundancy*: Species and habitats are not found at a single location but are found at multiple locations and in high enough numbers to be viable in the long term.
>
> • *Representativeness*: The species and habitat present should represent the range of species and habitats once more broadly present. (p.66)

These statements were adapted into six values and goals guiding this WQOs update, described in detail below, through discussions with the Burrard Inlet Water Quality Roundtable. The WQOs are developed to both describe how clean the water quality should be in the future so that these values can be achieved or, in some cases, continue to be achieved.

Value: Shellfish Consumption by humans:

Goal: Healthy, wild shellfish can be harvested safely by present and future generations.

Background: Coast Salish people obtained 90% or more of their protein from marine species prior to contact with Europeans (Chisholm et al 1983). Shellfish, including clams, cockles, oysters, mussels, urchins and crabs, were a staple of the pre-contact Tsleil-Waututh diet. Shellfish were harvested regularly and continuously from Burrard Inlet beaches for centuries (Morin 2015). Shellfish harvesting is an important value to First Nations; a traditional saying is, "When the tide was out, the table was set," indicating historical abundance, food availability and centrality of intertidal resources for Indigenous ways of life.

Bivalve shellfish harvesting has been closed in Burrard Inlet since the 1970s due to contamination concerns (Jamieson and Lessard 2000). Limited food, social and ceremonial (FSC) harvesting sites were opened in recent years following studies by Tsleil-Waututh Nation and ongoing monitoring with the Canadian Shellfish Sanitation Program[6]. TWN's bivalve FSC harvests are closely managed and monitored by TWN and DFO. Recreational fishing continues in Burrard Inlet for crabs, and commercial and FSC fishing occurs in areas of Burrard Inlet for Dungeness crab, shrimp and prawns (BCMCA 2011; see Maps 14a and 14b).

Tsleil-Waututh Nation has a strong vision and need to restore bivalve shellfish harvesting opportunities in the inlet. The goal of restoring water quality to the levels required for bivalve shellfish harvesting may potentially be achieved via a medium-term goal of achieving levels to enable harvest from marginally affected areas according to procedures recommended by the Canadian Shellfish Sanitation Program.

Value: Finfish Consumption by humans:

Goal: Healthy, wild finfish can be harvested safely by present and future generations.

Background: Marine fish, particularly salmon, herring, anchovy and eulachon were fundamental to the pre-contact Tsleil-Waututh diet, culture and economy. Following colonial settlement, herring were extirpated in Burrard Inlet by 1898 (Mathews 1955, Morin 2015). Herring eggs were found by Tsleil-Waututh Nation survey crews in Indian Arm in 2019, strengthening the need to upgrade WQOs to support fish and fish habitat, and signaling that the goals and values outlined in this report are within reach. Presently, food, social and ceremonial (FSC) and recreational fishing occurs in certain areas of Burrard Inlet for anadromous fish and groundfish. Commercial fishing occurs in areas of Burrard Inlet for groundfish, including rockfish, lingcod and dogfish (BCMCA 2011, DFO 2017). Recreational and commercial fishing areas are displayed on Maps 14a and 14b. A small shore-based commercial fishery for surf smelt exists in the inlet, as does a recreational surf smelt fishery (KWL 2017).

---

[6] The Canadian Shellfish Sanitation Program (CSSP) is administered by three federal departments/agencies:
- Environment and Climate Change Canada– responsible for monitoring bacteriological water quality in shellfish harvest areas, identifying and evaluating sanitary pollution sources, and recommending the classification assigned to shellfish harvest areas.
- Canadian Food Inspection Agency – responsible for overall CSSP coordination; the control, handling and processing of shellfish; the marine biotoxin control program and liaising with foreign governments on matters relevant to shellfish sanitation.
- Department of Fisheries and Oceans – responsible for the management of fisheries, licensing fishing for shellfish, enforcement of closure regulations, and enacting the opening and closing of shellfish harvest areas under the authority of the Fisheries Act and Regulations.

Values: Marine Aquatic Life and Wildlife[7]:

Goal: Water quality supports biodiversity, and viable, healthy populations of species in the long-term. Species and habitats are found at multiple locations and represent the range of species and habitats once more broadly present.

Background: Aquatic life in the context of WQOs includes organisms whose life cycles are entirely or partly in the water. Wildlife is a broader term that includes aquatic life, as well as terrestrial amphibians, reptiles, birds and mammals. Burrard Inlet houses more than 1200 wildlife species (Stone et al 2013), including all seven Pacific salmon species and 68 other fish species (City of Port Moody 2011, Haggarty 2001, Levings et al. 2004) including forage fish, 53 bird species (Gaydos and Pearson 2011, Stone et al. 2013) and several marine mammal species (BCCSN 2015). It has been named an Important Bird Area (BSC 2017). Spatial data are not available for most species; available spatial data are presented in Map 13. The most complete species list to date was compiled for the Burrard Inlet Environmental Action Program in 2011 and those relevant to aquatic environments, in adult or larval/juvenile stages, are tabulated in Appendix C. The area houses up to 45 species at risk, flagged in these tables. Potential and actual forage fish spawning areas around Burrard Inlet have been identified in recent years (R. de Graaf, unpublished data), and a need has been identified for water and sediment quality objectives to protect forage fish embryos (R. de Graaf, *pers. comm.*; Cook 2018).

Value: Cultural practices and recreational uses:

Goal: Water and sediment are safe and clean for cultural, spiritual, and recreational activities.

Background: Burrard Inlet is an important area for activities that involve primary contact with the water, including First Nations cultural, spiritual and ceremonial practices, and recreation such as swimming. Secondary contact cultural activities include Coast Salish canoe pulling. People also enjoy various secondary contact recreational water sports and boating throughout the inlet. Recreation occurs throughout the year, peaking in summer. Coastal recreation sites are presented in Map 7. Vancouver Coastal Health and Fraser Health monitor compliance with federal recreational water quality guidelines based on *E. coli* counts from sampling conducted by Metro Vancouver. Those health authorities may decide to close areas to swimming if levels exceed the guidelines. Vancouver Coastal Health does not consider False Creek a primary contact recreational water body (VCH 2018). Guidelines for secondary contact tend not to be as rigorous as for primary contact, and the most recent Health Canada guidelines for recreational water quality only provide advice regarding secondary contact activities, due to a lack of epidemiological data available to derive precise guidelines (Health Canada 2012). Thus, if objectives are protective of primary contact values, they also protect secondary contact values. Health Canada considers immersive activities such as swimming, bathing and wading to be primary contact, 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).

[7] Marine aquatic life and wildlife are 2 separate values grouped together here as they share a similar goal and background details.

Value: Institutional Water Uses[8]:

Goal: Water uses meet institutional needs without negatively affecting water quality at intake sites, outflow sites or the receiving environment.

Background: The Vancouver Fraser Port Authority (VFPA) has navigational jurisdiction in all of Burrard Inlet except False Creek. It manages federal lands and waters in the entire area east of a line just west of First Narrows. Industrial activity around Burrard Inlet includes more than 40 companies within VFPA land management areas, and additional industries in False Creek. Vessels that travel in the inlet include container ships, bulk carriers, cruise ships, pleasure crafts and public transit ferries (KWL 2017). Marine industrial locations and commercial transport terminals and routes are presented in Map 17. Several facilities have, or had in the past, authorized discharges under BC ENV permits or regulations and codes of practice (see Map 8). While there are several licensed water withdrawals from groundwater and tributaries to Burrard Inlet (see Map 9; to be discussed in Phase 2 of this update), provincial water withdrawal licenses are not issued for use of sea water (Johnson 2017). Other water tenures and leases include tenures for bridges, commercial activities, community facilities, electric power lines, ferry terminals, parks, marinas, navigational aids, private moorage, public wharves, public works, roadways, sewer/effluent lines, telecommunication lines and water lines (see Map 12). VFPA has also identified certain areas for terminal, industrial and commercial use (Map 12). Non-industrial economic interests and institutional uses such as ecotourism businesses owned by TWN rely on safe, clean water in Burrard Inlet.

A list of the water quality parameters of concern for each value, as relevant to the Burrard Inlet context, is presented in Table 2.

Table 2. Water quality parameters of concern for each value

Value to protect	Water quality parameter groups known to have a negative effect on the value
Shellfish consumption by humans	biotoxins, dioxins and furans, flame retardants, metals (arsenic, cadmium, lead, mercury), microbiological indicators, microplastics and marine debris, nutrients, organotins, PAHs, pesticides (current use, legacy), PFCs, phenols, physical (pH), PPCPs
Finfish consumption by humans	dioxins and furans, flame retardants, metals (arsenic, cadmium, copper, lead, mercury, zinc), microplastics and marine debris, organotins, PAHs, PCBs, pesticides (current use, legacy) , PFCs, phenols, physical (dissolved oxygen, temperature), PPCPs
Marine aquatic life	chlorates, chlorinated ethanes, chlorine, chlorophenols, cyanide, dioxins and furans, endocrine-disrupting chemicals, flame retardants, hormones, metals (aluminum, arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, zinc), microplastics and marine debris, organotins, PAHs, PCBs, pesticides (current use, legacy) , PFCs, phenols, physical (dissolved oxygen, pH, salinity/conductivity, temperature, turbidity/total suspended solids), PPCPs, styrene, sulphide, underwater noise

[8] Examples of institutional uses are industrial, commercial and municipal intakes and discharges, on-water uses such as shipping. This value also includes economic ventures that rely on safe, clean water, such as Tsleil-Waututh owned ecotourism businesses.

Value to protect	Water quality parameter groups known to have a negative effect on the value
Wildlife	dioxins and furans, flame retardants, metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc), microplastics and marine debris, organotins, PAHs, PCBs, pesticides (current use, legacy) , PFCs, phenols, PPCPs
Cultural practices and recreational uses	chlorophenols, microbiological indicators, microplastics and marine debris, nutrients, physical (turbidity/total suspended solids)
Institutional water uses	depends on use

1.8 Water uses, land uses and other factors that affect water quality and values in Burrard Inlet

Several inputs into Burrard Inlet have been considered in the development of the WQOs. Those considered in 1990 are summarized in Table 3. A more extensive and up-to-date suite of inputs has been considered for the proposed updated WQOs, and is summarized in Table 4. The categories of inputs are described in general below, and details of the inputs into each sub-basin are described in subsequent sections.

1.8.1 Population and development

The municipalities surrounding Burrard Inlet fall within the Metro Vancouver regional district and include Vancouver, Burnaby, Port Moody, Anmore, Belcarra, North Vancouver (District), North Vancouver (City) and West Vancouver. Portions of the City of Coquitlam also drain into Burrard Inlet (see Map 1). They are collectively projected to experience population increases to a total of 1.2 million in 2021 and 1.4 million in 2041 (Metro Vancouver 2011). Increased human population can lead to increased inputs into the marine environment both directly and via sewer and stormwater systems. Increases in the area of impervious surfaces and pollutant runoff resulting from upland development are among the largest stressors on water quality, and the most complex to address. There are up to 407 stormwater outfalls entering Burrard Inlet (see Map 4), although the exact number could not be confirmed at the time of writing (see "Stormwater runoff" in section 1.8.3).

Shoreline modifications including hardening have resulted in a loss of natural filtration capacities of nearshore riparian habitat, particularly from the perspective of flow rates and intensity. More than 75% of the inlet's shoreline has been modified in some way with boat ramps and slips, bulkheads, shipping terminals, marinas or floats, landfill, wharves, riprap, or sheet pile. With respect to coastal class, 31% of the shoreline is classified as man-made, 42% is sediment, 14% is rock and sediment and 13% is rock (see Map 11). The most human-modified proportion of shoreline is in the Inner Harbour (more than 90%), and the least modified is in Indian Arm. Undisturbed shorelines include rocky shores, banks and cliffs; wave-cut platforms; sand or gravel beaches; tidal flats and salt or brackish-water marshes (Coastal and Ocean Resources 2018).

1.8.2 Port activities and shipping

Cargo volume handled by the Port of Vancouver (Burrard Inlet, Fraser River and Roberts Bank) quadrupled from 1970 to 2010 (Deloitte 2015). Foreign vessel arrivals, including cruise ships, have been increasing since 2009 (K. Keskinen, VFPA, *pers. comm.*). Shipping container traffic in Burrard Inlet is expected to increase with planned expansions to the Centerm container terminal (Ocean Shipping Consultants 2016). Increases to oil tanker traffic have also been proposed. Increases in port

development and shipping also increase risks of spills, authorized and unauthorized discharges, and stormwater runoff into the inlet.

1.8.3 Authorized discharges and outfalls

Provincial authorizations

The authorizations presented in this document were by the Province of BC, and do not represent authorizations by TWN. The terms "authorization" and "permit" in this document are used to refer only to provincial authorizations and permits.

The BC ENV is responsible for the protection, management, and conservation of BC's water, land, air, and living resources. To achieve this mandate, ENV administers the *Environmental Management Act* (EMA) which regulates the introduction of industrial and municipal waste into the environment and prohibits any discharge that may cause pollution.

EMA is a tiered-approach regulation that provides various regulatory tools depending on the risk of the prescribed activity. High-risk activities require a permit, medium-risk activities are regulated through codes of practice or industry-specific regulations, and low risk activities do not require an authorization but are subject to EMA section 6(4), the requirement to not pollute. These regulatory tools are defined as follows:

- **Permit**: a site-specific authorization granting permission to discharge waste to the environment from a specific industry under a specific set of terms for a particular facility, activity, or operation.
- **Operational Certificate:** the approval of a waste management plan completed by regional government bodies to control disposal of municipal garbage/sewage (specific to regional governments).
- **Registration:** a registration under a Regulation or Code of Practice which sets out standard terms and conditions under which a specific type of industry, business, operation or activity may discharge waste.

Throughout this report, the terms "authorization" or "authorized discharge" are used to refer to any of these regulatory tools.

All EMA-regulated authorizations (historic and active) located within the Burrard Inlet watershed are displayed in Map 8, with an accompanying table of details provided in Appendix F. Details and history of the authorizations, with a focus on describing changes since 1990, are provided in Appendix G.

The discharges into Burrard Inlet considered in 1990 are presented in Table 3. Authorized discharges into the inlet under BC ENV Regulations and Codes of Practice were not considered at that time.

A more comprehensive and up-to-date summary of active, planned, cancelled, withdrawn and historic discharges into Burrard Inlet is presented in Table 4. Active and operational provincial authorizations that may discharge into Burrard Inlet include 21 effluent permits, 1 operational certificate, 5 refuse permits, 8 hazardous waste regulation registrations, 3 municipal wastewater regulation registrations, 5 concrete and concrete product facilities, and 6 petroleum storage and distribution facilities.[9] Summary tables of these authorizations and further details about each of them are presented in Appendices F and

[9] The number of authorizations reflect active and operational authorizations as of August 31, 2018.

G. Basic details about authorizations with high discharge volumes and greater environmental concern are described by sub-basin in the following sections of this report.

Sewer overflows and discharges

Combined sewers collect sanitary sewer and stormwater discharges into the same pipe. While no longer constructed around Burrard Inlet today, combined sewers are a legacy of previous practices and still exist within the Cities of Vancouver and Burnaby[10]. During normal conditions, all the sanitary and storm water collected in combined sewers is transported to wastewater treatment plants (WWTPs) prior to discharge whereas during peak rainfall events, the stormwater overwhelms the capacity of the sewer system and combined sanitary and storm water is discharged directly to the receiving environment – this is referred to as a combined sewer overflow (CSO).

The number of active CSO outfalls to Burrard Inlet has decreased from 28 in 1990 to 24 as of 2017 (Tables 3 and 4, and Appendix H). Active and historical sewer overflow outfall locations are presented in Map 3 and include outfalls for CSOs, sanitary sewer overflows and lift station emergency overflows (unpublished data from Metro Vancouver, City of Vancouver and City of Burnaby). Discharge volumes at each CSO outfall are reported monthly and annually. Discharge volumes are variable within a single year and between years, depending on rainfall. The relationships between capacity, overflows and precipitation are complex and not well understood. Sewer separation is being undertaken by multiple jurisdictions, and complete separation requires separation at both road and property levels. Municipalities report on combined sewer separation as part of their biennial Liquid Waste Management Plan reporting. A summary of closed and active CSO outfalls is provided in Appendix H.

Combined sewers in Metro Vancouver are being separated into separate sanitary and storm sewer pipes. While this will reduce the number of combined sewer outflows and discharges of untreated sewage into the inlet, it will also increase the volume of untreated stormwater discharges. This change in volume is likely to be marginal but requires further investigation[11] (Weismiller 2018). To 2017, the majority of combined sewers had been separated in the Metro Vancouver region, with approximately 1000 km of combined sewer length remaining to be separated (Metro Vancouver 2017b). In the City of Vancouver, 53% of combined sewers had been separated as of 2017 (City of Vancouver, unpublished data). The one active CSO outfall managed by the City of Burnaby is estimated at 70% separation at street level, although this does not account for combined systems within private property (Weismiller 2018). A strategy in Metro Vancouver's Integrated Liquid Waste Management Plan to reduce wet weather overflows in the Vancouver Sewerage Area is to work with the cities of Burnaby and Vancouver to prevent combined sewer overflows by 2050 and separate combined sewers at an average rate of 1% per year (Metro Vancouver 2010). The Canadian Council of Ministers of the Environment has described standards and risk management activities related to combined and sanitary sewer overflows as part of its national Strategy for the Management of Municipal Wastewater Effluent (CCME 2009).

As sewers are separated in the remaining combined sewer areas around Burrard Inlet, there remains the potential of unintentional cross-connections between sanitary and stormwater sewer pipes, for example within private property.

[10] The City of New Westminster also has combined sewers. They do not flow into Burrard Inlet, so New Westminster is not discussed in this report.

[11] Under current conditions, excess flows containing stormwater are redirected out of the sanitary systems at a low-flow weir structure at the head of a CSO outfall.

Sanitary sewers are not designed to transport stormwater or to overflow as part of typical operation. However, during emergency situations, such as power outages or significant rainfall events, these systems may overflow to prevent backflow into people's homes. Today, there are five wastewater lift station emergency overflow outfalls and three sanitary sewer overflow outfalls that have the potential to discharge into Burrard Inlet (see Map 3). A priority station due to chronic overflows is the Lynn Branch Siphon which ultimately discharges to the Inner Harbour.

Discharges to ground from sewerage systems with a flow rate of less than 22.7 m^3/day and serving single family residences are authorized under the *Public Health Act* by the Sewerage System Regulation managed by the BC Ministry of Health. Such sewer discharges exist in Indian Arm, and there have been concerns around failures of some of these systems. Spatial information for these discharges are available but at the time of writing were not in a format that could be included in this report.

Stormwater runoff

Urbanization in Metro Vancouver has led to the conversion of vegetated watersheds into piped stormwater systems with direct outflow into Burrard Inlet. Stormwater runoff directly enters Burrard Inlet from urban and industrial stormwater outfalls. A compilation of stormwater outfalls from the municipal and Vancouver Fraser Port Authority (VFPA) stormwater network is displayed on Map 4. The total displayed on this map is 407 outfalls; however, this total is approximate – due to limitations in the VFPA dataset, it cannot be confirmed for accuracy and may include some redundancy.
Natural underground or overland flow may enter some of these pipes in upstream areas.Runoff also flows into approximately 226 tributary streams which flow into the inlet, potentially impacting both freshwater and marine water quality. The tributary points displayed on Map 4 represent the end points of municipal stream vector data; smaller streams and seasonal streams may not be included. The water from these tributary points is largely from natural sources (e.g. underground and overland flow); however, inland stormwater outfalls may drain into upstream reaches of some of these tributaries.

Entry of a complex mixture of contaminants into Burrard Inlet via stormwater outfalls is a growing concern. The quantity of contaminants released into the inlet via stormwater discharge is a significant knowledge gap. In Puget Sound, Washington State Department of Ecology studies have identified that the largest source of pollutants is not from regulated point source discharges such as industrial discharge pipes, but from products used every day by residents. Burrard Inlet is likely similar (KWL 2017).

1.8.4 Other inputs: illicit, persistent and emerging

Other potential sources of pollution include illicit waste discharges such as dumping and boat discharges around marinas and anchorages, spills, leakage from on-site sewage disposal systems, leaching or migration from contaminated sites and deposition of air-borne pollutants. Contamination also remains from historical or legacy activities, persistent pollutants and bioaccumulating substances. Logging and log storage in the watershed and nearshore environment have also affected water quality either directly or by a loss of ecosystem features that would protect water quality.

The entry of pharmaceuticals, personal care products and microplastics into aquatic environments is a growing but poorly understood concern. These emerging contaminants are not effectively eliminated as part of existing wastewater treatment mechanisms. Research programs have begun to study some of these contaminants and their effects on aquatic life (e.g. Ocean Wise 2018).

1.8.5 Climate change and ocean acidification

Increases in atmospheric greenhouse gases can have several impacts on water quality, for example due to ocean acidification (decreased pH) and climate change. Climate change effects on marine water quality include increased temperature, changes to salinity and nutrients, and reduced dissolved oxygen levels (Bindoff et al. 2007, Schmidtko et al. 2017). These changes can further cause cascading or cumulative effects on other water quality parameters (KWL 2017). Increased storm frequency and intensity associated with climate change can result in increased flushing of contaminants into water bodies and increase the frequency of sewer overflows (US EPA 2009).

1.8.6 Water quality improvement initiatives

Water quality management initiatives have been launched around Burrard Inlet, including the following:

- Local governments are involved in initiatives related to stormwater management, including piloting and exploring green infrastructure strategies to allow infiltration or filtration of stormwater prior to entry into storm drains. All Metro Vancouver municipalities have developed Integrated Stormwater Management Plans to guide stormwater management and maintain or improve watershed health during redevelopment. They continue to develop updates and implement the actions in those plans through policy and best management practices for development and capital projects.
- Each municipality in Metro Vancouver is working to separate combined sewers by 2050 in the Vancouver Sewerage Area and 2075 in the Fraser Sewerage Area.
- The City of Vancouver created a working group on False Creek water quality (P. Lingl, *pers. comm.*).
- The District of West Vancouver is involved in the Municipal Natural Assets Initiative to understand the financial benefits of stream daylighting (the removal of concrete or other obstructions that are covering waterways and restoring them towards their previous condition) (MNAI 2018).
- Green infrastructure initiatives are underway in Burnaby, Vancouver and North Vancouver.
- The Lions Gate Waste Water Treatment Plant is being upgraded.
- TWN, the BC Institute of Technology, VFPA and others have been involved in estuarine habitat enhancement measures.

Table 3. Discharges into Burrard Inlet identified and considered for 1990 WQOs

Sub-Basin	Permits	Identified permit concerns	CSO outfalls	Other input sources
False Creek	3: CSO, stormwater, cooling water	Bacteria, oil	7	Stormwater outfalls, marinas
Outer Harbour	1: waste water treatment		5	Landfill leachate, stormwater outfalls
Inner Harbour	6: bulk loading, cooling, aquarium	pH, TSS, S, Cu, Zn, Pb, Ni, oil, other	9-10	Landfill leachate, stormwater outfalls
Central Harbour	8: oil, manufacturing plants, cooling water	pH, Cl, metals, oil, NH_4, Cn, phenols	4	Stormwater outfalls
Port Moody Arm	13: sewage, landfill leachate, cooling, oil, bulk storage and loading, chemical plants, sawmill, stormwater	Cl, oil, phenols, PAHs, H_2S, S, Pb, Zn, other metals	2	Stormwater outfalls
Indian Arm	None		0	Watercraft, storm-water outfalls

Table 4. Discharges into Burrard Inlet identified and considered for this WQOs update
ENV = BC ENV authorized discharge. Status as of 2017 for CSO outfalls and 2018 for others. Detailed information is provided in the following sections, plus Appendices F, G and H.

Discharge type	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
ENV Effluent Permit	1 active	1 active (Operational Certificate)	6 active 3 cancelled	6 active	4 active 5 cancelled	4 active 1 cancelled
ENV Hazardous Waste Regulation	2 active		2 active	1 active 1 cancelled	3 active	
ENV Municipal Wastewater Regulation		1 active	1 active		1 active	
ENV Code of Practice Concrete and Concrete Products			3 active	2 active		
ENV Organic Matter Recycling Regulation			1 active (not operational)	1 planned cancellation	1 active (not operational)	
ENV Petroleum Storage and Distribution	1 withdrawn 1 cancelled		2 active	2 active	2 active	
Combined sewer overflow outfalls	4 active 3 historic	5 active 1 historic	11 active 6 historic	4 active 1 historic		
Recreational boating activities	8 marinas, liveaboards, 1 yacht club, small craft harbour, 2 public docks, fuel dock	2 public docks, 3 yacht clubs, private docks	6 marinas, liveaboards 3 yacht clubs, 4 public docks, 2 fuel docks	Public dock, private docks	2 marinas with liveaboards, public dock, private docks	3 yacht club outstations, marina, public dock, yacht club, fuel dock, private docks
Marine transport	8 ferry docks	20 anchorages, shipping vessels	8 anchorages, marine terminals, shipping vessels, ferries	2 anchorages, marine terminals, shipping vessels	Marine terminals, shipping vessels	3 anchorages, shipping vessels
Stormwater outfalls (approximate)	17	38	190	54	76	32 (southern areas)
Sewage		1 sanitary sewer	2 sanitary sewer	2 wastewater		> 64 domestic

Discharge type	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
		overflow outfall	overflow outfalls, 3 wastewater lift station emergency overflow outfalls	lift station emergency overflow outfalls		outfalls
Resuspension from dredging		Present	Present		Present	
Inputs from Fraser River and Strait of Georgia		Strong influence				
Wood waste and treated wood	Creosote structures	Creosote structures		Former log storage	Active and former log storage	Former log storage, creosote structures, buried waste
Historical activities	Sawmills, shingle mills, wood preserving, construction, steelmaking[12]				Timber processing, oil refining, steel manufacturing, lead bullets[13], spills	Abandoned logging equipment

2. PARAMETERS OF CONCERN IN BURRARD INLET

2.1 Water Quality Status

The water quality of Burrard Inlet is affected by the input of various contaminants as well as naturally occurring physical and biological processes. Contaminants may enter Burrard Inlet via point and non-point sources that flow into the inlet directly, whereas others may enter from the Fraser River, other areas in the Salish Sea, or beyond. Atmospheric pollutants may also settle into the water. Persistent pollutants may settle into the sediment over decades and some contaminants are bioaccumulative. Physically, water quality in Burrard Inlet is largely influenced by geographical features including narrows and underwater sills, which restrict the overall circulation of the basin and lead to intensified mixing at certain regions, as well as by tidal currents, freshwater inputs and sediment transport. Contaminants may be transported among sub-basins. Biologically, primary production, food web and decomposition affect their uptake and fate. The relative importance of each of these factors changes with different parameters and is examined in more detail in the technical reports associated with each water quality parameter.

[12] Historical industrial activities in False Creek transformed the natural wetland ecosystem to brownfields prior to redevelopment in the late 1990s (ENV 1992).

[13] City of Port Moody Environmental Protection Committee, *pers. comm.*

Certain parameters of concern associated with specific activities or factors affect individual sub-basins and are described in the sections below. Other activities and factors, including marine shipping and boating, stormwater outfalls and the use of creosote pilings, affect the whole inlet. Parameters such as pH and temperature can reflect global or regional climate trends. Contaminants of emerging concern have been detected but are not yet fully understood. For example, endocrine-disrupting chemicals in fish tissue have been identified as a concern throughout Burrard Inlet (Metro Vancouver 2017a).

At least 18 water quality monitoring programs organized by various agencies have existed in Burrard Inlet over nearly 50 years (Map 5). To date, these programs have not been coordinated. As a result, data quality and detection limits vary among datasets and there are more water data than sediment and tissue data. Many knowledge gaps exist, for example high resolution physical water quality data, data on contaminants of emerging concern, and knowledge of contamination hotspots for metals, polycyclic aromatic hydrocarbons (PAHs) and persistent organic pollutants (POPs). Furthermore, many pollution sources are not well characterized, so their relative contributions to loadings into Burrard Inlet are unknown. It is essential that future programs be coordinated to provide effective and efficient monitoring to address these knowledge gaps.

2.2 Summary of parameters of concern

Following a coarse screening of 3 key data sets (BC ENV attainment monitoring, Metro Vancouver water quality monitoring, Ocean Wise Pollution Tracker Program) and review of the authorized and other discharges into the inlet, several classes of parameters have been identified as of concern in Burrard Inlet. A summary of current parameters of concern is presented by sub-basin in Table 5, although this may not be comprehensive. This list is more extensive than the parameters considered in 1990. Parameters are being prioritized for data analyses and updates to WQOs through consideration of the values they affect; persistence, bioaccumulation or toxicity; availability of acceptable updated guidelines or other information that can help update the WQO; and whether they are a known issue in Burrard Inlet.

Each parameter of concern in Burrard Inlet will be discussed in greater detail in individual technical reports/ chapters. These technical reports will contain analyses of relevant datasets compared to water quality benchmarks associated with the most sensitive values potentially affected by the parameter. Recommendations will be made in those reports with respect to how the goals associated with each of the values could be attained.

Table 5. Summary of current parameters of concern by sub-basin
D = of concern due to authorized discharges; M = of concern following monitoring data; S = suspected, but monitoring data not yet available at time of writing; ? = possible concern, not yet confirmed

Parameter group	Relevant values	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Alkylphenols	Shellfish consumption Finfish consumption Aquatic life Wildlife	S	D	D	D	S	S

Parameter group	Relevant values	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Biotoxins and harmful algal blooms	Shellfish consumption	?	?	?	?	?	?
Chlorates	Aquatic life				D		
Chlorinated ethanes: dichloroethane	Aquatic life			D			
Chlorine / chlorine-produced oxidants	Aquatic life			D	D		
Chlorophenols	Aquatic life Cultural practices and recreational uses	?	?	?	?	?	?
Cyanide	Aquatic life					?	
Dioxins and furans	Shellfish consumption Finfish consumption Aquatic life Wildlife	?	M	M	M	M	M
Endocrine-disrupting chemicals not otherwise covered	Aquatic life	M	M	M	M	M	M
Flame retardants - HBCD	Shellfish consumption Finfish consumption Aquatic life Wildlife	?			M	M	
Flame retardants - PBDEs	Shellfish consumption Finfish consumption Aquatic life Wildlife	?	M	M	M	M	
Hormones	Aquatic life	?	?	?	?	?	?
Hydrocarbons: oil and grease, PAHs (including creosote)	Shellfish consumption Finfish consumption Aquatic life Wildlife	M	M	M	D	D	M

Parameter group	Relevant values	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Metals	Shellfish consumption Finfish consumption Aquatic life Wildlife	M: As, Cd, Cr, Cu, Hg, Ni, Pb, Zn	M: Cd, Hg, Pb	M: Cd, Cr, Cu, Fe, Hg, Pb, Zn	M: As, Cd, Cr, Cu, Hg, Ni, Pb, Zn	M: As, Cd, Cr, Cu, Hg, Ni, Pb, Zn	M: Cd, Cu, Pb, Zn
Microbiological[14]: *E. coli*, enterococci, fecal coliforms	Shellfish consumption Cultural practices and recreational uses	M	M	M	M	M	M
Microplastics and other marine debris	Shellfish consumption Finfish consumption Aquatic life Wildlife Cultural practices and recreational uses	S	S	S	S	S	S
Nutrients: Ammonia	Shellfish consumption Cultural practices and recreational uses	D					D
Nutrients: Phosphorus	Shellfish consumption Cultural practices and recreational uses			D			D
Organotins, e.g. tributyl tin	Shellfish consumption Finfish consumption Aquatic life Wildlife	M	M	M	M	M	M

[14] Choice of microbiological indicator is discussed in depth in Chapter 2

Parameter group	Relevant values	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
PCBs	Finfish consumption Aquatic life Wildlife	M	M	M	M	M	M
Pesticides (legacy and current)	Shellfish consumption Finfish consumption Aquatic life Wildlife	S	M	M	M	M	M
PFCs	Shellfish consumption Finfish consumption Aquatic life Wildlife			M	M	M	
Physical: dissolved oxygen, pH, suspended solids	Shellfish consumption Finfish consumption Aquatic life	D	D	D	D	D	D
Physical: turbidity	Shellfish consumption Finfish consumption Aquatic life	D	D	D	D	D	
Physical: total organic carbon	Shellfish consumption Finfish consumption Aquatic life			D	D	D	
PPCPs	Shellfish consumption Finfish consumption Aquatic life Wildlife Cultural practices and recreational uses	S	S	S	S	S	S
Styrene	Aquatic life				D	D	
Sulphide	Aquatic life			S	S	S	S
Underwater noise	Aquatic life	S	S	S	S	S	S

3. FALSE CREEK

3.1 Characteristics

False Creek is a small marine arm connected to the Outer Harbour. It is relatively shallow, with a depth range of 4 to 8 m and little tidal exchange (BIEAP 2011). False Creek lacks adequate circulation and flushing, which tends to cause pollutants to accumulate toward its eastern end at Creekside Park. While the majority of the basin has a mean depth of approximately 5 m, there is a sill under the Cambie Street Bridge which reduces the mean depth to about 3 m at this location (ENV 2006) This reduces the circulation between the east and west basins of False Creek and prevents dilution of outfall discharges (Nijman and Swain 1990).

Historically, False Creek received the waters of several streams via salt marshes and tidal flats, resulting in a rich ecosystem supporting clams, oysters, crabs, mussels and fish (FCWS 2007). Those marshes and tidal flats were infilled in the early 20th century to create industrial land. Of all the basins, it is the most developed and urbanized; no natural shoreline or marine riparian zones remain except for those associated with recent habitat creation projects (KWL 2017). While the shoreline of False Creek is predominantly residential today, from the 1920s to 1970s, it was an industrial area with facilities for canning, meatpacking, lumber services, machinist shops and others (Heritage Vancouver 2015).

3.2 Values

Discussions are ongoing among several jurisdictions about the improvement of water quality in False Creek to support a variety of human uses, as well as to restore habitat values. The updated values for False Creek, compared with the water uses designated in 1990, are presented in Table 6.

Table 6. Updated values and designated water uses for False Creek, compared to 1990

Value	1990	Updated	
		Short-term (by 2025)	Long-term (by 2050)
Shellfish Consumption			✓
Finfish Consumption		✓	✓
Aquatic Life (including reproduction)	✓	✓	✓
Wildlife (including reproduction)	✓	✓	✓
Cultural practices and recreational uses		Secondary contact	✓

3.3 Provincial authorizations

The Province of BC has permitted one effluent discharge to False Creek and authorized four discharges of contaminated soil to the surrounding land (see Table 7). The only provincial effluent permit (PE-2300) does not have a direct discharge to False Creek and therefore the risk to water quality is low. The four other provincial authorizations are for the discharge of contaminated soil and were part of the remediation projects for Pacific Place and the Southeast False Creek lands. The contaminated soil at these sites has been transferred or buried according to the requirements under the Contaminated Sites Regulation. As there is no leachate or runoff discharged from these sites, the risk of environmental impact to False Creek is low. The history of these sites is available in Appendix G.

Table 7. Authorized discharges into False Creek. Details are available in Appendix G.

Permittee	Authorization type	Auth. No.	Discharge Type	Permitted volume (m3/day)
Ocean Construction Supplies Ltd.	Effluent Permit	PE-2300	No direct discharge: Stormwater to sanitary	50
BC Ministry of Environment Lands, and Parks	Hazardous Waste Regulation (HWR) Registration	RS-12224	Contaminated soil	Not applicable (N/A)
BC Ministry of Environment Lands and Parks	Refuse Permit	PR-11628	Contaminated soil	N/A
Chinese Merchants Association Parking Association	Refuse Permit	PR-12912	Contaminated soil	N/A
255-285 East 1st Avenue Holdings Ltd.	HWR Registration	RS-106230	Contaminated soil	N/A

3.4 Other point and non-point sources of pollution

Other current potential sources of pollution in False Creek include four CSOs, heavy traffic of small vessels, 8 marinas (4 of which have pumpout stations), liveaboard vessels, a smallcraft harbour with a pumpout station, 2 public docks, 8 ferry docks, a yacht club with a pumpout station, a fuel dock, leaching from creosote structures, 17 stormwater outfalls and runoff from a heavily altered shoreline (see Maps 3, 3a, 4, 12 and 17).

3.5 Parameters of concern

Parameters of concern for False Creek in 1990, and present parameters of concern, are presented in Table 8. This is not necessarily a comprehensive list. Objectives established for this sub-basin in 1990 are presented in Appendix E, Table E.1.

False Creek has been a sub-basin of municipal and community interest due to its high counts of microbiological indicators of water quality, combined with recreational uses such as kayaking and rowing that could result in contact with the water, including accidental immersion. Due to the sub-basin's low flushing rate, continued sources of bacterial contamination, and a heavily developed coastline in False Creek, the same parameters of concern since 1990 still exist. In addition, other stormwater- and wastewater-related pollutants including emerging contaminants such as microplastics, and pharmaceuticals and personal care products (PPCPs) are of current concern.

Table 8. Activities and parameters of concern to water quality in False Creek: 1990 (from Nijman and Swain 1990) vs. present

	1990	Current
Activities of concern **Parameters of concern**	CSOs, cooling water, stormwater outfalls, marinas	CSOs, creosote, marine vessels and infrastructure, stormwater
Endocrine-disrupting chemicals		X
Metals and metalloids: arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc	X	X
Microbiological: enterococci, fecal coliforms	X	X + *E. coli*
Microplastics		X
Nutrients and algae: nitrogen-total ammonia	X	X
Oil and grease	X	X
Organotin compounds: tributyl tin	X	X
Pesticides		X
Phenols		X
Physical: dissolved oxygen, suspended solids, turbidity	X	X + pH
Polychlorinated biphenyls (PCBs): Total PCBs	X	X
Polycyclic aromatic hydrocarbons (PAHs): acenaphthene, acenaphthylene, anthracene, benzo (g, h, i) perylene, benzo(a)anthracene, benzo(a)pyrene, benzofluoranthene, chrysene, dibenzo (a,h) anthacene, fluoranthene, fluorene, indeno (1,2,3- c,d) pyrene, naphthalene, phenanthrene, pyrene, total HPAHs, total LPAHs	X	X
PPCPs		X
Underwater noise		X

4. OUTER HARBOUR

4.1 Characteristics

The Outer Harbour is the western sub-basin of the inlet, divided from the Inner Harbour by First Narrows, and opening to the Strait of Georgia. Its average depth is 45 m, with a maximum depth of 100 m at its mouth (defined here as the line between Point Atkinson and Point Grey) (Haggerty 2001). Its southwest area includes sand and mud flats, supporting species such as flatfish (MacDonald and Chang 1993), and several beaches exist along its southern shore and in English Bay. Some of these beaches have been augmented with sand (BIEAP 2011). Although industrial development in the Outer Harbour has been low, much of its shoreline is hardened and developed (KWL 2017), including the construction of seawalls along both its northern and southern shores. At least 18 streams flow into the Outer Harbour, including the Capilano River, whose flow has been modified for a drinking water reservoir, and Cypress Creek. Several small creeks and/or their estuaries have been enhanced for fish habitat including Spanish Bank Creek, Salish Creek, and McDonald Creek.

4.2 Values

The updated values for the Outer Harbour, compared with the water uses designated in 1990, are presented in Table 9.

Table 9. Updated values and designated water uses for Outer Harbour, compared to 1990

Value	1990	Updated	
		Short-term (by 2025)	Long-term (by 2050)
Shellfish Consumption			✓
Finfish Consumption		✓	✓
Aquatic Life (including reproduction)	✓	✓	✓
Wildlife (including reproduction)	✓	✓	✓
Cultural practices and recreational uses	✓ (recreation)	✓	✓

4.3 Provincial authorizations

The Province of BC has authorized two discharges into the Outer Harbour (Table 10). Although UBC holds a MWR registration to use reclaimed water in a research facility, this site has never discharged effluent into the environment. The MWR registration for the site is required, however, due to the use of reclaimed water. As there is no discharge, this site does not pose a risk to water quality in Burrard Inlet.

Table 10. Authorized discharges into the Outer Harbour

Permittee	Authorization type	Auth. No.	Discharge Type	Permitted volume (m3/day)
The University of British Columbia	Municipal Wastewater Regulation Registration	RE-104901	No discharge: Reclaimed water for reuse	N/A
Metro Vancouver (Lions Gate Wastewater Treatment Plant)	Operational Certificate	ME-30	WWTP discharge to Burrard Inlet	318,000

The other provincially authorized discharge into the Outer Harbour is the Lion's Gate Wastewater Treatment Plant (operational certificate ME-30). Greater Vancouver Sewerage and Drainage District (GVSDD, Metro Vancouver) operates the wastewater treatment plant located near First Narrows just east of the Capilano River. The primary treatment plant opened in 1961 and services the District of West Vancouver and North Vancouver and the City of North Vancouver. As the volume of effluent discharged from this plant far exceeds the volume discharged from any other provincially authorized facility into Burrard Inlet, and thus the potential for environmental impact is high, more information is provided below. Greater detail about this effluent permit can be found in Appendix G.

4.3.1 Greater Vancouver Sewerage and Drainage District (ME-30)

The Province of BC originally granted effluent permit (PE-30) to the GVSDD in 1959. This provincial permit has been amended several times. In April 2002, the BC Minister of Environment approved the Greater Vancouver Regional District (GVRD) Liquid Waste Management Plan (LWMP), a plan that had been in preparation since 1986. Subsequently, on April 23, 2004, the present provincial operational certificate ME-30 superseded provincial permit PE-30 in accordance with GVRD's LWMP.

In February 2009, the Canadian Council of Ministers of Environment (CCME) developed the Canada-Wide Strategy for the Management of Municipal Wastewater Effluent (CWS-MMWE). This "harmonized framework" requires all wastewater treatment facilities to achieve minimum National Performance

Standards which address common pollutants in wastewater discharges (Table 11). In addition, site-specific effluent discharge objectives are also required (CCME 2009).

Table 11. A comparison of current ME-30 requirements and National Performance Standards.

Parameters	Current Requirements: ME- 00030, 2004	National Performance Standards
Maximum BOD_5 daily concentration	130 mg/L	25 mg/L, monthly average
Maximum TSS daily concentration	130 mg/L	25 mg/L, monthly average
Chlorine Residual (if chlorine is used as a disinfectant)	-	0.02 mg/L

A priority of the CWS-MMWE strategy is to upgrade all primary treatment plants to secondary treatment. Through Metro Vancouver's updated LWMP which was approved in 2011 (known as the Integrated Liquid Waste and Resource Management Plan, ILWRMP), Metro Vancouver is committed to upgrading the Lion's Gate Wastewater Treatment Pant to secondary treatment by December 31, 2020 (Metro Vancouver 2018b). The construction of the new plant is currently in progress. Once construction is complete and the new plant is in operation, the primary treatment plant will be decommissioned (Metro Vancouver 2018b). The new plant will be located two km east of the current site; however, the submerged outfall will continue to be used at its current location (a minimum of 228 m offshore discharging at a minimum depth of 17.3 m below mean low water). The provincial Operational Certificate will also be amended to comply with the National Performance Standards (Table 11).

4.4 Other point and non-point sources of pollution

Other current potential sources of pollution in the Outer Harbour include five CSOs, a sanitary sewer overflow outfall, two public docks, 20 anchorages, shipping vessels, three yacht clubs, 38 stormwater outfalls, creosote structures, resuspension from dredging and a strong influence on the water column of inputs from the Fraser River and the Strait of Georgia (see Maps 3, 3a, 4, 12, 16 and 17).

Monitoring data in the Outer Harbour indicate high levels of alkylphenols, dioxins and furans, metals (e.g. mercury, lead, cadmium), organotins, PAHs, PBDEs, PCBs, pesticides and PPCPs, with varied levels at each site monitored (Ocean Wise 2018).

4.5 Parameters of concern

Parameters of concern for the Outer Harbour in 1990, compared with current parameters of concern are presented in Table 12. This is not necessarily a comprehensive list. Objectives established for this sub-basin in 1990 are presented in Appendix E, Table E1.

Table 12. Activities and parameters of concern to water quality in the Outer Harbour: 1990 (from Nijman and Swain 1990) vs. present

	1990	Current
Activities of concern **Parameters of concern**	WWTP, landfill leachate, stormwater outfalls	WWTP, CSOs, sewage overflows, marine vessels and infrastructure, creosote, stormwater, dredging, external sources
Dioxins and furans		X
Endocrine-disrupting chemicals		X
Flame retardants: PBDEs		X
Metals and metalloids: arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc	X	X: Cd, Hg, Pb
Microbiological: enterococci, fecal coliforms	X	X + *E. coli*
Microplastics		X
Organotin compounds: tributyl tin	X	X
PAHs: acenaphthene, acenaphthylene, anthracene, benzo (g, h,i) perylene, benzo(a)anthracene, benzo(a)pyrene, benzofluoranthene, chrysene, dibenzo (a,h) anthacene, fluoranthene, fluorene, indeno (1,2,3-c,d) pyrene, naphthalene, phenanthrene, pyrene, total HPAHs, total LPAHs (lower molecular weight)	X	X
PCBs: total PCBs	X	X
Pesticides		X
Phenols: alkylphenols, creosote		X
Physical: dissolved oxygen, suspended solids, turbidity	X	X + pH
PPCPs		X
Underwater noise		X

5. INNER HARBOUR

5.1 Characteristics

The Inner Harbour of Burrard Inlet is defined as the area between First and Second Narrows. It is separated from the other harbours by sills at depths of 18 and 14.5 m, respectively, at each narrows (BIEAP 2011). The depth range in the Inner Harbour is 21 to 66 m. Circulation and flushing are high due to tides and currents. It is one of the most industrialized sub-basins with heavy port activity, cruise ship and floatplane terminals and transportation connections via road and rail. More than 80% of its shoreline has been altered (Stantec 2009). Three major stream mouths are located on the northern shore of the sub-basin: Mackay, Mosquito and Lynn creeks. Recent restoration projects have taken place at the estuaries of these three creeks, including increasing the complexity and riparian revegetation.

5.2 Values

The updated values for the Inner Harbour, compared with the water uses designated in 1990, are presented in Table 13. The heavily industrialized nature of this sub-basin limits the short-term values that guide the updating of WQOs.

Table 13. Updated values and designated water uses for the Inner Harbour, compared to 1990

Value	1990	Updated	
		Short-term (by 2025)	Long-term (by 2050)
Shellfish Consumption			✓
Finfish Consumption			✓
Aquatic Life (including reproduction)	✓	✓	✓
Wildlife (including reproduction)	✓	✓	✓
Cultural practices and recreational uses	✓ (recreation)	✓	✓

5.3 Provincial authorizations

The Province of BC has authorized fifteen facilities within the Inner Harbour (see Table 14). The following eight provincial authorizations are considered low risk to the water quality of Burrard Inlet for various reasons and thus are not discussed in detail in this section:

- Three ready-mix plants registered under the provincial Code of Practice (COP) for the Concrete and Concrete Products Industry (for this industry's provincial requirements, see Table 6 in Appendix G):
    - Lafarge Canada Inc. (North Vancouver): RE-107465
    - Pacific Site Constructors Inc.: RE -107213
    - Lafarge Canada Inc. (Vancouver Harbour): RE-107468

The storm and process water discharged from these facilities must meet the effluent requirements listed in the COP (Table 6 in Appendix G). The effluent discharges from these facilities pose a low risk to Burrard Inlet due to the nature of the contaminants in the wastewater, and because the wastewater is recycled, enters infiltration basins, or receives adequate treatment prior to discharge into Burrard Inlet.

- The hazardous waste facility at Vancouver Shipyards is registered under the provincial HWR (RS-17175). The treated process water and stormwater runoff from the site is discharged to the municipal sewer under a GVSDD permit. Since there is no direct discharge into the environment, the risk of hazardous waste contamination to Burrard Inlet from this facility is low.
- The Great Northern Packing Ltd. provincial effluent permit (PE-7810) for the discharge of process water was cancelled in 2008. There are no expected persistent environmental impacts to

Burrard Inlet from this facility as the permit was only used to discharge effluent in emergency situations up to seven times in one year.

- The B.C. Pavilion Corporation has a registration (RE-18362) under the provincial MWR to use reclaimed water for flushing toilets and green roof irrigation at the Vancouver Convention Centre. Since there is no discharge from this facility and any water that is not used for reclamation is disposed to the City of Vancouver municipal sewer, there is no risk to Burrard Inlet water quality from this site.
- The Southcoast Petroleum Ltd. truck stop cardlock facility, registered under the provincial Petroleum Storage and Distribution Facilities Stormwater regulation (RE-105286), stores fuel in underground tanks. Site runoff is treated and discharged to the City of Vancouver storm drain in Powell Street. The risk to water quality from this facility is low.
- TMBC Treat Med BC Inc. operates a biomedical hazardous waste treatment facility under provincial HWR registration RS-107253. Surface water and groundwater should not be impacted by the operations at this facility because all hazardous waste is stored inside a secure warehouse facility. Process water from the facility is discharged to the sanitary sewer and must comply with HWR Schedule 1.2 column 3 standards (see Table 9 in Appendix G).

The history and operations of each of the sites mentioned above is discussed in detail in Appendix G. The sites with large discharge volumes or greater environmental concern are discussed below with more detailed site histories and information on them also found in Appendix G.

Table 14. Provincially authorized discharges in the Inner Harbour

Provincial Authorization Holder	Provincial Authorization Type	Provincial Auth. No.	Discharge Type	Provincially Permitted Volume (m^3/day)
Lafarge Canada Inc. (North Vancouver Plant)	COP for the Concrete and Concrete Products Industry	RE-107465 (Replaced PE-2440)	No direct discharge: Process and stormwater runoff to ground	There is no maximum discharge rate
Pacific Site Constructors Inc.	COP for the Concrete and Concrete Products Industry	RE-107213	No discharge: Process and stormwater is reused	N/A
Lafarge Canada Inc. (Vancouver Harbour Plant)	COP for the Concrete and Concrete Products Industry	RE-107468	Process water and stormwater to Burrard Inlet	There is no maximum discharge rate
Vancouver Shipyards Co. Ltd. (Seaspan Marine Corporation)	HWR Registration	RS-17175	No direct discharge: Treated process and runoff water to sanitary sewer	144

Provincial Authorization Holder	Provincial Authorization Type	Provincial Auth. No.	Discharge Type	Provincially Permitted Volume (m^3/day)
Great Northern Packing Ltd.	Effluent Permit	PE-7810 (cancelled in 2012)	Process to Burrard Inlet	900, only in emergency situations
B.C. Pavilion Corporation	MWR Registration	RE-18362	No discharge: reuse of reclaimed water	151
Southcoast Petroleum Ltd.	Petroleum Storage and Distribution Facililities Stormwater Regulation (PSDFSR) Registration	RE-105286	Stormwater to storm drain	There is no maximum discharge rate
TMBC TreatMed BC Inc. doing business as TreatMed	HWR Registration	RS-107253	No discharge: Process water to sanitary sewer	No maximum discharge rate
KM Canada Terminals ULC operating as Kinder Morgan Canada	PSDFSR Registration	RE-14000	Stormwater to Burrard Inlet	There is no maximum discharge rate
	Effluent Permit	PE-1386	Discharges of storm and process water to Burrard Inlet	Discharge 1.1: 10,900 Discharge 1.2: 13, 100
Domtar Inc.	Effluent Permit	PE-17522	Groundwater	1,020
Neptune Bulk Terminals Canada Ltd.	Effluent Permit	PE-6898	Process and stormwater to Burrard Inlet	12,000
Univar Canada Ltd.	Effluent Permit	PE-5508 (cancelled in 2008)	Stormwater to Burrard Inlet	1,575
Canada Place Corporation	Effluent Permit	PE-7944	Cooling water to Burrard Inlet	23,700
Lantic Inc.	Effluent Permit	PE-1668	Cooling, process, and stormwater to Burrard Inlet	Discharge 1.1: 3,000 Discharge 1.2: 5,000 Discharge 1.3: 67,000
West Coast Reduction Ltd.	Effluent Permit	PE-8426	Process and stormwater to Burrard Inlet	Maximum rate: 6300 Annual Average: 1,850

5.3.1 Lantic Inc. (PE-1668)

The Lantic Inc. sugar refinery in Vancouver produces up to 240,000 tonnes of sugar per year from imported raw cane sugar (Lantic 2018). There are three process wastewater discharges from the refinery to Burrard Inlet authorized under provincial effluent permit PE-1668. The majority of the effluent is saltwater from Burrard Inlet that is used for barometric condenser cooling during the refining process. The provincial permit was last amended in April 2012 to accommodate a name change and to update the permit. Three separate discharges are included in the provincial permit with a combined maximum daily discharge rate of 75,500 m^3/day.

The major risks to water quality in Burrard Inlet from this refinery are the high discharge temperatures and bacterial growths that may be promoted by sugar in the effluent. Discharges from the facility have exceeded provincial permit limits for flow, temperature and TSS on several occasions in the past few years.

5.3.2 KM Canada Terminals ULC Operating as Kinder Morgan (Vancouver Wharves)

KM Canada Terminals ULC (KMCT), operating as Kinder Morgan Canada Terminals Limited Partnership, runs a marine bulk loading facility that transfers over four million tons of bulk cargo annually to offshore export markets and domestic markets. The main export products include sulphur, copper concentrates, diesel, bio-diesel, grain products and imported zinc and lead concentrates (KM 2018). The facility is located in North Vancouver, BC, just east of the Lion's Gate Bridge.

KMCT has two Province of BC authorizations for this site, a provincial effluent permit (PE-1386) and a registration under the provincial Petroleum Storage and Distribution Facilities Stormwater Regulation (PSDFSWR) (RE-1400). There are two discharges specified in the 2015 amended effluent permit. Combined, the two effluent discharges have a maximum daily rate of 24,000 m^3/day. The PSDFSWR registration covers the stormwater runoff from the fuel storage tanks on site. This runoff is directed to oil-water separators before being directed to the effluent treatment works authorized by the Province of BC under the provincial effluent permit.

Metals are contaminants of concern from this site as Environment Canada and ENV have previously raised concerns about metal contaminant loadings from this site affecting sediments in Burrard Inlet (ENV 1993b).

5.3.3 Canada Place Corporation (PE-7944)

Under provincial effluent permit PE-7944, the Canada Place Corporation (CPC) is authorized by the Province of BC to discharge cooling water effluent to Burrard Inlet from its hotel and convention centre at Canada Place in Vancouver. Sea water is used to indirectly cool heat exchangers for air conditioning units in the hotel before being discharged back to the Inlet.

Issued on February 17, 1988, the provincial permit authorizes a maximum discharge rate of 23,700 m^3/day with a maximum temperature of 24^oC and maximum chlorine residual of 0.1 mg/L. The permit was last amended by the Province of BC in 2017 removing the chlorine requirement because CPC stopped adding chlorine to the cooling system. The addition of chlorine was no longer necessary as CPC switched to using digitally controlled copper anodes which inhibit bacteria and sea life from adhering to the cooling system.

The main contaminants of concern from this discharge were chlorine produced oxidants from the residual chlorine; however, that is no longer a concern. Furthermore, data from the past five years indicates that CPC has never exceeded the provincially permitted authorized discharge rate, temperature or chlorine residual concentration. Data from 2017-2018 indicate a discharge flow

significantly lower than the permitted volume with an average of 3,269 m^3/day, and an average temperature at discharge of 15.3^oC. As a result, the risk to water quality in Burrard Inlet from this discharge is low.

5.3.4 Neptune Bulk Terminals Canada Ltd. (PE-6898)

Neptune Bulk Terminals (Canada) Ltd. (NBT) has been operating a large multi-product bulk terminal since 1970. Located in North Vancouver, the terminal temporarily stores Canadian potash, steelmaking coal and phosphate rock before being transferred to rail and marine transit. Coal and dry bulk (potash and phosphate rock) are handled in two separate shipping areas.

Under the last Province of BC permit amendment in 2004, the wastewater from this facility is generated from stormwater and operations such as the wash down of trains during unloading, water sprayed on conveyor belts to remove accumulated coal from paved surfaces, and dust suppression on coal piles (KWL 2006). All waste water from the coal handling area is directed to the coal water treatment plant (CWTP) and multiple settling ponds. Treated water from the CWTP is discharged to Burrard Inlet via an outfall with a maximum permitted discharge rate of 12,000 m^3/day. In the past three years, there have been some TSS exceedances and three failed 96-h fish bioassay tests from the permitted coal water discharge. In each case of an exceedance, NBT investigated the cause and took remedial actions to improve the results and meet the limits in the Province of BC permit.

The dry bulk treatment system receives runoff from the potash and phosphate rock areas and various collection sumps and settling ponds on site. The effluent treatment includes multiple ponds and oil skimmers before discharge to the MV sanitary sewer system. NBT has recently entered the Province of BC's pre-application phase to permit the dry bulk treated runoff to be discharged to Burrard Inlet.

5.3.5 West Coast Reduction Ltd. (PE-8426)

West Coast Reduction Ltd. (WCR) operates the animal and fish by-product reduction and rendering plant in Vancouver. Constructed in 1964, the plant converts inedible animal by-products to protein meals, fats and oils used in the world's feed, oleo chemical and soap industries. WCR also collects cooking oil from thousands of restaurants in the Lower Mainland and refines it into a useable product.

The Province of BC has authorized WCR to discharge process effluent to Burrard Inlet from their rendering plant under provincial effluent permit PE-8426. The permit was last amended in December 2014. Through the permit, the Province of BC authorizes the discharge of process effluent from the air emissions scrubber and stormwater from the site treated in two oil and grease interceptors before discharging to Burrard Inlet through the outfall. The annual average rate of discharge permitted is 1850 m^3/day and the maximum discharge rate is 6300 m^3/day.

A recent inspection of the facility affirms that WCR has not exceeded any of the Province of BC's permit requirements in the past two years. The treatment works and overall equipment were found to be in good order.

5.3.6 Domtar Inc. and Seaspan ULC (PE-17522)

From the 1920's to the 1960's, Domtar Inc. and various predecessors operated a wood preserving facility on the Vancouver Shipyards site in North Vancouver, the parcel now owned by Seaspan ULC which has operated a shipyard since the late 1960's. The historical use of the western part of the site as a wood-preserving plant resulted in highly contaminated soil, sediment and groundwater, which have been shown to have migrated into Burrard Inlet. The primary contaminants of concern on the site are creosote, PAHs, metals and tributyltin (TBT) (BC Environmental Appeal Board 2014).

Domtar Inc. and Seaspan ULC. are responsible for the remediation of the Vancouver Shipyards Site. As part of the remediation plan, the Province of BC has authorized Domtar Inc. and Seaspan ULC under provincial effluent permit PE-17522 (issued in November 2004) to discharge treated groundwater to Burrard Inlet from the pump-and-treat system located at the site. The maximum rate of discharge authorized under the permit is 1,020 m^3/day.

Domtar Inc. and Seaspan ULC recently completed the groundwater collection and treatment plant and are in the process of commissioning the treatment plant to meet provincial permit limits. To date, the effluent treatment plant had not yet met the discharge quality required under PE-17522; however, they have been removing 95% of the PAH constituents prior to discharge to Burrard inlet at a reduced discharge rate. Although they have yet to consistently meet the permit limits, the partially treated discharge is an improvement to the local receiving environment impacted by this site. They have requested suspension of the existing permit and issuance of an approval by the Province of BC with less stringent discharge limits. ENV is currently reviewing the application (Dankevy, *pers.comm*. 2019).

5.3.7 Univar Canada—previously owned by Dow Chemical Canada Inc. (PE-5508)

Univar Ltd., a large industrial and agricultural chemical distributor, operates the West Coast Distribution Centre in North Vancouver. The bulk liquid chemical marine terminal stores caustic soda (NaOH) and ethylene glycol. These chemicals are transferred via truck, rail or marine vessel.

Effluent Permit PE-5508 was issued in 1979 and authorized the discharge of stormwater effluent from the chemical loading facility to Burrard Inlet. Stormwater directed to the chemical storage tank spill containment dykes was neutralized prior to discharge through a submerged outfall into Burrard Inlet. The maximum daily discharge for permit PE- 5508 was 1,575 m^3/day.

In 2008, Univar Canada Ltd. submitted a request to the Province of BC to amend provincial permit PE-5508 as the ownership changed from Dow Chemical Canada Inc. to Univar Canada Inc. and the facility discontinued the storage of ethylene dichloride. The provincial permit had not been reviewed since the introduction of the *Waste Discharge Regulation* (WDR) in 2004. After reviewing the WDR, Univar determined that the terminal's operation does not fall under the WDR definition of a "chemical and chemical products industry" as it does not manufacture or blend any products and therefore wouldn't require a provincial permit under EMA, and requested its cancellation. ENV cancelled the permit in December 2008 (ENV 2009). Although the provincial permit was cancelled, the discharge continues and Univar is responsible to take all measures to prevent pollution. Univar has advised that they will continue to monitor and treat the effluent discharges.

Limited historical data indicate that prior to the cancellation of the provincial permit the discharge was in compliance with permit conditions. Therefore, significant impacts to the water quality of Burrard Inlet are not expected from this discharge.

5.4 Other point and non-point sources of pollution

Other current potential sources of pollution in the Inner Harbour include 11 CSOs, 6 marinas (5 of which have pumpout stations), liveaboard boats, 3 yacht clubs, 4 public docks, 2 fuel docks, 2 sanitary sewer overflow outfalls, 3 wastewater lift station emergency overflow outfalls, 190 stormwater outfalls, stormwater runoff from a mostly hardened shoreline, marine terminals, a cruise ship terminal, 2 ferry (Seabus) docks, resuspension from dredging, marine shipping and 8 anchorages (see Maps 3, 3a, 4, 12 and 17).

Monitoring data from the Inner Harbour indicate high levels of alkylphenols, dioxins and furans, metals (e.g. cadmium, lead, mercury), microbiological indicators, organotins, PAHs, PBDEs, PCBs, pesticides, PFCs and PPCPs (Ocean Wise 2018).

5.5 Parameters of concern

Parameters of concern for the Inner Harbour in 1990, compared with current parameters of concern, are presented in Table 15. This is not necessarily a comprehensive list. Objectives established for this sub-basin in 1990 are presented in Appendix E, Table E1.

Table 15. Activities and parameters of concern to water quality in Inner Harbour: 1990 (from Nijman and Swain 1990) vs. present

	1990	**Current**
Activities of concern	Bulk loading, cooling, aquarium, landfill leachate, stormwater	Marine vessels and infrastructure, bulk loading, cooling, CSOs, sewage overflows, fuel storage and distribution, stormwater, marine terminals, dredging, wood preserving
Parameters of concern		
Chlorinated ethanes: 1,2-dichloroethane or ethylene dichloride	X	X
Chlorine		X
Chlorophenols: total chlorophenols	X	
Dioxins and furans		X
Endocrine-disrupting chemicals		X
Flame retardants: PBDEs		X
Metals and metalloids: arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc	X	X: Cd, Cr, Cu, Fe, Hg, Pb, Zn
Microbiological: enterococci, fecal coliforms	X	X + *E. coli*
Microplastics		X
Nutrients and algae	X: ammonia	X: phosphate-phosphorus
Organotin compounds: tributyl tin	X	X
PAHs: acenaphthene, acenaphthylene, anthracene, benzo (g, h,i) perylene, benzo(a)anthracene, benzo(a)pyrene, benzofluoranthene, chrysene, dibenzo (a,h) anthacene, fluoranthene, fluorene, indeno (1,2,3- c,d) pyrene, naphthalene, phenanthrene, pyrene, total HPAHs, total LPAHs (lower molecular weight)	X	X
PCBs		X
Pesticides		X
PFCs		X
Phenols: alkylphenols, creosote		X
Physical: dissolved oxygen, suspended solids, turbidity	X	X + pH, TOC
PPCPs		X
Sulphide: undissociated	X	X
Underwater noise		X

6. CENTRAL HARBOUR

6.1 Characteristics

Central Harbour is separated from the Inner Harbour on its west by Second Narrows. To its northeast is Indian Arm, and Port Moody Arm is at its eastern end. It is well mixed and flushed by tides and has a depth range of 17 to 65 m (BIEAP 2011). Its shoreline is a combination of natural and armoured, and there are some concerns about shoreline erosion (Stantec 2009). A total of 19 tributary streams flow into the Central Harbour. The Maplewood mudflats in its northwest portion are a significant ecological area that was once a portion of the estuary of the Seymour River and Lynn Creek (KWL 2017).

6.2 Values

Updated values for the Central Harbour, compared with the water uses designated in 1990, are presented in Table 16. Updated goals associated with the values reflect aspirations within the mixed-use nature of backshore activities in this sub-basin.

Table 16. Updated values and designated water uses for Central Harbour, compared to 1990

Value	1990	Updated	
		Short-term (by 2025)	Long-term (by 2050)
Shellfish Consumption			✓
Finfish Consumption		✓	✓
Aquatic Life (including reproduction)	✓	✓	✓
Wildlife (including reproduction)	✓	✓	✓
Cultural practices and recreational uses	✓ (recreation)	✓	✓

6.3 Provincial authorizations

The Province of BC has authorized eight facilities within the Central Harbour (Table 17). The following two provincial authorizations are considered low risk to water quality of Burrard Inlet and are discussed in detail in Appendix G.:

- Two ready-mix concrete plants registered under the provincial COP for the Concrete and Concrete Products Industry:
  - Lehigh Hanson Materials Limited (RE-107100)
  - Lafarge Canada Inc. (Kask Brothers) (RE-107463). This ready-mix concrete plant was closed in 2016 and is in the process of decommissioning, so there is no active discharge to the Inlet.

The sites with large discharge volumes or greater environmental concern are discussed below with more detailed site histories and information on them also found in Appendix G.

Table 17. Provincially authorized discharges in the Central Harbour

Provincial Authorization Holder	Provincial Authorization Type	Provincial Auth. No.	Discharge Type	Provincially Permitted Volume (m^3/day)
Lehigh Hanson Materials Limited-doing business as Ocean Concrete	COP for the Concrete and Concrete Products Industry	RE-107100	Process water and stormwater runoff to storm sewer	There is no maximum discharge rate
Lafarge Canada Inc. (Kask Brothers)	COP for the Concrete and	RE-107463 (Replaces PE-6833)	Process water and stormwater	There is no maximum

Provincial Authorization Holder	Provincial Authorization Type	Provincial Auth. No.	Discharge Type	Provincially Permitted Volume (m^3/day)
(Decommissioned in 2016)	Concrete Products Industry		runoff to settling pond	discharge rate
Chemtrade Electrochem Inc.	Effluent Permit	PE-18	Process water, cooling water, and domestic sewage to Burrard Inlet	Discharge 1.1: 90,000 Discharge 1.2: 140
	Refuse Permit	PR-1698	Process refuse, solar salt	N/A
Revolution ORS Acquisition GP Inc. doing business as Terrapure	Effluent Permit	PE-5748	No direct discharge: Stormwater cooling and wash water to tile field	Maximum rate: 250 Annual average: 60
	HWR Registration	RS-8511	No direct discharge: Stormwater, cooling water, and wash water to tile field	N/A
Sterling Pulp Chemicals Ltd. (ERCO)	Effluent Permit	PE-395	Cooling water and stormwater to Burrard Inlet	7,160
Parkland Refining (B.C) Ltd. (was Chevron)	Effluent Permit	PE-4970	Stormwater, process water and contaminated groundwater to Burrard Inlet	Discharge 1.1: 19,550 Discharge 1.2: 18,000
	Refuse Permit	PR-7112	No discharge; stormwater regulated under PE-4970	N/A
Shell Canada Products Limited	PSDFSR Registration	RE-449	Stormwater to Burrard inlet	No maximum discharge rate
Trans Mountain Pipeline ULC	Effluent Permit	PE-3678	Stormwater to Burrard Inlet	Maximum rate: 415 Annual average: 26
	PSDFSR Registration	RE-14058	Stormwater to Burrard Inlet	There is no maximum discharge rate

6.3.1 Chemtrade Electrochem Inc. (PE-18 and PR-1698)

The chlor-alkali plant east of the Iron Worker's Memorial Bridge in North Vancouver has been operating since 1957. The plant manufactures sodium hydroxide (caustic soda), chlorine, hydrogen and hydrochloric acid.

Chemtrade Electrochem Inc. holds two permits from the Province of BC for the operations at the chlor-alkali plant*:* an effluent permit (PE-18) and a refuse permit (PR-1698). Through permit PE-18, the Province of BC authorizes the discharge of effluent composed mostly of cooling water to Burrard Inlet. The original permit was granted to Hooker Chemicals Ltd when the plant was built in 1957 and has been amended numerous times, mostly to accommodate changes in ownership and minor changes in permit requirements.

This plant has one of the highest provincially authorized discharge rates within Burrard Inlet (90,000 m^3/day). The effluent discharged from this site is comprised mostly of thermal cooling water but may also contain trace levels of chlorine, chlorates, suspended solids, copper, zinc and nickel (Golder 2007). The major concerns to water quality associated with the discharge are pH fluctuations associated with the handling of hydrochloric acid and caustic soda and chlorine residual values which may result in chlorine produced oxidants or organochlorine compounds. In addition, the presence of metals in the effluent could potentially impact sediments or benthic organisms in the long-term.

The 2017 ENV inspection reported that for the period of 2016-2017 the flow did not exceed provincial permit limits with the exception of a shut-down in October 2016 for facility maintenance (ENV 2018c). The characteristics of the effluent met provincial permit limits except for two zinc exceedances.

6.3.2 Revolution ORS Acquisition doing business as Terrapure (PE-5748 and RS-8511)

Terrapure's Short Term Hazardous Waste Storage and Treatment Facility in North Vancouver maintains a tank farm for the bulk storage of hazardous waste and operates a hazardous waste treatment process for refining waste oil. Stormwater, cooling water and wash water from the hazardous waste reprocessing facility is treated onsite before being discharged to a subsurface tile field around 290 meters north of Burrard Inlet.

The facility has been operating under a provincial effluent permit PE-5748 since 1980 and provincial special waste permit PS-8511 since 1991. In 2006 the provincial permit requirements for PE-5748 and PS-8511 were consolidated into an Operational Plan under the Hazardous Waste Regulation (HWR) registration, now referred to as RS-8511. The transition from the permits to the operational plan was scheduled for July 7, 2006. Since then, the facility has been regulated under the operational plan and the permit. The provincial permit may be cancelled; however, until it is, the effluent quality from this facility must meet both the provincial effluent permit (PE-5748) requirements and the provincial HWR registration (RS-8511) requirements from the HWR Schedule 1.2 column 2 (Table 9 in Appendix G).

The main contaminants of concern from this facility are petroleum hydrocarbons. In the past three years, the stormwater effluent has met the Schedule 1.2 column 2 standards except for three exceedances of total oil and grease and six exceedances of pH values below the provincially authorized range. The groundwater monitoring program is used to determine if contaminant migration is occurring. Since the discharge from this facility is to ground at a distance from the shore, the risk to the water quality of Burrard Inlet from this facility is low.

6.3.3 ERCO previously Sterling Pulp Chemicals Ltd. (PE-395)

ERCO Worldwide, a division of Superior Plus Inc., operates a sodium chlorate manufacturing plant in North Vancouver. Sodium chlorate ($NaClO_3$) is produced in solution and crystal forms and shipped by

rail, barge or truck. The Province of BC issued effluent permit PE-395 in 1971, through which the Province authorizes the discharge of cooling water and stormwater from the sodium chlorate manufacturing plant.

The effluent from the plant has consistently met provincial permit limits. The main contaminant of concern from this facility is sodium chlorate in the cooling water. Sodium chlorate is a strong oxidizing compound that dissolves easily in water and may produce chlorine-produced oxidants. Recorded flows and sodium chlorate concentration in the past two years have been significantly lower than permitted limits.

6.3.4 Parkland Refining (B.C.) Ltd. - previously Chevron (PE-4970 and PR-7112)

The oil refinery and products terminal in Burnaby processes over 7,950 cubic metres per day of crude oil into gasoline, jet, diesel fuel, asphalt and light petroleum gas (Chevron 2009). The site is divided into a bulk handling facility (tank farm) on the west side of the site and the oil refinery on the east of the site. Of the four historical refineries in the Burrard Inlet watershed, this is the only one still operating as a refinery. The other three have transitioned to bulk loading terminals.

PE-4970

The Province of BC has authorized two effluent discharges from this facility under provincial permit PE-4970. One is for the discharge of stormwater, process effluent and contaminated groundwater from the petroleum bulk handling area and the other of stormwater, non-contact cooling water and contaminated groundwater from the petroleum refinery area. The refinery also treats and stores hazardous waste from its operations authorized by the Province of BC under permit PR-7112 (see below).

The major potential contaminants of concern from these discharges are petroleum hydrocarbons including BETX (benzene, ethylbenzene, toluene and xylenes) and volatile petroleum hydrocarbons.

PR-7112

The refinery operations at this site generate hazardous wastes. From 1985-2000, a landfill was used for the temporary storage and biological treatment of the generated hazardous waste. The land treatment facility has not been in use since 2000 and was completely decommissioned in October 2008. No waste or hazardous waste residues remain on the former landfill.

Currently, hazardous waste is temporarily stored onsite in designated areas prior to being shipped offsite to facilities approved by the Province for treatment and disposal. Parkland Refining (B.C.) is in the process of replacing provincial PR-7112 with a registration under the provincial Hazardous Waste Regulation to reflect the updated operations. The risk to water quality from the current hazardous waste storage operations is low. Stormwater runoff from the facility is monitored under PE-9470.

6.3.5 Shell Canada Products Limited (RE-449)

The Shell Canada petroleum products finishing terminal is located in Burnaby. The facility operated as an oil refinery from 1932 to 1993 when the refinery was decommissioned (ENV 1993a). Since 1993, the facility has operated as a distribution terminal (tank farm) for refined petroleum products.

Through provincial effluent permit PE-449, the Province of BC authorized the discharge of treated stormwater from the Shell facility to Burrard Inlet until it was cancelled by the Province in 2005. After this, the Province of BC registered stormwater discharge from the terminal under the provincial Petroleum Storage and Distribution Facilities Stormwater Regulation.

The major contaminants of concern from this discharge are hydrocarbons.

6.3.6 Trans Mountain Pipeline ULC (PE-3678, RE-14058)

The Westridge Marine Terminal, operated by Trans Mountain Pipeline ULC, is located in Burnaby. The Terminal has been in operation since 1956 and handles a mix of crude oil, aviation jet fuel and petroleum products. Crude oil is received through the pipeline and transferred to barges and tankers for shipping. There are three jet fuel storage tanks with secondary containment located at the Terminal. The Terminal receives jet fuel by tanker; the jet fuel is offloaded into the storage tanks, and delivered via a pipeline to a tank farm at the Vancouver International Airport terminal (Kinder Morgan 2015).

Effluent permit (PE-3678), issued by the Province of BC in 1974, authorizes the discharge of effluent from the Terminal to Burrard Inlet. The permit has been amended to reflect changes in the facility operations. The existing provincial permit, last amended in 2014, authorizes the discharge of treated stormwater collected from the area around the three jet fuel tanks from two locations, east and west outlets, to Burrard Inlet.

The Westridge Terminal also has a registration under the Petroleum Storage and Distribution Facilities Stormwater Regulation (RE-14058) and must therefore comply with all its operation and maintenance requirements. The only effluent requirement under the Regulation is for the total extractable hydrocarbons (TEH) concentration in the effluent to be below 15 mg/L[15]; however, the permit (PE-3678) requirement of 5 mg/L is more protective.

The contaminants of concern from this facility are hydrocarbons and petroleum by-products present in stormwater discharges or accidental spills in the handling of crude oil. Data from the past five years indicates that the effluent discharges from this facility have continuously met British Columbia's permit requirements.

Trans Mountain Pipeline ULC received a provincial authorization to discharge treated stormwater during initial construction activities which monitored TSS and turbidity. In 2019, Trans Mountain submitted a request to the Province to amend permit PE-3678 to discharge treated stormwater and groundwater from additional construction activities. Parameters of particular concern during construction activities are expected to include pH, TSS and turbidity, although this is not a comprehensive list of potential parameters of concern.

6.4 Other point and non-point sources of pollution

Wood waste from former log storage is an issue in the Maplewood area of the Central Harbour, with several 'hotspot' locations identified, particularly toward the centre of the mudflats. Those areas generally contained higher concentrations of total organic carbon and total volatile solids, but also the highest quantity of silt. Levels of arsenic, cadmium, copper and/or lead were found to exceed CCME marine interim sediment quality guidelines. PAH levels in the mudflats also exceeded CCME guidelines but were not correlated with the presence of wood waste (Teranis 2017). The sediments were not observed to be toxic to invertebrates in laboratory tests, however, and wood waste was not observed to impair invertebrate abundance or diversity compared to reference areas in the mudflats (Steer 2018).

Other current potential sources of pollution in the Central Harbour include 4 CSOs, a public dock, 2 wastewater lift station emergency overflow outfalls, 2 anchorages, marine shipping terminals and vessels, and 54 stormwater outfalls (see Maps 3, 3a, 4, 12 and 17). Monitoring data in the Central

[15] As of November 2018, a method for the analysis and calculation of Total Extractable Hydrocarbons (TEH) in water using the BC ENV method for Extractable Petroleum Hydrocarbons (EPH) with a hydrocarbon range of nC10-nC30 has been posted for review as there are no longer laboratory standards for TEH.

Harbour indicate high levels of alkylphenols, dioxins and furans, HBCD, lead, mercury, organotins, PAHs, PBDEs, PCBs, pesticides and PFCs.

6.5 Parameters of concern

Parameters of concern for the Central Harbour in 1990, compared with current parameters of concern, are presented in Table 18. This is not necessarily a comprehensive list. Objectives established for this sub-basin in 1990 are presented in Appendix E, Table E1.

Table 18. Activities and parameters of concern to water quality in the Central Harbour: 1990 (from Nijman and Swain 1990) vs. present

	1990	Current
Activities of concern	Oil, manufacturing plants, cooling water, stormwater	Chemical manufacturing, hazardous waste storage and treatment, petroleum storage and distribution, CSOs, marine vessels and infrastructure, stormwater, log storage, sewage overflows
Parameters of concern		
Chlorates		X
Chlorine: chlorine-produced oxidants or total residual chlorine	X	X + organochlorine compounds
Dioxins and furans		X
Endocrine-disrupting chemicals		X
Flame retardants: HBCD, PBDEs		X
Metals and metalloids: arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, zinc	X	X: As, Cd, Cu, Hg, Ni, Pb, Zn
Microbiological: enterococci, fecal coliforms	X	X + *E. coli*
Microplastics		X
Organotins		X
PAHs: acenaphthene, acenaphthylene, anthracene, benzo (g, h, i) perylene, benzo(a)anthracene, benzo(a)pyrene, benzofluoranthene, chrysene, dibenzo (a,h) anthacene, fluoranthene, fluorene, indeno (1,2,3- c,d) pyrene, naphthalene, phenanthrene, pyrene, total HPAHs, total LPAHs (lower molecular weight)	X	X
PCBs: total PCBs	X	X
Pesticides		X
PFCs		X
Phenols: alkylphenols, creosote	X	X
Physical: dissolved oxygen, pH, suspended solids, turbidity	X	X + TOC
PPCPs		X
Styrene		X
Sulphide		X
Underwater noise		X

7. PORT MOODY ARM

7.1 Characteristics

Port Moody Arm, extending eastward from the Central Harbour, is a shallow water sub-basin with an average depth of 10 m. Circulation and freshwater input are low (BIEAP 2011), although it receives waters from 35 tributaries. It is the most productive sub-basin with respect to phytoplankton and plant growth, due to water column stability, warmer temperatures and higher nutrient levels (Stockner and Cliff 1979). Its eastern end contains intact shorelines, riparian areas and tidal flats and its freshwater streams support chum, coho and Chinook salmon (KWL 2017). Industrial development occurred around Port Moody Arm beginning in the early 1900s, including saw mills, oil refineries and shipping terminals (City of Port Moody 2011). This development was initially unregulated; its impacts on water quality destroyed shellfish beds in Port Moody (Morin 2018). Industrial development has since decreased, resulting in overall improvements to the health of the area (City of Port Moody 2011).

Over time, the build-up of sediment may have buried contaminants, but there are concerns that these can resurface due to regular dredging for navigation (City of Port Moody EPC 2018). Shoreline erosion has also been identified as a concern in Port Moody Arm (Stantec 2009).

7.2 Values

The updated values for Port Moody Arm, compared with the water uses designated in 1990, are presented in Table 19.

Table 19. Updated values and designated water uses for Port Moody Arm, compared to 1990

Value	1990	Updated	
		Short-term (by 2025)	Long-term (by 2050)
Shellfish Consumption			✓
Finfish Consumption		✓	✓
Aquatic Life (including reproduction)	✓	✓	✓
Wildlife (including reproduction)	✓	✓	✓
Cultural practices and recreational uses	✓ (recreation)	✓	✓

7.3 Provincial authorizations

The Province of BC has authorized seven facilities in the Port Moody Arm sub-basin (Table 20). The facilities below were considered low risk and are discussed in detail in Appendix G:

- Crystal Creek States has a provincial MWR registration (RE-17552) that authorizes the discharge to ground of wastewater treated in a secondary treatment plant. As the permitted volume is low and the facility is located approximately 1.6 km from Burrard Inlet, it is unlikely that this discharge poses a risk to water quality.
- The Province of BC has authorized Strata Corporation LMS 3081 to discharge wastewater from a secondary treatment plant to ground under provincial effluent permit PE-4606. The risk to the water quality of Burrard Inlet from this discharge should be low as as it is approximately 1.3 km away from the Inlet. There have been some compliance issues at the site which are discussed in Appendix G.
- Simon Fraser University is registered as a hazardous waste storage facility (RE-11883) under the provincial HWR for the storage of old electrical equipment containing PCBs. Since the waste is safely stored and protected from the weather, there is no risk of surface water contamination.
- Chemtrade Chemicals Canada Ltd. holds a provincial permit (PE-1133) to discharge storm water runoff to the ground from an aluminum sulphate plant. Most of the the storm water is recycled and

used in the production operations; therefore, the risk to water quality from this facility is considered low.

- The Burrard Generating Station (BGS) operated by BC Hydro stopped generating electricity in 2015. With the decommissioning of the cooling system, the provincial permit was no longer required under the Waste Discharge Regulation and thus was cancelled in 2016. The facility does still provide voltage support to the BC Hydro transmission and distribution system in the Lower Mainland; however, an authorization by the Province of BC is not required for this activity.

The sites with large discharge volumes or greater potential environmental concern are discussed below with more detailed site histories and information on them is also found in Appendix G.

Table 20. Provincially authorized discharges in Port Moody Arm

Provincial Authorization Holder	Provincial Authorization Type	Provincial Auth. No.	Discharge Type	Provincially Permitted Volume (m^3/day)
0985381 B.C. Ltd. (Crystal Creek States)	MWR Registration	RE-17552	No direct discharge: Wastewater to ground	35
Strata Corporation LMS 3081 (Anmore Green Estates)	Effluent Permit	PE-4606	No direct discharge: Wastewater to ground	61
Simon Fraser University	HWR Registration	RE-11883	NA (contained PCB storage)	N/A
Chemtrade Chemicals Canada Ltd.	Effluent Permit	PE-1133	No direct discharge: Stormwater to infiltration pond	200
British Columbia Hydro and Power Authority	Effluent Permit	PE-7178 (Cancelled in 2016)	Storm and process water	Discharge 1.1: 1,650 Discharge 1.2: 550 Discharge 1.3: 1,700,000 Discharge 1.4: 72
Imperial Oil Ltd.	Effluent Permit	PE-445	Storm and process water to Burrard Inlet	Discharge 1.1: 8,200 Discharge 1.2: 3,312.5
	HWR Registration	RS-8589	Stormwater runoff, drainage and leachate	3,312.5 (included in 1.2 of PE-445)
Petro-Canada Products (Suncor Energy)	PSDFSR Registration	RE-14093	Stormwater to storm sewer	There is no maximum discharge rate

Provincial Authorization Holder	Provincial Authorization Type	Provincial Auth. No.	Discharge Type	Provincially Permitted Volume (m^3/day)
	Effluent Permit	PE-22	Stormwater to Burrard Inlet	1,725
	PSDFSR Registration	RE-14094	Stormwater to Burrard Inlet	There is no maximum discharge rate
	HWR Registration	RS-8420	No direct discharge: Stormwater to sanitary	1,725
	Refuse Permit	PR-1453	N/A	N/A

7.3.1 Imperial Oil Ltd. (PE-445 and PS/RS-8589)

Imperial Oil Ltd. operates the IOCO bulk petroleum products terminal on the north shore of Port Moody Arm just east of the Burrard Generating Station. From 1915 to 1995, IOCO operated as an oil refinery that manufactured gasoline, butane, propane, diesel fuel, jet fuel, and fuel oil. The refinery operations were closed in July 1995. Since then, the facility operates as a distribution terminal. The site has a complicated history due to changes to the operations as well as regulations.

Effluent Permit PE-445

The Province of BC has authorized the IOCO facility to discharge a combined volume of 11,512.5 m^3/day composed of stormwater runoff, groundwater and process water under provincial effluent permit PE-445. The permit was first issued in 1971 and has been amended several times. In 1998, the permit was amended to reduce the monitoring frequency and lower the concentration of the characteristics of the discharge to reflect the changes from a refinery to a terminal. The Province removed the sulphide effluent limit from the permit but sulphide monitoring continued and anytime the concentration exceeded 25 ug/L, the company had to notify ENV. In the most recent amendment in 2000, the Province allowed the discharge of stormwater runoff from a special waste facility on site (authorized by the Province under PS-8589) to be included in the original permitted discharges (more information on this below).

PS-8589/RS-8589

The site also had a permit (PS-8589) issued by the Province of BC in 1992 under the Special Waste Regulation. Through this, the Province authorized the company to store, manage and treat special wastes including PCB wastes and special wastes originating from petroleum refining and processing. Stormwater generated from the special waste management facility was discharged to a biox plant and then to the sanitary sewer under Metro Vancouver jurisdiction. After the refinery closed in 1995, the facility no longer generated the types of wastes it was designed for and the biox plant was closed.

Through concurrent amendments to PE-445 and PS-8589 in 2000, the Province allowed the discharge from the special waste facility authorized under PS-8589 to be included within the effluent permit PE-445 as Discharge 1.2.

In 2007, IOCO requested that permit PS-8589 be cancelled since the facility meets the criteria of the HWR for short-term, on-site passive storage. Since treatment is no longer carried out and hazardous waste is passively stored at the facility, ENV cancelled the permit in 2007 and transitioned it into the HWR registration RS-8589.

There is no risk of stormwater coming into contact with the stored material as the facility is no longer used for the treatment of special waste but only for the storage of containerised materials. As stipulated by the provincial HWR, the facility has submitted a contingency plan which is regularly updated and maintained. Furthermore, the facility is equipped with curbs and berms to retain any accidentally spilled hazardous waste on site. There are four groundwater monitoring wells, one up gradient and three downgradient, to ensure that contaminants from the special waste facility do not enter the groundwater.

7.3.2 Suncor Energy Products Partnership (PE-22, RE-14093, RE-14094, RS-8420, PR-1453)

The Suncor Burrard Products Terminal (BPT) is situated on 430 acres of land on the boundary of Port Moody and Burnaby. The facility used to be a petroleum refinery until 1993, when its operations were reduced to a petroleum products terminal. Terminal operations are divided among three sites: the Upper Terminal, the Middle Terminal and the Lower Terminal. Suncor Energy (previously Petro-Canada) has five separate provincial authorizations for different aspects of the operations located across the three sites:

1. The Upper Terminal, located in Port Moody, contains the fuel processing units, main tank farm and the fuel blending facilities. It has one effluent permit for stormwater (PE-22), one hazardous waste registration (RS-8420), and one refuse permit (PR-1453).
2. The Middle Terminal, located on the south side of Barnet Highway in Burnaby, contains the secondary tank farm and truck facilities. The Province has authorized the site's fuel storage operations under a Petroleum Storage and Distribution Facilities Stormwater Regulation (RE-14093).
3. The Lower Terminal, located in Burnaby, Port Moody, and along Burrard inlet, contain the marine and rail facilities. The Province has authorized the site's fuel storage operations under a Petroleum Storage and Distribution Facilities Stormwater Regulation (RE-14094).

PE-22

The Province has authorized the discharge of treated stormwater runoff from the Upper Terminal with an effluent permit (PE-22). The Province has amended this permit several times to reflect ownership and operational changes.

A review of the effluent quality data from the past five years shows that the stormwater effluent quality from the Upper Terminal met the provincial permit limits. The annual average daily flow has been below the permit limit of 1,725 m^3/day and the maximum recorded oil and grease concentration has been 1.5 mg/L which is lower than the permit limit of 5 mg/L. The major parameters of concern from this facility are hydrocarbons (oil and grease).

RE-14093 and RE-14094

The Middle and Lower Terminals, with 10 and 16 fuel storage tanks respectfully, are not covered under permit PE-22. Therefore, the oil/water separators at these locations are registered by the Province under the Petroleum Storage and Distribution Facilities Stormwater Regulation. As specified in the regulation, the stormwater effluent from these locations must have a total extractable hydrocarbon (TEH) concentration below 15 mg/L, monitored monthly.

Data from the middle plant shows that the TEH concentration in the stormwater effluent has been quite low, near detection limits while historical observations from the lower plant state that the TEH concentrations have met the regulatory limits.

RS-8420

The BPT also manages a short term hazardous waste storage and treatment facility in the Upper Terminal. The Province of BC originally authorized the facility to manage the hazardous waste storage facility under Special Waste permit PS-8420 issued in 1990. In April 2007, the Province cancelled the permit and transitioned it to an operational plan under the HWR registration, RS-8420.

Under the HWR registration, Province has authorized the BPT to store hazardous waste consisting of hydrocarbon contaminated water, soils and waste oil generated through the process operations on site. The facility also accepts oil/water separator sludge and oily wastewater from operations at other Suncor marketing sites in BC. The facility treats hydrocarbon-contaminated water at the water treatment facility bio-reactor. The treated and delisted water is discharged to the process water effluent treatment works and then to a municipal sanitary sewer under GVRD (Metro Vancouver) permit SC-100086-FSA.

PR-1453

The Province of BC has authorized Suncor Energy Products Inc. to discharge refuse from the petroleum products processing, storage and distribution facility to a landfill located on the north side of the upper plant site. Since the facility was reduced from a refinery to an oil storage and distribution terminal, the amount of refuse has decreased significantly and there is no expected risk to water quality from this landfill.

7.4 Other point and non-point sources of pollution

Other current potential sources of pollution in Port Moody Arm include log storage, 76 stormwater outfalls, shipping terminals and vessels, 2 marinas with liveaboards and a pumpout station, a public dock, private docks, and the possibility of contaminant resuspension via dredging (see Maps 3, 3a, 4, 12, 16 and 17).

Monitoring data for sediment and tissue in Port Moody Arm indicate high levels of metals (e.g. copper, lead, mercury, cadmium, zinc), PAHs, PCBs, PBDEs, PFCs, HBCD, pesticides, dioxins and furans, PPCPs, and endocrine-disrupting chemicals (Metro Vancouver, unpublished data; Ocean Wise 2018).

7.5 Parameters of concern

Parameters of concern for Port Moody Arm in 1990, compared with current parameters of concern, are presented in Table 21. This is not necessarily a comprehensive list. Objectives established for this sub-basin in 1990 are presented in Appendix E, Table E1.

Table 21. Activities and parameters of concern to water quality in Port Moody Arm: 1990 (from Nijman and Swain 1990) vs. present

	1990	Current
Activities of concern	Sewage, landfill leachate, cooling, oil, bulk storage and loading, chemical plants, sawmill, stormwater	Log handling and timber processing, petroleum operations, sewage overflows, stormwater, historical industry and spills, marine vessels and infrastructure, dredging, contaminant retention
Parameters of concern		
Chlorine: chlorine-produced oxidants or total residual chlorine	X	
Cyanide: e.g. weak acid dissociable	X	X
Dioxins and furans		X
Endocrine-disrupting chemicals		X
Flame retardants: HBCD, PBDEs		X
Metals and metalloids: arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc	X	X
Microbiological: enterococci, fecal coliforms	X	X + *E. coli*
Microplastics		X
Organotin compounds: tributyl tin	X	X
PAHs: acenaphthene, acenaphthylene, anthracene, benzo (g, h,i) perylene, benzo(a)anthracene, benzo(a)pyrene, benzofluoranthene, chrysene, dibenzo (a,h) anthacene, fluoranthene, fluorene, indeno (1,2,3- c,d) pyrene, naphthalene, phenanthrene, pyrene, total HPAHs, total LPAHs (lower molecular weight)	X	X
PCBs: total PCBs	X	X
Pesticides		X
PFCs		X
Phenols	X	X
Physical: dissolved oxygen, suspended solids, turbidity	X	X + pH, TOC
PPCPs		X
Sulphide	X	X
Styrene	X	X
Underwater noise		X

8. INDIAN ARM

8.1 Characteristics

The largest of the sub-basins, Indian Arm is a coastal fjord with a mean depth of 120 m and a maximum depth of 218 m. It is surrounded by steep mountains on its east and west sides, the Indian River estuary at its north end and a 27-m deep sill separating it from the Central Harbour and Port Moody Arm to the south (BIEAP 2011). Water exchange within Indian Arm is limited, with full replacement every 3 years (Allen 2017). In many ways, it is the most pristine of the sub-basins. Most of the adjacent watersheds and shoreline are largely undeveloped, and much of the land surrounding the arm is protected within Say Nuth Khaw Yum Provincial Park (co-managed by BC Parks and TWN). It is also the least productive sub-basin (Stockner and Cliff 1979). Its waters are cold and clear, with low dissolved oxygen at depth (Levings *et al.* 2004). Indian Arm contains two Rockfish Conservation Areas (Fisheries and Oceans Canada 2015). In addition to the Indian River, 151 tributaries flow into Indian Arm either ephemerally or year-round. Another significant freshwater input is from the Buntzen Diversion (WorleyParsons Komex 2006).

8.2 Values

In containing some of the more pristine areas of Burrard Inlet, Indian Arm is seen as having the most potential for shorter-term realization of values related to water quality. The updated values for Indian Arm, compared with the water uses designated in 1990, are presented in Table 22.

Table 22. Updated values and designated water uses for Indian Arm, compared to 1990

Value	1990	Updated	
		Short-term (by 2025)	Long-term (by 2050)
Shellfish Consumption		✓ (bivalves)	✓
Finfish Consumption		✓	✓
Aquatic Life (including reproduction)	✓	✓	✓
Wildlife (including reproduction)	✓	✓	✓
Cultural practices and recreational uses	✓ (recreation)	✓	✓

8.3 Provincial authorizations

There are five wastewater effluent discharge permits issued by the Province of BC in the Indian Arm sub-basin, of which four are operational (see Table 23). The treatment works described in PE-13446 managed by the Farrer Cove Waste Water Management Association have not yet been constructed; however, the permittee intends to keep the permit in case they decide to proceed with construction. There are also two effluent discharges to ground (PE-4806 and PE-5112) which have low discharge volumes and are located more than two kilometres away from Indian Arm. There is a low likelihood of impact to Burrard Inlet water quality from these sites (see Appendix G for site history). The two other effluent discharges to Indian Arm are discussed below.

Table 23. Provincially authorized discharges in Indian Arm

Provincial Authorization Holder	Provincial Authorization Type	Provincial Auth. No.	Discharge Type	Provincial Permitted Volume (m^3/day)
Farrer Cove Waste Water Management Assoc.	Effluent Permit (Not operational)	PE-13446	Wastewater to to Burrard Inlet	7.4
Countryside Village Ventures Ltd.	Effluent Permit	PE-4806	No direct discharge: wastewater to ground	44
37852 B.C. Ltd. (Anmore Campgrounds)	Effluent Permit	PE-5112	No direct discharge: wastewater to ground	30
Seymour Resorts Ltd.	Effluent Permit	PE-0027	Wastewater to Francis Creek	Jun 1- Sep 30: 100 Oct 1- May 31: 200
Evangelical Laymen's Church of Canada (Vancouver)	Effluent Permit	PS-8035	Wastewater to Burrard Inlet	24

8.3.1 Mt. Seymour Resorts Ltd. (PE-0027)

The Province of BC has authorized Mt. Seymour Resorts Ltd., previously owned by E.H. Pletsch Holdings, to discharge treated wastewater from its secondary treatment plant to Francis Creek under effluent permit PE-0027. The secondary sewage treatment plant was constructed and permitted by the Province in 1958 to treat the wastewater from the washrooms and restaurant of the ski facility. Due to increased flow, the Province has amended the permit several times. The most recent amendment in 1999 increased the maximum daily flow from 68.2 m^3/day to 100 m^3/day from June 1st to September 30th and 200 m^3/day from October 1st to May 31st. The wastewater treatment outfall pipe discharges to Francis Creek approximately one kilometre down slope from the treatment plant and then ultimately discharges to Deep Cove.

A recent ENV inspection report states that the sewage treatment plant is being regularly inspected and maintained. There are indications, however, that it has operated beyond its intended lifespan and requires replacement (ENV 2018e). A permit amendment would be required for plant modification.

Prior to discharge, the effluent quality must meet the requirements of the permit with maximum BOD_5 concentrations of 20 mg/L and total suspended solids of 30 mg/L. Analytical data from the past ten years indicate that suspended solids and BOD_5 limits were not met on a few occasions. In addition, fecal coliforms are monitored monthly although there is no prescribed limit for fecal coliforms in the permit. Data from the past ten years shows high fecal coliform concentrations on several arbitrary occasions.

The high fecal coliform counts could be a concern as shellfish harvesting is a short-term goal in Indian Arm and Deep Cove is a heavily used recreational area. Flows in Francis Creek are unknown, so the potential concentrations of fecal coliforms reaching Indian Arm cannot be determined from current information.

8.3.2 Evangelical Laymen's Church of Canada-Vancouver (PE-8035)

The Evangelical Laymen's Church of Canada-Vancouver manages Camp Howdy, a summer camp with 150 beds located near Farrer Cove, Belcarra. The camp ownership changed from the Young Men's Christian Association of Greater Vancouver in 2007. Wastewater from the camp is treated in a secondary wastewater treatment plant and sand filter before being discharged into Indian Arm from an outfall 466 m west of Farrer Creek. Used mainly for seasonal and occasional events, the effluent discharge volume is typically low.

Through effluent permit PE-8035, the Province of BC authorizes a maximum discharge of 24 m^3/day with maximum concentrations of 20 mg/L for $CBOD_5$ and 30 mg/L for total suspended solids.

During an ENV inspection in 2017, the treatment works were found to be well maintained and in excellent condition. Limited discharge data from recent years, however, makes it difficult to determine the effluent water quality and its potential impact to Indian Arm (ENV 2018d).

8.4 Other point and non-point sources of pollution

Other potential sources of pollution in Indian Arm include 1 marina, 1 yacht club, 1 public dock, 1 fuel dock, private docks, 3 yacht club outstations, 3 anchorages, shipping vessels, 32 stormwater outfalls (in southern areas of the sub-basin), and logging in the Indian River watershed (see Maps 3, 3a, 4, 12, 16 and 17). Buried wood waste, creosote pilings and abandoned logging equipment, as well as creosote wood bridges in the Indian River watershed, may also contribute contaminants into Burrard Inlet.

With the exception of Deep Cove and the Village of Belcarra, many of the homes, cabins and commercial properties (e.g. Camp Howdy, Camp Jubilee, Wigwam Inn, BC Hydro) around Indian Arm are not connected to municipal wastewater systems. Wastewater disposal in these cases is via land-based septic fields or outfalls into the marine environment. The total wastewater flow from 64 domestic-origin outfalls around Indian Arm was 95 m^3/day in 2006. It was predicted that this would increase to 223 outfalls discharging 380 m^3/day. Outfalls are estimated to represent less than 1% of total freshwater input into Indian Arm. Future discharge quality predictions range from 10-90 mg/L TSS, 10-60 mg/L nitrogen, 1-30 mg/L phosphorus and 10^3-10^7 MPN/100mL fecal coliforms (WorleyParsons Komex 2006).

Monitoring data for sediment and tissue in Indian Arm indicate exceedences of PCBs, dioxins and furans, cadmium, current use pesticides, alkylphenols and organotins (Ocean Wise 2018), as well as endocrine-disrupting chemicals (Metro Vancouver, unpublished data).

8.5 Parameters of concern

Parameters of concern for Indian Arm in 1990, and present parameters of concern, are presented in Table 24. This is not necessarily a comprehensive list. Objectives established for Indian Arm in 1990 are presented in Appendix E, Table E1. Parameters of concern have been expanded to reflect a greater understanding of inputs.

Table 24. Activities and parameters of concern to water quality in Indian Arm: 1990 (from Nijman and Swain 1990) vs. present

	1990	Current
Activities of concern **Parameters of concern**	Watercraft, stormwater	Treated wastewater discharge, marine vessels and infrastructure, stormwater, sewage outfalls, wood waste and logging infrastructure
Dioxins and furans		X
Endocrine-disrupting chemicals		X
Metals: cadmium, copper, lead, zinc	X	X
Microbiological: enterococci, fecal coliforms	X	X + *E. coli*
Microplastics		X
Nutrients: ammonia, phosphorus		X
Organotin compounds: tributyl tin	X	X
PAHs		X
PCBs		X
Pesticides		X
Phenols: creosote		X
Physical: dissolved oxygen	X	X + pH, suspended solids
PPCPs		X
Sulphide		X
Underwater noise		X

9. DATA ASSESSMENT AND ATTAINMENT MONITORING CONSIDERATIONS

The water quality data (water, sediment and tissue) currently available for Burrard Inlet are extensive but inconsistent in goals, location, methodology, frequency and reporting format. Monitoring programs include ambient, permit-related, pre-and post- disposal at sea, use-specific (e.g. swimming, shellfish harvestability), and dedicated research on particular parameters. The most comprehensive database to date has been compiled as part of this WQOs update initiative. It incorporates more than 18 data owners, 479 monitoring sites and 300,000 observations over 46 years with a greater number of observations recorded per year after 2012.

All available data could not be merged and analyzed together due to inconsistencies and incompatibilities among data sets. Furthermore, a detailed data assessment was not feasible for every parameter due to time constraints. An initial data screening was completed to identify parameters of concern, using three primary data sets: BC ENV's attainment monitoring; Metro Vancouver's ambient, recreational and receiving environment monitoring; and Ocean Wise's Pollution Tracker Program. Modest data assessments based on key datasets were completed for selected parameters and are incorporated into the subsequent chapters of this report.

Monitoring of WQOs is referred to as attainment monitoring. Details of the attainment monitoring schedule recommended in 1990 are available in Nijman and Swain (1990), divided by sub-basin and subsequently by monitoring site. Attainment monitoring recommended in 1990 was decided by site, not by water quality parameter, so frequency and timing of monitoring is variable for a single parameter.

General recommendations for monitoring in 1990 included to:

- Monitor waste discharges at the same time as receiving water monitoring;
- Conduct all sampling on an ebb tide for consistency;
- Time sampling in consideration of the period of increased rainfall (October-March) and the period when Fraser River freshet contributes significantly to surface water (April-June); and
- Include at least three replicate samples from the same sediment sampling site outside any initial dilution zones of discharges.

The number of parameters that are currently of concern among all sub-basins suggests a need for a comprehensive ambient water quality monitoring program throughout the inlet. The number of different monitoring programs (see Map 5), their inconsistency with each other, and the difficulty experienced in compiling and collating data sets suggests that there could be value in greater coordination among programs. Specific considerations for monitoring will be described by parameter in subsequent chapters.

LITERATURE CITED

AECOM. 2016. Simon Fraser University stormwater management strategy drainage area map. Simon Fraser University.

AECOM. 2017. Integrated stormwater management plan: University Endowment Lands (draft). Prepared for the Province of British Columbia.

Allen, S. 2017. Burrard Inlet: the extended sill of a fjord. Presentation to Burrard Inlet Science Symposium, 24 October.

B.C. Environment, Lands and Parks Environmental Protection. 1995. Memorandum Re: Sterling Pulp Chemicals PE 395.

BC Environmental Appeal Board. 2014. DECISION NOs. 2010-EMA-005(c) and 2010-EMA-006(c).

BC Hydro. 2000. Burrard thermal generating station report.

BC Hydro. 2005. Coquitlam-Buntzen project water use plan. https://www.bchydro.com/content/dam/hydro/medialib/internet/documents/environment/pdf/wup_coquitlam_water_use_plan_pdf.pdf (Accessed 31 December 2019).

BC Ministry of Environment, Lands and Parks (ENV). 1993a. Major Technical Report PE-449 Shell Refinery

BC Ministry of Environment, Lands and Parks- Environmental Protection (ENV). 1993b. Technical Report (Major) for Vancouver Wharves Ltd.

BC Ministry of Environment, Lands and Parks (ENV). 1995. Technical report (minor) for British Columbia Hydro and Power Authority.

BC Ministry of Environment, Lands and Parks (ENV). 1996. Canada Place Corporation Technical Report for a Minor Amendment.

BC Ministry of Environment, Lands, and Parks (ENV). 1998. Technical Report (Minor) for Greater Vancouver Sewage and Drainage District application for a minor amendment.

BC Ministry of Environment, Lands, and Parks (ENV). 2000. Technical Report for Imperial Oil limited PS-8589 and PE-445.

BC Ministry of Environment, Lands, and Parks (ENV). 2001. British Columbia Sugar Refining Company Technical Report (Major).

BC Ministry of Environment, Environmental Sustainability and Strategic Policy Division (ENV). 2002. Ambient Water Quality Guidelines for Chlorate.

BC Ministry of Environment and Climate Change Strategy (ENV). 2004. Memorandum Neptune Bulk Terminals (Canada) Ltd. Minor Ammendment.

BC Ministry of Water, Land, and Air Protection (ENV). 2005. Memorandum RE: Registration of Shellburn Terminal under the Petroleum Storage and Distribution Facilities Stormwater Regulation.

British Columbia Ministry of Environment (ENV). 2006. Assessment of bacteriological indicators in False Creek: With recommendations for bacteriological water quality objectives for recreational uses.

BC Ministry of Environment and Climate Change Strategy (ENV). 2009. Memorandum: Transfer and Cancellation of Permit 5508.

BC Ministry of Environment Environmental Protection Division (ENV). 2013. RS-17175 Ministry Assessment.

BC Ministry of Environment and Climate Change Strategy- Environmental Protection Division (ENV). 2015. Memorandum: Minor Amendment for Permit 1386.

BC Ministry of Environment and Climate Change Strategy (ENV). 2017a. Countryside Village Ventures Ltd PE-4806:

Inspection Report number 072273.

BC Ministry of Environment and Climate Change Strategy (ENV). 2017b. TMBC Treatmed BC Inc. doing business as Treatmed RS-107253: inspection report number 071464.

BC Ministry of Environment and Climate Change Strategy (ENV). 2017c. Vancouver Shipyards Co. Ltd. RS-17175: Inspection Report 069925.

BC Ministry of Environment and Climate Change Strategy (ENV). 2018a. 379852 B.C. Ltd. (Anmore Campgrounds) PE-5112: Inspection Report Number 073144.

BC Ministry of Environment and Climate Change Strategy (ENV). 2018b. Anmore Green Estates Information. https://www2.gov.bc.ca/gov/content/environment/air-land-water/site-permitting-compliance/anmore-green-estates (accessed July 30, 2018)

BC Ministry of Environment and Climate Change Strategy (ENV). 2018c. Chemtrade Electrochem Inc. PE-18: Inspection Report 085448.

BC Ministry of Environment and Climate Change Strategy (ENV). 2018d. Evangelical Laymen's Church of Canada PE-8035: Inspection Report Number 073174.

BC Ministry of Environment and Climate Change Strategy (ENV). 2018e. Mt. Seymour Resorts Ltd. PE-27: Inspection Report Number 73187.

Bindoff, N.L., J. Willebrand, V. Artale, A, Cazenave, J. Gregory, S. Gulev, K. Hanawa, C. Le Quéré, S. Levitus, Y. Nojiri, C.K. Shum, L.D. Talley and A. Unnikrishnan, 2007: Observations: oceanic climate change and sea level. In: climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Bird Studies Canada. No date. IBA site summary: English Bay & Burrard Inlet Vancouver, British Columbia. Important Bird Areas Canada. http://www.ibacanada.ca/site.jsp?siteID=BC020&lang=EN (Accessed June 2018)

British Columbia Environmental Appeal Board. 2013. Decision Nos. 2010-EMA-005(c) and 2010-EMA-006(c).

British Columbia Marine Conservation Analysis (BCMCA) Project Team. 2011. Marine atlas of Pacific Canada: a product of the British Columbia Marine Conservation Analysis. Available from www.bcmca.ca (Accessed May 2018).

Burrard Inlet Environmental Action Program (BIEAP). 2002. Consolidated environmental management plan for Burrard Inlet (CEMP). Burrard Inlet Environmental Action Program. January 2002.

Burrard Inlet Environmental Action Program (BIEAP). 2011. Consolidated environmental management plan for Burrard Inlet: update (CEMP). Burrard Inlet Environmental Action Program. November 2011.

Butler, R.W., A. R. Couturier and E. Dickson. 2015. Status and distribution of marine birds and mammals in Burrard Inlet and Indian Arm, British Columbia. Pacific WildLife Foundation & Bird Studies Canada. Unpublished report. Port Moody, BC and Port Rowan, Ontario.

Canadian Council of Ministers of Environment (CCME). 2009. Canada-wide Strategy for the Management of Municipal Wastewater Effluent. https://www.ccme.ca/files/Resources/municipal_wastewater_efflent/cda_wide_strategy_mwwe_final_e.pdf (Accessed May 16, 2018)

Canexus Chemicals Ltd. (Canexus). 2006. Technology Conversion Project Overview: Presentation to the Burrard Environmental Review Committee.

Chemtrade Electrochem (Chemtrade). 2018. Follow-up Report: Permit #18, Report #DGIR 173757.

Chevron Canada Ltd. (Chevron). 2009. Hazardous Waste Regulation Section 4 operational plan (Burnaby Refinery).

Chisholm, B., Nelson, D. and H. Schwarcz. 1983. Marine and terrestrial protein in prehistoric diets on the British Columbia coast. Current Anthropology 24: 396-398.

City of Port Moody. 2011. What swims beneath: a fish survey of Port Moody Arm. March 2011.

City of Port Moody Environmental Protection Committee (EPC). 2018. Personal communications at committee meeting. 18 June.

Coastal and Ocean Resources, 2018. ShoreZone Habitat Mapping Summary Report for the Burrard Inlet survey area. Produced for the Tsleil-Waututh Nation, Vancouver, British Columbia, Canada, 43 p.

Cook, S. 2018. Using ShoreZone to model suitable forage fish spawning habitat. Model and report produced for WWF-Canada.

Deloitte. 2015. Port 2050 scenarios update final report. Port of Vancouver, 73 pp.

ENTECH Environmental Consultants Ltd. (ENTECH) . 2014. TreatMed Hazardous Waste Regulation Section 4-Operational Plan. Prepared for Treatmed BC Inc.

False Creek Watershed Society (FCWS). 2007. False Creek's watershed: then and now. http://www.falsecreekwatershed.org/uploads/2/0/5/0/20500086/falsecreek_swatershedfinal.pdf (Accessed May 2018).

Fisheries and Oceans Canada (DFO). 1995. Lost streams map poster.

Fisheries and Oceans Canada (DFO). 2001. A study of the Thermal Regime of Port Moody Arm, Burrard Inlet, BC. Fisheries and Oceans Canada (DFO). 2015. Rockfish Conservation Areas – Area 28. http://www.pac.dfo-mpo.gc.ca/fm-gp/maps-cartes/rca-acs/areas-secteurs/28-eng.html (Accessed May 2018)

Fisheries and Oceans Canada (DFO). 2017. Groundfish, Pacific Region 2017: Integrated fisheries management plan summary. http://www.pac.dfo-mpo.gc.ca/fm-gp/mplans/2017/ground-fond-sm-2017-eng.html (Accessed June 2018).

Golder Associates (Golder). 2007. Review of Canexus Plant Trends in Discharge Effluent Characteristics into Burrard Inlet. Prepared for Canexus Chemicals Ltd.

Golder Associates Ltd. (Golder). 2014. 2013 Annual report for 50 Pemberton Avenue Wastewater Treatment Plant and Waste Facility. Prepared for Vancouver Shipyards Co. Ltd.

Haggarty, D.R. 2001. An evaluation of fish habitat in Burrard Inlet, British Columbia. M.Sc. Thesis, University of Victoria.

Health Canada. 2012. Guidelines for Canadian recreational water quality, third edition. Water, Air and Climate Change Bureau, Healthy Environments and Consumer Safety Branch, Health Canada: Ottawa.

Heritage Vancouver. 2015. Terminal avenue industrial buildings: Vancouver's disappearing heritage district. http://heritagevancouver.org/top10-watch-list/2015/8-terminal-avenue-industrial-buildings/ Accessed October 2018.

Jamieson, G.S., and J. Lessard. 2000. Marine protected areas and fishery closures in British Columbia. Canadian Special Publication of Fisheries and Aquatic Science 131, 414 pp.

Johnson, Kym. 2017. Personal communication, November 27. BC Ministry of Forests, Lands and Natural Resources Operations & Rural Development.

Kerr Wood Leidal (KWL). 2006. Assessment of the Coal Area Wastewater System. Prepared for Neptune Bulk Terminals (Canada) Ltd.

Kerr Wood Leidal (KWL). 2012. UBC campus existing drainage overview. Unpublished spatial data.

Kerr Wood Leidal (KWL). 2017. Tsleil-Waututh Nation Burrard Inlet Action Plan. Prepared for Tsleil-Waututh Nation, 145 pp.

Keskinen, Kim, Vancouver Fraser Port Authority. 2018. Personal communication, May 31.

Keystone Environmental Ltd. (Keystone). 2014. Vancouver Shipyard Co. ltd. Waste Water Treatment Plant Operational Plan. Prepared for Vancouver Shipyard Co. Ltd., 10 pp.

Kinder Morgan. 2015. Jet fuel system. https://www.kindermorgan.com/pages/business/products_pipelines/jet_fuel.aspx (Accessed February 12, 2020)

Kinder Morgan- Canada (KM). 2018. Terminal Business in Canada. https://www.kindermorgan.com/business/canada/terminal_business.aspx (Accessed June 26, 2018)

Lantic Inc. 2018. History. http://www.lanticrogers.com/en/about-us/history/ (Accessed July 9, 2018)

Lesack, P. and S.J. Proctor. 2019, Vancouver's Old Streams, 1880-1920, https://doi.org/10.5683/SP2/UEJGTV, Scholars Portal Dataverse, V1. Vancouver Aquarium and University of British Columbia

Levings, C.D., Stein, J.E., Stehr, C.M. and S.C. Samis. 2004. Introduction to the PICES practical workshop: objectives, overview of the study area, and projects conducted by the participants. Marine Environmental Research 57: 3-18.

Lingl, Paul. City of Vancouver. Personal communication, March 2018.

MacDonald, J.S. and B.D. Chang. 1993. Seasonal use by fish of nearshore areas in an urbanized coastal inlet in southwestern British Columbia. Northwest Science 67: 63–77.

Mathews, J. S. 1955. Conversations with Khatsahlano 1932-1954. Vancouver City Hall: Vancouver.

Metro Vancouver. 2010. Integrated liquid waste and resource management: a liquid waste management plan for the Greater Vancouver Sewerage & Drainage District and member municipalities. Metro Vancouver, 38 pp.

Metro Vancouver. 2011. Metro Vancouver Regional Growth Strategy Projections: Population, Housing and Employment 2006 – 2041. Assumptions and Methods.

Metro Vancouver. 2017a. Biennial report: 2015-2016. Integrated liquid waste and resource management. Volume 1: Metro Vancouver report. Metro Vancouver, 92pp.

Metro Vancouver. 2017b. Liquid Waste - Total length of combined sewers remaining in the municipal systems. http://www.metrovancouver.org/dashboards/services/liquid-waste/Pages/Total-length-of-combined-sewers-remaining-in-the-municipal-systems.aspx (Accessed May 2018).

Metro Vancouver. 2017c. The 2016 Greater Vancouver Sewerage and Drainage District Environmental Management and Quality Control Annual Report

Metro Vancouver. 2018a. Lions Gate (West Vancouver). http://www.metrovancouver.org/services/liquid-waste/treatment/treatment-plants/lions-gate/Pages/default.aspx (Accessed April 16, 2018)

Metro Vancouver. 2018b. Why build a new wastewater plant? http://www.metrovancouver.org/services/liquid-waste/construction-maintenance/north-shore-wwtp/why-build/Pages/default.aspx (Accessed April 16, 2018)

Ministry of Environment. 1990. Ambient water quality objectives for Burrard Inlet, Coquitlam-Pitt River area: overview report. Province of British Columbia.

Ministry of Environment (ENV). 1992. Pacific Place remediation project: Parcels 1, 4, 5, 6 and remedial plan summary. Public communications booklet. BC Ministry of Environment, Lands & Parks, Soil Remediation Group.

Morin, J. 2015. Tsleil-Waututh Nation's history, culture and Aboriginal interests in eastern Burrard Inlet. Prepared for Gowling Lafleur Henderson LLP: Toronto.

Morin, J. 2018. Historical impacts to the marine resources of Burrard Inlet and TWN resource harvesting. Presentation to TWN cumulative effects meeting, 22 August.

Municipal Natural Assets Initiative (MNAI). 2018. MNAI communities. http://mnai.ca/pilot-communities/ (Accessed

June 2018).

Nijman, R.A. 1990. Ambient water quality objectives for Burrard inlet Coquitlam-Pitt River area: Overview report. B.C. Ministry of Environment, 29 pp.

Nijman, R. and L.G. Swain. 1990. Coquitlam-Pitt River area: Burrard Inlet water quality assessment and objectives: technical appendix. Ministry of Environment, Province of British Columbia.

Ocean Shipping Consultants. 2016. Container traffic forecast study: Port of Vancouver, 2016. Prepared for the Vancouver Fraser Port Authority, 226 pp.

Ocean Wise. 2018. Pollution Tracker. pollutiontracker.org (Accessed September 2018).

Opus DaytonKnight Consultants Ltd. (Opus). 2016. Memorandum: Dry Bulk Effluent Discharge. Prepared for BC Ministry of Environment.

Opus International Consultants (Canada) Ltd. (Opus). 2018. Landfill Groundwater Monitoring Program. Prepared for Chemtrade Electrochem Inc.

Personal Communication with Stephen Dankevy (Senior Contaminated Sites officer, Land Remediation Section) on July 4, 2018.

Revolution Environmental Solutions Acquisition GP Inc (Terrapure). 2009. Hazardous Waste Regulation Section 4 Operational Plan.

Schmidtko, S., Stramma, L. and M. Visbeck. 2017. Decline in global oceanic oxygen content during the past five decades. Nature 542: 335-339.

Stantec. 2009. Burrard Inlet shoreline change – baseline assessment final report. Prepared for the Burrard Inlet Environmental Action Program. December 2009.

Steer Environmental Associates. 2018. Ecological risk assessment: Maplewood mudflats. Report prepared for Tsleil-Waututh Nation, 251 pp.

Stockner, J. G. and D.D. Cliff. 1979. Phytoplankton ecology of Vancouver Harbour. Journal of the Fisheries Research Board of Canada 36: 1–10.

Teranis Consulting. 2017. Maplewood mudflats – sediment and wood waste characterization. Report prepared for Tsleil-Waututh Nation, 141 pp.

Terrapure Environmental North Vancouver Facility (Terrapure). 2018. Hazardous Waste Regulation: North Vancouver Facility 2017 Annual Report.

Thomson, R.E. 1981. Oceanography of the British Columbia coast. Ottawa: Department of Fisheries and Oceans.

Tourism Vancouver. 2018. Market research. https://www.tourismvancouver.com/about/research/ (Accessed May 2018)

Tsleil-Waututh Nation (TWN). 2015. Assessment of the Trans Mountain pipeline and tanker expansion proposal. Treaty, Lands and Resources Department, 90 pp.

U.S. Environmental Protection Agency (US EPA). 2009. The effect of climate change on water resources and programs. Distance Learning Module on Watershed Management. Watershed Academy Web, 14 pp.

Vancouver Coastal Health. 2018. Beach water quality reports. http://www.vch.ca/public-health/environmental-health-inspections/pools-beaches/beach-water-quality-reports (Accessed May 2018)

Vancouver Fraser Port Authority (VFPA). 2018. Port of Vancouver safe boating guide: Burrard Inlet. https://www.portvancouver.com/wp-content/uploads/2017/10/SafeBoatingGuide-BurrardInlet.pdf (Accessed June 2018).

Weismiller, R. 2018. City of Burnaby. Personal communications.

WorleyParsons Komex. 2006. Indian Arm sewage disposal review. Prepared for Vancouver Port Authority, 81 pp.