Tsleil-Waututh Nation Research Report

March 10, 2022

A review of Burrard Inlet water quality data to understand the impacts of contamination on Tsleil-Waututh Nation's safe harvesting practices

Treaty, Lands and Resources Department
Tsleil-Waututh Nation / səlilwətaɬ

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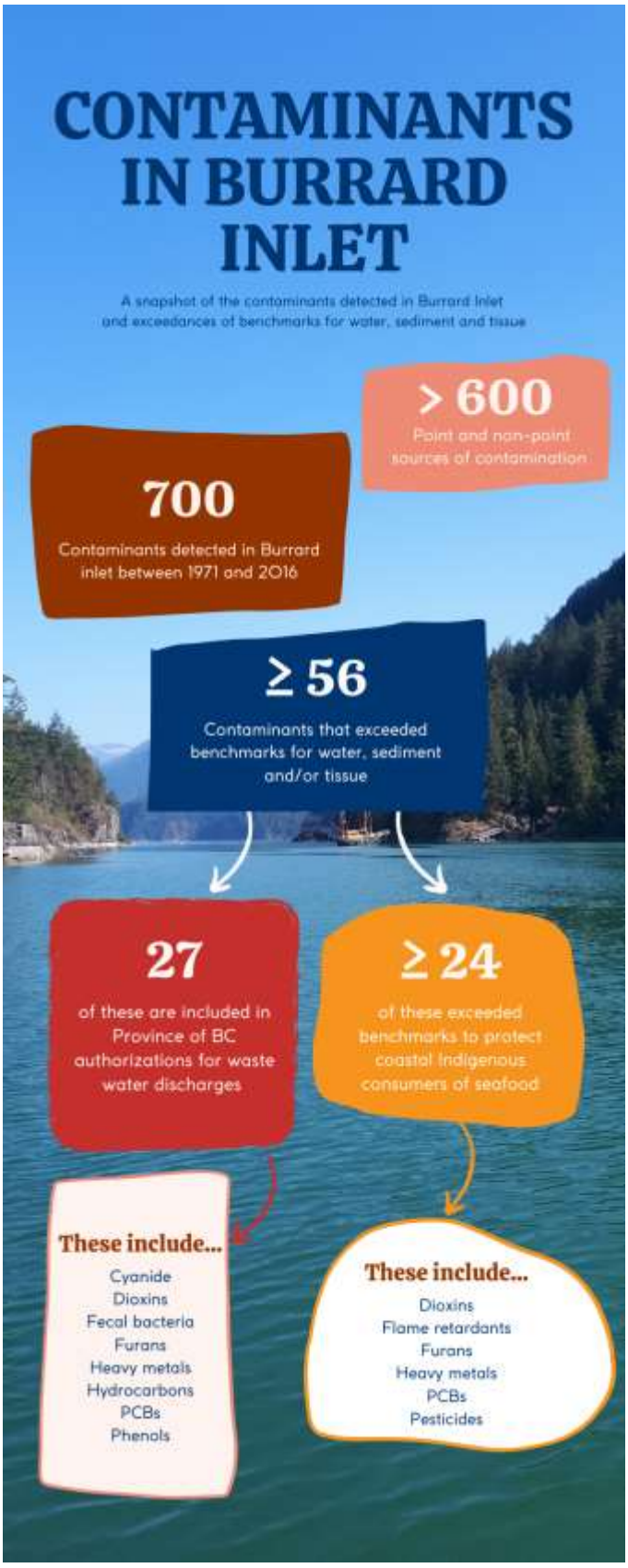
Abstract

Tsleil-Waututh Nation (TWN) has lived in their territory centred on Burrard Inlet since time immemorial, and maintains legal obligations to protect, defend and steward their territorial lands, waters, and resources. Since European contact, however, colonial development has severely degraded the territory, including contamination in Burrard Inlet that has led to long-term shellfish harvesting and swimming closures. This has diminished TWN's ability to practice important cultural activities that require healthy, clean waters, and has fundamental consequences on TWN people, community health, life ways, and ability to exercise constitutionally-protected rights. Recently, TWN and British Columbia's Ministry of Environment and Climate Change Strategy have collaborated to update Water Quality Objectives for Burrard Inlet, which are intended to promote the protection and stewardship of Water Values in the inlet. Among these Water Values is seafood consumption by humans. This work included an extensive review of available datasets on contaminants in Burrard Inlet, and establishment of contaminant thresholds protective of different rates of consumption of shellfish and finfish. Comparing the available datasets to these thresholds found 700 contaminants in Burrard Inlet, at least 56 of which exceeded benchmarks for marine water, sediment and/or tissue that are protective of defined Water Values. Of those, at least 24 exceeded benchmarks protective of human consumption of seafood at rates relevant to coastal Indigenous people. Of the contaminants that exceeded benchmarks, 27 are included within Province of BC authorizations for waste water discharges. The review also identified more than 600 known point sources and outfalls from non-point sources of contaminants, including stormwater outfalls, provincially authorized discharges, sewage discharges, leaching, leaks and spills, among others. This contamination has fundamental consequences on TWN people and their ability to exercise constitutionally-protected rights. Contamination in Burrard Inlet must be managed on a basin-wide scale and consider cumulative effects and the condition of the receiving waterbody in its entirety, rather than managing contamination on a source-by-source basis. Necessary changes to reduce contamination in Burrard Inlet include joint TWN-BC decision making and collaborative implementation of the Water Quality Objectives, establishment of the updated objectives as binding regulation, basin-scale cumulative effects management, and communication about the WQOs to decision makers across jurisdictions.



Introduction

Purpose of This Document

This summary report follows data review conducted as part of an innovative project that Tsleil-Waututh Nation (TWN) has undertaken in collaboration with the provincial Ministry of Environment and Climate Change Strategy (BC ENV) to update the provincial Water Quality Objectives (WQOs) for Burrard Inlet, outlining contaminants in Burrard Inlet that are of concern to human and aquatic ecosystem health, and some of their sources.

The objectives of this report are as follows:

- Describe the context, activities and results of TWN's project, undertaken in collaboration with BC ENV, to update the provincial WQOs for Burrard Inlet (referred to in this document as the "WQOs Project"; study area defined in Figure 1);
- Explain our compilation and analysis of an extensive dataset on contaminants in Burrard Inlet, which represents the first Inlet-wide compilation of these quantitative and spatial data;
- Outline our process to identify relevant thresholds, or "benchmarks", for contaminants that would be protective of consumption of shellfish and finfish by coastal Indigenous peoples;
- Provide a summary of the contaminants that our data analysis found to have exceeded these benchmarks in Burrard Inlet, and discuss the impacts of these exceedances; and
- Make recommendations for action to reduce these exceedances and improve water quality in Burrard Inlet.

Post-Contact Changes to Water Quality in Burrard Inlet

Tsleil-Waututh people harvested shellfish regularly and continuously from Burrard Inlet beaches for millennia prior to European contact (Morin 2015). A traditional Tsleil-Waututh saying is "When the tide was out, the table was set," indicating historical abundance, food availability and centrality of intertidal resources for their way of life. Marine fish, particularly salmon, herring, anchovy and eulachon were also fundamental to the pre-contact Tsleil-Waututh diet, culture and economy (Morin 2015). While fish and shellfish harvesting remain essential values to the Nation, contamination in Tsleil-Waututh territory has severely reduced safe harvesting opportunities. Tsleil-Waututh have always maintained legal obligations to protect, defend and steward their territorial lands, waters, and resources.

Ongoing and growing pressures of industrial and urban development around Burrard Inlet following European contact have significantly degraded the water quality and overall environmental health of the inlet and pose a continued threat to TWN rights.

Contamination in Burrard Inlet has been a serious issue for well over a century, as urban and industrial development in the area started in the mid to late 1800s, without Tsleil-Waututh Nation's input or consent. Early and ongoing approaches to this development illustrate attitudes toward the inlet and its aquatic life that are in direct opposition to Tsleil-Waututh stewardship responsibilities. For example, in the 1880s, a commercial herring fishery in the Inlet used dynamite-based fishing practices, extracted fish oil at a reduction plant in Coal Harbour and dumped the refuse into the Inlet. People at the time maintained that the dumping of refuse is what drove herring out of eastern Burrard Inlet by 1885 (Matthews 1932). In the late 1800s, settler representatives encouraged residents to use wharves to dump garbage into the inlet's waters, initially into intertidal areas and later into subtidal waters. When those approaches didn't solve the garbage disposal problem, a local industry proposed to build a barge to dump garbage in deeper water once per day (MacDonald 1977). Another example of contamination comes from a 1913 report by the BC Commissioner of Fisheries that described an oil refinery on the south shore of

the Inlet, just west of Port Moody, as allowing "to escape large quantities of oil and waste, which flow onto the water and float there as a slight but continuous foam… [for] a distance of a mile or a mile and a half." The same report further described that around the refinery "for three-quarters of a mile all life was killed off along the beach" (Thompson, 1913: 50).

These accounts demonstrate that early development was unregulated and had excessive impacts on water quality and aquatic life within Burrard Inlet. As a prime example, bivalve shellfish fisheries have been closed throughout Burrard Inlet since 1972 due to contamination (Jamieson and Lessard 2000). Some TWN community members had stopped eating shellfish before 1972, as people had become sick from eating shellfish long before the closure. Historical records indicate that shellfish beaches were destroyed by pollutants associated with an oil refinery as early as 1912 (Thompson 1913). In addition, "no swimming" advisories are regularly issued due to health risks (e.g., VCH 2020).
As stated in the updated WQOs policy document published by BC ENV and TWN, "TWN considers the level of contamination in Burrard Inlet to have long surpassed acceptable levels; the cumulative impacts of contamination from urban and industrial development on water quality have impacted TWN's Aboriginal rights and interests by reducing or eliminating opportunities to fish, harvest shellfish and practice culture" (ENV and TWN 2021: 2).

In addition to disrupting the socio-economic, cultural and physical well-being of TWN and other local Indigenous communities, contamination and other impacts on Burrard Inlet also affect the health of the broader region. Since the closure of the Burrard Inlet Environmental Action Program (BIEAP) in 2013, there has not been a coordinated, science-based approach to environmental stewardship in Burrard Inlet. Many water quality issues persist, while knowledge gaps remain and action to reduce contamination is slow and inadequate (ENV and TWN 2021).

Background on the Collaborative Water Quality Objectives Project

BC's *Environmental Management Act* provides the Minister authority to prepare and publish policies, strategies, objectives, guidelines and standards for the protection and management of the environment. Under this Act, the Province establishes WQOs for specific waterbodies to promote the protection and stewardship of water resources. According to the Province of BC (2021b), "WQOs provide approved policy direction to guide the balance between human use, values and healthy aquatic environments by guiding statutory decisions that may impact the quality of a specific waterbody". BC's *Environmental Management Act* mandates the province to establish WQOs for specific waterbodies to promote the protection and stewardship of water resources.

An early step in this process is defining relevant local Water Values to be protected in a specific water body; examples of these Water Values are swimming, shellfish harvesting, and the health of aquatic species. Potential contaminants that would affect those Water Values are then identified and quantified. Finally, WQOs are determined for those contaminants in water, sediment and animal tissues, based on threshold levels that would protect those Water Values. The WQO is set to protect the Water Value that is most sensitive to any particular contaminant. For example, if seafood harvesting is identified as a Water Value most sensitive to the concentrations of a particular metal in animal tissue, then the WQO for that metal in tissue is based on a level that represents low risk to seafood consumers.

WQOs formalize expectations with respect to water quality for a given waterbody and inform resource management decisions. Once approved, WQOs constitute formal BC ENV policy and must be considered in any decision affecting water quality made within ENV (ENV and TWN 2021). For example, WQOs provide guidance to set concentration or loading limits for provincially-authorized authorized wastewater discharges, and assess performance and effectiveness of water quality management activities. For best results, they need to be integrated with other management activities, including those of other jurisdictions, such as Integrated Stormwater Management Plans, land/water use planning and federal authorizations.

The original WQOs for Burrard Inlet (developed in 1990) were intended to be provisional at the time of writing and are out of date. BC ENV, Metro Vancouver and TWN had all identified a need to update the Burrard Inlet WQOs. It was identified that new WQOs were needed to ensure that: they are based on updated science and monitoring data; contaminants of emerging concern are considered as part of the overall health impacts on Burrard Inlet; and Indigenous knowledge and values are integrated into the analysis and development of contaminant management strategies and monitoring.

Improving the water quality in Burrard Inlet following the adoption of updated WQOs will help advance TWN's goal of being able to sustainably harvest healthy, wild marine resources, and to practice spiritual, cultural, ceremonial, and recreational activities in clean water free of risk from contamination and harmful pathogens (ENV and TWN 2021). TWN identified updating the Burrard Inlet WQOs as the highest priority in the Burrard Inlet Action Plan (TWN 2017). TWN has obtained resources to coordinate the process and is playing a leadership role in direct collaboration with BC ENV to update the WQOs for Burrard Inlet.

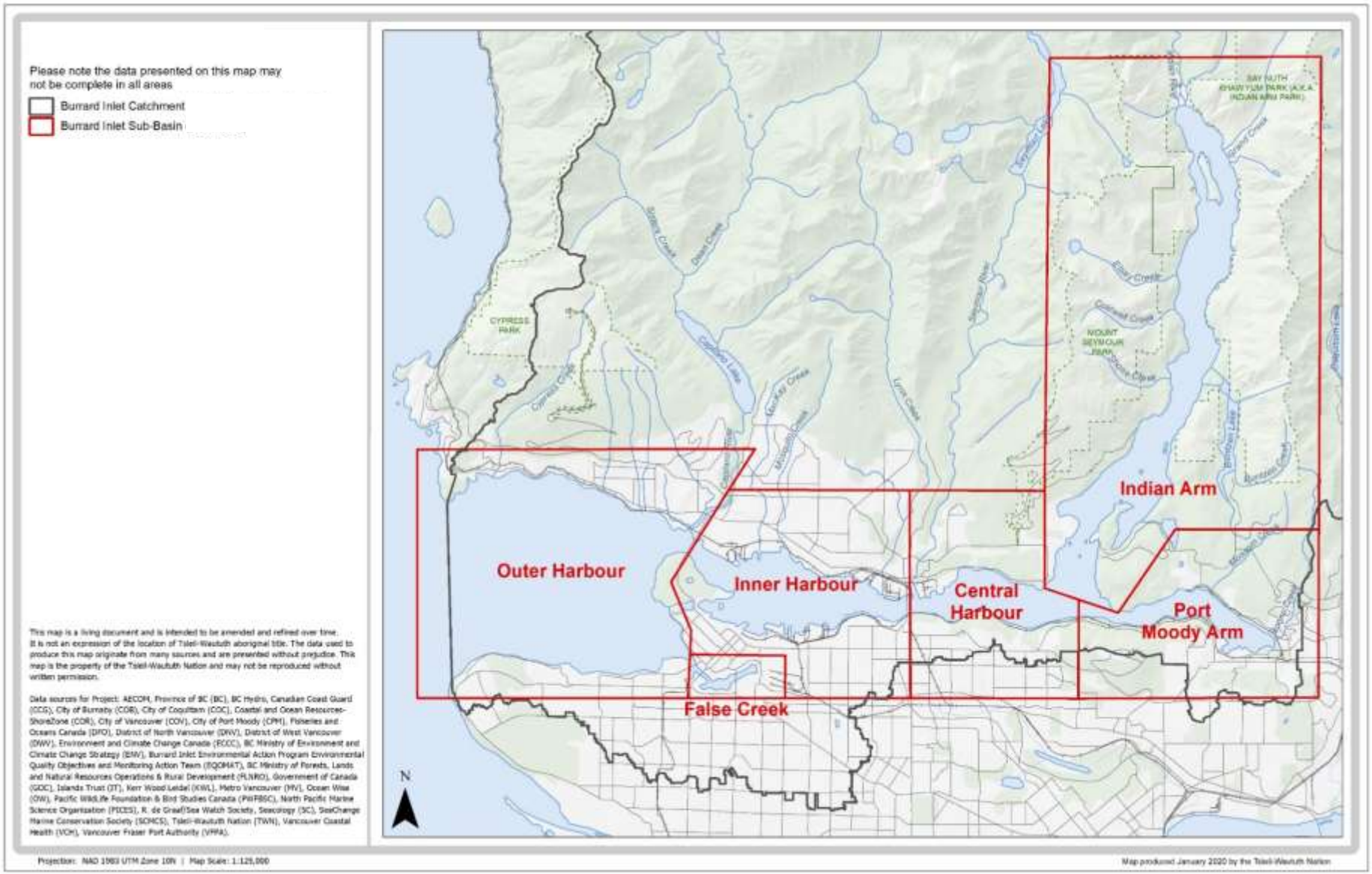


Figure 1. Burrard Inlet and sub-basins, as defined for the WQOs Project

Tsleil-Waututh Nation's Leadership Role in Collaboration with BC ENV

The WQOs Project is led by TWN and BC ENV and coordinated by a team comprised of representatives from both organizations. TWN has played a leading role in driving these policy changes, including initiating and coordinating the process, sourcing the majority of the funds required, establishing and convening multi-sector advisory and review bodies, engaging technical experts and contractors, and ensuring a holistic perspective is applied throughout the process. BC ENV has acted as co-convener for the project, provided important funding, gained support and technical guidance from senior BC ENV staff, supported the multi-sector advisory bodies, and ensured that the final WQOs are adopted as provincial policy.

The overall vision of the Burrard Inlet WQOs (as developed by the multi-sector Burrard Inlet Water Quality Roundtable, established and coordinated by TWN) 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* (Rao et al. 2019).

The following Water Values to be protected in Burrard Inlet were identified at the outset of the WQOs Project to guide the process (Rao et al. 2019):

- human consumption of shellfish;
- human consumption of finfish;
- aquatic life (including reproduction);
- wildlife (including reproduction);
- cultural practices and recreational uses; and
- institutional water uses.

TWN's Burrard Inlet Action Plan (TWN 2017) provided the basis for identifying the above Water Values for Burrard Inlet. Within the Action Plan, 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; and
- high levels of biodiversity and healthy populations of key species are viable and continue to persist in the long term.

Building a Common Understanding of Contamination in Burrard Inlet, in Consideration of Human Health

An essential aspect of updating WQOs is reviewing available reports and data to understand the current state of contamination in a given waterbody. This includes spatial information about activities and infrastructure that are relevant to water quality, as well as quantitative measurements of water quality parameters, including contaminants. To enable this review, TWN commissioned the largest scale compilation and review of water quality data for Burrard Inlet ever conducted, bringing together many existing datasets.

Because Burrard Inlet is central to TWN people, widely used by the public for recreation, transportation and fishing, and is integral to a major metropolitan area and Canada's largest port, it has been studied or monitored by First Nations, federal and provincial governments, municipalities, non-governmental organizations, academics and other researchers over many decades. Analyses of these disparate datasets

was challenging. Until recently, there has been limited collaboration or coordination between these different groups, and no shared understanding of current contamination levels in the Inlet. Different organizations have collected data for specific and varying purposes, and have used different formats, methods and laboratories. As a result, different datasets are generally not directly comparable for detailed analyses. In addition, some data are not publicly accessible; TWN has obtained some of those via data sharing agreements that include restrictions on further publicizing or sharing the data.

A key component of the WQOs Project has been an in-depth review of available data for contaminants in Burrard Inlet, and comparison of these data to benchmarks relevant to TWN. This has required the derivation of thresholds for low-risk consumption of seafood at rates relevant to Indigenous populations. Prior to the WQOs Project, there was limited understanding of the effects of a broader suite of contaminants (e.g., heavy metals, hydrocarbons, contaminants of emerging concern and others) in Burrard Inlet on the health of coastal Indigenous consumers. For example, common understanding of the effects of contamination in the Inlet on human health tends to focus on shellfish harvesting closures and swimming closures primarily or exclusively based on levels of microbial contamination. Previous benchmarks for levels of other contaminants (e.g., seafood export guidelines for contaminant concentrations in tissue) are not necessarily protective of coastal Indigenous populations who aspire to consume seafood at subsistence rates.

Methods for Establishing Water Quality Objectives for Burrard Inlet

The Collaborative Organizational Structure of the WQOs Project

To define contaminant-specific WQOs for Burrard Inlet, the WQOs Project hired specialized consultants to draft technical reports for each contaminant or contaminant class. Each report contains: background information about the contaminant and its effects on the identified Water Values; a description of the most relevant benchmarks for data assessment; an assessment of the most important available data on contaminant levels in Burrard Inlet; proposed WQOs for water, sediment and tissue (often the most conservative benchmark); and recommendations for monitoring and management to reduce contamination.

These reports are reviewed by the joint TWN-BC ENV Coordination Team, a multi-sector Technical Working Group, and a multi-sector Roundtable. Revisions are made to the reports as appropriate, based on comments submitted as part of the reviews.

TWN and BC ENV are collectively responsible for final approval of the reports, resulting in policy that is adopted by both TWN and BC ENV. Because of the wide range of contaminants present in Burrard Inlet, WQOs are being approved iteratively as technical reports are completed for each contaminant or contaminant class.

Water Quality Data Assessment

TWN and their contractors compiled more than 60 geospatial datasets relevant to water quality (Rao et al. 2019: Maps). These data appear in a series of maps[2] that have been published online as part of the WQOs Project (Rao et al. 2019: Maps), specifically the following:

[2] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-objectives/biwqo_0_intromaps_01apr2020.pdf

- Burrard Inlet catchment and tributary system,
- Sources of spatial data delineating the Burrard Inlet catchment and tributary system,
- Burrard Inlet and sub-basins,
- Point sources,
- Combined sewer overflow outfalls,
- Non-point sources of pollution,
- Water quality monitoring sites,
- Sensitive habitats,
- Coastal recreation sites,
- BC ENV authorizations,
- Licensed water withdrawals,
- Local government boundaries,
- Shoreline classification,
- Water tenures and leases,
- Species distribution,
- Recreational fishing,
- Dredge sites, and
- Marine industry and commercial transport.

Another essential aspect of the WQOs Project was assessing the best available quantitative data on contaminants in marine water, sediment and animal tissues in Burrard Inlet. Therefore, the WQOs Project included reviewing, assessing and collating as much data about contaminants in Burrard Inlet as was feasible, representing information from 1971 to 2016 (Appendix C). Many individual agencies have monitored different contaminants and other water quality parameters in Burrard Inlet for diverse purposes. These data collection programs have not been coordinated and their results had not been compiled at a basin-wide scale and made public before the WQOs Project. TWN and their contractors collected and compiled 11 major water quality datasets into a quantitative database (Appendix C). They also obtained and reviewed additional available data and datasets; however, these were of lower priority due to factors such as limited time frame or poorer data quality, and were not compiled due to resource limitations.

Together, these comprise the most comprehensive quantitative and geospatial databases to date for water quality in Burrard Inlet.

Contaminant data were screened against benchmarks, where available, that were protective of the Water Value(s) most sensitive to any particular contaminant. The most sensitive Water Values are generally aquatic life, or human consumption of finfish and shellfish. These various benchmarks were usually obtained from BC Water Quality Guidelines, Environmental Quality Guidelines from the Canadian Council for Ministers of the Environment, Health Canada guidelines and recent scientific papers. If Canadian benchmarks were unavailable, benchmarks from other jurisdictions were used. Efforts were made for consistency with the work of the Southern Resident Killer Whales Contaminants Technical Working Group convened by Environment and Climate Change Canada. In general, and with a few exceptions, water and sediment data were screened against benchmarks protective of aquatic life and tissue data were screened against benchmarks protective of coastal Indigenous populations' consumption of seafood.

Establishing Relevant Health Benchmarks

In Canada, there are no federal or provincial benchmarks for many contaminants in fish or shellfish tissue that are protective of coastal Indigenous consumers, i.e., relevant to subsistence-level seafood consumption rates. As a result, a risk-based approach was used as part of the Burrard Inlet WQOs Project to calculate human-health based screening values (SVs) for fish and shellfish tissue using Health Canada's toxicological reference values and risk assessment methodologies (Thompson and Stein 2021, using Health Canada 2010a,b,c, 2012, 2021; Richardson 1997, Richardson and Stantec 2013). In many cases these SVs are being adopted as WQOs.

A risk-based approach considers: the contaminant *receptors* (subsistence fisher, recreational fisher, the general BC population, pregnant woman, child and toddler); *exposure* to the contaminant (how much fish the receptors consume); and the contaminant *toxicity* (what is known about the contaminant and how it affects different receptors). Receptor characteristics were defined from Richardson and Stantec (2013), exposure was calculated through fish ingestion rates from Richardson (1997) and Health Canada (2010b), and toxicity was defined through toxicological reference values (TRVs) prescribed by Health Canada (2010a,b, 2021). SVs were calculated for contaminants by Thompson and Stein using TRVs, equations and oral slope factors from Health Canada (2010a, 2012, 2021). Tissue SVs were selected to capture a range of potential fishers, with the most sensitive receptor to carcinogenic contaminants being an adult from a subsistence fishing population, and the most sensitive receptor to non-carcinogenic contaminants being a toddler from a subsistence fishing population. Further details on the methodology and equations used are provided in Thompson and Stein (2021).

Tissue SVs are conservative threshold values against which contaminant concentrations in fish tissue can be compared and assessed for potential risks to human health (Thompson and Stein 2021). Fish and shellfish tissue in this context refer to country foods, that is, foods produced in an agricultural (not for commercial sale) backyard setting or harvested through hunting, gathering, or fishing activities (Health Canada 2010a). SVs provide general guidance to environmental managers and represent a suggested safe level of a contaminant in fish tissue based on a conservative estimate of a person's fish consumption per day. These calculated SVs were used as benchmarks for comparison during the analysis of available Burrard Inlet data on contaminants in animal tissue.

Contaminant Prioritization Based on Exceedances

When the measured concentration of a certain contaminant is higher than a benchmark, or threshold, identified to protect a Water Value, it is considered an exceedance. In general, benchmarks used in the WQOs Project for contaminants in marine water and sediment are protective of aquatic life – although not all are conservative enough to be protective of top predators such as killer whales, as many do not account for bioaccumulation and biomagnification. Most benchmarks used in the WQOs Project for contaminants in tissue are protective of human consumption of seafood at subsistence rates. Exceptions are that benchmarks for microbiological indicators in water are protective of human consumption of shellfish, and benchmarks for PBDEs in tissue are protective of aquatic life and human consumption of seafood. No direct relationship can be drawn between benchmarks to protect aquatic life and benchmarks to protect human consumption of seafood, as the methods for deriving each benchmark are not comparable.

For the purposes of prioritizing work on the contaminants of most concern to identified Water Values, TWN commissioned coarse analyses of available water quality data to identify the contaminants in Burrard Inlet that have exceeded available benchmarks.

Hundreds of contaminants and other water quality parameters from at least 22 classes (see Appendix A) have been identified as being of potential concern in Burrard Inlet, so a comprehensive review of all available data was not possible within the WQOs Project's budget and timeline. Therefore, contaminants and other water quality parameters were prioritized based on criteria such as data availability, concentrations in exceedance of existing benchmarks in recent years, and known issues of concern to Water Values. Through the WQOs Project, WQOs are being developed or updated for these priority contaminants and water quality parameters.

The priority contaminants reflect analyses completed as of October 2021 within the WQOs Project and do not represent a comprehensive review of all available information on contaminants in Burrard Inlet. The absence of a contaminant or other water quality parameter from these priority lists does not mean that it is irrelevant to Burrard Inlet, or that it is not of concern. There are limited to no data, and/or no reference benchmarks, for many contaminants; however, these are still of concern in Burrard Inlet. Examples include microplastics or most pharmaceuticals and personal care products (Braig et al. 2019a,b). It should also be noted that data are limited for some of these contaminants in certain media, for example for polycyclic aromatic hydrocarbons (PAHs) in tissue.

Results

Joint TWN-BC ENV Approval of Water Quality Objectives for Burrard Inlet

The updated WQOs policy document and associated technical reports, collaboratively produced and approved by TWN and BC ENV, are being published iteratively on the following dedicated BC ENV website: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-objectives/south-coast-region-water-quality-objectives/burrard-Inlet-water-quality-objectives

Contaminant Exceedances of Established Benchmarks

The extensive review of existing Burrard Inlet water quality data identified 700 contaminants detected in Burrard Inlet. These contaminants occur or occurred in water, sediment, and/or fish or shellfish tissue. At least 56 of these contaminants have exceeded benchmarks for marine water, sediment and/or tissue at any time in any of the datasets reviewed (Appendix A). This number is likely greater, because some exceedances are groups containing many individual contaminants. Of those 56, at least 24 were found to have exceeded benchmarks protective of human consumption of seafood at rates relevant to coastal Indigenous consumers. Again, some of these are groups of contaminants that may include multiple individual chemicals. The 24 contaminants exceeding these benchmarks are listed below, with additional details provided in Appendix A:

- Heavy metals[3]: arsenic, cadmium, lead, mercury, nickel, selenium, zinc
- Pesticides (current use): atrazine, permethrin
- Pesticides (legacy): aldrin, chlordane, diazinon, dieldrin, endosulfan, endrin, heptachlor, hexachlorobenzene, methoxychlor, Mirex, oxychlordane, DDE/DDE/DDT
- Polybrominated diphenyl ethers: BDE-47
- Non-dioxin-like polychlorinated biphenyls (PCBs)
- Dioxin-like PCBs, polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDDs, PCDFs)

[3] Natural sources may contribute to elevated levels of some metals, e.g. arsenic, selenium.

This summary of exceedances is limited to contaminants for which data were above detection limits, and for which benchmarks were available for at least one of marine water, sediment or tissue. It includes information reviewed as of October 2021; however, analyses are still underway, so the number of exceedances may increase. This is not an exhaustive list, because there are likely to be additional contaminants in the Inlet for which benchmarks are not available, and for which limited data have been collected. Details of the media and years in which exceedances were observed, and by which monitoring programs, are provided in Appendix D.

The water quality parameters included within Province of BC authorizations for waste water discharges are also identified in Appendix A (from Rao et al., 2019: Appendix F), and comprise more than 27 contaminants whose concentrations have exceeded relevant benchmarks for marine water, sediment or tissue in Burrard Inlet. Some of these exceedances are for contaminant classes, such as PCBs, that include many individual contaminants.

Those contaminants for which data were available, and which exceeded benchmarks most frequently and recently, were identified as priorities for the development of WQOs. Additional water quality parameters were prioritized because, even in an absence of systematic data collection or reliable benchmarks, they are known to be of concern in Burrard Inlet. Priority contaminants and other priority water quality parameters are flagged in Appendix A. Examples include microplastics, pharmaceuticals and personal care products, physical water quality parameters and contaminants of emerging concern.

The list of contaminants of concern in Burrard Inlet includes many that are synthetic and/or have only anthropogenic origins, including persistent organic pollutants that are known to bioaccumulate and biomagnify in the food web. Contaminants whose origins are only or primarily anthropogenic are also flagged in Appendix A. The list also includes some contaminants that are naturally elevated, or may be of both natural and anthropogenic origin (e.g. metals) but are elevated largely because of anthropogenic sources.

The Breadth of Contaminants in Burrard Inlet

The 700 individual contaminants identified in Burrard Inlet can be divided into 22 classes (Appendix A). The list provided in Appendix A is not comprehensive, as monitoring data are not available for many chemicals, and some contaminant classes are comprised of hundreds of individual contaminants, with varying pathways of toxic effects. Some are carcinogenic and/or bioaccumulative. Many (e.g., pharmaceuticals and personal care products, contaminants of emerging concern, microplastics) have been inadequately studied to understand their range of ecological and human health effects, particularly once they enter the marine environment. Some toxic chemicals and chemical derivatives are only beginning to become known (e.g., the tire-derived contaminant 6PPD-quinone), suggesting that others have yet to be identified.

Contamination Sources Throughout Burrard Inlet

The spatial and contextual analyses completed through the WQOs Project has demonstrated that a complex combination of sources have contributed contaminants into Burrard Inlet, including the following (from Rao et al. 2019):

- Several categories of provincially-authorized discharges (including the Lions Gate Wastewater Treatment Plant and many industrial discharges);

- Combined sewer overflows;
- Recreational boating activities;
- Marine transport;
- Stormwater and urban runoff;
- Sanitary sewer overflows;
- Wastewater lift station emergency overflows;
- Domestic outfalls
- Leaky septic systems;
- Wood waste
- Leaching from treated wood
- Potential contributions from land-based contaminated sites, of which there are up to 4234 within the Burrard Inlet drainage basin (Province of BC 2021a)[4];
- Resuspension from dredging and redistribution of legacy contaminants;
- Inputs from the Fraser River and the Strait of Georgia;
- Illegal dumping;
- Spills and leaks of oil, hydrocarbons and other substances;
- Improper disposal;
- The lasting effects of historical activities and legacy contaminants (e.g., pesticides, PCBs and other persistent organic pollutants).

These sources are listed by sub-basin and totalled in Table 1; detailed information on each source is provided in Rao et al. (2019), as well as Appendices F, G and H to that report. The locations of these sources are provided in the maps associated with that report. As shown in Table 1, the Inlet is, and has been, affected by more than 600 known contaminant sources, some of which (e.g., stormwater outfalls) are non-point sources, as well as many unmapped and uncounted sources (e.g., from recreational and liveaboard vessels, logging, and the continued use of creosote-treated wood), and daily commercial marine traffic that can include hundreds of vessel transits per day (MarineTraffic 2021).

Oil and other industry activities were established around Burrard Inlet in the early 1900s without authorization from TWN and without environmental regulation, leading to the destruction, by pollution, of shellfish beaches (Morin 2018). Some contaminant discharges in the Inlet currently authorized by the Province of BC have their origins in the 1950s (Rao et al. 2019), and many of these authorizations require limited to no monitoring of the receiving environment (i.e., the area in the Inlet into which the discharge enters). The water quality parameters integrated into the provincial authorizations for these discharges are identified in Appendix A (from Rao et al. 2019: Appendix F).

A non-exhaustive list of contaminants associated with various human activities is presented in Appendix B.

[4] The spatial data layer available from the Province of BC contains data on known and potentially contaminated properties that have been screened, investigated or cleaned up since the recording of site maintenance began (Province of BC 2021a). Further data and analysis are needed to obtain a more accurate number of contaminated sites in the Burrard Inlet drainage basin, and an understanding of their contaminant contributions to Burrard Inlet.

Table 1. Discharges and potential/risk of discharges into Burrard Inlet by sub-basin, as of 2017 for CSO outfalls and 2018 for others.

ENV = BC ENV authorized discharge. From Rao et al. (2019, and appendices). ENV authorizations are described in the *Environmental Management Act* (2003)[5]

Discharge type	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm	***Total active and historical***
ENV Effluent Permit	1 active	1 active[6]	6 active 3 cancelled	6 active	4 active 5 cancelled	4 active 1 cancelled	*31*
ENV Hazardous Waste Regulation	2 active		2 active	1 active 1 cancelled	3 active		*9*
ENV Municipal Wastewater Regulation		1 active	1 active		1 active		*3*
ENV Code of Practice Concrete and Concrete Products			3 active	2 active			*5*
ENV Organic Matter Recycling Regulation			1 active	1	1 active		*3*
ENV Petroleum Storage and Distribution	1 withdrawn 1 cancelled		2 active	2 active	2 active		*8*
Combined sewer overflow outfalls	4 active 3 historic	5 active 1 historic	11 active 6 historic	4 active 1 historic			*35*
Recreational boating activities	8 marinas, liveaboards, 1 yacht club, 1 small craft harbour, 2 public docks, 1 fuel dock	2 public docks, 3 yacht clubs, private docks	6 marinas, liveaboards 3 yacht clubs, 4 public docks, 2 fuel docks	1 public dock, private docks	2 marinas with liveaboards, 1 public dock, private docks	3 yacht club outstations, 1 marina, 1 public dock, 1 yacht club, 1 fuel dock, private docks	*> 44 + > 56,000 m² of dock space in Indian Arm alone + liveaboards*
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	*> 41 + vessels*[7]
Stormwater outfalls (approximate)	17	38	190	54	76	32 (southern areas)	*407*

[5] Under the BC *Environmental Management Act* (EMA), 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 still subject to EMA section 6(4), the requirement not to pollute. A 'registration' under a Regulation or Code of Practice sets out common or standard terms and conditions under which an industry, business, operation or activity may discharge waste.

[6] Operational Certificate for Lion's Gate Wastewater Treatment Plant

[7] For example, 171 vessels were in port at 09:40 on 27 October 2021, with 69 expected arrivals (MarineTraffic 2021).

Discharge type	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm	*Total active and historical*
Sewage		1 sanitary sewer overflow outfall	2 sanitary sewer overflow outfalls, 3 wastewater lift station emergency overflow outfalls	2 wastewater lift station emergency overflow outfalls		> 64 domestic outfalls	*> 72*
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	Creosote structures[8]	Former log storage	Active and former log storage	Former log storage, creosote structures, buried waste	
Historical activities	Sawmills, shingle mills, wood preserving, construction, steelmaking[9]				Timber processing, oil refining, steel manufacturing, lead bullets[10], spills	Abandoned logging equipment	
TOTAL (active and historical)	**50+**	**72+**	**253+**	**77+**	**95+**	**111+**	***658+***

[8] Also a former creosoting facility, currently classified under BC's Contaminated Sites Regulations

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

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

Discussion

Contamination in Burrard Inlet

This review demonstrated that contamination in Burrard Inlet is extensive, with 700 individual contaminants identified in the Inlet between 1971 and 2016. This contamination has been caused by innumerable complex sources, and severely impacts TWN's ability to harvest traditional foods, as at least 24 contaminants in animal tissue have exceeded benchmarks protective of human consumption of seafood at rates relevant to coastal Indigenous consumers (Appendix A). This impact to TWN harvesting opportunities has been continuous since at least 1972, when the ongoing closure of bivalve harvesting in Burrard Inlet was initially implemented due to contamination.

Our comprehensive data compilation suggests that systematic monitoring of Burrard Inlet by non-Indigenous jurisdictions was not conducted prior to the 1970s; however, impacts of post-industrial pollution on shellfish in Burrard Inlet, and therefore TWN's ability to harvest traditional foods, began decades prior.

As this is the most comprehensive review of contaminant data in Burrard Inlet ever completed, it is the strongest information available regarding total contamination in the inlet today. Significant additional work is required to further elucidate details of contamination throughout the Burrard Inlet ecosystem, and to implement a regulatory framework that effectively manages contamination in a way that preserves constitutionally-protected Aboriginal rights and Indigenous ways of life.

Importance of the WQOs Project's Holistic Approach

The WQOs Project represents a ground-breaking approach to water quality policy development. Under the leadership of TWN in collaboration with BC ENV, it has been the first initiative to accomplish the following important components of water quality management on a Burrard Inlet-wide scale:

- Convening representatives of First Nations and other levels of government (local, regional, provincial, federal), as well as other sectors that influence or have an interest in water quality;
- Convening major data holders;
- Compiling and analyzing water quality data (including water, sediment and tissue data);
- Comparing these data to benchmarks protective of collectively-identified Water Values that incorporate Indigenous values;
- Jointly approving thresholds (WQOs) protective of these Water Values;
- Assessing the implications of contaminant concentrations on human health, particularly consumption of seafood at rates relevant to coastal populations; and
- Mapping of point-sources of contaminants, outfalls from non-point sources of contaminants, water- and sewer-sheds, and other spatial information relevant to water quality.

Complexity of Accumulated Sources

Because of the multiplicity of active and historical sources of contaminants in the Inlet, exemplified by Table 1, it is extremely difficult to conclusively identify individual contaminant discharges that cause the exceedances preventing TWN from harvesting safe, healthy foods from the marine waters of their territory. Accordingly, this issue cannot be resolved by managing discharges and other activities in isolation from each other.

Many of the contaminants that exceeded benchmarks in the Inlet have been authorized by the Province of BC for discharge to Burrard Inlet, indicating that these provincially-authorized discharges have contributed to contamination in the Inlet and cumulative effects on TWN rights. Moreover, many identified contaminants are entirely anthropogenic and could only have entered the Inlet following urbanization and industrialization of the Burrard Inlet drainage basin, shoreline, and nearshore areas. While some metals naturally occur at background levels, anthropogenic sources of these metals are likely to have boosted their concentrations.

Cumulative Impacts of Contaminants in Burrard Inlet on TWN and Shellfish Harvesting

The effects of contamination associated with urban, industrial and port development have accumulated over many generations and have diminished the ability to harvest healthy foods from TWN's territorial waters for over a century (Thompson 1913). Problematically, this long-standing contamination may facilitate the approval of ongoing and increasing contaminant sources; after an ecosystem is degraded, that condition may be viewed as a new baseline that is acceptable to maintain or further degrade. From a development perspective, this can result in ever-easier justification of impacts to already degraded systems and can lead to a risk that specific ecosystems are sacrificed for economic development without adequate consideration of constitutionally-protected Aboriginal rights in Canada. TWN vehemently rejects the current state of contamination in Burrard Inlet as the *de facto* condition, however, and is actively working to restore the nation's rights and the health of their territorial waters. Importantly, the Canadian judicial system recently acknowledged that as more impacts accrue in a First Nation's territory, development becomes ever-harder to justify under Canadian law, as the Crown must still fulfill its constitutional obligations to uphold Indigenous ways of life (Yahey v British Columbia, 2021 BCSC 1287). This legal precedent corroborates TWN's perspective on cumulative effects. Therefore, in ecosystems where contamination already precludes Indigenous harvesting, any activities and authorizations must consider the impacts of historical and existing contamination and cumulative effects on the life ways of local Indigenous peoples.

Cumulative effects are not adequately addressed in municipal, provincial, federal or port authorizations processes. Each authorization is considered on its own without considering the condition of the receiving waterbody in its entirety, the ability for First Nations to practice constitutionally-protected rights, or the effects of other activities, whether authorized or unauthorized. Historically, many activities took place in Burrard Inlet without regulation and/or without monitoring requirements. Monitoring of point sources continues to be inadequate, and monitoring of non-point sources is practically non-existent. Water quality has not been systematically monitored in Burrard Inlet by the BC ENV since 2010 due to reduced funding and staff capacity. Because of the long history of contamination and the plethora of sources, monitoring, managing and reducing contamination must occur at a system-wide scale, and consider cumulative effects of contamination on the defined Water Values. The continued presence of contaminants, lack of data on multiple contaminants of concern, and failure of jurisdictions to analyze data on an Inlet-wide scale demonstrate that, to date, monitoring and management of contamination in Burrard Inlet has been inadequate in scope and scale.

One reason that no individual agency has accounted or managed for cumulative effects in the inlet, or the contributions of individual authorizations to cumulative effects, is because there has not been an Inlet-wide understanding or depiction of contamination sources prior to the WQOs Project. The WQOs Project represents the first basin-wide compilation of contamination sources and data for Burrard Inlet. Included in this compilation is ostensibly basic spatial information such as the locations of all discharges, including

stormwater outfalls, around the Inlet (Rao et al. 2019: Maps: maps 3, 3a and 4). The effort required by TWN and their contractors to create these maps, even using data provided by relevant jurisdictions, demonstrated that the information is not organized by these jurisdictions in a manner that would enable cumulative effects analyses.

To diligently manage the cumulative effects of contamination, a regulatory framework is required that implements enforceable management actions based on a systematic monitoring program throughout Burrard Inlet aimed at protecting Water Values. For example, if systematic monitoring determines that specific contaminants exceed thresholds for specific Water Values, stricter regulations must be implemented for those contaminants and their potential sources in the surrounding lands and waters. A major gap in the current system is regulation of contaminants in urban runoff, due to the complexity of this runoff and the magnitude of its impact.

Knowledge Gaps

The data assessment completed within the WQOs Project identified many knowledge gaps, which are outlined in detail in the technical reports prepared on each contaminant or contaminant class[11]. Knowledge gaps specific to the understanding of cumulative effects on water quality and its effects on TWN's consumption of seafood from Burrard Inlet are outlined below.

Calculation of safe harvest levels in consideration of multiple contaminants: Currently, microbial pollution is a priority contaminant considered for shellfish fishery openings and closures; however, the WQOs Project demonstrates that additional contaminants need to be considered by decision-makers to determine safe seafood harvest levels, beyond the limited suite of contaminants that is currently considered. Furthermore, there are limited data for contaminants in crustacean tissue, although recreational and commercial crab fisheries take place in several areas of Burrard Inlet. Health authorities and other decision-makers need to consider possible exposure to contaminants through these fisheries and educate harvesters accordingly.

Limited data: Data are limited for many contaminants, particularly the levels of contaminants of emerging concern in seafood tissue, meaning that information is lacking that would be required to calculate safe consumption limits for Tsleil-Waututh people. Also, most analyses of contaminants in tissue have been for English sole and blue mussels. Further research is needed to determine the extent of contamination in preferred food species, as well as in waters of particular importance for cultural practices.

Inadequate understanding and poor management of non-point sources of contamination: There are many non-point contaminant sources with consequent water quality impacts that have not been quantified and are not properly managed. Below are a few examples

- Contaminant loadings via stormwater/urban runoff are not well understood or addressed. It was only through TWN's efforts during the WQOs Project that an Inlet-scale map of watersheds, sewersheds and stormwater outfalls was created and made public (Rao et al. 2019: Maps).
- Contaminated sites in the Burrard Inlet drainage basin, as identified by the Province of BC (2021a), have not yet been analyzed in detail, and their contributions to contamination in Burrard Inlet, for

[11] Available on the Burrard Inlet Water Quality Objectives website: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-objectives/south-coast-region-water-quality-objectives/burrard-inlet-water-quality-objectives

example through atmospheric deposition, groundwater contamination or urban runoff, are not well understood.
- The full extent of docks, marinas and live-aboard vessels in the Inlet, as well as their associated water quality impacts (e.g., leaching and structural pollutants from pilings and other components, waste discharges, dumping, leaks, spills, deposition from air emissions, underwater noise) has not been mapped, quantified or properly managed.
- Comprehensive maps of the locations of historical logging operations are not available to enable an analysis of the extent of their water quality impacts, such as wood waste deposition and resulting changes to water and sediment chemistry.

Chemical mixtures: While the extent of contamination from individual chemicals is only beginning to become public, largely as a result of the WQOs Project, very little is known about the additive and synergistic effects of combinations of these chemicals in the marine environment.

A Bold Plan for Contaminant Reduction in Burrard Inlet

Proper water quality management requires institutional coordination between all levels of Canadian government, local First Nations, the Vancouver Fraser Port Authority, industries, and stakeholders. This must include the following overarching commitments:
- A concerted and coordinated approach to reducing the entry of contaminants into the Inlet with the intent of protecting Water Values, involving concrete, timely actions;
- Contaminant management in consideration of the entire Inlet and the drainage basin that feeds into it, rather than management of individual contaminant sources in isolation;
- Implementation of a permanent, well-coordinated and public-facing water quality monitoring program that considers a comprehensive suite of contaminants in Burrard Inlet and their consequent impacts to relevant Water Values; and
- Integration of the Burrard Inlet WQOs and concrete actions toward contaminant reduction as part of liquid waste management plans and other municipal, regional, provincial, and federal planning processes relevant to Burrard Inlet.

The following specific steps are feasible, incremental options for decision-makers to incorporate and adopt the Burrard Inlet WQOs and reduce contamination throughout the Inlet:

- **Joint decision-making and collaborative development of a plan to implement the WQOs to achieve contaminant reductions:** The co-development and co-approval of the updated Burrard Inlet WQOs sets the stage for collaborative implementation of these objectives by TWN and BC ENV incorporating elements such as, but not limited to, the following:
    - Establishment of a mechanism(s) for collaborative decision making by TWN and BC ENV, for example on authorizations for waste water discharges.
    - The transformation of WQOs from policy into a binding regulatory framework – in recognition of TWN teachings, or snəəwayəəɬ – aimed at contaminant reduction in Burrard Inlet so that they can be legally enforced and fully effective in protecting Water Values.
    - Establishment of mechanisms, via this binding regulatory framework, to apply the WQOs to existing processes, including municipal and port planning processes, liquid waste management plans, infrastructure related to stormwater and urban runoff, and referrals.

  - Legally binding reductions targets for current dischargers that align with the WQOs and their associated timelines.
  - Application of the WQOs within effluent and/or at the point of discharge, rather than outside an initial dilution zone.
  - Reopening authorizations, such as provincially authorized permits, to make them consistent with the WQOs, including requirements for influent, effluent and receiving environment monitoring, as well as contributions to an Inlet-wide environmental management structure.
  - Source control for both point- and non-point sources of pollution. The latter will require changes to the management of rainwater and urban runoff.
  - Application of contaminant-specific recommendations as recommended in the associated technical reports[12] (ENV and TWN 2021). Many of these recommendations have been compiled in Appendix E, which also incorporates input from a multi-sector Action Working Group convened by TWN in 2021.
- **Basin-wide cumulative effects management**:
  - Basing regulation, management, and land/water use decisions on an understanding of contaminants in the entire Burrard Inlet system, including activities in terrestrial and upstream areas of the contributing watersheds, and not simply considering individual discharges or project proposals.
  - Creation of a comprehensive water quality loading model that describes the contaminant loadings associated with all the different sources and estimates the reductions needed in these loadings to attain the WQOs.
  - Consideration of the cumulative effects of all contributors to water quality in Burrard Inlet, both current and historical, in any management decision.
  - Regular monitoring and adaptive management to attain the WQOs, ensure water quality improvements and reduce cumulative effects.
  - Application of the Burrard Inlet Action Plan in all decision-making pertaining to Burrard Inlet. This includes Goal A of the plan, which is to "improve water quality and reduce contamination". All projects and activities around the Inlet must contribute to achieving this goal.
- **Communication to decision makers across jurisdictions**:
  - Provision of the results of the WQOs Project to decision makers to inform policy recommendations, including the setting of safe consumption limits for food, social and ceremonial harvests.

Literature Cited

ATSDR (Agency for Toxic Substances and Disease Registry). (2021). Polycyclic aromatic hydrocarbons (PAHs). https://wwwn.cdc.gov/TSP/substances/ToxSubstance.aspx?toxid=25 (Accessed October 2021).

Braig, S., Delisle, K., and Noël, M. (2019a). Water Quality Assessment and Proposed Objectives for Burrard Inlet: Microplastics Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C.

Braig, S., Delisle, K. and M. Noël. (2019b). Water Quality Assessment and Proposed Objectives for Burrard Inlet: Pharmaceuticals & Personal Care Products Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C.

[12] https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-objectives/south-coast-region-water-quality-objectives/burrard-inlet-water-quality-objectives

Braig, S., Delisle, K, Noël, M., LeNoble, J., Thompson, H.C., and Rao A.S.. (2021). Water Quality Assessment and Proposed Objectives for Burrard Inlet: Polycyclic Aromatic Hydrocarbons (PAHs) Technical Report. Prepared for Tsleil-Waututh Nation and the Province of B.C.

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

ENV (BC Ministry of Environment). (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.

ENV (British Columbia Ministry of Environment and Climate Change Strategy) and TWN (Tsleil-Waututh Nation). (2021). Water Quality Objectives for Burrard Inlet. Water Quality Objective Series, WQO-02. Prov. B.C., Victoria B.C.

Health Canada. (2010a). Part II: Health Canada toxicological reference values (TRVs) and chemical-specific factors, Version 2.0. Federal Contaminated Site Risk Assessment in Canada, 69 pp.

Health Canada. (2010b). Federal contaminated site risk assessment in Canada. Supplemental guidance on human health risk assessment for country foods (HHRA $_{Foods}$). Contaminated Sites Division. Safe Environments Directorate. Ottawa, ON (CA): Health Canada. http://publications.gc.ca/collections/collection_2012/sc-hc/H128-1-11-641-eng.pdf (Accessed July 2020)

Health Canada. (2010c). Federal contaminated site risk assessment in Canada. Part V: Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals. Contaminated Sites Division. Safe Environments Directorate. Ottawa, ON (CA): Health Canada. http://publications.gc.ca/collections/collection_2011/sc-hc/H128-1-11-639-eng.pdf (Accessed July 2020)

Health Canada. (2012). Federal contaminated site risk assessment in Canada. Part I: Guidance on human health preliminary quantitative risk assessment (PQRA), Version 2.0. Ottawa, ON (CA): Health Canada. http://publications.gc.ca/collections/collection_2018/sc-hc/H128-1-11-632-eng.pdf (Accessed July 2020)

Health Canada. (2021). Federal contaminated site risk assessment in Canada. Health Canada toxicological reference values (TRVs) and chemical-specific factors, Version 3.0. Ottawa, ON: Health Canada.

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

MacDonald, N. (1977). The Canadian Pacific Railway and Vancouver's development to 1900. BC Studies 35: 3-35.

MarineTraffic. (2021). Vancouver (Port). https://www.marinetraffic.com/en/ais/details/ports/682/Canada_port:VANCOUVER (Accessed October 2021).

Matthews, J.S. (1932). Early Vancouver, Volume 2. Narrative of the Pioneers of Vancouver, BC, Collected During 1932. (2011 Edition) City of Vancouver Archives.

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.

Province of BC (British Columbia). 2021a. Data catalogue: Environmental remediation sites. https://catalogue.data.gov.bc.ca/dataset/environmental-remediation-sites (Accessed February 2022).

Province of BC (British Columbia). 2021b. Water quality objectives. https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-objectives (Accessed 27 January 2022).

Rao, A., Sanchez, M., Sutherland, D., and Lilley, P. (2019). Water Quality Assessment and Proposed Objectives for Burrard Inlet: Introduction. Prepared for Tsleil-Waututh Nation and the Province of B.C.

Richardson, G. M. (1997). Compendium of Canadian Human Exposure Factors for Risk Assessment. Ottawa: O'Connor Associates Environmental Inc.

Richardson, G.M and Stantec Consulting Ltd. (2013). 2013 Canadian Exposure Factors Handbook Life Expectancy, Body Dimensions, Inhalation, Time-Activity, and Soil Ingestion. University of Saskatchewan, Toxicology Centre: Saskatoon.

Stehr, C. and T. Horiguchi. 2001. Environmental Assessment of Vancouver Harbour: Data Report for the PICES Practical Workshop. PICES Scientific Report # 16.

Thompson, W. (1913). Report on the Clam-Beds of British Columbia. Reprinted without change of paging from the Report of the B.C. Commissioner of Fisheries, 1912.

Thompson, H.C. and Stein, D. (2021). Tissue Quality Objectives Recommendations for Burrard Inlet. Prepared for Tsleil-Waututh Nation and the Province of B.C.

TWN (Tsleil-Waututh Nation). (2017). Tsleil-Waututh Nation Burrard Inlet Action Plan. Prepared by Kerr Wood Leidal, 145 pp. Available online from https://twnsacredtrust.ca/burrard-inlet-action-plan

VCH (Vancouver Coastal Health). (2020). Beach water quality reports. http://www.vch.ca/public-health/environmental-health-inspections/pools-beaches/beach-water-quality-reports (Accessed 12 October 2021).

Yahey v British Columbia, 2021. The Supreme Court of British Columbia (BCSC) 1287.

Appendix A: Water Quality Parameters of Concern in Burrard Inlet

Table A1. Water quality parameters, prioritization, and known exceedances of reference benchmarks in Burrard Inlet

[1] Benchmarks for marine water and sediment are protective of aquatic life, except microbiological indicators which are protective of human consumption of shellfish. Not all of these benchmarks are protective of higher trophic levels, however. Benchmarks for tissue, where available, are protective of human consumption of seafood (tissue benchmarks for PBDEs are protective of aquatic life, which have a lower threshold; the exception is the benchmark for BDE-47, which is based on human consumption of seafood). See technical chapters for details. The absence of an exceedance for many parameters indicates a lack of data or lack of benchmark, rather than a non-exceedance.

Water Quality Parameter Class * = ***priority***	**Water Quality Parameter** * = ***priority***	**Media in which Parameter Exceeded Benchmark[1]**			**Only / Primarily Anthropogenic Origin?**	**Included in Provincial Authorizations for Wastewater Discharge?** *(Rao et al. 2019)*
		Marine Water	**Sediment**	**Tissue**		
Acoustic*	Underwater noise*				X	
Biotoxins and harmful algal blooms						
Chloride						X
Chlorine						X
Chlorophenols	Pentachlorophenol	X			X	
Contaminants of emerging concern*	Alkylphenol (e.g. nonylphenol and ethoxylates)*	X			X	
	Amines*					
	Bisphenol*				X	
	Flame retardants*				X	
	Organotins*				X	
	Perfluorinated compounds*				X	
	Phthalate esters*				X	
	Quinones (e.g. 6PPD)*				X	
Cyanide	Cyanide	X				X
Fluorine						X

Water Quality Parameter Class * = ***priority***	**Water Quality Parameter** * = ***priority***	**Media in which Parameter Exceeded Benchmark[1]**			**Only / Primarily Anthropogenic Origin?**	**Included in Provincial Authorizations for Wastewater Discharge?** *(Rao et al. 2019)*
		Marine Water	**Sediment**	**Tissue**		
Hydrocarbons*	Acenaphthene		X		X	X
Hydrocarbons*	Anthracene		X		X	X
	Benzo(a)pyrene	X	X		X	X
	Chrysene	X	X		X	X
	Fluoranthene		X		X	X
	Fluorene		X		X	X
	Naphthalene		X		X	X
	2-methylnaphthalene		X		X	X
	Oil and grease*	X			X	X
	Phenanthrene		X		X	X
	Pyrene		X		X	X
	Total polycyclic aromatic hydrocarbons (PAHs)* (> 100 compounds, with 17 identified as priority by CCME and US EPA; Braig et al. 2021, ATSDR 2021)					X
Heavy metals and metalloids*	Aluminum					X
	Antimony					X
	Arsenic*	X	X	X		X
	Barium					X
	Boron					X
	Cadmium*	X	X	X		X
	Chromium		X			X
	Cobalt					X

Water Quality Parameter Class * = ***priority***	**Water Quality Parameter** * = ***priority***	**Media in which Parameter Exceeded Benchmark[1]**			**Only / Primarily Anthropogenic Origin?**	**Included in Provincial Authorizations for Wastewater Discharge?** *(Rao et al. 2019)*
		Marine Water	**Sediment**	**Tissue**		
	Copper*	X	X			X
	Iron					X
	Lead*	X	X	X		X
	Manganese	X				X
	Mercury*	X	X	X		X
	Molybdenum					X
	Nickel*	X	X	X		X
	Selenium	X	X	X		X
	Silver	X	X			
	Thallium	X				
	Tin					X
	Vanadium	X				
	Zinc*	X	X	X		X
Microbiological Indicators*	E. Coli*	X				
	Enterococci*	X				
	Fecal coliform*	X				X
Microplastics*	Microplastics*				X	
Nutrients	Ammonia					X
	Phosphorus					X
Other organics	1,2 dichloroethane					X
	Benzene					X
	Calcium carbonate					X
	Ethyl benzene					X
	Ethylene glycol					X

Water Quality Parameter Class * = ***priority***	**Water Quality Parameter** * = ***priority***	**Media in which Parameter Exceeded Benchmark[1]**			**Only / Primarily Anthropogenic Origin?**	**Included in Provincial Authorizations for Wastewater Discharge?** *(Rao et al. 2019)*
		Marine Water	**Sediment**	**Tissue**		
	Methyl tert-butyl ether					X
	Organic halogens					X
	Toluene					X
Other organics	Total organic carbon					X
Pesticides: current use*	Atrazine		X	X	X	
	Permethrin			X	X	
	Lindane-HCH		X		X	
	Sodium chlorate					X
Pesticides: legacy*	Aldrin		X	X	X	
	Chlordane		X	X	X	
	DDT		X	see below	X	
	Diazinon		X	X	X	
	Dieldrin		X	X	X	
	Endosulfan			X	X	
	Endrin		X	X	X	
	Heptachlor		X	X	X	
	Hexachlorobenzene		X	X	X	
	Methoxychlor			X	X	
	Mirex			X	X	
	Oxychlordane			X	X	
	DDD, DDE and DDT			X	X	
Pharmaceuticals and personal care products*	Pharmaceuticals and personal care products*				X	
Phenols	Phenols	X				X

Water Quality Parameter Class * = ***priority***	**Water Quality Parameter** * = ***priority***	**Media in which Parameter Exceeded Benchmark[1]**			**Only / Primarily Anthropogenic Origin?**	**Included in Provincial Authorizations for Wastewater Discharge?** *(Rao et al. 2019)*
		Marine Water	**Sediment**	**Tissue**		
Physical*	Dissolved oxygen					X
	pH					X
	Salinity					
	Temperature					X
Physical*	Total suspended solids					X
	Turbidity					X
Polybrominated diphenyl ethers (PBDEs)* (209 possible congeners)	Total PBDEs		X		X	
	Tetra-BDE			X	X	
	BDE 47			X	X	
	Penta-BDE			X	X	
	Hexa-BDE			X	X	
Polychlorinated biphenyls (PCBs), dioxins and furans*	Total PCBs		X		X	X
	Total PCDDs and PCDFs		X		X	X
	Total non-dioxin-like PCBs			X	X	X
	Total dioxin-like PCBs, PCDDS, and PCDFs			X	X	X
Sulphides	Sulphides					X

Appendix B: Anthropogenic Sources of Contaminants

Table B1. Known anthropogenic sources of contaminants (not comprehensive). From Rao et al. (2019).

Source	Parameters
Agricultural chemicals including fertilizers	Zn, Hg, Cd, Cu, pesticides
Ammunition	Pb
Appliances	Zn, PBDEs
Atmospheric deposition (urban dust + foreign sources)	PBDEs, Cu
Batteries	Cd, Ni, Pb, Zn
Biocides (e.g. moss control products)	Zn, Cu, pesticides
Brakes	Zn, Cu
Catalysts and pigments	Ni
Cement and concrete	Zn
Chemtrade	Cu
Chlor-alkali production	Hg
Cigarettes	Cd
Coal burning	Hg, Ni
Coatings	Cd, Zn, Cu, Microplastics
Computer and electrical manufacturing	Ni, Pb, Zn, Hg, Cu
Crumb rubber	Microplastics, Pb
CSOs	Microbiological, PPCPs, PAHs, Ni, Pb, PBDEs, Zn, Hg, As
Dental amalgams	Hg
Disposal of Hg-containing materials	Hg
Domestic and wild animals	Microbiological
Drywall	Hg
Dyes, paints	Pb, Hg
Firefighting	Zn
Flooding (hydro)	Hg
Food processing facilities	Microbiological
Petroleum combustion	PAHs, Ni
Galvanized surfaces	Zn
Historical discharges	Ni, Pb, As
Indian Arm campfires	Cd
Iron processing	Ni
Manufacturing	Ni, Pb, Hg, As
Marinas, recreational boating	Microbiological, PPCPs, PAHs
Marine anodes	Zn
Metal smelting, plating, finishing, alloys and other metal work	Cd, Ni, Pb, Hg, Cu, As
Metallurgical gold	Hg
Motor oils, fuels and lubricants	Cd, PAHs, Zn, Cu
Oil tankers	PAHs
Old Premier St landfill	Pb, Zn
Old recycled plastics	PBDEs
Older contaminated soils	Pb
Pacific Coast Terminals	Zn
Paving	Ni
Petroleum refineries/facilities	Pb, PAHs, Zn, Cu
Pigments	Cd
Pipelines	PAHs
Pipes	Ni, Pb, Zn, Cu

Power generation	Zn, Hg
Preserved wood	PAHs, Zn, As
Road building	Cu
Road markings	Microplastics
Roofs, gutters, downspouts, siding	Ni, Zn
Rubber curing agents	Cd
Sanitary discharges and sewage disposal systems from cabins, resorts and summer camps	Microbiological
Sawmills	Zn
Scientific supplies	Hg
Shoreline waste/pollution	Microplastics
SSOs	Microbiological, Ni, PBDEs, PPCPs, microplastics, PAHs, Cd, Zn, Hg
Stabilizers	Cd
Stormwater	Cd, Ni, microbiological, PPCPs, PAHs, Pb, PBDEs, Zn, Hg, Cu, As
Tar-sealed parking lots	PAHs
Telephone/trolley wires	Cd
Terrapure	Cu
Textiles and textile manufacturing	Microplastics, Cu
Timber product processing	Ni
Tobacco products	Ni
Transport mishandling	Microplastics, PAHs
Vancouver Wharves (bulk ore handling)	Ni, Pb, Zn, Cu
Vehicle radiators	Cd
Vehicle tires	Microplastics, Zn, Cu
Waste incineration	Cd, Ni, Hg
Wastewater treatment plant (and Nutrifor sewage sludge)	Cd, Ni, microbiological, microplastics, PPCPs, PAHs, PBDEs, Zn, Hg

Appendix C: Water Quality Datasets

Table C1. Major Water Quality Datasets Compiled and Analyzed by Tsleil-Waututh Nation and their Contractors for the Burrard Inlet WQOs Project

Data Owner	Dataset	Date Range
Environment and Climate Change Canada	Benthic Contaminants Study, Goyette and Boyd	1985, 1986, 1987
	Disposal at Sea	2009, 2012-2017
	Polycyclic aromatic hydrocarbon study	1991
	Canadian Shellfish Sanitation Program	1990- 1992, 1997, 2006-2017
BC Ministry of Environment and Climate Change Strategy	Water Quality Objectives Attainment Monitoring – Environmental Monitoring System and Historical Data	1971-1980, 1982, 1985-1994, 2000, 2002, 2003, 2009, 2020
Metro Vancouver	Burrard Inlet Ambient Monitoring Program	2007-2016
	Recreational Monitoring Program	1993-2016
Burrard Inlet Environmental Action Program	Environmental Quality Objectives and Monitoring Action Team program	1995
North Pacific Marine Science Organization (PICES)	Sediment sampling (Stehr et al. 2001)	1999
Ocean Wise Conservation Association	Pollution Tracker Program	2015, 2016, 2018, 2019

Appendix D: Contaminant Exceedances by Medium, Year and Dataset

Details regarding recorded exceedances of benchmarks for contaminants in marine water, sediment and tissue in Burrard Inlet are provided in tables D1, D2 and D3 below. The tables summarize the medium (marine water, sediment or tissue) of the exceedances, the years in which they occurred and the datasets in which they were recorded. The date range when each monitoring program was operational is provided in Appendix C.

Table D1. Summary of recorded exceedances in Burrard Inlet marine water

	Datasets and years in which exceedances were recorded in Burrard Inlet marine water			
	ENV Attainment	**ECCC Shellfish Sanitation**	**Metro Vancouver Ambient**	**Metro Vancouver Recreational**
Benzo(a)pyrene	2001			
Chrysene	2001			
Arsenic	1975, 1989, 1991, 1993, 2002, 2009		2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016	
Cadmium	1973, 1974, 1975, 1976, 1977, 1982, 1989, 1990, 1991, 1993, 1994, 2002, 2009, 2017		2007, 2008	
Copper	1972, 1973, 1974, 1975, 1976, 1977, 1978, 1982, 1989, 1990, 1991, 1992, 1993, 1994, 2001, 2002, 2009		2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016	
Cyanide	1988, 1989, 1990, 1991, 1993			
E. Coli			2013, 2014, 2015, 2016	2013, 2014, 2015, 2016
Enterococci	2002, 2003, 2009		2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016	

	Datasets and years in which exceedances were recorded in Burrard Inlet marine water			
	ENV Attainment	**ECCC Shellfish Sanitation**	**Metro Vancouver Ambient**	**Metro Vancouver Recreational**
Fecal Coliform	1973, 1974, 1975, 1976, 1977, 1978, 2002, 2003, 2009	1990, 1991, 1992, 1997, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014	1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012	2013, 2014, 2015, 2016
Lead	1972, 1973, 1974, 1975, 1976, 1977, 1978, 1982, 1989, 1990, 1991, 1992, 1993, 1994		2014, 2015	
Manganese	2002			
Mercury	1973, 1975, 1976, 1977, 1989, 1990, 1991		2012	
Nickel	1972, 1973, 1974, 1975, 1976, 1977, 1978, 1982, 1989, 1990, 1991, 1992, 1993, 1994, 2002, 2009		2007	
Nonylphenol and ethoxylates			2008	
Oil and grease	1973, 1978, 1979, 1980		2007	
Pentachlorophenol	1993		2014, 2015	
Phenols	1988, 1989, 1990, 1991, 1992, 1993, 1994,		2007, 2009, 2010, 2012, 2013, 2016	
Selenium	2009		2008, 2009, 2015	
Silver	2000, 2001			
Thallium			2008	
Vanadium	2000, 2001			

	Datasets and years in which exceedances were recorded in Burrard Inlet marine water			
	ENV Attainment	**ECCC Shellfish Sanitation**	**Metro Vancouver Ambient**	**Metro Vancouver Recreational**
Zinc	1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1989, 1990, 1991, 1992, 1993, 1994, 2000, 2001, 2002, 2009		2007, 2012	

Table D2. Summary of recorded exceedances in Burrard Inlet sediment

	Datasets and years in which exceedances were recorded in Burrard Inlet sediment						
	ECCC Benthic	**ECCC PAH and Dioxin/Furan Study**	**ECCC Disposal at Sea**	**ENV Attainment**	**Metro Vancouver Ambient**	**Pollution Tracker**	**PICES**
Acenaphthene		1991	2009, 2013, 2014, 2015, 2016	1994, 2000, 2002	2008, 2011, 2013, 2015	2015, 2016, 2018	
Anthracene		1991	2009, 2013, 2014, 2015, 2016	1994, 2000, 2002	2008, 2011, 2013, 2015	2015, 2016	
Benzo(a)pyrene		1991	2009, 2013, 2014, 2015, 2016, 2017		2008, 2011, 2013, 2015	2015, 2016	
All benzofluroanthenes			2016				
Chrysene		1991	2009, 2013, 2014, 2015, 2016, 2017	1994, 2000, 2002		2015, 2016	
Fluoranthene		1991	2009, 2013, 2014, 2015, 2016, 2017	1994, 2000, 2002	2008, 2011, 2013, 2015	2015, 2016	
Fluorene		1991	2009, 2013, 2014, 2015, 2016	1994, 2000, 2002		2015, 2016	
Naphthalene		1991	2009, 2013, 2014, 2015, 2016, 2017	1994, 2000, 2002	2008, 2011, 2013, 2015	2015, 2016	
2-methylnaphthalene			2009, 2013, 2014, 2015, 2016		2008, 2011, 2013, 2015	2015, 2016, 2018	
Phenanthrene		1991	2009, 2013, 2014, 2015, 2016, 2017	1994, 2000, 2002	2008, 2011, 2013, 2015	2015, 2016, 2019	1999

Pyrene		1991	2009, 2013, 2014, 2015, 2016, 2017	1994, 2000, 2002	2008, 2011, 2013, 2015	2015, 2016	
Aldrin						2015, 2018	
Arsenic	1985		2009, 2013, 2015, 2016	2002	2008, 2011, 2013, 2015	2015, 2016, 2018	
Atrazine						2015, 2018	
Bisphenol A						2015	
Cadmium	1985, 1986, 1987		2009, 2012, 2013, 2014, 2016, 2017	1988, 1989, 1990, 1991, 1992, 1993, 1994, 2000, 2002	2011, 2013, 2015	2015, 2018, 2019	1999
Chlordane					2011	2015, 2016	
Chromium	1985, 1986, 1987		2009, 2013, 2014, 2015, 2016, 2017	1988, 1989, 1991, 1992, 1993, 2000	2008, 2014, 2015	2015, 2018	1999
Copper	1985, 1986, 1987		2009, 2012, 2013, 2014, 2016, 2017	1988, 1989, 1990, 1991, 1992, 1993, 1994, 2000, 2002	2008, 2011, 2013, 2015	2015, 2016, 2018, 2019	1999
DDD					2008		
DDT					2008, 2013		
Diazinon						2015, 2018	
Dieldrin						2015, 2018	1999
Endrin					2008, 2013	2015, 2018	
HBCD						2015, 2016	
Heptachlor						2015, 2018	
Hexachlorobenzene						2015, 2018	
Lead	1985, 1986, 1987		2009, 2012, 2013, 2015, 2016	1988, 1989, 1990, 1991, 1992, 1993, 1994, 2000, 2001, 2002	2008, 2011, 2013, 2015	2015, 2016, 2018	1999

Lindane-HCH					2011	2015, 2016, 2018	1999
Mercury	1985, 1987		2009, 2012, 2013, 2014, 2016, 2017	1990, 1991, 1992, 1993, 2000, 2002	2008, 2011, 2013, 2015	2015, 2016, 2018	
Nickel	1985, 1986, 1987		2009, 2012, 2013, 2016, 2017	1988, 1989, 1990, 1991, 1992, 1993, 1994, 2000, 2002	2008, 2011, 2013, 2015	2015, 2016, 2018	1999
Selenium			2013		2013, 2015		
Silver			2016	2000, 2002			
Total PBDEs					2008, 2011, 2013, 2015	2015, 2016	
Total PCBs			2013, 2016	1991, 1992, 1993, 1994, 2002, 2020	2008, 2011, 2013, 2015		1999
Total PCDFs and PCDDs				2020	2008, 2011, 2013, 2015	2015, 2018	
Zinc	1985, 1986, 1987		2009, 2012, 2013, 2014, 2015, 2016, 2017	1988, 1989, 1990, 1991, 1992, 1993, 1994, 2000, 2002	2008, 2011, 2013, 2015	2015, 2016, 2018	1999

Table D3. Summary of recorded exceedances in Burrard Inlet tissue (English sole and Blue mussel)

	Datasets and years in which exceedances were recorded in Burrard Inlet tissue				
	English Sole Fish Tissue				**Blue Mussel Tissue**
	ECCC Benthic	**ENV Attainment**	**Metro Vancouver Ambient**	**PICES**	**Pollution Tracker**
Aldrin					2015, 2018
Arsenic	1985, 1986	2002, 2003	2007, 2012		2015, 2016, 2018, 2019
Atrazine					2015, 2018

	Datasets and years in which exceedances were recorded in Burrard Inlet tissue				
	English Sole Fish Tissue				**Blue Mussel Tissue**
	ECCC Benthic	**ENV Attainment**	**Metro Vancouver Ambient**	**PICES**	**Pollution Tracker**
Benzo(a)pyrene				1999	
Bisphenol A					2015
Cadmium	1985, 1986		2007, 2012	1999	
Chlordane				1999	2015, 2016
Copper	1985, 1986				
DDD+DDT+DDE			2007, 2012	1999	2015, 2016
Diazinon					2015, 2018
Dieldrin				1999	2015, 2018
Endosulfan					2015, 2018
Endrin					2015, 2018
HBCD					2015, 2018
Heptachlor					2015, 2018
Hexachlorobenzene				1999	2015, 2018
Lead	1985, 1986		2007, 2012	1999	2015, 2016, 2018, 2019
Mercury	1985, 1986	1991	2007, 2012		2016
Methoxychlor					2015, 2018
Mirex				1999	2015, 2018
Oxychlordane					2015, 2018
Permethrin					2015, 2018
PFOA					2015, 2018
PFOS					2015, 2018
Selenium			2007, 2012		2016
Total PCBs		1991, 1992, 1994	2007, 2012		2015, 2016, 2018
Total PCDFs, PCDDs, and dioxin-like PCBs			2007, 2012		2015, 2016, 2018

	Datasets and years in which exceedances were recorded in Burrard Inlet tissue				
	English Sole Fish Tissue				**Blue Mussel Tissue**
	ECCC Benthic	**ENV Attainment**	**Metro Vancouver Ambient**	**PICES**	**Pollution Tracker**
Tetra BDE			2007, 2012		
Penta BDE			2007, 2012		
Hexa BDE			2007		
Zinc	1985, 1986		2007, 2012	1999	2015, 2016, 2018

Appendix E: Implementation Action Plan

The management actions listed in the table below, to improve water quality in Burrard Inlet, have been drawn from the contaminant technical reports prepared as part of the WQOs Project. This action plan is still a work in progress.

Table D1. Summary of management recommendations from draft and completed WQO technical reports, Burrard Inlet Action Plan and Burrard Inlet Water Quality Roundtable suggestions

Category	Action	Target Entity	Target Date
Directed research and monitoring	Capture the water quality during the "first flush" after a dry period from the storm water system to the streams and Inlet		
	Review monitoring, reporting, and oversight of authorized industrial discharges	BC ENV	
	Use of improved monitoring techniques for stormwater - such as composite sampling and flow-weighted sampling		
	Targeted monitoring to identify where pollution loads are greatest and then working upstream to identify potential sources. Characterize pollutant loadings from stormwater and other non-point sources of pollution to Burrard Inlet.		
	Investigate the sources of microbiological water quality issue in Eagle Creek (West Vancouver) and the Indian River (north end of Indian Arm)		
	Increase oversight and monitoring of unreported oil and fuel spills in Burrard Inlet. Currently, Transport Canada, under the Canadian Shipping Act requires the reporting of any accidental discharge of deleterious substances.	Transport Canada	
	Work collaboratively to develop marine sediment quality guidelines protective of higher trophic level species, such as killer whales. Measures are required to further document and understand the impacts of PBDEs on marine mammals.	BC ENV ECCC	
	Monitor and research the environmental effects of alternative flame retardant chemicals in the marine environment in order to develop appropriate and timely guidelines for the use of these chemicals, and prior to their application in consumer products.		
	Continue bacterial source tracking investigations for key areas of Burrard Inlet		
	Look into other (more innovative?) water sampling methods than just grab sampling. Composite sampling of entire runoff events or passive sampling for long-term ambient monitoring.		
	Increased and standardized compliance monitoring for authorized discharges	BC ENV	
	Expand water quality and flow monitoring for rivers, creeks, and stormwater outfalls entering Burrard Inlet		
	Update the existing point source discharge inventory for Burrard Inlet to include new outfalls and point sources of pollution every five years		

Category	Action	Target Entity	Target Date
	Conduct a review of information in the provincial Contaminated Sites Registry and federal Contaminated Sites Inventory on contaminated sites in close proximity to Burrard Inlet		
	Update inventory and review status of on-site sewage disposal systems in Indian Arm in coordination with Vancouver Coastal Health	Vancouver Coastal Health, Metro Vancouver, Belcarra	
Economic incentives and disincentives	Develop an industry-specific eco-certification program to encourage adoption of best management practices for reducing non-point source pollution		
	Set up challenge/friendly competition		
	Create a cost for plastic polluters and make plastic products more valuable to encourage reuse, repair and recycling		
	Encourage the use of electric-powered vehicles (private and commercial)	Transport Canada	
Education	Produce collective infographic to show pollution sources, sinks and effects on our values to be shared widely	Public and decision-makers	
	Public education, awareness and regulation towards the following: · Use of reduced zinc or zinc-free roofing materials; · Use of moss control and anti-fouling products that do not contain zinc; · Use of non-metal fencing and building materials; · Vehicle maintenance to prevent drips and leaks of motor oil; and · Proper disposal and recycling of marine anodes	Public	
	Develop a targeted, region-wide social marketing campaign focused on pollution prevention from households and specific industries		
	Improve education, awareness, and regulation to ensure proper disposal of batteries and other metal-containing materials including vehicle wash water, wastes and coatings	Public	
	Create specific education and awareness campaigns to target individual sources of microbiological pollution (e.g., pet waste).	Public	
	Create public awareness and education on ways to reduce microplastic pollution from washing textiles in residential laundry machines.	Public	
	Increase awareness campaigns and engage more stakeholders in reducing plastic use.	Public	
	Increase organized beach clean-ups		
	Education regarding the environmental hazards of pharmaceuticals.	Public health and health care practitioners	
	Increased awareness and adherence to Vancouver city bylaw that currently bans the disposal of medications in the garbage, and existing drug return initiatives, e.g. the	Public	

Category	Action	Target Entity	Target Date
	B.C. Medication Return Program which allows the public to return any unused or expired medications to participating pharmacies free of charge		
	Outreach and education to businesses through programs such as Salmon Safe		
	Social media campaign and educational website for stormwater pollution that is tied to salmon and whales - connect to storm drain marking programs		
	Engage with individuals, communities, industry and governments to reduce release of plastics, microplastics, tire particles, and other structural pollutants into the Inlet		
Implementation of existing legislation and regulations	Implement ISMPs	BC ENV Metro Vancouver Local governments	
	Opportunities through existing legislation/regulations, e.g. Water Sustainability Act, Codes of Practice, Municipal by-laws		
	Implement Vancouver city bylaw that currently bans the disposal of medications in the garbage	City of Vancouver	
	Ensure that BC ENV permit holders and other Port of Vancouver tenants are preventing the discharge of lead into waterways	BC ENV	
Legislation or regulation	Senior-level regulation of urban stormwater discharges	BC ENV	
	Work with Transport Canada to designate and keep Burrard Inlet as a no-sewage-discharge zone for boats	Transport Canada	
	Improve tire manufacture to address issues with 6PPD	Tire manufacturers association?	
	Limit oil tanker traffic		
	Phase out copper brake pads	Transport Canada?	
	Advocate for municipal, regional, or provincial development standards that protect watershed health and the health of receiving environments such as Burrard Inlet	Municipal governments Metro Vancouver BC ENV	
	Reduce large vessel wakes to reduce the effects of sediment re-suspension	Port Transport Canada	
	Divert PBDE-containing products (produced prior to bans) from the waste stream to appropriate hazardous waste disposal sites.		
	Call for emergency review of 6PPD under CEPA (without leading to it just being replaced by another toxin)	ECCC contaminants group	
	Advocate for a regional requirement that new authorized industrial discharges consider projects in the context of cumulative effects to Burrard Inlet from all forms of development		

Category	Action	Target Entity	Target Date
	Advocate for municipal, regional, or provincial development standards that protect watershed health and the health of receiving environments such as Burrard Inlet.		
	Reduce the use of recycled tires for rubber crumb in artificial turf, tracks and playground surfaces around the Lower Mainland, and determine other environmentally friendly options to recycle tires.	Local governments, school boards	
	Limit or ban the use of microbeads and single-use plastics in consumer products	ECCC? Health Canada?	
	Limit or ban the use of triclocarban and other potentially harmful PPCPs in consumer products	ECCC? Health Canada?	
	Strengthen pre-treatment requirements for hospital waste discharge	Health Canada?	
	Limit or ban the use of creosote pilings	Port, DFO	
	Reduce the use of nickel-containing metal coatings, galvanized metals, pipes, fittings, roofing, paving or other materials that come into contact with domestic wastewater or rainwater.		
	Ban lead ammunition in all forms of hunting, as has been done in Sweden and Denmark (Ocean Wise 2019);	BC *Wildlife Act*	
	Ban lead fishing tackle, as has been done in Denmark and the United Kingdom (Ocean Wise 2019);	BC *Wildlife Act*	
	Implement mandatory inclusion of PBDE sampling under the Minimum Analytical Requirements during ocean disposal assessments (CEPA).	*CEPA*	
	Establish regulations specifying that biosolids may not be used in surface applications and may only be buried by a certain depth of clean soil or fill to mitigate the impacts of sedimentation on downstream receiving watercourses.		
	Require, for example through inclusion in ISMPs, for regular cleanout of catch basins and testing of the material for leachability (e.g., Greenland 1999);		
	Require non-biocide alternatives to copper-based anti-fouling paints	Transport Canada?	
	ENV Permit refresh to reduce authorized contaminant discharges and require monitoring	BC ENV	
	Advocate for adoption of provincial or federal laws and approaches to identify, reduce use of, or phase out and properly dispose of toxic materials, particularly those that persist or bioaccumulate in the marine environment		
Remediation	Monitoring designed to inform problem solving actions (such as the remediation of cross-connections as per project completed re. TWN on-reserve creeks)		
	Continue to improve spill prevention and response planning and execution for oil, fuel, and other types of spills in Burrard Inlet		
	Remediation of historically contaminated areas and hotspots to ensure that lead and other heavy metals cannot become suspended or made bioavailable.		
Source control	Reduce the frequency, duration, and magnitude of CSOs and SSOs (such as attenuation tanks, inflow & infiltration		

Category	Action	Target Entity	Target Date
	reduction measures, and other sanitary volume reduction measures)		
	Prioritize the implementation of source controls to reduce the volume of stormwater being discharged into Burrard Inlet		
	Undertake measures to reduce the entry of microplastics into Burrard Inlet		
	Build on source control work that was being done by BIEAP partners related to specific industries and sources prior to 2013, e.g. proposal to do a regional eco-certification of businesses. Potential linkage with Salmon Safe certification program.		
	Prevent discharges from the Lynn Drive siphon		
	Prevent tire particles from entering the Inlet		
Technology and practice	Implement green infrastructure measures, plant-based bioretention and other upland improvements to reduce entry of contaminants into marine waters via stormwater. For example, require stormwater mitigations as part of new projects, and regular cleanout of catch basins and testing of the material for leachability, for example through inclusion in ISMPs.		
	Assess pump-out facilities and other discharge alternatives for recreational vessels in Burrard Inlet		
	Clean paved surfaces with vacuum assisted dry sweepers to remove debris that can sorb zinc in runoff and prevent this debris from entering the stormwater system;		
	Develop a water quality model and decision-support tool for Burrard Inlet for one or more pollutants of concern based on limiting pollutant loads to levels that allow achievement of WQOs		
	Year-round disinfection of effluent at the current and future Lions Gate WWTP	BC ENV Metro Vancouver	
	Accelerate the rate of connection by individual landowners to new separated sewers through incentives and other measures		
	Separate the combined sewers that connect to the Heather Street, Balaclava, Brockton Point, and Clark Drive CSOs		
	Invest in improved and new waste management infrastructure to deal with plastic wastes		
	Replace, coat or paint galvanized surfaces and explore roof treatments to keep zinc out of runoff		
	Place water intakes in locations that would avoid fouling to avoid the use of zinc and copper anodes		
	Revisit recommendations from 2019 Burrard Inlet Science Symposium: stormwater edition		
	Compile action plan, with progress against the plan continually monitored		