INVESTIGATING LOCAL PREPAREDNESS FOR MANAGING ENDOCRINE DISRUPTORS

by

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Abstract

Innovations in the biochemical industry have outpaced regulatory risk management controls, exposing human and environmental populations to the risks and uncertainties posed by endocrine disruptors (ED). ED exposure originates from everyday products such as pharmaceuticals and personal care products designed for attending to medical conditions and aesthetic qualities of life; however, exposure can bind, block, or mimic hormone receptors threatening irregular cognitive development and reproductive growth. Globally, governments are revising policies and negotiating alternative risk management approaches to reduce adverse impacts of environmental exposure. In light of growing international regulatory interests and the Government of Canada's intention to update the Chemicals Management Plan, future regulations governing EDs are expected, and local governments will be required to respond. A major source of ED contamination is municipal sewage and wastewater systems as EDs are discharged from a range of sources: industrial discharge, agricultural run-off, disposal of pharmaceuticals, and domestic sewage. Local governments are positioned at the intersection of these uses and are responsible for wastewater management. Source control policy and end-of-pipe wastewater treatment are common management strategies implemented by local governments to manage contaminants; however, knowledge gaps and uncertainties posed by EDs and available wastewater treatment plant technologies present additional challenges. This research is designed to understand local government perceptions on future challenges, preferred management strategies, and required resources to manage EDs.

This work was completed through a case study using a Canadian local government as the case. Initial desktop research of chemicals management in Canada established Canada's regulatory context and distinguished the jurisdictional responsibilities of local, Provincial, and Federal

Governments. The case study was described through document analysis of local government management plans and policies to understand the governance structure and existing management strategies. Empirical material was collected through semi-structured interviews with local government staff and decision-makers knowledgeable and involved in the community's source control program and wastewater treatment processes. The aim of this work is to build an understanding of the preparedness of local Canadian governments by investigating the local response to future regulation, identify expected challenges and outline the resources to help local governments meet future demands.

Lay Summary

Chemicals management in Canada demands that local governments are prepared to respond to national-level policy changes. Central to managing exposure to EDs are influences on public behaviour, industry practices, and sewage management. Local governments at this interface provide direct influence on public regulation, consumer behaviour, and environmental discharge. This research focuses on local governments' preparedness to address ED contaminants through wastewater management strategies and seeks to understand local responses to future regulation, identify expected challenges and outline the resources to help local governments meet future demands. The results of this study highlight that local governments are in favour of regulating EDs; however, management is perceived as challenging due to existing knowledge gaps and uncertainties coupled with perceived limited jurisdictional authority, political support and financial resources. This case study research offers lessons to Canadian local governments about the need to pursue policy action and to make decisions in light of uncertainty.

Preface

This master's thesis is the original and unpublished work of Brianne Della Savia. This research received ethical approval from the University of British Columbia's Behavioural Research Ethics Board (BREB) in January 2020 (Ethics ID: H12-03317-A011). The approved project was designed, carried out, and analysed with the guidance and continuous feedback from my supervisor, Dr. Gunilla Öberg, committee member Dr. Nadja Kunz and graduate student peers from RES 502 - *Master's Interdisciplinary Case Analysis and Research Design* taught by Dr. Stephanie Chang. The protocol for the semi-structured interviews was designed based on teachings from CONS 528 – *Social Science Research Methods and Design* taught by Shannon Hagerman and feedback from Dr. Gunilla Öberg.

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List of Abbreviations

Abbreviation	Definition
BC	British Columbia
BPA	Bisphenol A
BREB	Behavioural Research Ethics Board
CBOD	Carbonaceous biochemical oxygen demand
CEPA, 1999	Canadian Environmental Protection Act, 1999
CCME	Canadian Council of Ministers of the Environment
CMP	Chemicals Management Plan
CPP	Cities for Climate Protection (Campaign by ICLEI)
DSL	Domestic Substance List
ECCC	Environment and Climate Change Canada
ED	Endocrine Disruptor
HBCD	Hexabromocyclododecane
HC	Health Canada
ICLEI	International Council for Local Environmental Initiatives
OECD	Organisation for Economic Co-operation and Development
SCESD	Standing Committee on Environment and Sustainable Development
SWOT	Strengths Weaknesses Opportunities and Threats
TSL	Toxic Substance List: Schedule 1
PAH	polycyclic aromatic hydrocarbons
PBDE	polybrominated diphenyl ethers
PCB	polychlorinated biphenyls
PFAS	per- and polyfluoroalkyl substances

Abbreviation	Definition
PFAS	per- and polyfluoroalkyl substances
PFOA	Perfluorooctanoic acid
PPCP	Pharmaceuticals and Personal Care Products
TIE	Toxicity Identification Evaluation
TSS	Total suspended solids
U.S.	United States of America
US EPA	United States Environmental Protection Agency
VEL	Virtual Elimination List
WWTP	Wastewater Treatment Plant

Glossary

Term	Definition
Contaminant loading	*"Contaminant Loading"* refers to the concentration of a pollutant is a defined volume of water.
End-of-pipe treatment	*"End-of-Pipe treatment"* refers to WWTP solutions and technologies prior to discharging effluent to the environment
Hazardous Waste	According to Provincial Governments in Canada waste(s) may be defined as *"hazardous"* for many different reasons such as, *"a) They are corrosive, ignitable, infectious, reactive and toxic (the "acute" hazard characteristics);* *b) They have the potential to harm human health or the environment in a subtle manner over long periods of time (the "chronic" hazards) and/or* *c) They may range from paints, oils and solvents to acids, heavy metal-containing sludges and pesticides"* Provincial Governments have specific criteria qualifying *"hazardous waste"* outlined in their Environmental Management Act or Hazardous Waste Regulations.
Liquid Waste	*"Liquid Waste"* refers to the liquid disposed to the sewers (the underground pipes transporting the sewage from the source to the WWTP), typically by households, businesses and/or storm drains. Other common terms used interchangeably include 'wastewater', 'liquid waste', 'sewage', 'influent' and 'effluent'.
Senior Government	*"Senior Government"* refers to Provincial and Federal Governments.

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I offer sincere thanks to all students, faculty, staff, and researchers who are members of the EGESTA Lab and the Institute for Resources, Environment and Sustainability (IRES, UBC). Each of you have supported my graduate school journey by motivating curiosity and inspiring me to 'think big', through critique and supportive feedback throughout courses and final rounds of thesis edits, celebrating big and small wins, and most importantly friendship. I am grateful to have shared this experience and I hope to keep in touch.

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Chapter 1: Introduction

1.1 Endocrine Disruptors

This research focuses on a class of contaminants that pose challenges for regulators in Canada and around the world: Endocrine Disruptors (EDs). Endocrine Disruptors are a class of chemicals that have the potential to interfere with regular hormonal function and cause irregularity in physical, neurological, and/or reproductive development (Burkhardt-Holm, 2010; Wilkinson et al., 2016). Rachel Carson's book, *Silent Spring*, drew attention of the public to the human and environmental impacts of pesticides in the 1960s (Carson, 1962). This was later followed by Theo Colborn's work in the 1990s who drew connections between irregular reproductive health and exposure to certain chemicals (Colborn et al., 1997; Krimsky, 2002). This work attracted the attention of scientists and health experts who recognized the significance of her work and helped to further research and raise awareness of the possibility that chemicals could interact with the hormonal system. Scientific and human health researchers gained interest, and EDs revealed a new dimension of chemical risk that led governments, researchers, industry producers, and concerned public to engage in debates about how these substances ought to be regulated. To this day, EDs pose a challenge to scientists, regulators, and stakeholders for the complexity and uncertainty around their evaluation. As the emerging science investigating ED interactions with human and environmental systems develops, persistent knowledge gaps and a lack of consensus among stakeholders continue to stagnate regulatory action.

For this research, it is important to distinguish EDs from other types of chemicals in order to understand why some argue that regulatory innovation and reform are needed to manage this class of contaminants. Understanding the risks and uncertainties helps to explain the rationale for

unresolved research questions, disagreements, and inaction among stakeholders and regulatory authorities.

1.1.1 Understanding Endocrine Disruptors

Over the last few decades, an increasing number of scientists are arguing that EDs ought to be managed as a new class of contaminants (Dietrich et al., 2013; Lofstedt, 2011; Munthe et al., 2017; Solecki et al., 2017). This is to a large extent because of the difficulties involved in establishing a 'threshold' dose, e.g., an exposure level that can be considered safe. First, the sensitivity of the hormonal system is different at different developmental stages and there is increasing evidence that extremely low doses may be harmful at specific stages in the embryonic development, while the same dose can have no impact at other stages of development. Second, there is commonly a lag between exposure and effect, for example the adverse effect caused by exposure during the early stages of conception may not be seen until puberty. Finally, there are indications that the dose-response curve can be non-monotonic, meaning that a higher dose does not necessarily lead to a larger effect. (Burkhardt-Holm, 2010; Kabir et al., 2015; Wilkinson et al., 2016). Taken together, the argument is that, because of the factors mentioned above, present day approach to assessing the potential harm posed by chemicals is not suitable for EDs. Even though carcinogens share some of these characteristics, the argument is that the challenge for regulators is different as compared to other substances, due to the complexity of the hormonal system and the complexities involved in assessing adverse effects.

Advanced product development and innovation across the chemical industry have created an extensive, and growing list of compounds and substances that show ED properties (Burkhardt-Holm, 2010; Kabir et al., 2015; Wilkinson et al., 2016). Central exposure routes are via

consumer products such as pharmaceuticals, personal care products, material coatings, and food packaging. These products are designed for attending to medical conditions and improving the comfort, convivence, and aesthetic qualities of life, however, not all chemicals were created equal. It is argued that EDs differ from most other classes of contaminants in the mechanism by which they act in the human or animal body. Scientific evidence suggests specific vulnerabilities resulting from the interruption of regular hormonal signals and development cycles. EDs can bind to, block, or mimic hormone receptors potentially leading to irregular cognitive and neurological activity, physical development, reproductive growth and some EDs are thought to be linked to certain cancers. Many EDs are also persistent and bioaccumulative leading to long-term risks to ecological systems.

1.1.2 Sources and Routes of Exposure

EDs are not identified by a specific usage or chemical structure, hence, human exposure can originate from a range of products. For example, exposures can originate from agricultural pesticides, material coatings, plasticizers, flame retardants, active pharmaceuticals, and personal care products (PPCP). See Table 1 for a list of chemical substances with ED effects used in common everyday items (Kabir et al., 2015). Humans and the environment may be exposed to EDs through various exposure routes including breathing air particles containing evaporated, adsorbed or particulate substances, absorption through skin contact, or consuming food and/or water that has been either directly contaminated or whereby contamination is transferred through food and drink packaging (Burkhardt-Holm, 2010; Kabir et al., 2015; Wilkinson et al., 2016). One of the major routes that local governments are responsible for is via sewage and wastewater, which is the focus of the present thesis. EDs can enter into wastewater through various pathways

depending on their source including direct discharge into natural water bodies or land applications; indirect discharge by agricultural and urban runoffs that contain pesticides, fertilizers, or industrial solvents; and sewage and wastewater treatment effluents that contain compounds that persist through wastewater treatment, metabolite compounds that persist in urine and feces, or by-products that develop in result of the treatment processes (Burkhardt-Holm, 2010; Daughton, 2003; Petrie, 2015; Petrović et al., 2003; Wilkinson et al., 2016). As it is a prominent source, the management of wastewater offers an opportunity to reduce EDs.

Table 1 Common Endocrine Disruptors and Chemicals Shown to Have Endocrine Activity Adapted from Kabir et al. (2015)

Common Endocrine Disruptors	Uses
Lead, phthalates, cadmium	Paint for Children's products
BPA, phthalates, phenol	Food packaging and materials
Brominated flame retardants, PCBs	Electronics and building materials
Phthalates	Personal care products and medical tubing
Triclosan	Antibacterial
Perfluoro chemicals	Waterproof and flame retardant material and clothing
Parabens, phthalates, glycol ethers	Cosmetics, personal care products, cleaners
Nonylphenol	Surfactants and detergents
Ethinyl estradiol	Contraceptive

1.1.3 Risks and Uncertainties

Naturally, the body depends on the secretion of hormones to trigger development and send signals from the brain to the body's organs, however, when hormone receptors are blocked or activated by synthetic substances that interact with hormone receptors, the body's natural response and timelines are interrupted. For some hormones, less than 5% of receptors need to be

occupied to trigger an active response (Burkhardt-Holm, 2010). By binding, blocking, or mimicking the body's hormonal receptors, emerging science claims EDs can cause unintentional and irreversible changes to the body's development cycles resulting in incomplete or miscalculated development.

Literature on EDs claims health risks posed by ED exposure are complicated depending on the timing, duration, concentration, and conditions of exposure. Sensitivity to hormonal intervention is heightened during certain windows of exposure including fetal development, early childhood, puberty, and pregnancy (Burkhardt-Holm, 2010; Rahman et al., 2009; Wilkinson et al., 2016). Evidence suggests ED interference with the hormonal system can result in delayed effects, latency periods, and intergenerational complications that can take months to years to realize. Exposure can also result in distinct and individual health outcomes depending on the concentration and potency of the substance(s), and environmental stressors (Burkhardt-Holm, 2010; Wilkinson et al., 2016). For example, Craig and Ziv-Gal (2018) claim that during fetal development exposure to breast milk containing EDs can result in permanent reproductive dysfunctions in the offspring or irregular cognitive development realized during childhood.

An increasing number of studies suggests that EDs pose wide-spread health risks to people and the receiving environments as continued exposure to these synthetic chemicals is virtually unavoidable due to society's dependence on them (Petrie et al., 2015; Wilkinson et al., 2016). The dependency on chemicals in consumer goods and the rate of disposal and discharge into water, air, and soil has led to virtually every human and natural environment being continuously exposed to trace-level doses of EDs. ED literature claims multiple or continued exposures can result in synergistic or additive effects that cause toxicity levels to multiply and accelerate natural responses (Bolong et al., 2009; Burkhardt-Holm, 2010; Fowler et al., 2012; Wilkinson et

al., 2016). The composition of certain parent compounds can also transform through treatment or natural processes to breakdown into by-products and metabolites that can change the substance's bioavailability and toxicity to be weaker or greater than the parent compound (Boxall et al., 2004; Fowler et al., 2012; Rahman et al., 2009). The irregularity and compounding factors complicate the dose-response relationship suggesting that exposure thresholds and linear models may be ineffective for predicting risks, which makes the selection of universal management strategies an ongoing challenge.

The risks and potential health hazards associated with exposures tied to EDs is receiving increasing attention by researchers, organizations, and governments around the world. Management decisions have been delayed in some jurisdictions because regulators are grappling with scientific uncertainties and how to best manage this class of substances. The research on EDs is characterized by many knowledge gaps and uncertainties, and a central question is whether changes in the present approach to chemical risk assessment can be adjusted such that toxicity assessments include the potential harm posed by EDs or if there is a need to manage them differently than other toxicants. Those in favour of specific treatment of EDs emphasize that the challenges involved in assessing the potential consequences in light of irregular dose-response curves, potential latency periods and the potential for compounding effects are too large and that this points to a need for a major overhaul of the regulatory system needs.

1.2 Note on Terminology

Wastewater treatment plays a central role in chemicals' management as wastewater treatment plants (WWTPs) are a major source of many chemicals to the environment. For this thesis, the focus will be management strategies aimed at minimizing the risks posed through wastewater

management. There are various terms used related to wastewater management that are used to describe the 'stuff' that is mixed with water and discharged from households, businesses, hospitals etcetera and discharged into underground pipes to treatment plants. To complicate matters, some locations combine sewage with stormwater drains. Common terms include 'wastewater', 'liquid waste', 'sewage' and 'influent', and 'effluent'. These terms are at times used interchangeably and inconsistently by local governments, stakeholders, the public, WWTP professionals and scientists. In this thesis, the term 'liquid waste', 'wastewater' and 'sewage' refer to the liquid disposed to the sewers (the underground pipes transporting the sewage from the source to the WWTP), typically by households, businesses, and/or stormwater drains. I will be using 'effluent' when referring to the treated wastewater that is discharged from WWTPs. There are also multiple terms used to refer to the semi-solid by-product that remains after treatment. The terms include, "semi-solid residuals", "sewage sludge", "treated sewage sludge" and "biosolids". Depending on the level of treatment and where you are in the world, this by-product can be called different things. In North America, the treated WWTP by-product is typically called "biosolids" whereas in Europe the same treated by-product is called "treated sewage sludge" (Öberg & Mason-Renton, 2018). The mixed use of these terms is often a source of confusion, especially in international dialogues.

1.3 Chemicals' Management in Canada

Chemicals management is a topic with both environmental and human health impacts that cross local, provincial and national boundaries. In Canada, responsibilities are shared among all levels of government. Federal and Provincial Governments collaborate to set nation and province-wide management strategies and the implementation and administrative responsibilities are

downloaded to local governments. The hierarchy is important to consider for this research as decisions by the Provincial and Federal Governments impact local management strategies. The subsequent subsection summarizes each level of government's roles and responsibilities related to chemicals management. For a full description of chemicals' management in Canada see Chapter 3.1.

1.3.1 Jurisdictional Differences

At the Federal level, chemicals management is jointly administered by the Ministry of Environment and Climate Change Canada (ECCC) and Health Canada (HC) (Government of Canada, 2019b). Canada-wide regulations, guidelines, and research programs are supported by two key components: the Canadian Environmental Protection Act 1999 (CEPA 1999), and the Chemical Management Plan (CMP). Through this legislation, the Federal Government determines which chemicals are toxic, establishes risk assessment criteria, and can prohibit specific chemicals from Canadian Markets. Canada's risk management approach is largely *"risk-based"* which refers to assessing the combination of probability and severity of the chemical to cause harm and typically is enforced through maximum thresholds (Government of Canada, 2021a; Lofstedt, 2011). An example of Canadian regulation targeting chemical-specific restrictions is the Toxic Substance list: Schedule 1. The alternative to Canada's risk-based approach is known as *"hazard classification"* which refers to assessing chemicals based on their intrinsic properties and potential to cause adverse effects. In the EU, regulatory decisions for food and drugs are often based on hazard assessments and are implemented through policies justified by the precautionary principle (Lofstedt, 2011).

Provincial and Territorial Governments are responsible for protecting and improving human and environmental health through provincial legislation such as Alberta's Environmental Protection and Enhancement Act. Although the specifics detailed in these Acts differ, in all cases it serves as provincial guidance to set priorities to protect existing natural assets and promote sustainable operations and development practices. The obligation to meet these requirements is then transferred to local governments to design and enforce local policies and programs. Municipalities and other forms of local government such as special-purpose boards, agencies, and commissions are well-positioned to deliver services and develop programs and policies to reflect the needs of residents and stakeholders (Finn, 2008). Local governments are positioned at the intersection of production, consumption, and disposal. They are equipped with the authority to design and implement bylaws, taxes, and programs to achieve mandates set out by the Federal and Provincial Governments. In the case of wastewater management, many local governments have adopted source control regulations, such as sewer use bylaws, and educational campaigns to manage total contaminant loading discharged into the sewer system as well as end-of-pipe treatment systems to regulate effluent quality prior to environmental discharge.

1.3.2 Management of Endocrine Disruptors

EDs are not distinguished as a specific chemical class in Canadian chemicals' management. The Federal Government recognizes the risk of adverse endocrine effects and have procedures in place to assess such effects. Whether or not EDs merit distinction within Canadian chemicals' management is under debate. The core of the management debate is around the applicability of existing risk assessment criteria and whether the present system allows for an adequate evaluation of the chemical characteristics of EDs. In a review of CEPA 1999, the Government of

Canada received criticism from the Standing Committee on Environmental and Sustainable Development (SCESD) specific to CEPA 1999's narrow definitions of "toxic", lack of risk assessment criteria specific to the standards of evidence and cause and effects data that target EDs and more generally for creating hurdles for categorizing substances as "toxic" (Standing Committee of Environmental and Sustainable Development, 2017). The SCESD argues that EDs pose heightened susceptibility for vulnerable populations, low-dose responses, and additive, synergistic and intergenerational effects, which are not captured through the existing system.

In response to the review, the Government of Canada responded favourably to many of the Committee's recommendations to enhance terminology, improve assessment requirements and expand ED-related research programmes. However, the Government defended existing management mechanisms that allow for the capture of EDs through existing risk assessments. The Government's response to the SCESD's recommendation report reinforces the need for improved policy action, as well as the complexity of this regulatory challenge as management solutions are highly debated, even within Canada.

The national discussions and interest in improving chemicals' management at the Federal level sets the context for this research. Based on global and national interests in managing EDs, it is expected that changes will be made to chemical regulation and the implications will have direct effects on the management of endocrine disruptors.

1.4 Source Control and End-of-Pipe Management Strategies

Chemical management is a complicated policy issue because chemical contaminants enter the environment from a variety of sources and exposure routes. Human exposure can result from

breathing air contaminated by evaporated substances, absorption through skin contact, and/or consuming food or water that has been directly or indirectly contaminated. EDs can be commonly found at low to ultra-low doses in everyday products such as pharmaceuticals and personal care products, food packaging, plasticizers, and domestic or industrial solvents (Kabir et al. 2015; Rahman et al., 2009). Many of these are directly or indirectly discharged into sewage and wastewater resulting in high concentrations of ED contaminants found in liquid waste. Because of this, management strategies that target liquid waste can provide a means of reducing ED exposures. As mentioned above, this is the focus of the present thesis.

Wastewater management can be achieved through strategies that aim to prevent or reduce pollution prior to discharge to the receiving environment. Metz and Ingold (2014) classify these mechanisms as either 'source control' or 'end-of-pipe treatment' strategies. They include government controls, economic incentives, and informational campaigns. Chapters 1.4.1 and 1.4.2 are based on Metz and Ingold's (2014) descriptions of source control and end-of-pipe treatment strategies, unless otherwise stated.

This research focuses on understanding local governments' capacity and preparedness to manage EDs. Local governments are at the intersection of consumption and disposal of liquid wastes as most have the responsibility to provide liquid waste management services to their communities and are required to have a liquid waste management plan. The exception is Newfoundland and Labrador where wastewater management is a Provincial responsibility (Lazar & Seal, 2005). These plans identify context-dependent issues and layout community-specific solutions related to sewage, stormwater, and other liquids that will be discharged to the environment. The localized approach is intended to give local governments the autonomy they need to create programs

tailored to their communities and commonly include both source control and end-of-pipe treatment solutions. These two approaches are described below:

1.4.1 Source Control

Source control strategies are regulatory controls and industry innovations that aim to reduce the load of pollutants in wastewater before they enter treatment facilities or reach the environment through other routes. This approach addresses pollutants at the source and is a preventative approach to reducing discharge and exposure to humans and the environment (Sinsheimer et al., 2002). As such, source control strategies are also known as *pollution prevention* mechanisms.

Source control strategies promote eliminating, minimizing, or substituting chemical contaminants to reduce the overall impacts from industry, institutional and domestic uses (Sinsheimer et al., 2002). Regulatory instruments include discharge bylaws, guidelines, tax incentives, educational programming, and research/development programs and can be categorized into three groups: 1) command and control mechanisms, 2) economic incentives and 3) information-based campaigns. See Table 2 for full descriptions. These upstream approaches help foster behaviour-change among consumers and promote chemically sustainable practices for industry stakeholders (Finnveden et al., 2013).

Table 2 Source Control Strategies as Defined by Metz and Ingold (2014)

Command and Control Mechanisms	Command and control mechanisms are government-led projects or programs where the regulatory authority determines abatement strategies and operational logistics. Governing agencies can either take a direct approach through strict emission and discharge standards, an indirect approach via technology and processing

	standards, or apply land-use planning restrictions to limit exposures (Blackman, 2000).
Economic Incentives	Economic incentives are market mechanisms that incentivize behaviour through financial means. This includes government financial subsidies, rebates, investments, and penalties (carrots and sticks) to incentivize the adoption of new technologies or processes. Incentive programs can be operationalized directly through financial penalties and discharge permits or indirectly as green taxes and subsidies. The goal of pursuing the use of economic incentives is to motivate individual firms to reduce consumption and discharge of hazardous substances.
Information-based campaigns	Informative promotion and educational programming aim to increase the knowledge capacity and awareness of behavioural impacts to selective audiences. The campaigns can be tailored to homeowners, industry producers, or suppliers with messaging designed to target best practices, disposal requirements, or general information. The effectiveness of this approach is often dependent on how the target audience perceives the evidence, the relevance, and the urgency of the information. Campaigns may include print material, pop-up sessions, workshops, or social media campaigns.

1.4.2 End-of-Pipe Treatment

Central to managing liquid waste is ensuring wastewater effluents meet health and safety standards, such as provincial water quality guidelines and infrastructure requirements. Municipal sewers collect discharges from domestic, industrial, and agricultural uses, and in the case where there are combined sewers, they also collect stormwater runoff that may contain pollutants that need to be treated prior to discharge into the recipient (lake, river, or the ocean). Accelerated use and disposal of chemicals into sewers, including EDs, have prompted the need for wastewater treatment plants (WWTP) to provide end-of-pipe treatment, as these systems originally were set up to handle odour and pathogens.

Similar to Source Control strategies, Metz and Ingold (2014) explain that end-of-pipe management strategies can be implemented through 1) regulatory requirements, 2) economic incentives, and 3) informative campaigns (Metz & Ingold, 2014). See Table 3 for summary.

Table 3 End-of-Pipe Management Strategies as Defined by Metz and Ingold (2014)

Regulatory requirements	Government authorities responsible for treatment plant design can require mandatory infrastructure upgrades or implementation of the best available technologies to standardize water quality through processing requirements. For example, in 2012, the Canadian Government introduced the requirement for all WWTP effluent to reach secondary treatment standards through the Fisheries Act (Government of Canada, 2021b).
Economic incentives	Advanced wastewater treatment technologies are expensive investments for local governments or individual firms; therefore, subsidies can be made available to help finance technical upgrades. Economic instruments can incentivize or accelerate equipment upgrades.
Informative campaigns	Informational campaigns are not exclusive to public influence, rather, they can also target government authorities and industry firms. Education on novel research or innovative best practices can influence decisions about treatment plant design or provide operator-specific training. Information-based programming can be used to inform voluntary action to improve treatment processes without additional monetary incentives or regulatory restrictions. Campaigns may also be used to negotiate public-private-partnerships to share responsibilities.

1.4.3 Wastewater Treatment Plants

End-of-pipe management strategies focus on WWTP design to ensure water quality prior to environmental discharge. In Canada, WWTPs are designed and managed by local governments allowing the plant to reflect the community's needs and allocate the resources available. Most large cities have a centralized wastewater treatment system consisting of four main components: the conveyance infrastructure (also known as sewers) that collects and transports wastewater

from residential homes, businesses and industries to the next component: the wastewater treatment plants where wastewater is treated (Government of Canada, 2020e). (See Figure 1-1). When treated, the treated effluent is discharged via long underwater conduits (sewage outfalls) that discharge the treated effluent to the recipient (lake, river, or ocean). The fourth component is the residuals treatment facility where the semisolid residual that remains after treatment (sludge) is disposed of or processed into biosolids (See Figure 1-1).

Wastewater treatment plants can be designed with various technologies. According to the Government of Canada (2020e), the stages of wastewater treatment in Canada are defined as the following:

> *No treatment: No treatment process or only screening and/or grit removal.*
>
> *Primary treatment: Removing a portion of suspended solids and organic matter by physical and/or chemical processes.*
>
> *Secondary treatment: Removing organic matter and suspended solids using biological treatment processes and secondary settlement.*
>
> *Tertiary treatment: Removing specific substances of concern (solids, nutrients and/or contaminants) after secondary treatment using a number of physical, chemical or biological processes (Government of Canada, 2020e).*

In Canada, the Fisheries Act regulates effluent quality through the Wastewater Systems Effluent Regulation. This law was updated in 2012 requiring all municipal WWTP effluents to reach secondary treatment performance standards by 2020 (Government of Canada, 2021b). The performance standards for secondary treatment include the average effluent concentrations of oxygen demand (CBOD), total suspended solids (TSS), total residual chlorine, and the maximum concentration of un-ionized ammonia. Although these do not address EDs, Provincial

Governments have the ability to implement additional treatment technologies that exceed these minimum standards, however, they are not enforceable by law (Canadian Water Network, 2020). Examples include the Government of BC and the Government of Alberta which both have surface water guidelines that target a wide range of contaminants, some of which are EDs (Canadian Water Network, 2020).

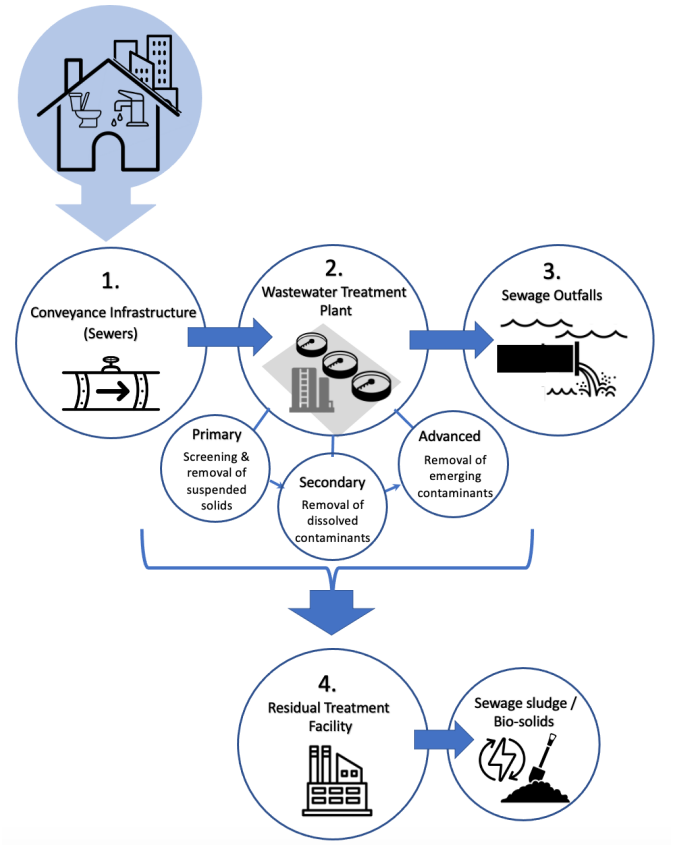

Figure 1-1 Original Illustration of End-of-Pipe Wastewater Treatment Components

Figure 1-1 is an illustration of the components included in end-of-pipe wastewater treatment in Canada. There are four main components including: 1) conveyance infrastructure, also known as sewers, that transport wastewater across the city to centralized wastewater treatment plants, 2) centralized wastewater treatment plants that include various treatment technologies known as primary, secondary and tertiary phases. Conventional plants include primary and secondary treatment, and each level of treatment treats and purifies the water to a higher level. 3) Sewage outfalls that discharge treated effluent back to the environment through long underwater conduits and 4) Residuals treatment facilities where sewage sludge and scum (the by-products of the treatment process) are processed to create

biosolids for reuse or are disposed. (Original illustration inspired by Government of Canada, 2020e; Metro Vancouver, 2019; City of Calgary, n.d.; See footnote [1] for icon credits)

1.4.4 Managing Endocrine Disruptors in WWTPs

Endocrine Disruptors pose a challenge for existing operations because conventional WWTPs, consisting of primary and secondary treatment, are not designed to address this broad class of contaminant (Bolong et al., 2009; Deblonde et al., 2011; Kim et al., 2007; Rogowsha et al., 2019). EDs may be biologically stable (Rott et al., 2018; Tijani et al., 2016), exist at ultra-low concentrations (for example, nanograms per liter (ng/L) to micrograms per liter (µg/L)) (Ibáñez et al., 2013; Petrie, 2015), and are difficult to degrade through treatment, limiting the ability of existing technologies to remove them from the wastewater effluent (Ibáñez et al, 2013; Petrie, 2015; Petrović et al., 2003; Sichel et al., 2011; Wilkinson et al., 2016). EDs can be challenging to detect in a wastewater treatment process, posing challenges to monitoring treatment (Petrović et al., 2003). Further, the fate of ED contaminants during the treatment process can be transformed through chemical and biological processes to create degradation products with weaker or unknown toxicity (Bolong et al. 2009; Burkhardt-Holm 2010; Petrović et al. 2003; Rogowska et al., 2020). The effects and feasibility of advanced wastewater treatment technologies are still relatively understudied; however, some research has concluded that advanced technologies such as separation processes including nano-filtration and reverse osmosis combined with degradation processes including advanced oxidation, have the greatest capacity to reduce emerging contaminants from the liquid effluent (Bolong et al., 2009; Petrović et al., 2003; Rizzo et al.,

[1] Adnen Kadri *Renewable energy*; Creative Staff *Factory* ; Emka Angelina *Toilet*; Firza Alamsyah *Factory*; il Capitano *House;* Laymik *Farm;* Luis Prado *Outfall*, Made by Made *City*; ProSymbols *Shovel and mud*; Universal Icons *Waves*; Vectorstall *sink* and Zach Bogart *Water flow tube* from the Noun Project 2021

2019. Researchers studying the removal efficiency of WWTPs have observed varying removal rates for emerging contaminants of approximately 40-50% for some active pharmaceuticals, up to 70% for BPA and > 90% for some phthalates and plasticizers (Deblonde et al., 2011), yet insignificant removal, < 20%, for others such as certain PPCP, synthetic estrogens, phthalates and nonylphenols (Bolong et al., 2009; Deblonde et al., 2011; Petrović et al., 2003). The addition of advanced technologies to wastewater treatment plants does not guarantee complete contaminant removal from the effluent and toxicity challenges remain present in the sewage sludge (Bolong et al., 2009; Langdon et al., 2010; Deblonde et al., 2011). These technologies are also often impractical in many situations due to their high capital and operational costs, stemming from the energy-intensive processes, high cost of consumables, and the need for experienced operators (Bolong et al., 2009; Doerr-MacEwan & Haight, 2006; Ibáñez et al, 2013; Mohseni, personal communication, 2018; Rizzo et al., 2019; Rogowska et al. 2020; Sichel et al., 2011). WWTPs in Canada are largely unequipped with the technologies aimed to target Eds (Petrovic, 2003; Statistics Canada, 2019), thus many researchers suggest upstream source control strategies as cost-effective ways to promote pollution prevention (Doerr-MacEwan & Haight, 2006).

1.4.5 Solids Management

Another dimension of concern in liquid waste management is the semi-solid residual that is formed as a treatment by-product. Sludge and scum collected from the treatment process contain a high concentration of organic matter and nutrients with trace level pollutants captured within, and it is well documented that the sludge contains EDs (Clarke & Smith, 2011; Petrie et al., 2015). This solid by-product of WWTPs can be further processed to be repurposed as ‘biosolids’

as they are known in North America (Langdon, 2010) or ‘treated sewage sludge’ in Europe (Öberg & Mason-Renton, 2018). The end-product is a granular earth-type substance that is rich in nutrients and organic matter (EPA, 2021). Despite WWTP upgrades and additional processing to form biosolids, environmental occurrence of ED pollutants at trace levels (mg/kg to ng/kg) is observed (Clarke & Smith, 2011; Clarke & Cummins, 2015; Kim et al., 2007). Some risk assessors claim that the detected levels may pose significant and widespread consequences due to their persistence, especially if land applied (Clarke & Smith, 2011; Clarke & Cummins, 2015). Yet others explain that land applications do not pose a significant risk to human and environmental health (Clarke & Cummins, 2015; Langdon, 2010). In Canada, there are two categories of biosolids ‘Class A’ and ‘Class B’. However, this classification where ‘Class A’ is the highest level of classification, refers to the level of detectable pathogens, and does not address potential ED contamination.

Chapter 2: Methods

Study Design and Research Aims

This research was approached through a pragmatic lens aiming to better understand local government preparedness to address future ED regulation. This research sought to understand the challenges facing local governments with respect to ED management, potential management strategies, and resources that enable local governance. I chose to focus on management strategies that are the responsibility of local governments in Canada, and which pose a prominent source of ED exposure: wastewater management. Although EDs can be discharged to the environment through various exposure routes, wastewater poses a major source of exposure as many EDs such as pharmaceuticals and personal care products, including medications, soaps, and lotions, are directly or indirectly discharged into sewers. Strategies such as source control and end-of-pipe treatment offer management strategies to reduce ED discharges. Understanding the local government's preparedness to manage EDs through wastewater management aims to contribute lessons learned that benefit the chosen case as well as other local governments across Canada.

The design of this study aimed to engage with a problem that has little or no documented theory and is a means of narrating new perspectives that contribute to disciplinary knowledge (Creswell, 2014). Qualitative and exploratory inquiry allowed for exploration of this novel research topic through a case study and qualitative analysis. I chose to first conduct a desktop review of Canada's regulatory context to establish Canada's approach to managing chemicals, and specifically EDs, and to identify jurisdictional responsibilities related to chemicals management for local, Provincial, and Federal Governments. Next, the case study was described through review of publicly available local government documents such as the liquid waste management

plan, committee documents, policies, and programs to develop an understanding of the organizational hierarchy and existing management strategies. Empirical data was collected via semi-structured interviews with local government staff and decision-makers. Interviews provided perspectives on ED management, future challenges and required resources from staff and decision-makers knowledgeable and responsible for local wastewater management. Once complete, the interviews were transcribed, coded in NVIVO, and analyzed using an inductive approach. To address my research aim, I designed my analysis to investigate four central themes: challenges, management strategies, scenario response and resources.

2.1 Research Questions

Inquiry into Canadian Chemicals Management and a local government case study provided a landscape to investigate novel unexplored questions about the preparedness of local governments to address future ED regulation. The focus of this research was wastewater management as it poses a prominent source of ED exposure and is the responsibility of local governments.

The narrative developed through this case study research highlights the perspectives shared by my study respondents and aims to illustrate lessons from the perceived management challenges, preferred management strategies, and required resources for ED management.

This research was guided by the following research questions:

- Q1: What is the regulatory context for chemicals' management in Canada? How are jurisdictional responsibilities distributed among local, Provincial, and Federal Governments in Canada?
- Q2: How do local governments perceive the challenge of managing EDs?

- Q3: How do local governments perceive effective management of EDs? What are the preferred management strategies?
- Q4: What are the resources required for local governments to address EDs?

2.2 Chemicals' Management in Canada

The first part of this research involved building an understanding of chemicals' management in Canada. In order to build the context in which Canadian local governments are situated, I describe the regulatory structure and jurisdictional authority of Federal, Provincial, and local Governments through secondary research. Chapter 3.1 was developed based primarily on the review of the Government of Canada's informational websites, legislation, and reports to or from the SCESD. Some literature referencing the relationship between the orders of government was also helpful to understand political dynamics in Canada. Understanding chemicals' management in Canada was an iterative process beginning with responsibility and jurisdictional authority. Once I developed an understanding of the regulatory documents and risk assessment processes, I specifically investigated ED management. Through informational webpages and reports, I gained an understanding of the Government of Canada's current control over EDs and critiques of CEPA 1999 from the SCESD.

2.3 Case Study

Another part of this research involved describing the case study. To describe the case, I relied on primary web-based documents. See Table 4 for a list of background materials referenced. First, I developed an understanding of the local government's structure and hierarchy followed by a review of the programs, regulations, and policy documents related to chemicals and wastewater

management. Building an understanding of this was an iterative process of reading, comparing, and locating responsible departments, staff, and decision-makers. As a result of the review, I identified distinct power dynamics and roles within the local government as well as a departmental distinction between source control strategies and end-of-pipe wastewater management. Chapter 3.2 outlines the full case description.

2.4 Purposeful Case Selection

Purposeful case study selection was used to identify an information-rich case where local government staff and decision-makers were knowledgeable about the topic and whereby lessons learned could help inform other local governments. I chose to conduct my research on a Canadian local government with knowledge on liquid waste management, and familiarity with emerging contaminants, including EDs.

According to Flyvbjerg (2006), defining and characterizing the case helps to understand how results can be interpreted. Following the case-descriptions defined by Flyvbjerg (2006), this case study represents an *information-based case* defined as *extreme* and *critical. Information-based*, as opposed to *random-selection* was chosen for the ability to select a case for its distinguished values and expected characteristics. For my research, this meant I targeted a local government based on my expectations of experience and knowledge on liquid waste management, emerging contaminants, and management strategies. Flyvbjerg (2006) identifies four types of information-oriented cases, two of which describe the chosen case. Background research and document review (See Table 4 for a list of documents reviewed) suggest this local case can be described as an *extreme* and *critical* case because of the existing program development and experience with liquid waste management. *Extreme* cases refer to exemplary or distinguished examples that allow

for analysis of specific challenges and discussion about the causes and implications, whereas *critical* refers to cases with *"strategic importance in relation to a general problem"* (p. 229). According to Flyvbjerg (2006), logical deductions can be made from *critical* cases that represent most likely or least likely cases: if something is applicable in one critical case, it will be applicable in all cases. For this research, I selected a case that had recently finished an evaluation of wastewater management options, which included challenges related to the management of emerging contaminants, including EDs. As Flyvbjerg (2006) explains, challenges and resources identified in a critical case would also be present for cases with similar or less experience and /or expertise, in this case with liquid waste management. Based on my case selection, I can expect their experiences to serve as lessons learned for other communities.

Table 4 Background Documents Reviewed for a Case Study on Local Governments' Preparedness to Manage Endocrine Disruptors

(In order to maintain participant anonymity, documents have been described with generic titles and without revealing specific details or references.)

1. Organizational structure
2. The local government's websites/ webpages on source control, liquid waste management, wastewater treatment, and related projects
3. Liquid Management Plant
4. Sewer use bylaw including waste discharge permits, authorizations, and codes of practice
5. Liquid Waste Management Committee Terms of Reference, biographies, and meeting agendas/ minutes
6. Treatment plant project committee Terms of Reference, biographies, and meeting agendas/ minutes

2.5 Interviews

The final stage of data collection was conducting semi-structured interviews with local government staff and decision-makers from the chosen case study. The aim of the interviews was to gain an understanding of the respondents' perceptions of ED management, preferred management strategies, and required resources.

2.6 Target and Study Population

For this research, the target population was informants from different positions within the local government who are engaged in liquid waste management. My goal was to create a sample population knowledgeable of chemical management and reflective of the organizational structure and local government roles. The aim was to bring knowledge of decision-making, program design, administration, and operation. Collectively, I sought to capture perspectives from local decision-makers, program managers/ directors, and senior department staff or supervisors.

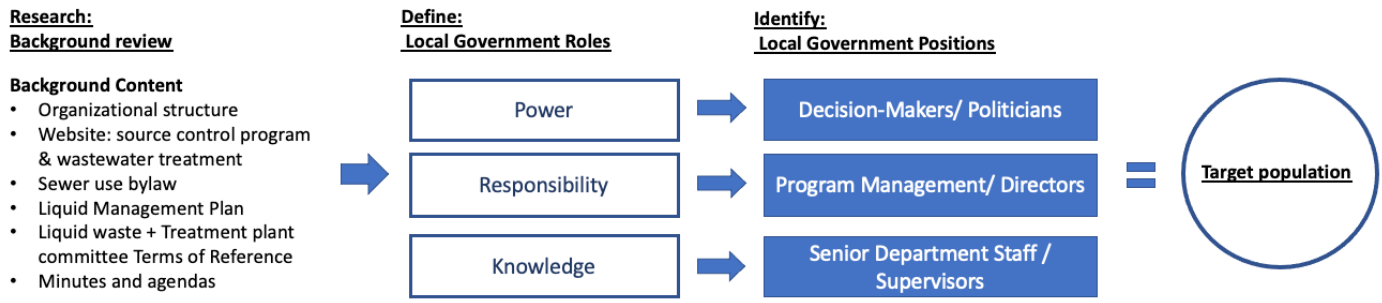

Figure 2-1 Target Population Process for Case Study Research of Local Governments' Preparedness to Manage Endocrine Disruptors.

Figure 2-1 illustrates the three-step process I took to generate my target population. First, I conducted a background review of publicly available documents and webpages to learn about the local government's organizational structure and wastewater management including end-of-pipe treatment and source control. Based on my understanding, I identified distinct power dynamics and roles: power,

responsibility, and knowledge. Third, I identified case-specific positions: decision-makers and politicians, program management and directors, and senior department staff or supervisors.

As illustrated in Figure 2-1, I arrived at my target population through a series of steps: First, I reviewed publicly available background material. This initial background review helped me to establish an understanding of the organizational structure, decision-making process, legislative requirements, and department staff responsibilities. See Table 4 for a list of documents reviewed.

Based on this review, I identified distinct power dynamics and roles within the local government's organization and decision-making process. I identified individuals that were responsible for making decisions (power), implementing decisions (responsibility) and informing decisions (knowledge/ expertise). See Table 5 for how I defined these terms. Also made apparent through my review was the departmental distinction between source control strategies and technical end-of-pipe wastewater treatment management. This local government's Council/ Board is advised by committees and project groups specific to the type of management strategy as well as directional documents that cover liquid waste management as a whole. For example, the government's liquid waste management plan sets out goals and ambitions to manage sewage and wastewater regardless of the management strategy, whereas 2020 upgrades to the WWTP were directed by a special project board. I identified corresponding local government positions including decision-makers and politicians, program management and/ directors, and senior department staff or supervisors. To develop my target audience, I used purposive sampling to target local staff representative of these distinct criteria. The following potential participants were identified using publicly available background material (See Table 4 for background materials reviewed):

- Community Chief Admin Officer and Board member
- Chair and vice-chair of the wastewater treatment project board
- Chair and vice-chair of the liquid waste management committee
- General manager of environmental services
- Project manager of the wastewater treatment project
- Wastewater project team
- Source control program supervisor
- Marine monitoring program supervisor

Email invitations were sent to individuals in the ten positions listed above with positive responses obtained from four, which are listed in Table 6. Respondent recruitment continued until I had respondents who contributed perspectives from the local government roles and corresponding positions: power, responsibility, and knowledge.

Due to the events surrounding the outbreak of Covid-19 in the spring of 2020, I was unable to secure more interviews. For this research, the responses from the four respondents collectively represent positions of power, responsibility, and knowledge that inform liquid waste management in the local government.

Each respondent is different from one another in that they provide a unique perspective based on their position and role in the local government. I have given each respondent an alias that corresponds to their position. These code names are used to reference the respondents throughout this thesis. For example, Respondent 2 supervises the source control program therefore they have been titled Source Control. A more detailed description of the respondents is found in Table 6.

Table 5 Definition of Three Central Concepts Used in a Case Study of Local Governments' Preparedness to Manage Endocrine Disruptors

Power:	Power is the authority and political jurisdiction to govern and manage. At the local level, this includes decision-makers responsible for senior government mandates and legislated requirements.
Responsibility	Responsibility is upholding and implementing local resolutions, agreements, and actions. At the local level, this includes staff requirements detailed in plans, bylaws, or agreements by those who have power.
Knowledge:	Knowledge is specialized expertise and information that informs management strategies, including both technical and policy approaches. At the local level, this includes information that informs decisions including staff reports and recommendations, knowledge and experiences, and stakeholder input and information shared through institutional, academic, or intergovernmental partnerships.

Table 6 Overview of Respondents for Case Study Research on Local Governments' Preparedness to Manage Endocrine Disruptors

Respondent Number	Alias	Description
Respondent 1	Monitoring	Position: Monitoring program supervisor, 11 years. Involved in the program for 16 years. Local government staff member responsible for collecting environmental monitoring data to meet regulatory compliance, understands the health of the receiving environment, and provides internal feedback to policy and technical operations staff. Monitoring's role(s):

Respondent Number	Alias	Description
		1) **Responsibility:** accountable for overseeing and conducting required marine monitoring testing including the water column and receiving environment. 2) **Knowledge:** contributes observational monitoring data that informs compliance and management decisions.
Respondent 2	Source Control	Position: Environmental science officer and source control program supervisor. Involved in the program for 18 years. Local government staff member responsible for supervising and delivering the source control program. This includes designing, developing, and implementing pollution prevention programs and regulations. Source Control's role(s): 1) **Responsibility:** involved in the production and delivery of the source control program. 2) **Knowledge:** communicates program review information via staff reports and conveys feedback, approvals, or criticisms from the public, stakeholders, and the programs' achievements to decision-makers.
Respondent 3	Manager	Position: General manager of environmental services department. Involved in the community and related positions for 18 years. Local government management staff overseeing and managing department responsible for community source control programing and regulations. Manager's role(s): 1) **Responsibility:** responsible for the delivery of all liquid waste management directives and mandates, specifically of the source control program, policies, and monitoring under the liquid waste management plan. As program manager, they also have the seniority to make program design changes to best suit local context.

Respondent Number	Alias	Description
		2) **Knowledge role:** communicates program review information via staff reports and covey feedback, approvals, or criticisms from the public, stakeholders, and overall effectiveness in the local context.
Respondent 4	Politician	Position: Community politician and liquid waste management committee chair for 2 years and local mayor for 4th term totalling 13 years. Local government decision-maker and liquid waste committee chair representing local jurisdictions. As committee member/ chair, in-part responsible for directing staff, requesting information or reports, and approving project / program design and budgets. Politician's role(s) • **Power:** local decision-maker and politician with voting authority at the community level as well as specific for liquid waste management. As decision-maker influences and enables those in responsible / knowledge roles.

2.7 Justification of Sample Size

Respondents each come from different but related wastewater management positions and are involved as informants, program supervisors, program managers, and/or politicians. Together, they provide insights from the different local government roles I identified in the local decision-making process: power, responsibility, knowledge. Collectively their responses present the different perspectives involved in chemicals management at the local level including administrators, managers, and decision-makers. According to Baker and Edwards (2012) a core strength of qualitative research is the ability to *"build a convincing analytical narrative based on 'richness, complexity and detail' rather than on statistical logic."* (p.5). In my research, respondents include diverse and high-quality contributions, in terms of role and position. Further, the

pragmatic application of this research to real life local governance heightens the value of the study population's resemblance to the existing organizational structure (Baker & Edwards, 2006, p. 6). For example, there is only one general manager of environmental services.

2.8 Research Instruments

Semi-structured interviews were selected as my research instrument as they allow for interactive and reflexive conversation as the interview guide can be supplemented with prompts specific to the stories and experiences shared (Brinkmann & Kvale, 2014; Schensul et al., 1999). Holstein and Gubrium (2015) identify this as an *active interview* where the interviewer crafts the inquiry through actively responding to the shared experiences and opinions. This approach allows for interactive conversations with the respondents whereby the interviewer's and interviewees' background and knowledge collectively shape the dialogue resulting in the co-creation of knowledge.

The relationship I established with the respondents was important to foster a welcoming environment. For example, prior to beginning the formal interview with Source Control, I shared my experience of travelling to the office and we shared admiration for the views from the office window. I felt that this casual dialogue was amicable and eased any nerves prior to starting the interview. Listening with acceptance and curiosity promoted connection where the respondent openly shared experiences and opinions. It is important in *extreme* and *critical* cases to have the flexibility to draw on specific expertise revealed during the conversations. For example, when speaking with Manager about local responses to a new federal action, this respondent reflected on their experiences as a moderator in public consultations. Although the information shared was not directly relevant to the questions, the structure of the interview allowed me to use prompts to

delve deeper into their experience of public engagement. In comparison, had this research been carried out through surveys or structured with closed interview questions, there would not have been an opportunity to follow up on this type of contextually important knowledge due to the rigidity of the instruments.

2.9 Interview Data Collection

This research received ethical approval from the University of British Columbia's Behavioural Research Ethics Board (Ethics ID H12-03317-A011). The approved project was designed and conducted with guidance and continuous feedback from my supervisor, Dr. Gunilla Öberg and Committee member Dr. Nadja Kunz and graduate student peers from RES 502 –*Master's Interdisciplinary Case Analysis and Research Design* taught by Dr. Stephanie Chang. The protocol for the semi-structured interviews was based on CONS 528 - *Social Science Research Methods and Design* taught by Dr. Shannon Hagerman and feedback from Dr. Gunilla Öberg.

Empirical data collection was scheduled and conducted in Winter – Spring 2020 and coincided with the 2020 global COVID-19 outbreak and national and local state of emergencies that ensued. This fieldwork recruitment was impacted by the unprecedented conditions and evolving knowledge that has resulted in social distancing and changes in office routines and in-person contact. Three interviews were conducted in person in February prior to March 17th, the date Provincial Governments across Canada declared a state of emergency (Leyland, 2020). One phone interview was conducted with the fourth participant in June 2020 from my home office.

In-person interviews were conducted at the administrative office in boardrooms and private offices. This setting offered a convenient and familiar place for my respondents to ensure the comfort and privacy of my participants.

Each interview began with a brief introduction of myself and my academic interests. The interview formally began once the respondent agreed to have the interview recorded and the data collected for this UBC graduate research thesis.

The interview guide was designed to inquire about five specific subject areas including professional background, problem definition of EDs, available management strategies, response to future Federal ED regulations, and comparison between end-of-pipe treatment technologies and pollution prevention strategies. Table 7 summarizes interview questions and prompts. For each interview, I followed the same interview guide; however, the questions and prompts were delivered in response to the content shared by my respondents. By this, I mean that I posed questions to the respondents based on the topics discussed. For example, in response to the question on management strategies Monitoring began detailing their opinion on Federal initiatives and challenges with implementation. To follow their lead, I posed the question on the regulatory scenario before returning to the previous question.

Table 7 Overview of Interview Guide Used in Interviews About Local Governments' Preparedness to Manage Endocrine Disruptors, Carried Out in January – June 2020

Topic	Aim	Description of question/prompt
a) Introduction: Professional background	To understand the respondent's employment history and experience with this local government and to have respondent reflect on their position prior to answering the questions.	Asking the respondents to detail current and past positions with the local government and prompted them to detail the number of years in the field and main/ specialty areas of expertise.

	Topic	Aim	Description of question/prompt
b)	Problem Definition of EDs	To understand the respondent's knowledge of EDs and identify what challenges impacted management strategies.	Asking the respondents to explain what makes managing EDs challenging.
c)	Current Management Strategies	To understand the management strategies used and their applicability to future ED regulation.	Asking respondents to detail existing management efforts and prompted them to describe and explain their current capacities in relation to EDs
d)	Scenario: response and preparedness to future regulations	To understand how this local government would respond to such future regulation and to understand this local government's preparedness to address EDs.	A scenario was presented with the Federal government introducing a regulatory decree for EDs, such as triclosan or non-phenyl, then asking respondents what responses could be expected. Prompts further inquired into implementation, required resources, and challenges.
e)	Comparison: Pollution prevention VS. End-of Pipe Strategies	To understand professionals' understanding and preference between two prominent management solutions: pollution prevention and end-of-pipe technologies.	Asking the respondents to compare and contrast source control verse end-of-pipe treatment options.

2.10 Data Analysis

2.10.1 Coding

Interviews were recorded and transcribed with the permission and consent of the respondents. I coded using an inductive, grounded theory approach to identify the respondents' perception of the challenges, management strategies, and required resources. Following analytic methods outlined by Charmaz (2014) and Creswell (2014), this approach helped to emphasize the respondent's perspectives and preferences that emerged from the data, free from predetermined theories. I coded the data in three phases, see Table 8.

Table 8 Data Analysis Summary for Case Study Research on Local Governments' Preparedness to Manage Endocrine Disruptors

Phase 1: Identify Initial Themes	Coding of all materials thoroughly to identify emergent themes.
Phase 2: Focused Coding	Focused coding to define and identify themes under four research themes: • Challenges • Management Strategies • Scenario Response • Resources
Phase 3: Refine coding	Refinement of the codes and sub-codes identified within each theme.

In phase one, I identified initial themes directly from the interview responses (Charmaz, 2014; Saldana, 2012;). Data was analysed using incident-coding to account for all patterns and emergent concepts (Charmaz, 2014). Incident-coding refers to coding concepts and ideas, rather than single lines or words. I felt this was most appropriate to capture the stories and messages of my respondents. The second phase consisted of focus-coding to define and identify predominant themes under each research theme. Definitions for each theme and code were developed to maintain consistency during the analysis, see Table 9 for definitions. In phase three, I reviewed all material and codes to ensure the consistency of the themes and codes.

I chose to code thematically to reflect both explicit responses to the questions, as well as implicit explanations and descriptions throughout the interviews. Thematic coding was applied across the interviews, rather than segregating the answers to specific questions. This is because my respondents' answers to the questions sometimes spanned multiple themes or were revisited in subsequent questions as respondents talked through their perspectives and opinions. For example, the challenges I identified included the aspects that respondents stated were challenges, as well as characteristics and features which met my definition of "challenges". In this context, I

defined “challenges” as *any characteristics, feature(s), and/or barriers interfering with the local management of EDs.* During the interviews, I asked a question prompting respondents to detail their opinions on why EDs were challenging to manage, as well as, listened and prompted respondents to elaborate on challenges raised later in the interview. During Monitoring’s interview, they first explained their perspective of the local government’s limited jurisdictional authority in response to the question on challenges, and then they raised the point again in response to the regulatory scenario. Thematic coding allowed me to capture all instances where respondents discussed particular topics, regardless of when they surfaced during the interview.

Table 9 Thematic Definitions Used in Case Study Research on Local Governments’ Preparedness to Manage Endocrine Disruptors

Challenges of Managing Endocrine Disruptors	• Characteristics, feature(s), and/or barriers interfering with the local management
Management Strategies	• Policy Instruments, mechanisms, treatment technologies, or other strategies that are within the local government’s capacity • Comparison between source control and end-of-pipe treatment
Scenario Response to future regulation	• Expectations of addressing the future scenario. • Understanding perceptions of “how to get it right”
Required Resources	• Asset and/or means that enable management through strategies/ instruments available.

2.10.2 Analysing the Imaginary Regulatory Scenario

The respondents’ responses to the regulatory scenario were interesting both comparatively between one another and collectively. For each respondent, I created an illustration and a written description of their response to the regulatory scenario including sequential actions, management

strategies, and management considerations. Developing each respondent's story was an iterative and intuitive process. First, I reviewed the transcripts to make notes on all points raised during their response. Next, I summarized each respondent's imagined management response categorically including required actions, possible management strategies discussed, and management considerations. Then I translated the text into flow charts to graphically illustrate each respondent's perspective. Developing the final written stories and flow-chart illustrations was an iterative process of reviewing the transcripts, my drafted summaries, and initial drafts of the illustrations until the text and illustration clearly conveyed each respondent's story.

2.11 Notes on Format

Throughout the results section, I have included direct quotations from my respondents to illustrate and emphasize the points made. These quotations have been edited for grammatical correctness, readability, and clarity. Care was taken to not change the meaning or intent of the respondent. An example of the edits I have made is illustrated by a quotation by Manager:
Original quotation:

> *If there was going to be a limit for that [pause] um [pause] we would want to [pause] we would want to see if we have any data 'cuz sometimes we do do some extra sampling to help master's students.– Manager*

In Section 3.5.3 of this thesis have referenced this quotation, but I have made three edits. 1) I have replaced *"um" with a [pause],* 2) I removed the repeated phrases *"we would want to" and "do",* and 3) I have replaced *"cuz"* with the full word *"because".*
Final edited quotation:

> *If there was going to be a limit for that [pause] we would want to see if we have any data because sometimes, we do some extra sampling to help master's students. – Manager*

In cases where quotations do not begin at the start of a sentence, or in cases where there are unquoted sections of text I have used *[…]* to indicate this.

In cases where the respondent's dialogue paused, such as for reflective thought, I have indicated this with *[pause]*.

In order to maintain anonymity, reference to people and places have been removed. For example, in Section 3.5.3 Manger refers to their jurisdiction by name and I have removed the reference and made note in parentheses. For example,

> *At the end of the day, there is only so much we can do, and [*local government name removed] always weighs-in on new federal regulation, especially if it's something that we're going to be held to account but have no authority over. – Manager*

Chapter 3: Results

3.1 Chemicals Management in Canada

Chemicals management in Canada is a combined effort among all levels of government. Responsibilities are shared and distributed by the Constitution Act of 1967 among the two recognized orders of government: Provincial or Territorial Governments and the Federal Government (Government of Canada, 2018d). The division of powers allows for representation by the jurisdiction best suited to govern the issue. For example, matters of national interests such as national defense, census data, and currency are Federal Government responsibilities, while Provincial and Territorial Governments are responsible for matters such as natural resources, education, health, taxation, and municipal governments (Government of Canada, 2017d; 2017e). Chemical safety is a subject which all levels of government collaborate to manage. This is because the 'environment' is not a matter of interest explicitly delegated by the Constitution Act of 1967. To deliver chemical management in Canada, the Federal Government sets and enforces CEPA 1999 and the national CMP. These regulations determine which chemicals are toxic and establishes risk assessment criteria to contribute to the development of acceptable thresholds and management strategies across the country (Government of Canada, 2019b). The Provincial Governments establish provincially enforced regulation that meets or exceeds federal requirements and, in most cases, has downloaded administration to local governments. In these cases, local governments translate senior government regulations into enforceable bylaws and programs to achieve requirements.

In Canadian politics, local and municipal governments are commonly referred to as "*creatures of the province*" (Lazar & Seal, 2005, p. 28) denoting their direct relationship with their senior provincial governments. Provincial governments grant power and authority to local governments

through provincial legislation, such as Ontario's Municipal Act 2001 or Manitoba's Municipal Act (Government of Manitoba, 2021; Government of Ontario, 2020; Lazar & Seal, 2005). Local jurisdictions across Canada rely on senior government direction and guidance on subjects such as chemical safety and are ultimately responsible for the delivery of all local services. Aligned with this research, the responsibilities downloaded to local governments include the management of solid and liquid waste and the design and management of municipal waste treatment plants. Although management approaches differ between jurisdictions, chemical management at the local level generally involves implementing and administering end-of-pipe treatment technologies, discharge bylaws, and source control education programs that meet or exceed provincial and federal chemical safety standards.

Subsequent sub-sections detail each level of government's supportive policy and regulatory tools. To ensure the anonymity and confidentiality of the research participants, details regarding provincial and local governments will be described generally and examples of legislation or policies will be drawn from across Canada.

3.1.1 Federal Government

The CEPA 1999 outlines the national approach for protecting human and environmental health as *"an Act respecting pollution prevention and the protection of the environment and human health in order to contribute to sustainable development"* (Government of Canada, 2021a, p. iii). Under CEPA 1999, the Canadian Government identifies and assesses the risks posed by hazardous and toxic substances. Chemical management is enforced through the Chemicals Management Plan (CMP) and includes mechanisms such as the Domestic Substance List (DSL), Priority Substance List, Toxic Substance List: Schedule 1, and Virtual Elimination List.

The Canadian Government keeps an inventory of all chemicals in use, imported to, or manufactured for commercial use in Canada. In 1994, the Domestic Substance List was introduced and a total of 23,000 substances were registered to be in use between January 1, 1984 – December 31, 1986 (Government of Canada, 2017b). The Canadian Government identifies and defines all existing substances in Canada on the DSL. Aligned with the goals set by CEPA 1999, the Government completed categorizing all 23,000 DSL substances in 2006. The categorization identified 4,300 priority substances requiring further screening assessments, research, and regulatory measures. Priority substances are defined as

- *inherently toxic to people and the environments (the regulation defines this as persistent and/ or bioaccumulative in the environment) and*
- *substances with the greatest potential for exposure. (Government of Canada, 2017b)*

Priority Substances are assessed by ECCC and HC for the risks they pose and the likelihood of exposure. Substances determined as priority substances undergo risk and toxicity assessments to determine if they are toxic as defined by CEPA 1999 and warranted of further management and/ or regulation.

Any substances not included in the DSL inventory are considered novel substances and are subject to human and environmental risk assessment and notifications outlined in CEPA 1999 and the New Substances Notification Regulation (Government of Canada, 2014a; 2018a). New substances intended for commercial or research use in pharmaceuticals, medical devices, personal care products, veterinary practice, and food packaging are subject to what CEPA 1999 defines as the *cradle-to-grave* management approach. This process identifies new substances that pose risks to human or environmental health and empowers ECCC to intervene before the

substances are accepted into the Canadian market (Government of Canada, 2018a). The Government recognizes that other Act's assessment requirements overlap and to avoid regulatory duplication they have granted exemptions to certain legislation listed in CEPA 1999.

In Canada, the Federal Government takes the lead on the assessment, identification, and management of toxic substances through the CMP (Government of Canada, 2020d). The Toxic Substance List: Schedule 1 (TSL) is a list of toxic substances that are determined to meet the CEPA 1999 definition of *Toxic*. *Toxic* substances are identified depending on the risks they posed to human and environmental health. As stated in CEPA 1999,

> *A substance is toxic if it is entering or may enter the environment in a quantity or concentration or under conditions that: a) have or may have an immediate or long-term harmful effect on the environment or its biological diversity; b) have or may constitute a danger to the environment on which life depends or c) constitute or may constitute a danger in Canada to human life or health (Government of Canada, 2021a, p.39).*

As of March 2021, the list contains 151 substances (Government of Canada, 2020f). Substances are added to the TSL by recommendation of the Minister of the Environment and the Minister of Health and are approved by the Governor in Council. Generally, substances are recommended following priority assessment, screening, and review of other jurisdiction's risk assessments. The TSL serves as a resource for Canadians to identify which chemicals the Canadian Government defines as toxic. For all substances on the TSL, the Government provides informational links to data and/or decisions regarding exposure/ discharge limitations, substance information, scientific reports, and risk management reports.

In addition to TSL toxicity assessments, the Government identifies substances that pose the greatest risk to the environment. Under the CMP and Toxic Substances Management Policy, precautionary management strategies are prescribed to eliminate or manage these substances from circulation in Canada. All substances that meet the criteria listed in Table 10 are subject to the Virtual Elimination List (VEL) (Government of Canada, 2004).

Table 10 Priority Pollutant Criteria According to the Government of Canada (2014b) Used to Determine Management Strategies

A)	Persistent
B)	Bioaccumulative
C)	Toxic
D)	Predominantly result of anthropogenic activity.

The Virtual Elimination List (VEL) identifies substances the Government of Canada intends to eliminate from circulation and/or mitigate existing pollution present in the environment. The VEL is divided into two streams, *Track 1: Virtual Elimination from the Environment* and *Track 2: Life Cycle Management* (Government of Canada, 2004). Figure 3-1 illustrates the selection criteria. Track 1 includes chemical substances that meet all priority pollutant qualifying criteria (See Table 10). This policy aims to eliminate these substances at their discharge sources, and phase-out the chemical from production and use where lifecycle management strategies are not possible. Chemical pollution already present in the environment is targeted for remediation based on the results of risk assessments and cost-benefit analyses. Track 2 substances are subject to risk assessment analyses to determine *"the degree and likelihood of adverse effects resulting from*

exposure to a substance in the environment" (Government of Canada, 2004, p. 7) before risk management strategies are selected to account for relevant risks and socio-economic factors.

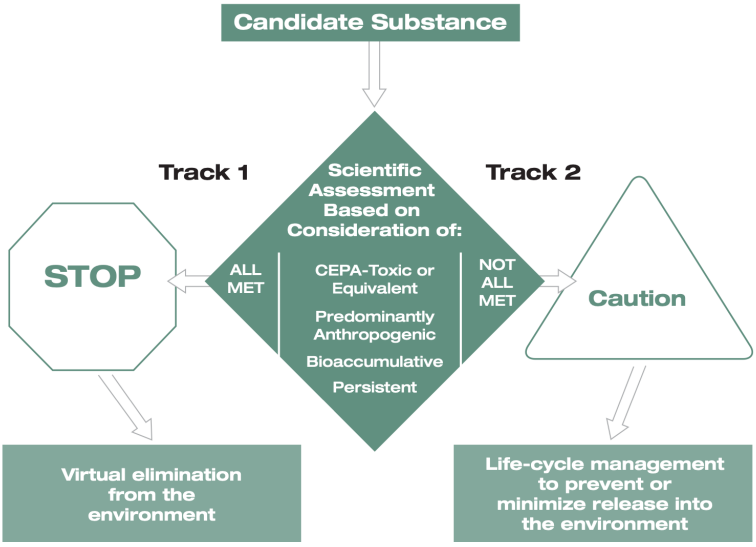

Figure 3-1 Toxic Management Selection Criteria According to the Government of Canada (2004) Used to Prioritize Substances in the Toxic Substances Management Policy

The Chemicals Management Plan (CMP) is Canada's overarching chemical strategy designed to *"reduce the risks posed by chemicals to Canadians and their environment" (Government of Canada, 2016b, para. 2)* It was introduced in 2006 and builds on the Toxic Substance Management Policy originally established in 1995. The goals of the CMP are achieved through supporting existing CEPA 1999 programs and introducing new chemical management initiatives (Chemicals Management Plan Science Committee, 2018). Through the CMP, together the ECCC and HC are reassessing and upgrading existing chemical regulations following a cyclical evaluation including information gathering, risk assessment, risk management, and enforcement, see Figure 3-2.

The CMP risk assessment process determines the environmental and human health risks of the substances including the development, transportation, use, and disposal of the substances. This process estimates the level of risk posed and the specific management strategies required. The Government may prescribe how a chemical substance can be used, how it is made, and/or the allowable amount or concentration released into the environment (Government of Canada, 2014b; 2016b). Enforcement can be mandated through the legislation deemed to be most appropriate, for example, the Food and Drug Act, Fisheries Act, or Hazardous Products Act. See Table 11, Table 12, and Table 13 for a full list of legislation related to chemicals management in Canada. Based on the government's assessment, enforcement can include regulations, agreements, pollution prevention notices, labelling requirements, guidelines, and codes of practice (Government of Canada, 2016b).

Figure 3-2 Government of Canada's (2014b) Chemicals Management Plan Management Cycle

As of September 2020, the government's assessment of over 4,000 priority substances is near completion (Government of Canada, 2019a). The completed risk assessment will detail chemical properties, quantities manufactured in or imported into Canada, releases to and concentrations in

the environment, environmental fate and behaviour, hazards, and nature of exposures (Government of Canada, 2018b). The project is estimated to be complete in March 2021 and HC and ECCC are currently establishing future *"...directions and objectives for chemicals management post- 2020"* (Government of Canada, 2018b, p. 7).

3.1.2 Provincial and Territorial Governments

The Provincial and Territorial Governments of Canada are responsible for human and environmental health within their geographical boundaries. All thirteen provinces and territories have enacted environmental regulations through provincial legislation such as Alberta's Environmental Protection and Enhancement Act and British Columbia's (BC) Environmental Management Act. Under this legislation, Provincial Governments can specify restrictions to prevent pollution, such as the BC's Hazardous Waste Regulation which mandates maximum concentrations of contaminants in solid and liquid waste discharges.

Political hierarchy in Canada promotes autonomy among Provincial and Territorial Governments to customize service delivery to reflect local provincial preferences. While sovereignty among provincial administration is supported, the collaboration between Provincial and Federal Governments is also central to decision-making at both levels. For matters concerning the environment, the Minister of Environment from each of the provinces and territories have come together to coordinate information sharing and standardized (UN Department of Economic and Social Affairs, n.d.). The Canadian Council of Ministers of the Environment (CCME) is a minister-led organization that provides leadership and research on matters of provincial and national interest to address priority issues related to environmental protection across Canada. Their key roles include performing research studies and establishing Canada-wide environmental

standards enforceable at either the provincial or federal level (CCME, 2014). CCME establishes national guidelines such as the Water Quality Guidelines and research and recommendation reports such as *Emerging Substances of Concern in Biosolids: Concentrations and Effects of Treatment Processes* to identify priority interests and determine best practices across different users and stakeholder groups (CCME, 2010).

3.1.3 Local Government

Within the Canadian context, local governments are delegated power by the Provincial Government for two primary reasons 1) administration of local services and 2) representation of local interests (Finn, 2008). Chemical management is a good example of the responsive role local governments take on as they are responsible for meeting standards and thresholds set by senior governments and must also design solutions in response to local contexts and stakeholder interests. In regard to chemicals management, key responsibilities include solid and liquid waste management. These services are comprised of technical end-of-pipe treatment plan designs, as well as, sewer use by-laws, discharge restrictions, and educational programming tailored to local conditions and contaminant loading.

Together, the Federal, Provincial and local Governments respond for enacting policies and regulations to protect human and environmental populations from the risks posed by chemical exposures. Government regulations and policies have a role in governing chemical safety and shaping consumption and disposal behaviours. Regulations are rules or laws enacted by legislation and are enforceable by authorities who have the power to administer penalties for non-compliance. They can be enforced at all levels of government; examples include BC's

Hazardous Waste Regulation or local sewer use bylaws. Policies compliment regulations as they *"set out clear rules and expectations for the delivery of programs and services"* (Government of British Columbia, 2021b, para.1) and are designed to help meet government or organization goals. For example, BC's Environmental Mitigation Policy provides clarifying guidance and direction aligned with existing legislation (Government of British Columbia, 2014). In regard to chemicals management, the Federal, Provincial and local Governments enforce a range of regulations, policies, and guidelines to manage chemicals in Canada. See Table 11, Table 12, and Table 13 for applicable policies and regulations.

Table 11 Canadian Federal Chemicals' Management Policies and Regulations (Government of Canada, 2014b, Government of Canada, 2017g, UN Department of Economic and Social Affairs, n.d.)

Canadian Environmental Protection Act, 1999 (CEPA)	**CEPA** outlines the national approach to protect human and environmental health and ensure sustainable development. Under CEPA 1999, the Government is responsible for chemical safety and regulating the use, distribution, and disposal of hazardous and toxic substances. At the national level, governing chemical safety and managing substances involves assessing the risks chemicals pose to human and environmental health, conducting research to advance current knowledge and improve management practices, and developing regulatory programs and standards to ensure ensuring long-term environmental protection (Government of Canada, 2017g). Chemical Safety is managed through the following: • **Chemicals Management Plan:** The Government of Canada's overarching strategy to manage chemical safety and use in Canada. The CMP includes multiple initiatives and research programs that run simultaneously. • **Toxic Substance List Schedule 1:** List of all substances that have been identified as *toxic* through the CMP's risk assessment. For each chemical, the government provides information regarding the state-of-science, risk management, exposure, and discharge restrictions. • **Toxic Substance Management Policy:** National approach on toxic substances which pose health risks to humans and the environment.

	The policy sets out a science-based framework to guide decision-makers and defines Track 1 and Track 2 substances of the Virtual Elimination List. • **Virtual Elimination List**: List of substances that meet the following four criteria A) persistent, B) bioaccumulative, C) toxic and D) predominantly result of anthropogenic activity. Substances meeting these criteria are subject to Track 1 or Track 2 management strategies aimed to eliminate or reduce environmental exposures. • **New Substance Notification Regulation**: Risk assessment and consultation requirements for new substances
Canadian Fisheries Act 1982	**Fisheries Act 1982** outlines federal jurisdiction over inland and coastal fisheries to protect fish and fish habitat from destructive activities in marine and inland waters. (Government of Canada, 2021b) • **Wastewater Systems Effluent Regulation, Fisheries Act** regulates the permitted discharge standards for wastewater effluent. This regulation is responsible for requiring secondary treatment for wastewater treatment plants prior to discharge beginning 2021.
Hazardous Product Act	**Hazardous Product Act** outlines communication requirements and workplace standards for risks and hazards posed by consumer products and chemical use (Government of Canada, 2018e). • **Hazardous Waste Regulations** specifies chemical classification and workplace health and safety requirements including Safety Data Sheets and other chemical safety labels (Government of Canada, 2015a; 2015c).
Pest Control Act	**Pest Control Product Act** is administered by Health Canada to protect the health and safety of humans and the environment from risks posed by pesticides and other products used to control pests. Under the Act, the government registers and manages the use of all pest control products used in Canada. (Government of Canada, 2021d)
Fertilizers Act	**The Fertilizers Act** regulates fertilizers and supplements to safeguard the Canadian food supply and to protect the health of animals, plants, and Canadian consumers. All fertilizers sold or imported into Canada are subject to enforcement of the Fertilizer Act and Regulations by the Canadian Food Inspection Agency (Government of Canada, 2020c).
Feeds Act	**The Feeds Act** manages the manufacture, sale, and import of livestock feed in Canada to ensure ingredients used are safe for animal and human consumption and environmental discharge. The Canadian Food Inspection Agency administers the Act, including two

	key components: pre-market assessments and the national inspection program (Government of Canada, 2019c)
Seeds Act	**The Seeds Act** manages quality standards and labelling requirements for seed and seed potatoes imported, exported, or released into the environment. The Canadian Food Inspection Agency set requirements for advertisements, accreditations, and sampling. (Government of Canada, 2015b).
Food and Drug Act	**The Food and Drug Act** establishes safety and quality standards for all foods and food packaging. The Canadian Food Inspection Agency is responsible to enforce the Food and Drug Act and its regulations (Government of Canada, 2008).
Canada Consumer Product Safety Act	**The Canadian Consumer Product Safety Act** is administered by Health Canada to protects Canadians from unnecessary risks and helps consumers make informed choices. The Act applies to children's toys, household products, and sporting goods, but excludes products regulated by other regulations such as vehicles, food and drugs, and animal products (Government of Canada, 2018c).
Health of Animals Act	**Health of Animals Act** manages and protects animal health. The Canadian Food Inspection Agency administers the Act by controlling disease and toxic substances that may impact human, aquatic or terrestrial animal health.
Canada Water Act	**Canada Water Act** manages water quality and the diversity of stakeholder interests across different economic, cultural, and societal sectors. The Government ensures quality standards are in place to protect human health and the environment (Government of Canada, 2020h).
Canadian Environmental Assessment Act	**Canadian Environmental Assessment Act** regulates development projects to help ensure development will not have adverse environmental impacts on the surrounding wildlife or ecosystems. The Canadian Environmental Assessment Authority ensures projects meet the assessment criteria and considers the severity of the environmental effects, prospective changes to the environment, alternative designs, and public comments (Government of Canada, 2020a)
Northwest Territories Water Act	**NWT Water Act** regulates the use of and discharges to NWT's water resources (Government of Canada, 2016a).
Nunavut Waters and Nunavut Surface Rights Tribunal Act	**Nunavut Waters and Nunavut Surface Rights Tribunal Act** regulates water resources in Nunavut to protect the water quality from waste and other contaminants (Government of Canada, 2021c)
Arctic Waters Pollution Prevention Act	**Arctic Waters Pollution Prevention Act** regulates the Canadian Arctic Waters as a 'zero discharge' zone prohibiting the disposal of waste into the Canadian Arctic (Government of Canada, 2012)

Canada Shipping Act	**Canada Shipping Act** regulates the safety of commercial and recreational marine transportation and the health of marine environments (Government of Canada, 2017a).
Transportation of Dangerous Goods Acts	**Transportation of Dangerous Goods Act** applies to both commercial and personal transportation of dangerous goods, including toxic and hazardous substances defined in CEPA 1999. The Act ensures vehicles, containers, packaging, and labels meet regulatory standards and that emergency measures are developed in case of an accident (Government of Canada, 2020g).
Canada Labour Code	**Canada Labour Code** regulates occupational workplace health and safety by setting out standards for employees and employers (Government of Canada, 2020b). Under the Act, Canada Occupational Health and Safety Regulations manage requirements for hazardous substances used or present in workplaces to prevent accidents and related injuries (Government of Canada, 2015a).

Table 12 Canadian Provincial Chemicals' Management Policies and Regulations

Provincial Environmental Management Act	**Provincial Environmental Management Act** regulates discharge and disposal of all industrial and municipal waste discharge, pollution, hazardous waste, and contaminated site remediation. All Provinces and Territories are required to have provincial environmental management Acts. Examples include Alberta's Environmental Protection and Enhancement Act and British Columbia's Environmental Management Act. Under these Acts, local Governments are required to develop *Liquid Waste Management Plans* to ensure public and environmental safety. • **Provincial Hazardous Waste Regulations** defines and regulates the management of hazardous waste, including toxic substances.
Provincial Municipal Act	**The Municipal Act** permits Provincial Governments to download service delivery to municipal and local governments. Under the Act, local and regional governments are granted the responsibility to manage solid and liquid waste. This involves bylaws and programming to manage the collection, conveyance, and disposal of sewage and its by-products.
Provincial Water Quality Guidelines	**Water Quality Guidelines** are established by provincial authorities to protect drinking water, community watersheds, and recreational waterbodies. Separate standards are specific for its intended use, for example working water, ambient water, and drinking water.

Provincial Pest Management Regulations	**Pest Management Regulations** regulate the residential and commercial use of pest management products. Safety standards are established to prescribe the use, storage, and disposal of pesticides to protect human and environmental health.
Provincial Liquid Waste Management Plan	**Liquid Waste Management Plans** help local governments manage sewage and liquid waste. Although administered locally, all plans must receive approval from the Provincial Ministry of Environment.
Provincial Transport of Dangerous Goods Act	**Provincial Transport of Dangerous goods act** regulates the shipping of dangerous goods via rail or road including vehicles, containers, packaging, and labels. The Provincial Government may support the Act with Dangerous Goods regulations, emergency response protocol, and spill reporting regulations.
Workplace Health and Safety Acts and Regulations	**Workplace Health and Safety** is managed provincially through the Occupational Health and Safety Regulations. Chemicals management is included to enforce limits on hazardous and controlled substances and detail employer and employee rights and responsibilities. Agencies responsible include SafeWork Manitoba and WorkSafe BC.

Table 13 Canadian Local Chemicals' Management Policies and Regulations

Waste Management Regulations	**Municipal Waste Management Regulation** permits local and regional governments to develop and enforce bylaws managing direct or indirect discharge of wastes into any sewer or drain connected to a sewer. **Municipal Wastewater Regulation** manages provincial discharge and effluent reuse standards, sewage facility operation, maintenance, and monitoring requirements (Government of British Columbia, 2021a)
Local Source Control Enforcement Policy	**Local Source Control Enforcement Policy** outlines source control program enforcement policies to ensure that discharges to sewers follow the permits, authorizations, orders, and codes of practice issues under the local Source Control program.
Sewer use and drainage Bylaw	**Local Sewer Use Bylaws** outlines the requirements and restrictions for discharge into municipal sewers. Bylaw may include specific regulations for *prohibited wastes, restricted wastes, and high-volume discharges.* Under this bylaw, specific restrictions and requirements can be required of high-risk facilities such as hospitals. For example, hospital pollution prevention plans.

3.1.4 Canadian Management of Endocrine Disruptors

Canada's existing risk assessment criteria and enforcement mechanisms do not explicitly regulate EDs as a chemical class. While *"hormone disrupting substances"* are recognized and defined by CEPA 1999 (Government of Canada, 2021a, p. 26), risk-based assessments enabled through the CMP do not require chemicals to be identified as EDs, nor are the toxicity tests for new substances designed with the standards of evidence and cause-and-effects data specific to EDs (Chemicals Management Plan Science Committee, 2018; Government of Canada, 2017c). Within Canada and around the world, it is debated whether or not EDs merit special attention. Central to this management debate is the applicability of existing risk assessment criteria and if the risks posed by EDs are sufficiently evaluated. Emerging science indicates that EDs differ from conventional contaminants, including similarly complex substances such as carcinogens, and that EDs are not adequately assessed due to the toxicological complexities they pose. First, evaluating the linkages between exposure and adverse health effects is challenging due to the potential for EDs to demonstrate non-monotonic, or non-linear, dose-response relationships. Existing risk assessment criteria evaluate toxicity based on linear models, whereby there is a direct linear relationship between the dose and the effect. Typically, an increased dose or exposure equates to a more severe impact, irrespective of the conditions or timing of exposure. However, this is not the case for some EDs as evidence shows that they may exhibit U-shaped or inverted U-shared response curves complicated by the timing or other conditions of exposure (Burkhardt-Holm, 2010; Diamanti-Kandarakis et al., 2009; Wilkinson et al., 2016). Second, monitoring the health impacts of ED exposure is further complicated as there may be delayed effects or 'latency periods' between exposure and the realized health effects. These adverse effects are typically realized during critical phases of development. For example, exposure to

EDs during fetal development or early childhood development could result in health effects not observed until puberty when reproductive organs develop and the body experiences a flux of hormonal changes (Boxall et al., 2004; Daughton, 2003; Kabir et al., 2015). Although the evidence related to this topic is growing, due to existing uncertainties and testing limitations latent effects are difficult to monitor and evaluate. Third, some studies suggest that that there is a potential for EDs to pose compounding effects due to the possibility of additive and/or synergistic properties (Burkhardt-Holm, 2010; Kabir et al., 2015; Wilkinson et al., 2016). Because exposure to EDs originates from a range of sources at low to ultra-low doses, there is concern that the existing chemical-by-chemical approach taken by the Government does not adequately consider the potential for compounding effects which could result in greater or unknown overall toxicity.

In 2016, CEPA 1999 was reviewed by the SCESD to strengthen the Act. The SCESD review made over 70 recommendations to improve CEPA 1999 and distinguish priorities for research and policy development to inform regulation post-2020. SCESD's recommendations and discussions focused on Part 5, Controlling Toxic Substances, to improve chemicals management (Chemical Management Plan Science Committee, 2018). Arguments in favour of increased management of EDs were highlighted in the recommendations and Part 5 was further critiqued for its narrow definition of *toxic substances* and for creating hurdles to categorizing substances as toxic substances. Table 14 is a summary list of the recommendations regarding EDs (Standing Committee on Environment and Sustainable Development, 2017, pp. 45-80).

Table 14 Summary of SCESD's Recommendations Regarding Endocrine Disruptors from 2017 Report: *Healthy Environment, Healthy Canadians, Healthy Economy: Strengthening the Canadian Environmental Protection Act, 1999.*

The Standing Committee on Environment and Sustainable Development reviewed CEPA, 1999 to make several recommendations to strengthen the Act, including improved chemical management (Standing Committee on Environment and Sustainable Development, 2017, pp. 45-80). SCESD recommended to:

- Amend the definitions of *"toxic"* to address EDs and the definition of *"vulnerable populations"* be added for clarity.
- Address low-dose responses explicitly, emphasizing the hazards substances pose and amending the risk assessments to reflect such hazards.
- Include assessment for synergistic and aggregate effects to account for cumulative impacts, including multiple points of exposure.
- Place the burden on industry producers to provide evidence that substances of very high concern can be used and/or emitted safely by requiring reverse-burden risk assessment.
- Acknowledge, that for some substances, there is no safe exposure limit, specifically for vulnerable populations, marginalized communities, and during critical exposure windows.
- Implement management practices and requirements that specially target EDs.
- Update outdated regulations to reflect best-available science and align regulation to be consistent with other OECD countries.

- Require a *duty to assess alternatives* for existing substances and prepare a national safer alternatives plan.

The Federal Government responded in support of the Standing Committee's comments and recommendations to amend CEPA 1999 terminology, improve assessment requirements, and expand related research programmes. They made many supportive statements such as their response related to cumulative and synergistic effects,

> *The Government supports the intent of this recommendation and will consider it as part of its work to reform CEPA. The Government also commits to reviewing best practices regarding cumulative risk internationally (Government of Canada, 2018b).*

The Government also followed up by requesting scientific support from the CMP Science Committee. The Federal Government established the CMP Science Committee in 2013 to support the delivery of the CMP with scientific expertise and best practice recommendations. The CMP Science Committee was called upon in 2018 to respond to the Government's interest and inquiry into how to best *"evolve the current approach for the identification and assessment of endocrine-disrupting chemicals"* (Chemicals Management Plan Science Committee, 2018, para. 3). The CMP Science Committee advised the Government on research gaps, testing methods, and short-, medium- and long-term goals. Aligned with Canada's evidence-based approach, the CPM Science Committee recommended developing a research program to evaluate the strengths, weaknesses, opportunities, and threats (SWOT) posed by ED-related issues. They claimed the SWOT analysis would improve the understanding and prioritization of ED research, risks assessment, risk communication, and provide structure to evaluate information and existing uncertainties. Specific suggestions were made to improve ED testing methods to capture

synergistic and compounding effects as well as impacts of non-chemical stressors such as physical, genetic, and social interactions which are particularly important for ED management. Current CEPA 1999 and CMP management approaches were criticized for supporting chemical-by-chemical testing and the SCESD proposed inviting

> *[…] an innovative approach to assess EDCs [that] could be designed [to get] closer to evaluating population-wide (including vulnerable populations) cumulative exposures and multigenerational effects under "real-world" exposure to multiple stressors* (Chemicals Management Plan Science Committee, 2018, Charge Question 3, para 3).

According to the CMP Science Committee, chemical management concerns need to extend beyond the cause and effect of single contaminants and provide broad consideration for physical, chemical, and social determinants of health.

In support of existing policy regimes, the Government of Canada also defended existing management mechanisms that allow for a broad interpretation of vocabulary and analyses that capture hormone disrupting effects through existing risk-based assessment requirements. The current CMP risk assessment does not explicitly manage EDs as a unique class of contaminants but rather incorporates their evaluation into existing assessment and reviews including scientific literature and best-practice research, human epidemiological studies, modelling results, and in-vitro or mammalian testing.

The challenge with bundling all chemical assessments together, rather than making ED assessment explicit is that conventional testing regimes are incompatible with the toxicity challenges posed by EDs such as non-monotonic dose-response, latency periods between exposure and health effects, and compounding exposures. Nonetheless, a handful of substances have been identified for their *"hormone disrupting"* effects through existing risk assessment regimes. Substances include:

perfluorooctanoic acid (PFOA) and its salts, polybrominated diphenyl ethers (PBDE), hexabromocyclododecane (HBCD), nonylphenol and its ethoxylates, bisphenol A (BPA), and certain flame retardants (Government of Canada, 2017c).

The exchange between the Government of Canada and the SCESD's recommendations reinforces the complexity of the challenge EDs pose to human health and the environment and acknowledges the need for increased research and heightened management of ED substances.

3.2 Local Government Case Description

This local government has the jurisdictional authority governing local-level decisions regarding the management of solid and liquid waste, drinking /wastewater treatment, infrastructure development, public health services, etc. The government's responsibilities related to wastewater management are detailed in their liquid waste management plan which outlines commitment to sustaining human and environmental health against adverse impacts of liquid waste. Specific responsibilities include control of specific source contaminants, development of marine monitoring program, management of stormwater quality and overflows into the environment, and treatment and disposal of wastewater.

3.2.1 This Local Government's Liquid Waste Management

This local government's wastewater management is comprised of four distinct components 1) pollution prevention source control program initiatives, 2) regulatory bylaws dictating sewer use allowances, 3) end-of-pipe wastewater treatment and 4) marine monitoring program. Below is a summary of each of the components that work together to manage liquid waste. The summaries are based on publicly available information collected from the local sewer discharge by-law, liquid waste management plan, annual reports to Council/ the Board and local government

webpages on sewage and wastewater management. For the sake of anonymity, the sources are not disclosed.

3.2.1.1 Source Control Program

The source control program is a pollution prevention initiative aimed to reduce discharges of pollution into the local sewer system. The goals of the source control program are to protect the receiving environment, sewage facilities and infrastructure, health and safety of the public and government employees, and the quality of sludge and biosolids. The discharge into sewers is covered by the provincial hazardous waste regulation where terms such as *"prohibited waste"* and *"restricted waste"* are defined. The program includes both regulatory and non-regulatory components designed to manage discharges from residential, commercial, industrial, and institutional users. The source control program is regarded as a low-cost management strategy as it reduces the input to the end-of-pipe WWTP systems that can pose treatment challenges, risks to employee health and safety, and/or cause unnecessary stress on existing infrastructure.

The regulatory component of the source control program is enforced through a bylaw specifying conditions and restrictions for discharge to the sewer system. This bylaw applies to all residents and businesses that discharge liquid waste into the sewer system. There are several components of the bylaw including general enforcement policies, waste discharge permits, authorizations, and codes of practice. These regulatory tools allow the local government to govern discharges at various scales. Waste discharge permits moderate discharges of significant volume (greater than 10 cubic meters/ day) or high contaminant loading of specific chemicals. Under a waste discharge permit, the local government can regulate onsite wastewater treatment, liquid waste

quality, and monitoring and reporting requirements. Authorizations are similar to waste discharge permits however they are issued to operations with lower volume and risk to the sewer system and the requirements are generally less onerous. Codes of practice are a set of regulations that apply to specific business sectors where certain practices or discharges are common. The codes of practice regulate approximately a dozen business sectors such as dental, dry cleaning, and laboratories. Each code of practice specifies requirements such as pre-treatment, safety precautions, collection and/or disposal modifications, and/or monitoring and reporting routines. Online resources are also available on this local government's website to help businesses comply with the regulation. This local government provides sector-specific web-based resources to assist businesses to adhere to and comply with specific codes of practice as well as user-friendly guides to help define terminology, such as *"prohibited waste"*, used in the bylaw.

The source control program also includes non-regulatory initiatives such as informative outreach campaigns focused on behaviour change to discourage unsafe or undesirable discharge practices. For example, this local government promotes a pharmaceutical return program targeted at homeowners to reduce the discharge of unused medication. The program includes promotional materials detailing the impact of common discharge practices, reasons for concern, and answers to frequently asked questions, as well as recommended actions that can be taken to prevent unsafe or undesirable discharges. To facilitate the medication return program this local government has partnered with the province-wide program and various pharmacies to facilitate the collection. Web-based educational materials are also published such as informative videos that define source control and explain how individual discharges impact the treatment process and ultimately the environment.

3.2.1.2 End-of-pipe Wastewater Treatment

The local government is responsible for managing wastewater for residential, commercial, industrial, and institutional customers. The community has a centralized wastewater treatment system consisting of four main components: 1. Sewers, 2. Wastewater Treatment, 3. Sewage Outfalls and 4. Residual Treatment Facility (See Figure 1-1).

This local government recently completed upgrades to the treatment process to align with the law introduced in 2012, which requires that all WWTP effluent reach secondary treatment performance standards. The upgrades to the local wastewater treatment system included additional tertiary treatment processing and residuals treatment where biosolids are produced. The project upgrades were completed by the December 2020 deadline in partnership with the local government(s), local First Nations communities, and funding from local, Provincial, and Federal Governments.

3.2.1.3 Marine Monitoring Program

This local government regularly monitors wastewater effluent quality and the receiving marine environments. Their program meets the provincial and federal requirements on levels of oxygen and chlorine, flow rate, and water clarity[2]. The program also includes monitoring practices that exceed their required mandates. The marine monitoring program follows a five-year rotation where different parameters of the treatment system(s) are monitored at different frequencies (See Table 15). The program targets three components of the WWTP outfalls: the wastewater

[2] Provincial requirements include flow, carbonaceous biochemical oxygen demand (CBOD) and total suspended solids (TSS) and Federal requirements include wastewater regulations for CBOD, TSS and total residual chlorine.

effluent, surface water and water column surrounding the outfalls, and the seafloor adjacent to the outfalls.

Included in the marine monitoring program is a list of priority pollutants. According to descriptions detailed in the local government's 2019 marine monitoring annual report, the list of priority pollutants was adapted from the United States Environmental Protection Agency (US EPA) National Recommended Water Quality Criteria and the US EPA's 2002 Priority Pollutant list and is reviewed periodically. For example, the list includes metals, non-phenyls, polycyclic aromatic hydrocarbons (PAH), phthalates, PPCPs, polybrominated diphenyl ethers (PBDE), polychlorinated biphenyls PCBs and per- and polyfluoroalkyl substances (PFAS).

Table 15 Marine Monitoring Components, Parameters and Monitoring Frequency from Canadian Local Government Case Study

Component	Parameter	Monitoring frequency
Wastewater	Flow	Daily
	Compliance monitoring	Federal – Weekly Provincial - Monthly
	Contaminant chemistry • Conventional parameters • Priority substances	• Monthly • Monthly or quarterly
	Toxicity	Acute – Quarterly Chronic – Annually
Surface Water & Water Column	Microbiological indicators	Quarterly
	Contaminant chemistry • Conventional parameters • Metals	
Seafloor	Sediment • Chemistry	Varies. Approximately biannually.

Component	Parameter	Monitoring frequency
	• Toxicity • Bioaccumulation	
	Benthic invertebrate, fish, and mussel assessments • Community structure • Tissue chemistry • Health indices	

3.3 Qualitative Interview Findings

This chapter details the results of the semi-structured interviews I conducted with respondents from the local government. I have chosen to divide my results into the following three sub-sections.

- **Challenges to ED management**: This section presents the challenges my respondents perceived about managing EDs.
- **Management Response**: This section presents each respondent's response to the regulatory scenario including required actions, possible management strategies, and management considerations.
- **Management preferences**: This section presents the comparison between source control and end-of-pipe treatment solutions as perceived by respondents.

3.4 Challenges to ED Management

3.4.1 Jurisdictional Authority

There were three perspectives of jurisdictional authority raised by my respondents, including:

1. Limited jurisdictional authority:
2. Choosing not to supersede federal regulations

3. Requirements to go beyond provincial or federal requirements

3.4.1.1 Limited Jurisdictional Authority

One of the points that clearly came up in the interviews was the barriers posed by the relatively limited jurisdictional authority granted to policy-makers at the local level. By 'jurisdictional authority' I am referring to the division of regulatory powers granted to local governments compared to Provincial or Federal Governments. In response to asking about the challenges of managing EDs, two of the respondents highlighted local governments' limited ability to control sewage discharges. They specified that they are unable to prohibit or ban substances from use or circulation, and rather, can only impose limits to reduce contaminant loading.

According to Monitoring even though the local government is responsible for sewage treatment within their geographical boundary, they are limited to reactive strategies. They stressed that the only regulatory control the local government has is to impose discharge limits with the aim of reducing substances in the effluent, but they are unable to eliminate chemicals from the market.

> *We only have a limited ability to control what that goes into the sewage system. So basically, we are receiving and having to deal with whatever chemicals commercial or industrial, or residential businesses put down the drain. And so, we have little regulatory authority to actually [pause] stop the use of said chemicals. We have some. I'll let [*Source Control] speak to it. We have some ability to try to regulate and reduce what goes in the drain but not stop. We don't have the ability to really ban anything. […] So that makes it hard. We basically have to deal with what we receive. – Monitoring*

Here, Monitoring stressed the limited authority local governments have to ban substances. Their tone made it clear that they felt frustrated by the jurisdictional limitations imposed on the local government.

Jurisdictional authority resurfaced again in the interview with Monitoring when they spoke about ways to address the challenges posed by EDs. Monitoring referenced recent municipal attempts to ban garden pesticides but stated that they experienced mixed results due to their limited ability to restrict retailers. According to Monitoring, the local government is limited to encouraging behaviour change which is not as effective as the Federal Government's powers to restrict retailers from selling certain products or banning specific contaminants.

> *[…] some municipalities have tried to ban, for example, certain garden pesticides and stuff and have had mixed success. We can't tell Home Depot to stop selling. We can encourage homeowners not to use, but we can't stop the stores from selling. That requires largely a federal ban. To say no to pesticide X. – Monitoring*

Here, Monitoring attributed the challenge of managing EDs to the limited jurisdictional authority held by local governments, which prevents them from controlling producers and retailers.

Politician also expressed feeling constrained by the limited jurisdictional authority granted to local governments. In a similar vein as Monitoring, Politician stressed that their jurisdictional authority limited their ability to control the producers. By producers, they referred to companies who utilize and incorporate chemicals in product development. For example, cosmetic companies developing "*shampoo or toothpaste"*. The statements made by Politician made it clear that they felt that for regulations to be effective, they need to prescribe which chemicals are allowed on the Canadian market, which requires Federal action.

> *[…] chemicals are getting into the system from all sorts of places that people just aren't aware. Until you change the producers, so until there are stronger regulations around what is allowed in that bottle of shampoo to toothpaste or whatever, we can source control as much as we can but we as municipal and regional governments do not have control of the*

producers. That is a higher level of government. Which is why we need end-of-pipe treatment. – Politician

Politician expressed that their current source control management efforts were inadequate against EDs because of ED's wide-spread use and the lack of public awareness of its sources. Politician stressed that prohibiting the production of specific substances through product restrictions would be effective, however, they are the responsibilities of *"a higher level of government"*.

Both Monitoring and Politician identified prohibiting or banning substances from the source as an effective strategy, emphasizing that this is the responsibility of the Federal Government and that local governments do not have the authority to control producers or retailers.

3.4.1.2 Choosing Not to Supersede Federal Regulations

When discussing their jurisdictional power in a bit more in detail, it became clear that while it is within their mandate to go beyond what is required by senior governments, this government chooses not to. This was illustrated by this local government's approach to meet and comply with senior government mandates, rather than superseding their superior governments. This section details examples that were highlighted by Monitoring, Source Control and Manager.

In their description of the source control program, Manager clearly laid out that this local government chooses to comply with all requirements of senior government mandates and does not regulate beyond their requirements. For example, they spoke about their source control program in regard to their obligations. Specifically, they emphasized that while their local government carries out inspections of all businesses to monitor that they follow the local codes of practice and that they also set contaminant reduction targets for specific contaminants, but they do not manage EDs because they are not required to do so.

> *No, we don't monitor for that [EDs] because we do not regulate that. We are not obligated to do that by [pause] the province. So, we do not have requirements under the discharge.*
>
> *[…] in terms of medications, emerging contaminants of concern, that's an area we may do some monitoring, but we are not regulated, and we are not regulating our industry. – Manager.*

Source Control echoed this view by explaining that they are in an administrative role where they must supply local services in a way that achieves senior government standards by translating provincial requirements into local bylaws.

> *"the way we regulate is we take the guidelines or limits that are set out by senior government and essentially put those into our bylaw." –Source Control*

In their explanation of challenges posed by EDs, they went on to say that it would be rare to impose limits that supersede senior governments, *"[…] it is very rare that we would set limits for things that we don't have that senior-level direction."* Although they stated that it would be possible in some instances, they could not recall any specific instance and grounded their position in their service delivery requirements.

> *So, we had this talk here about service delivery. We have a set of services that we are essentially delivering for the local governments. So, with the service delivery lens, we would not set that limit unless we had a very good reason to. – Source Control*

Aligned with the preceding perspectives, Monitoring also replied with reference to complying with *"senior government mandates"*. In response to the regulatory scenario, Monitoring explained that local governments do not have the mandate to perform the necessary tests to advance their understanding. They explained that a Toxicity Identification Evaluation (TIE) could be used to

evaluate the cause and effect of specific substances, but that local governments in the province are not currently *"mandated"* to perform those types of tests. From Monitoring's perspective, it was implicitly understood that they would not undertake certain actions without a mandate from the Provincial or Federal Government.

> *We really only have the mandate to assess compliance with our discharge regulations or the ability to characterize impacts in our monitoring, because sewage outfalls have a whole raft of chemicals in them. We have very little ability to attribute any effects we see in the receiving environment to a particular type of compound. We can only correlate or infer. So, for example, the compounds we see most readily in salmon surrounding the outfalls are metals and PAHs. So, because those are found in the highest concentrations, we can only infer that those are likely the ones that are having the greatest impact. But we don't the ability to do the research to definitively say that those (the metals and PAHs occurring in the highest concentrations) are the sole and only impact. – Monitoring*

> *You can do things like TIE type tests. Toxicity Identification Evaluation that's what it stands for. Where you take a whole effluent and then they start eliminating bits to try and figure what compounds are actually having the effects. […] But again, that's more academic. […] We don't have that true mandate, unless the province were to say you have to do a TIE test once a year. We can just say, okay here's our concentrations, here's the impacts we see in the environment. – Monitoring*

As illustrated in the quotations above, Monitoring stressed that they do not have the mandate to perform this academic-type research to determine causation. Their response implies that they feel restricted by the lack of resources to employ further testing.

Monitoring's use of the term *"mandate"* is misleading, and, from a formal point of view, it is incorrect. While it is true that Provincial and Federal Governments can mandate local governments to perform certain actions or comply with certain thresholds, the absence of a mandate does not mean that a local government is prohibited from taking action. It is clear from

Monitoring's use of *"not having a mandate"* that they understand and utilize the concept of 'not being obliged to' as synonymous with 'not being allowed to'.

Each of these respondents illustrated that this local government's programs are created to comply with their senior government demands. Although there are no explicit rules against exceeding senior government requirements the respondents were in agreement that this local government generally chooses to not go beyond regulatory requirements, even though in theory they are permitted to do so.

3.4.1.3 Requirements to Go Beyond Provincial or Federal Requirements

A closely related aspect of jurisdictional authority that was raised by my respondents was the requirements and conditions needed for them to exceed senior government requirements. Source Control explained that the local government could choose to enforce regulation that supersedes Provincial or Federal Government, however, it is *"very rare"*. According to Source Control, a decision to exceed Provincial or Federal Government regulatory requirements would need to be supported by strong scientific evidence and be aligned with their service delivery responsibilities. However, the only example any of my interviewees mentioned were standards to protect infrastructure or to provide a safety buffer.

> *Source Control: With the service delivery lens, we would not set that limit* [targeting endocrine disruptors] *unless we had a very good reason to.*
>
> *Interviewer: Right. Okay. And that reason would come from?*
>
> *Source Control: It would be very likely scientifically driven. There would be some sort of effect noted in the environment, there would be research to determine what the cause of that effect was and then the science could lead to a precautionary level. [pause] This is all theoretical, but we could choose to be slightly ahead of the provincial regulation on*

something if there was very strong science to lead us down that route. I can't think of, for this program, when that has happened.

Here, Source Control affirmed their understanding of the autonomy local governments have to design proactive policy. They identified the central challenge to be a question of the evidence needed to persuade the local government to go beyond the requirements set at the provincial or federal level. This was illustrated by comparing EDs to conventional contaminants, such as mercury or copper. Source Control explained that while thresholds for mercury and copper are supported by considerable amounts of scientific evidence there is not the same level of confidence in the information available about emerging contaminants, such as EDs.

We have federal and provincial guidelines we have to meet. But when you start getting into these compounds that are more emerging science, it's very difficult to know [pause] without senior government direction [pause] when is the turning point to start setting limits and reacting. – Source Control

Source Control is clear that scientific evidence and the local government's service delivery requirements are two factors central to the local government's decision to exceed senior governments' mandates. In reflection of their decision-making priorities, Source Control draws attention to the tension between science and policy in the form of a question,

The science is getting better. The effects of these compounds are better understood, and they are detectable. [pause] And so, the question is when will they [EDs] reach the point when we should consider regulating them? – Source Control

In summary, jurisdictional authority was discussed by my respondents in three perspectives. First, respondents highlighted the limitations of their authority and detailed that local

governments lack control over producers, which was described as a limitation to their ability to control EDs. Second, several respondents detailed that the local government is resistant to voluntarily setting stricter limits than what is required by senior governments and that they generally meet but do not go beyond what is mandated. Lastly, Source Control explained that while local governments do have the authority to design policies that supersede the requirements set by senior governments, it is rare that they do so and that such actions would need to align with their *"service delivery"* priorities and be accompanied with strong scientific evidence.

3.4.2 Chemical Complexity

The physical properties and the chemical complexity of EDs as a group was another area that came up in the interviews. According to my respondents, the complexities distinguish this class of contaminant from conventional contaminants, such as bacteria or heavy metals. My respondents identified EDs as challenging for the following reasons:

1) wide-spread use and disposal from every-day products
2) commonly present at trace levels close to or at instrumental detection limits
3) difficulties to link exposures to cause and effect data
4) changes to the chemical structure as a result of reactions during treatment and regular consumption or use.

Respondents expressed a high level of awareness and concern for how the complexities impacted local management decisions. These challenges have been summarized into three sub-sections: sources of pollution, technological limitations, and public communication.

3.4.2.1 Sources of Pollution

Source(s) of pollution was a challenge that surfaced in three interviews. Manager articulated that EDs are challenging from multiple perspectives and emphasized chemicals' widespread use in consumer products, monitoring complications due to low detection limits, and underlying uncertainties.

> *Well, they [EDs] are challenging from a number of different perspectives. They are challenging to monitor for, they are ubiquitous, we can detect them at very low levels and the research is in its infancy in terms of what the impacts are of EDs in the environment. – Manager*

As mentioned earlier, they used heavy metals as a point of comparison to illustrate the importance of access to data. Manager explained that while they have well-defined practices for heavy metals that are supported by extensive evidence the same amount of data does not exist for EDs. In addition, for heavy metals, it is well documented how specific industries respond to source control efforts, for example, regulatory efforts to control mercury discharges from dentistry practices. Again, the local government does not have the same knowledge of EDs.

> *Whereas ED, if they are in by-products of medications. [pause] You know if they are in everything. We can't regulate you and your birth control because we are concerned, we might see some of those impacts in the receiving environment. And they [EDs] are just so much more difficult for us to put a bylaw around, and they are more difficult to monitor for and more difficult for us to say what are the impacts are because we can detect them at such low, low levels. – Manager*

Monitoring also commented on the ubiquity of EDs. To illustrate their perspective, they explained that emerging contaminants such as PCBs and pharmaceuticals enter the waste streams from a variety of sources such as human excreta, improper discharge to sewers, and leachate from landfills. They specified that this was, in part, because of limited public awareness and the local government's perceived lack of authority to control these types of substances.

> *Some [compounds] are really easy [to locate the contaminant source] but many are not. If we were to say pharmaceuticals in wastewater, they come from everywhere. They come from people just excreting them, they come from people pouring them down the drain, which they aren't supposed to do. They come from, in theory, landfill leachate from whatever people put in the garbage. – Monitoring*

In response to the scenario, Source Control also spoke to the sources of pollution. They stated that setting source control limits can be a challenge because of the combined waste stream. They continued to explain that in order to comply with threshold-based regulations they do not enforce the absolute value on each household, but rather, ensure the average of each catchment is compliant. For example,

> *[…] if the limit [Federal] at the effluent is one nanogram per litre, random number, that doesn't mean that every household has to be regulated at that same number. Could be one hundred nanograms per litre at the household level and all these other waste streams that don't contain that brings down the average. – Source Control*

Source Control summarized this point stating admittedly that, *"we don't like to promote dilution is the solution to pollution argument but it's, it's also something that we can't avoid."* Source Control also stated that their source control program is designed to grant exceptions to businesses that cannot meet the thresholds established in the Sewer Use By-law. Through their permitting system, they

"will permit an exception to say, 1.5X the limit but then that puts the onus on us to make sure that everyone else stays good and not creating a problem." They finished their comment by stating that the same logic would apply to newly regulated compounds.

3.4.2.2 Technological Limitations: Monitoring and Treatment

In Monitoring's perspective, managing EDs at the local level is a challenge because they are present at trace levels, and wastewater technologies were not originally designed to manage these types of substances. In response to the question about the management challenges, the second point Monitoring mentioned was the limit of their technological capacity.

> *[…] the other piece is that wastewater treatment, at least conventional wastewater treatment, wasn't necessarily designed to reduce or eliminate these compounds. They were used to eliminate the large organic loading part of wastewater. Which as a benefit reduces or eliminates many of the emerging compounds but not all. […] So, we are faced with technologies that weren't designed to deal with things at trace level. – Monitoring*

Aligned with Manager's comparison of EDs to heavy metals, Monitoring also compared ED detection levels and treatment capacity to conventional contaminants. Monitoring stated that, aside from bacteria and heavy metals, the contaminants measured at the outfalls are not always detectable. *"the biggest signal we could see were metals, because most of the other contaminants are at really low level and bounce around being detect and non-detect. – Monitoring.* It was clear that Monitoring perceived the local wastewater treatment plants as inadequate to fully eliminate EDs and in their response implies that upgrades to the management approach are required in order to target ED contaminants.

In addition to the trace level presence, Monitoring also explained that EDs are challenging because they behave differently than conventional contaminants. They specified that EDs are susceptible to chemical changes that can occur during metabolic and treatment processing. Monitoring explained that the chemical reactions that occur during these processes often transform the original parent compound into new substances that are not measured by current monitoring practices.

> *One limitation with contaminant monitoring is that you often monitor the parent compounds. If you look at some drugs, [pause] our bodies, when we metabolize certain drugs, we add on, [pause] for example, one is called glucuronidic bond. That bond helps our bodies excrete the compound. The treatment plant can break that bond and can actually increase the concentration relative to the influent of that compound because it is no longer bound to the glucuronidic. […] The treatment plant can partition things, can change metabolites but we would never see that because our influent might be low because we are assessing the parent compound, but not looking for the glucuronidic equivalent. Whereas what's going out the outfall might actually be higher because the glucuronidic has been broken. So, treatment can do many things to different compounds. – Monitoring*

According to Monitoring description, chemical and biological reactions that can occur during treatment and metabolic processing can cause ED concentrations to increase yet go undetected. The respondent made it clear that EDs present complications for measuring and monitoring as the local government's equipment is not sufficiently advanced to assess different variations of contaminants.

3.4.2.3 Communication with the Public, Business Owners and Decision-Makers

Another dimension of ED's chemical complexity noted by my respondents was communication with the public, business owners, and decision-makers. According to Manager, communicating

complicated science would be a challenge due to the public and business owner's general lack of awareness about toxicology and chemical contaminants. In reflection of past community engagement experiences, they felt that engaging local audiences would require clear and concise messaging, which would be a challenge. They stressed that developing and delivering complicated content would require significant effort from government staff.

> *It's a whole world where you've got people that would have absolutely no idea what you're talking about. They wouldn't know where those contaminants were generated from, they wouldn't know a lot about what their impacts would be on the environment and there would be a lot that would have to go into, for a local government, into explaining that. – Manager*

> *[It takes] key messages, simplified videos all sorts of things to connect the dots, so that, generators would even understand what the impact was going be. I think it'd be a difficult thing to do because we're getting into the realm of some pretty obscure science for a lot of people. – Manager*

Manager's tone regarding educational efforts conveyed resistance and doubt in the effectiveness of communicating ED science. They completed their thought by comparing the education of EDs to conventional contaminants. They claimed that the business owners and the public know about heavy metals, high strength wastes, and other conventional pollutants but that EDs are *"a little more difficult to wrap your head around".*

In addition to communicating with business owners and the public, Manager, and Politician's comments regarding the relationship between decision-makers and staff also highlighted the value of communicating scientific complexities with decision-makers. The decision-makers dependence on staff reports was made clear by Manager and Politician who are both involved in the submission and review of staff reports to inform decisions.

In detailing the current management strategies used by the local government, Politician mentioned the exchange of information between decision-makers and department staff. They specified that they receive annual reports for their marine monitoring program and that it is their *"responsibility to look at: are there emerging substances or changes that need to be made?"* Politician explained that Council/ the Board relies on staff reports and if the information is deemed insufficient, they may repeatedly request more information and scientific advice. Politician reiterated that they feel it is important to be well informed about issues.

> *Well, the challenge for policy-makers is always to ensure that we are well informed and so, for me as a policy-maker and politician I want to make sure that I have seen and heard all sides of a recommendation and all bits of information. I think that's really important. We as policy-makers must do those deep dives and question. Our role is to question. Because, otherwise, you know, a rubber stamp is not what the world needs. But recognizing that we aren't the experts either is the challenge too. –Politician*

In both examples, Politician highlighted the importance of communication with decision-makers and that the information they receive can have a direct impact on decision outcomes.

Manager further specified that, as local government staff, they update Council/ the Board on changes to the source control program through annual reports and Q/A discussions. They specified that communication with Council/ the Board about changes to specific management strategies, such as adjustments to their plan required for particular contaminants, is generally kept at a high level. They stated that *"the Council/ the Board approves a very broad-based work plan and budget for the programming. They are concerned with regulatory compliance. They rely on staff to execute that."* Manager affirmed that they have a role in providing information to staff and

stressed that technical details are typically deferred to staff as Council/ the Board is *"a policy Council/ Board that is working at a very high level"*

In all stages of the policymaking process, Manager and Politician both highlight the importance of communication and that the complicated science must be communicated clearly.

3.4.3 Knowledge Gaps

As was illustrated in the sections above, my interviewees identified knowledge gaps in ED science as a challenge. My respondents presented a unified perspective that science needs to inform decisions and that there are existing knowledge gaps in the field that prevent management interventions. Examples of existing knowledge gaps were detailed by three respondents. Manager stated that EDs pose management challenges because the science is an *"emerging field",* the chemicals are *"ubiquitous"* and detectable at *"very low levels",* and the research is *"in its infancy".* Monitoring specified there is a lack of research on the effects of exposure, inconclusive information on safe rates of exposure as well knowledge gaps on possible end-of-pipe treatment technologies to address EDs. Source Control spoke of the improvements analytical science made over the past few decades and advancements made to increase detectability but highlighted the on-going absence of regulations.

Monitoring also highlighted their limited ability to address outstanding knowledge gaps, due to the lack of resources in combination with the lack of a specific requirement to conduct the research required to understand the implications of the data they are collecting.

> *[…] what our challenge is, that we can measure all these at high level and at high costs but for most of the compounds on the emerging substance list there's not really strong direct effects research to say that this level will cause this effect. And so, we don't have the mandate or the resources to do that kind of research. So basically, our data would feed into any*

> *academic or research institution that assesses the facts and then then we can say that our level of triclosan is above the level that would hurt a frog in the lab or something like that. – Monitoring*

According to Monitoring, knowledge gaps are addressed by research institutions, both academic and governmental. They detailed that the current role of local governments is to contribute monitoring samples and to record data to be used and analysed by researchers, but that they are not directly involved in the research projects. Consequently, local governments rely on research institutions to provide scientific guidance for their management decisions.

> *So, how I perceive what we are doing [pause] So all the contaminant monitoring we do largely gets incorporated into other research either by the Federal or Provincial Government or other academics and they look at that and say what we can do to reduce contaminants. – Monitoring*

Monitoring exemplified the types of research institutions that are responsible for advancing research whose work is funded by the Federal of Provincial Government to target specific research topics:

> *[…] there are a few agencies that do work on behalf of the Provincial and Federal Governments. So, like the Canadian Council of Ministries and Environment, and the CWWA, the Canadian Water and Waste Association. They both do a bunch of research [pause] of water and environment research variations. – Monitoring*

Monitoring clarified that they need the help of external researchers to interpret the relationship between their data and the environmental impacts, and without this support, there is a larger risk of inferring misleading correlations.

> *we have very little ability to attribute any effects we see in the receiving environment to a particular type of compound. We can only correlate or infer. – Monitoring*

However, Monitoring expressed concerns regarding what they perceived as a disconnect between the local level and institutionalized research. From their perspective, it is not clear how a local government might become involved in such studies or how they would benefit from participating.

> *It's not always obvious how you get into those programs, and, whether we would actually benefit from those programs is to be determined. Really, it would be contributing samples to a larger database or sort of characterize what is triclosan look like across the country. [pause] But it truly does rely on more academic studies to say well okay, what is the impact of that triclosan. – Monitoring*

Although Monitoring was aware of some existing partnerships between senior governments and research institutions, they made it clear that there is a disconnect between sampling and management teams, local government priorities, and external research institutions.

3.4.4 Risk Management

Another challenge raised by my respondents was risk management. Specifically, Politician defined challenges in terms of risk management. According to their understanding these substances can cause harm to the receiving environment, and their role, as a local decision-maker, is to collect information and evaluate the risk and determine a *"tolerable risk"*.

> *What I understand is that these are chemicals that can create challenges to the receiving environment, which is in our case the ocean and the life within the [*removed body of water]. So, in wanting to minimize any stressors on the receiving environment we have to look at*

> *what is the risk, what is a tolerable risk, and how is the effect based on the dilution factor. – Politician*

As a follow-up question, I prompted Politician to clarify how they defined *"tolerable risk"* by asking them to elaborate on the type of information they need to made decisions on what is tolerable. *"In your role, how much information do you get, and need to get in order to make those decisions and advise on what level, like you said, is tolerable?"* Politician explained that the information and research from staff are based on a triple-bottom-line giving weight to environmental effects, social benefits, and economic costs.

> *The information we get from staff will be based on triple bottom line. What is the effect on the environment, what is the social benefit, cost-benefit analysis, and what is the economic cost? […] So, it's up to the committee to request further information if it's feeling it doesn't have enough to make a decision, and sometimes the information is sufficient and sometimes we would request further information. – Politician*

Complementary to Politician's definition of "*tolerable risk",* Source Control also mentioned risk management in response to the source control program. In an explanation of the program components, they detailed various exceptions they have accommodated for where "*the overall risk of [these] small volumes to the sewage treatment system and the environment is small, if not negligible"* Examples included small volumes of biomedical waste and low yields of regulated substances that they felt overburdened local businesses. To follow up, I expressed interest in how the local government thinks about risk and asked if the definition of risk was discussed. Their response revealed that they view risk as related to multiple *"streams"* and that they prioritize 1) the environment, 2) the infrastructure, and 3) public and worker safety.

> *This program has multiple layers of, actually, they aren't even layers, they are just multiple streams of risk. We are really interested in protecting three things. One is the environment, second is the infrastructure, and third is public and worker safety. So, things that are environmental risk are quite often different than the things that are risks to the infrastructure. – Source Control*

It is clear from Source Control that different parts of liquid waste management subject different risks to different populations. It is clear that they are managing competing priorities when they state*, "we are always balancing those three risks"* in reference to the environment, the infrastructure, and public and worker safety.

3.4.5 Summary

This section illustrated the challenges perceived by my respondents. It is important to recall that this case study research presents the perspective of an *extreme* and *critical* case, one with a history of political interest in liquid waste management negotiations. The understandings and perspectives presented by my respondents do not summarize *all* challenges experienced by local governments. However, this case does identify important perspectives on the challenges that apply to other local governments with similar or fewer resources and/or experience with liquid waste management.

In summary, the problems EDs pose to the community government are characterized by:

a) limited jurisdictional authority to control sewage discharge and the local government's decision to meet their regulatory obligations
b) complexities of ED chemistry that cause complications to a) the technical capacity to monitor and treat EDs and b) communication with the public, business owners and decision-makers

c) persistent knowledge gaps that limit their ability to make informed decisions

d) competing priorities that impact risk management

3.5 Management Strategies in Relation to Future Regulatory Scenarios

The future scenario was designed to learn how the respondents perceived local management of endocrine disruptors. I prompted each respondent to imagine that the Federal government had introduced a new decree *"limiting the release of an ED, for example triclosan or nonylphenols."* After framing the scenario, I specifically asked the respondents, *"What would happen here in the [*name of local government removed]. What would you or the local government response be?"* The question allowed each respondent to interpret how the Federal government would introduce regulation and provide their perspective on how the local government would respond to such decree. Below is a summary of each respondent's response to the regulatory scenario.

3.5.1 Monitoring

Monitoring's perspective is that of a senior-level scientist with over a decade of experience as a monitoring program supervisor. They are responsible for overseeing the marine monitoring program and conveying results to managers and policymakers to inform decisions. Their position and experience with the marine monitoring program and liquid waste management team situates them as someone with considerable insight into the program implementation and operation.

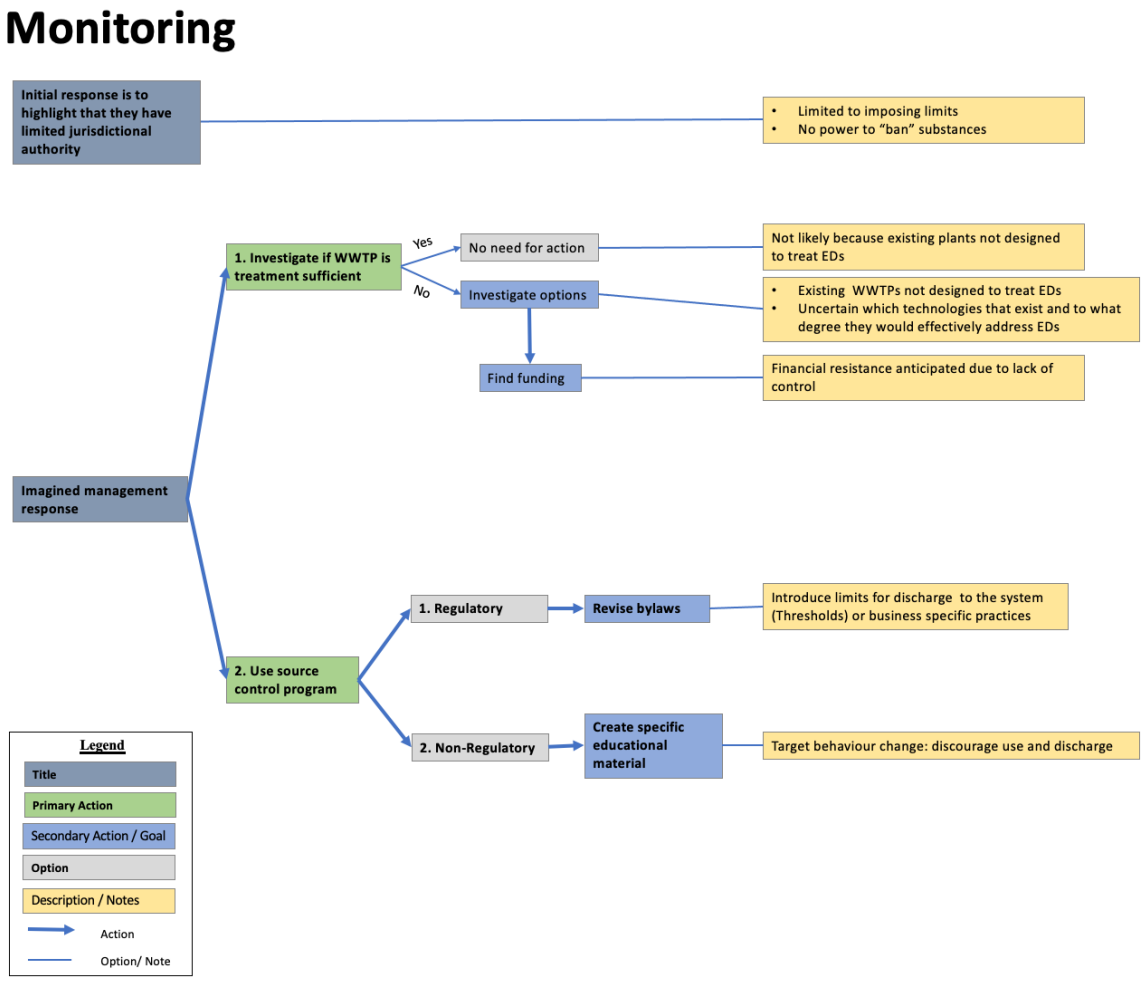

Figure 3-3 Monitoring's response to the regulatory scenario

Figure 3-3 illustrates the key points of Monitoring's response to the regulatory scenario. Respondents were asked to respond to a regulatory scenario where the Federal Government introduced a decree regulating the release of EDs. Monitoring's initial response was to highlight the local government's limited jurisdictional authority and the relative disadvantage of local governments due to their inability to control producers. Second, they highlighted two available strategies 1) End-of-Pipe WWTPs and 2) Source Control. They specified that existing treatment plants were not designed to treat EDs and if such regulations were introduced it would be a challenge to determine the required technologies to effectively address EDs. Monitoring also outlined the source control program components: 1) educational behaviour change initiatives and 2) regulatory limits.

Monitoring's initial response to the regulatory scenario was to highlight the challenges they expected the local government would face due to their limited jurisdictional authority (Figure 3-3). According to Monitoring, the local government lacks the ability to control the discharge of substances because they do not have the authority to *"ban"* substances. Rather, their role is *"imposing limits".* Monitoring voiced frustration that they are required to manage substance which they have no control over. According to Monitoring, the Federal Government has the greatest control over discharges leaving local governments unable to respond effectively. Several times in the interview, Monitoring returned to this point.

> *PCBs are the ones benefiting from treatment, in that they get reduced and removed with the solids portion of treatment. But they are still there, right. So, while there may be a ban at a higher level, the ability for us to control is really quite limited for some of these compounds. – Monitoring*

In essence, Monitoring conveyed that local governments are largely unprepared to address EDs. This point became clear when they illustrated the regulatory scenario with an explicit example concerning existing provincial water quality guidelines for ethinylestradiol. According to Monitoring, if existing guidelines, such as the limit on ethinylestradiol, became an enforceable law then compliance would be a challenge as they lack control over the substance and are unaware of effective technological solutions.

> *If the Fed government regulated to that level, to 0.2 mg / L or whatever it is of ethinylestradiol, if we have no ability to control that compound, we would either achieve that objective in the wastewater just by nature of how the treatment plant works. If we didn't, the challenge would be whether they would enforce that against the [*removed name of local jurisdiction]. If they did, who knows what other treatment technologies would need to be added on to the plant to reduce ethinylestradiol. – Monitoring*

Although not explicit, Monitoring alluded to the local government's unpreparedness. It was clear from the uncertainty in their response that EDs present an unprecedented challenge and local governments do not have ready-made solutions.

Monitoring also conveyed a sense of unfairness toward local governments due to the financial burden forced by such mandates. They hypothesized that if the local government was required to manage substance(s) they lack control over, such as ethinylestradiol, there would be financial resistance to fund such initiatives. They further emphasized a sense of unfairness when they expressed skepticism toward the availability of Senior Government grants.

Monitoring listed two action-pathways that they believed would comprise the local government's management response: review and revision of their 1. end-of-pipe treatment system and 2. their source control program. (See Figure 3-3). For the first action-pathway, they stated that EDs would pose a challenge because WWTPs are not designed to treat these substances. In the event that the Federal government was to hold local governments accountable, Monitoring believed it would pose a challenge due to technology restraints. This included voicing concerns and uncertainty about which technologies would be viable to address ED compounds. In light of planned upgrades to the treatment plant and new residuals facility, Monitoring stated that they would now also need to consider contaminant concentrations in both liquid effluent and the sewage sludge residuals and biosolids (See Figure 3-7).

For the second action-pathway, Monitoring detailed two types of source control initiatives (See Figure 3-3): regulatory and non-regulatory. They specified that the source control team would design a *"two-pronged"* approach with a focus on educational material discouraging the use and/or disposal of products containing the contaminant. Monitoring also briefly mentioned the regulatory component of the source control program. They outlined the regulatory approach

included public and business-specific requirements that set specific discharge limits, encouraged best practices, and monitored specific industry discharges. Monitoring continued to explain that the enforceable discharge limits were reviewed regularly for improvements.

3.5.2 Source Control

Source Control has over 18 years' experience with the local government and provides the perspective of a senior-level environmental science officer and supervisor of the source control program. In their position, they are involved in the development, delivery, and management of the source control program and receive direction from department managers and Council/ the Board as well as transfer knowledge when communicating with policy-makers, the public, and other jurisdictions.

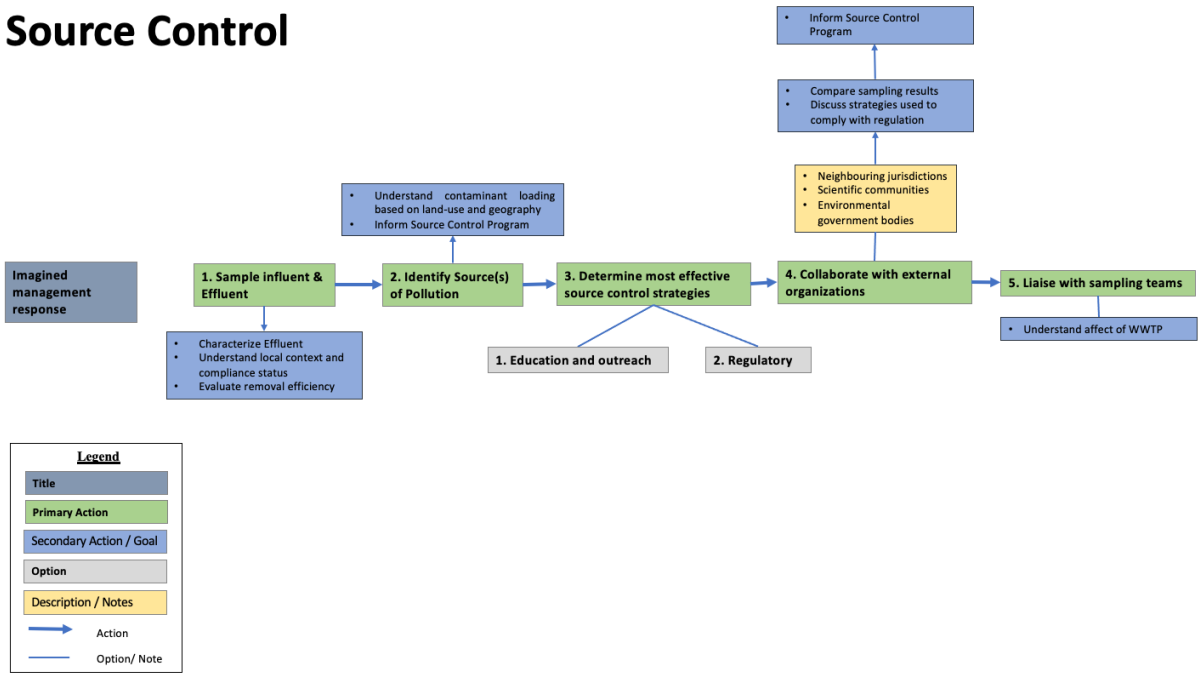

Figure 3-4 Source Control's Response to the Regulatory Scenario.

Figure 3-4 illustrates the key points of Source Control's response to the regulatory scenario. Respondents were asked to respond to a regulatory scenario where the Federal Government introduced a decree regulating the release of EDs. Source Control's initial response was a sequential list of actions including 1. Sample influent & effluent, 2. Identify source(s) of pollution, 3. Determine most effective source control strategies, 4. Collaborate with neighbouring jurisdictions, scientific communities, and environmental government bodies, and 5. Liaise with sampling teams. Source Control outlined two source control approaches: regulatory and non-regulatory.

Source Control responded to the scenario with a list of sequential actions that would help to inform the management decision. (See Figure 3-4). First, Source Control outlined that they would sample the influent to the WWTP, and effluent discharged to the environment. They explained that the intent would be to characterize the wastewater to understand if the regulated compound(s) are present in their wastewater and determine whether the present levels are compliant with the regulation. They explained that sampling the influents and effluents would also reveal the removal efficiency of the wastewater treatment plant technologies.

As illustrated in Figure 3-4, the next action Source Control described was to identify the sources of pollution (See Figure 3-4). They described *"key manhole sampling"*, which is a technique they use to locate sources of pollution. By collecting and analyzing samples from key areas of the city in combination with land-use and geography, this approach allows them to get a picture of the contaminant loading. For example, four times a year they collect samples from areas such as residential, downtown businesses, and light industrial. Source Control explained that this system makes it possible to track the source of a specific contaminant, which will help inform their source control program initiatives.

The third action Source Control detailed was that they would determine the most effective source control strategies. (See Figure 3-4). They explained their source control program has two components, 1) education and outreach and 2) regulation. According to Source Control, their

management approach would be aligned with their findings of the manhole analysis to target the source of pollution. For example, they would tailor education materials specifically for residential homeowners or create and enforce business-specific regulations to target the source of pollution.

During the interview, Source Control detailed each of these program components. They explained that non-regulatory programs consisted of *"educational campaigns"* specific for various business sectors and the broad public. These are administered through multiple techniques including social media, print, and in-person events. According to Source Control, these campaigns provide an opportunity for the local government to *"encourage behaviour change and reduce contaminant loads when we don't have regulation".* They also mentioned initiatives such as the provincial *"residential medication return program"* that they promote as additional pollution prevention measures.

According to Source Control, the regulatory program is a prescriptive approach that sets and enforces limits on acceptable discharges. They detailed that they enforce general sewer use discharge policies as well as codes of practice designed for specific businesses. Examples of business-sectors with codes of practice are automotive services and print shops. Source Control detailed that these business-specific requirements range from letters of agreement to detailed permits based on risks posed to the environment.

Once the source of pollution is known and the most effective strategy selected, Source Control stated the next action would be to collaborate with external organizations. Partners included neighbouring jurisdictions, scientific communities, and environmental government bodies around the world. (See Figure 3-4). They specified they would compare data and discuss the strategies different jurisdictions are using to comply with the required thresholds and respond to the

regulation. According to Source Control, these conversations would help to inform the regulatory limits enforced through the source control program.

Continuing their response to the scenario, Source Control stated that they would also liaise with the sampling teams. They explained that working *"hand-in-hand"* with the operators would allow them to *"look at the inputs and outputs of the treatment plant and see how the treatment plant removal is affecting things".*

Throughout Source Control's response to the scenario, they also discussed management conditions that influenced their perspective (See Figure 3-7). First, when describing the regulatory initiatives, Source Control highlighted that they would be designed to support reasonable and achievable limits and requirements. There were two distinct aspects of this detailed: 1. Accommodating the regional variation amongst WWTP infrastructure and 2. Accounting for the local context. The first consideration they mentioned was for the variation among WWTP infrastructure within their service area. Source Control noted that there is technical variation among the community's wastewater treatment plants due to differences in age, size, and equipment. According to Source Control, the local government would only support a regulatory response that applied universally across their jurisdiction rather than site-specific requirements. They explained that existing systems would be assessed to understand the best and worst-case scenarios, but ultimately decisions would be protective of all infrastructure. Source Control reiterated this point again towards the end of their response.

The second regulatory consideration Source Control detailed was for the businesses and industries that make-up the local context. They explained that they do not translate the Federal threshold limits directly into local policy but rather set their discharge limits with respect to the local context including total volume of expected waste and catchment-based considerations.

According to Source Control, they "*don't like to promote dilution is the solution to pollution"* but explained that it is something they cannot avoid because it brings down the average.

> *If the limit at the effluent is one nanogram per liter, random number, that doesn't mean that every household has to be regulated at that same number. Could be 100 nanograms/ L at the household level and all these other waste streams that don't contain that brings down the average. We don't like to promote the dilution is the solution to pollution argument but it's something that we can't avoid. – Source Control*

They also explained the regulatory program's design allowed for flexibility and accommodation for individual businesses unable to meet certain thresholds. Source Control explained that if a business was struggling to meet their discharge requirements because of difficult materials then the local government can grant an exception, for example, 1.5X the threshold limit. Source Control highlighted that in these cases the local government takes responsibility for monitoring compliance. *"but then that puts the onus is on us to make sure that everyone else stays good and not creating a problem".* It was clear from Source Control's perspective that as long as the ultimate effluent concentrations were compliant with senior government mandates, the flexibility of the program benefited the community at large.

Finally, Source Control described their management approach as *"reactive".* They explained that they are responsible for doing what is necessary to comply with Federal or Provincial Government mandates. According to Source Control, the local government is obedient to requests from the Provincial or Federal Governments and that their response is reflective of their jurisdictional hierarchy.

> *[…] because we are a regulatory program, when it comes to that [interaction with Federal Government] we are more reactive. If the senior government [Provincial or Federal*

Government] is bringing in something new it's unlikely we are going to argue with it. – Source Control

3.5.3 Manager

Manager's perspective is that of the General Manager of the environmental department. They have considerable knowledge of local government operations as they have worked in related positions within the local government for 18 years. They have been involved with local wastewater management from both the end-of-pipe and source control perspectives and are in a position of authority to develop, deliver and manage the local government's management response.

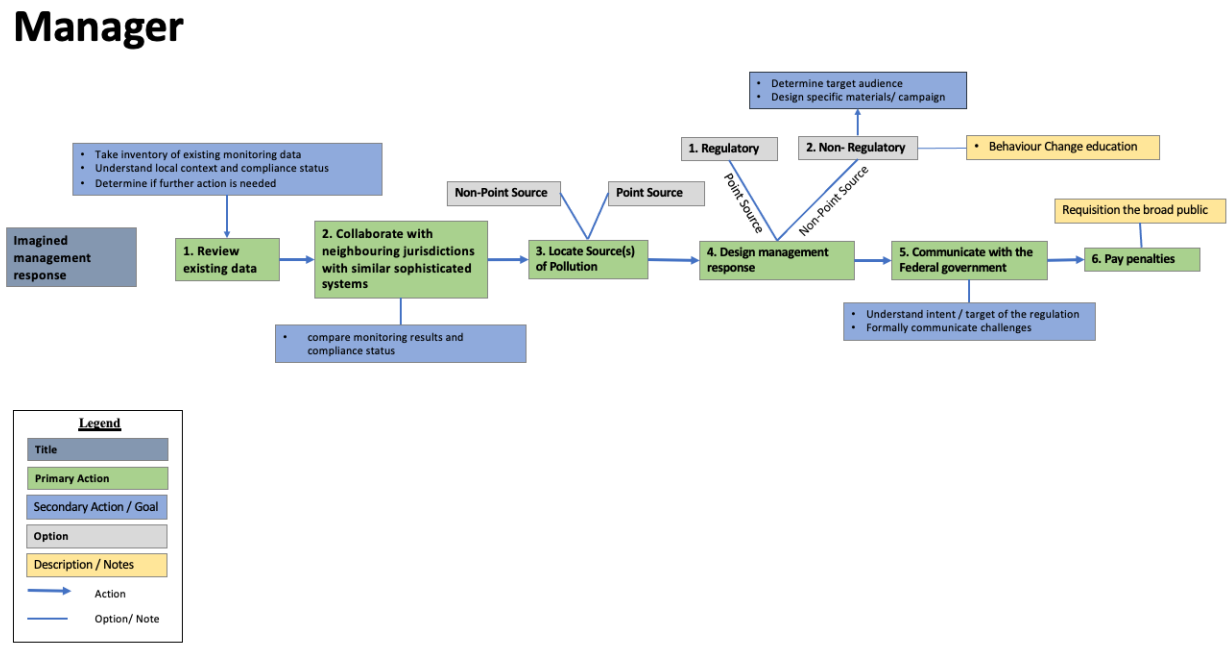

Figure 3-5 Manager's Response to the Regulatory Scenario

Figure 3-5 illustrates the key points of Manager's response to the regulatory scenario. Respondents were asked to respond to a regulatory scenario where the Federal Government introduced a decree regulating the release of EDs. Manager's initial response was a sequential list of actions including 1. Review existing data, 2. Collaborate with neighbouring jurisdictions with similar sophisticated systems, 3. Locate

sources of pollution, 4. Design management response, 5. Communicate with the Federal Government, 6. Pay penalties. According to Manager, locating the source of pollution is important as the management strategy will differ depending on if it originates from a point or non-point source.

Manager listed several sequential actions that they believed would take place and help to inform the management decision. (See Figure 3-5). First, Manager stated that there would be an internal review of existing data. According to Manager, the intention of this review would be to take inventory of the information they have and understand whether their current monitoring efforts are relevant to the new decree. Based on the data available, they could determine whether further action is required.

> *If there was going to be a limit for that [pause] we would want to see if we have any data because sometimes, we do some extra sampling to help master's students. – Manager*

Following a review of existing data, Manager detailed that they would collaborate with neighbouring jurisdictions that have marine monitoring programs at a similar level of sophistication as they do. (See Figure 3-5). They would reach out to compare monitoring results and compliance status.

The third action Manager described was locating the sources of pollution through a *"comprehensive study".* (See Figure 3-5). According to Manager, this was important because their management strategy would differ depending on whether the contaminant originated from point or non-point sources.

> *We'd want to do a pretty comprehensive study to figure out where this particular contaminant is going to be coming from. Is it going to be coming from a source that we can regulate or is it going to be coming from a source that we cannot? – Manager*

While explaining this action, their response implied that non-point sources are more challenging to manage than point sources. They emphasized that staff would be required to *"connect-the-dots"* between the contaminant and the specific source and design a program to encourage behaviour change.

Next, they indicated that their management response could take multiple forms: either regulatory or non-regulatory. (See Figure 3-5). They explained that if the source of pollution was generated from a known point source, then they could introduce specific regulations through their sewer use bylaw. However, if it was determined that the source(s) of contamination were generated from non-point sources then they would rely on non-regulatory programs such as educational campaigns. Manager expected that ED contaminants would likely originate from non-point sources and therefore they would determine the target audience, either homeowners and/or business owners, and design an educational campaign in an attempt to change their behaviour. For example, encouraging homeowners to stop flushing certain items into the sewer.

Recognizing the limitations of local government's management options, Manager explained that they take the opportunity to communicate challenges with the Federal Government. They explained that there is a formal process in place to correspond with the Federal Government when they stated,

> *At the end of the day, there is only so much we can do, and [*local government name removed] always weighs-in on new federal regulation, especially if it's something that we're going to be held to account but have no authority over. – Manager.*

Here, Manager also emphasized that they *"weigh-in"* on policy changes when it poses a conflict to their responsibilities. In situations where the local government is unable to achieve compliance with Federal regulations, Manager stated that they would seek to understand the intention and

purpose of the regulation. They hypothesized that perhaps the Federal regulation could be targeted at manufacturers or distributors,

> *It could be that the Federal government is trying to drive that particular contaminant out of even being sold or incorporated or what have you and it is really more targeted at manufacturers and products originally. –Manager*

Regardless of the ultimate goal of the regulation, Manager made it clear that limits set for the local government would need to be achieved or the local government would be subject to a financial penalty. In the event the local government was subjected to fines or fees, Manager detailed that the local government would need to download the cost to the public via taxes to cover the costs.

> *We may have fines to pay or surcharges to pay because it is in our effluent [pause] that would just go onto the tax base. We have to requisition to cover those costs to the broad public. – Manager.*

In addition to the sequential actions, Manager highlighted a management consideration upon reflecting on their past experiences with the liquid waste management program. (See Figure 3-7). They explained that due to the scheduled upgrades to the end-of-pipe treatment technology they anticipated financial stress from policy-makers due to redistribute limited financial resources. Manager stated that because the source control program and the WWTP budgets are weighed against each other they expected Council/ the Board to question the need for regulations and program monitoring.

[mimicking policy maker] …why do we still have to regulate, or visit all those codes of practice once every five years? Why do we have to regulate all of this, why can't we scale that back to help pay for the operating costs and the debt for the sewage treatment – Manager

Manager's response conveyed that the political pressure to redistribute the funds and *"downscale the source control program"* was due to the improved quality of effluent discharged to the receiving environment.

3.5.4 Politician

Politician addressed the regulatory scenario from the position of a decision-maker and politician. Their perspective was influenced by their 14 years of experience with local politics and the local government's liquid waste management program. Politician is in a position of power and authority as they are a member of the Council/ Board which makes decisions concerning the allocation of government resources and approval of the wastewater management plan.

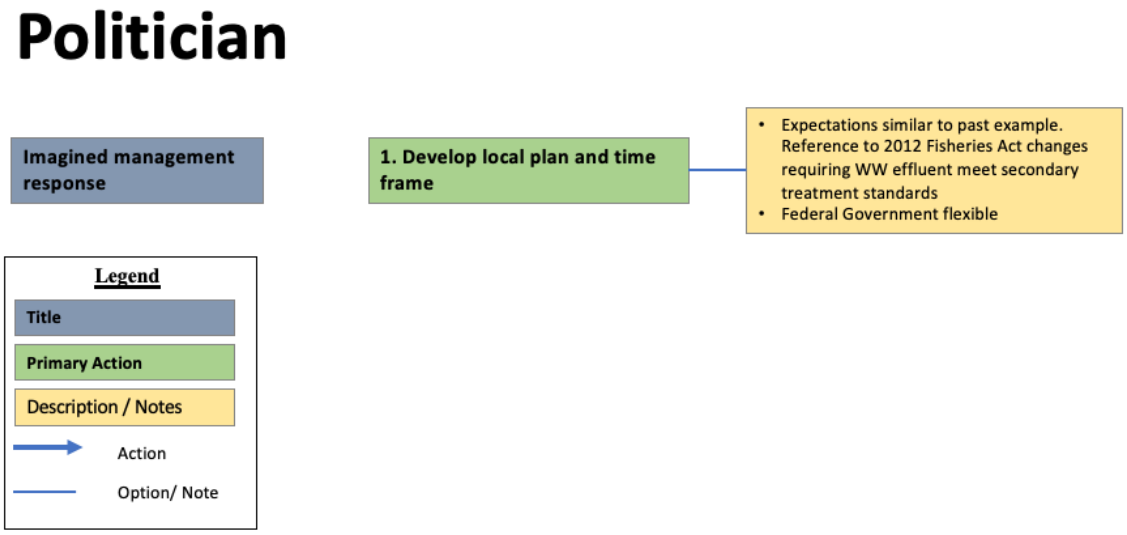

Figure 3-6 Politician's Response to the Regulatory Scenario

Figure 3-6 illustrates the key points of Politician's response to the regulatory scenario. Respondents were asked to respond to a regulatory scenario where the Federal Government introduced a decree regulating the release of EDs. Politician's initial response was to reflect on their past experience of the Federal Government introducing new regulatory requirements. They referenced the 2012 changes to the Fisheries Act which required WWTP effluents reach secondary treatment standards.

Politician used the introduction of the 2012 regulation as a point of comparison. This law was introduced through the Fisheries Act requiring WWTP effluent to reach secondary treatment standards. (See Figure 3-6). They imagined that their actions in response to the proposed scenario would be similar to their response to the introduction to that law: they would develop a plan and timeframe that aligned with the expectations of the Federal Government. Based on their previous experience, Politician thought that the Federal Government was likely to allow flexibility in the timeframe as long as actions taken progressed toward the ultimate goal. Politician briefly listed several components that the plan would be required to address including: the environment, public consultation, adjustments to the current plan, and financial commitment. In their description, they reiterated that compliance would come at a "*significant expense".*

To gain a better understanding of Politician's perspective on the regulatory scenario, I prompted them to imagine they were in a position to advise a new community without a source control program or wastewater treatment plant online. In response, Politician enthusiastically proclaimed that this obligation should be viewed as an *"opportunity"* to act proactively. In reflection of their experience with the Fisheries Act, they stated *"I saw this as an opportunity to change the way we look at waste and turn it into a resource"*. They explained that water is a scarce resource and encouraged a new community to pursue change as an opportunity to add water re-use, waste recovery, and energy generation into the plan.

It was clear from Politician's response that they imagined that their response to the imagined decree would be similar to their response to past Federal regulations and that they were well prepared to act.

3.6 Source control VS. End-of-Pipe

In order to compare different management approaches, the final question I asked the respondents was whether they preferred source control or end-of-pipe treatment strategies to address the future regulatory scenario. Academic literature cites these are the two most prominent strategies to address chemical discharges, however, it clearly distinguishes these two strategies from each other. In the interviews, this question was posed to understand the respondent's opinion of effective and efficient management.

The dominant perspective from my respondents was that source control and end-of-pipe treatment technologies ought to be delivered collaboratively. They expressed that pollution prevention strategies are preferred as a means of reducing overall contaminant loading and targeting contaminant removal at source, but that due to the nature of chemical use and discharge, end-of-pipe treatment is necessary to ensure effluent quality. Politician specified that source control is insufficient alone due to the wide range of contaminant sources and lack of public knowledge. They also suggested that source control will remain insufficient until senior governments impose stricter consumer product regulations.

> *Well, you know, I think if you could ultimately go with source control there would be much less to do at end-of-pipe. But they have to work in balance with each other. So, the more source control you can do the better it looks for the treatment process because you don't have chemicals going into the system. But chemicals are getting into the system from all sorts of places that people just aren't aware of. Until you change the producers, so until there are stronger regulations around what is allowed in that bottle of shampoo or toothpaste or*

> *whatever. We can source control as much as we can but we as [*reference to level of government removed] do not have control of the producers. That is a higher level of government. Which is why we need end-of-pipe treatment. – Politician*

Here, Politician is clear that under the existing circumstances, both systems are necessary to address EDs. They claim their limited jurisdictional authority inhibits their ability to address chemical management at the source: consumer products.

Source Control also revealed that staff perceive source control and end-of-pipe treatment as complementary systems. They specified that two-way communication between source control staff and wastewater treatment operators optimizes the delivery of liquid waste management.

> *For me, really, source control and treatment are really sort of two parts of the same system. We really work together. If source control isn't effective, then treatment suffers. […]*
>
> *So, the more we do to keep that out of their world the better. And the more they tell us what is going on, the more we can tweak source control to help. Yeah, I don't even see them as separate. – Source Control*

According to Source Control, the two strategies are dependent. This highlights the teamwork attitude the local government promotes, and the opportunities created to liaise with departments. Their perspectives underscore the cooperative nature in which liquid waste management is managed by the local government.

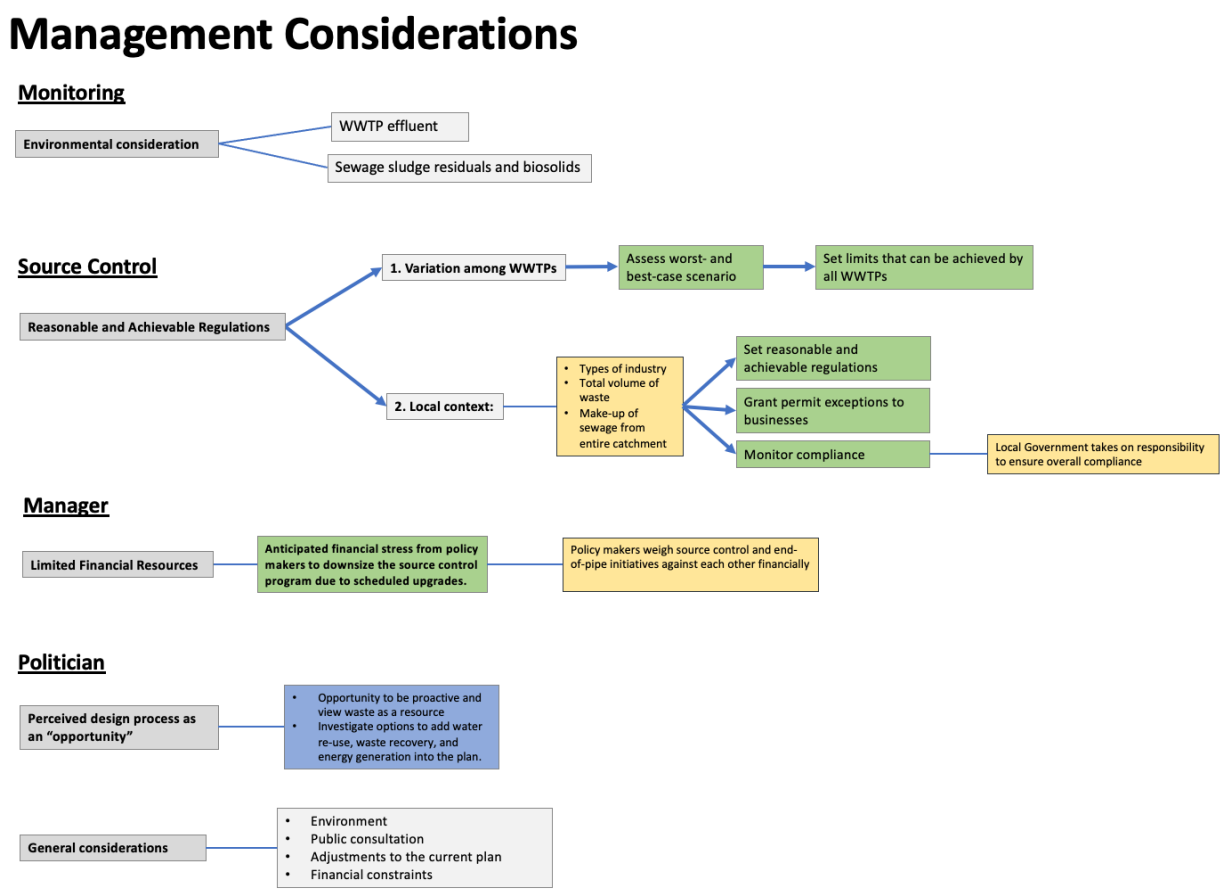

Figure 3-7 Respondents' Management Considerations from Interviews on Local Governments' Preparedness to Manage EDs

Figure 3-7 illustrates the summary of all considerations highlighted by Monitoring, Source Control, Manager, and Politician in responses to the regulatory scenario. Respondents were asked to respond to a regulatory scenario where the Federal Government introduced a decree regulating the release of EDs. Monitoring raised concern for environmental considerations due to changes in effluent quality and sewage sludge/ biosolids. Source Control emphasized the need to establish reasonable and achievable regulations in regard to 1. Variation among WWTPs and 2. Local contexts. Manager highlighted the need to consider limited financial resources and competing priorities. Finally, Politician perceived the design process as an "opportunity" to consider water re-use, water recovery, and energy generation.

3.7 Collective Scenario Response

The responses to the regulatory scenario provide an understanding of this local government's preparedness to address future ED regulation. The sequential actions and management considerations raised by the respondents highlight how this local government perceives effective and efficient management.

The interviews with my respondents varied slightly based on the respondents' experiences and roles within the organization. This was intentional and heightened the value of my empirical material. I have merged the key elements highlighted by each of my respondents to create a list of management strategies representative of this government. Figure 3-8 is an illustration of these elements.

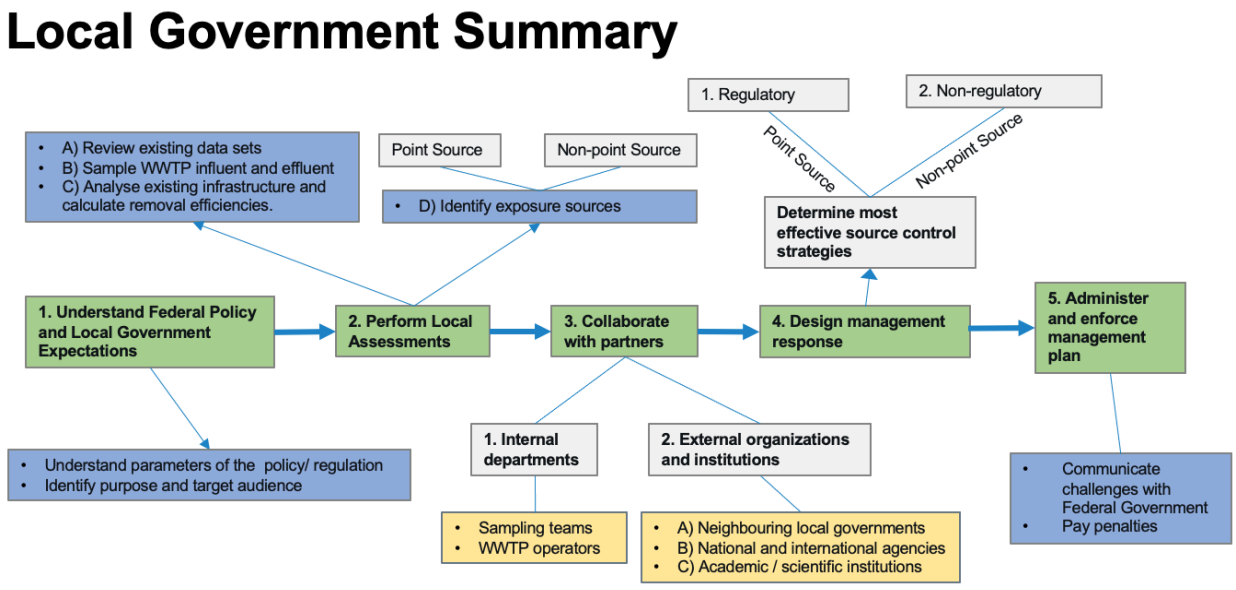

Figure 3-8 Summary of Local Government's Management Strategies for Case Study on Local Governments' Preparedness to Manage Endocrine Disruptors

Figure 3-8 illustrates the management strategies and sequential actions identified in response to the regulatory scenario by all four respondents. Each respondent was asked to respond to a regulatory scenario where the Federal Government introduced a decree regulating the release of EDs. Collectively, the sequential actions included 1. Understand Federal Government policy and local expectations, 2.

Perform local assessment including a. Review existing data, b. Sample WWTP influent and effluent, c. Analyze existing infrastructure and removal efficiencies and d. Identify exposure sources, 3. Collaborate with internal and external partners, 4. Design management response, and 5. Administer and enforce management plan.

3.7.1 Understanding Policy Intentions

An initial response according to Monitoring, Source Control, and Manager is to understand the intention, goals, and target audience of the Federal regulation. Understanding the motivations for regulatory changes helps local governments determine who the regulations are intended for: producers, consumers, or regulators. Equipped with the knowledge about the regulation's goals, local governments can gauge their expectations and respond most effectively.

3.7.2 Local Assessment

My respondents expressed the need to understand the Federal regulations within the local context. Since Federal Government regulations apply nation-wide, it is necessary to understand this local government's expectations and requirements. Respondents detailed various measurements necessary to assess local conditions including (See Figure 3-8):

A. Review existing data sets for applicable information
B. Sample WWTP influent and effluent
C. Analyse existing infrastructure and calculate removal efficiencies
D. Identify local exposure sources

3.7.2.1 Review Existing Data

According to Manager, an important step in the local assessment is to review existing data sets for applicable information. They detailed that their office was engaged in on-going data

collection in partnership with university students' graduate research. In the event of future regulatory thresholds, they suggested reviewing existing monitoring data for information that could provide insights into the community's compliance status. If no data was previously collected on the contaminant or parameter, they would need to initiate data collection.

Additionally, throughout the interviews, all respondents claimed the existing marine monitoring program was considerably well-developed and received good funding. Specifically, when describing the components of the monitoring program, Monitoring explained that the marine monitoring program voluntarily collects priority pollutant data from the receiving environment surrounding the wastewater treatment plant outfalls. Although they did not explicitly detail the use of this data in their response to the future regulatory scenario, it is important to highlight as according to Manager's perspective it would be evaluated.

3.7.2.2 Sampling

In response to the future regulatory scenario, Source Control and Manager discussed the need to sample in order to understand existing conditions. Both respondents detailed that the departments would work together to sample influent and effluent streams. According to Source Control's perspective, sampling data could be analyzed to understand local discharge compositions and help determine the need for additional management efforts. From their perspective, meeting senior government mandates is a top priority and in order to be compliant, they need to start with a local assessment of their water quality.

3.7.2.3 Assess Local Technology

The respondents also acknowledged the potential for existing wastewater technologies to reduce contaminant loading. Source Control advocated for liaising with treatment plant operators to assess local capacities to remove and reduce target contaminants. They specified that collaboration across departments to gather data would improve the efficacy of the local government's response and may also identify policy challenges to accommodate regional variation between treatment facilities. Source Control identified that assessing their technological capacity would be a useful step to responding effectively, however, the variation present would pose a challenge for creating a universal policy response.

3.7.2.4 Identify Local Exposure Sources

Source Control and Manager identified the need to gathering information on local sources of exposure. Manager specified that understanding where discharges originate would influence their management response. They explained that depending on if the contaminant was discharged from a point or non-point source, their approach would vary.

Source Control complements this position by explaining that their monitoring program includes geographic assessments where they gather and analyze data from different areas in the city to characterize discharge based on land use. For example, residential areas, downtown businesses, or light industrial sectors. They hypothesized that this could be utilized to learn where discharges originated and what management strategies would be most effective.

3.7.3 Collaborate with Partners

It was clear from the interviews that the local government does not operate in isolation, but rather collaborates their management responses with a) neighboring local governments, b) national and international government agencies, and c) academic institutions and scientific communities (See Figure 3-8). In response to the future regulatory scenario, Monitoring, Manager and Source Control detailed some of the local government's existing partnerships. They highlighted that the local government relies on research and collaborative partnerships to brainstorm, compare data, and problem solve.

3.7.4 Design Management Response

Following the categorization of the local context and collaborating with partners, respondents stated that they would determine the most effective source control strategies: regulatory or non-regulatory (See Figure 3-8). They would develop policies or programs that reflect the sources and routes of exposure. For example, Manager hypothesized that ED pollution would likely be diffused among multiple non-point sources and therefore educational behaviour change campaigns targeted at homeowners would be most effective.

3.7.5 Administer and Enforce Management Plan

The last step of the regulatory response would be to administer and enforce the management plan. According to Manager and Politician, once a plan is developed, the local government will continue to administer and enforce the plan in order to reach compliance. If the administration of the plan does not achieve the intended targets and the local governments cannot comply with the Federal government regulations, the local government would voice their challenges to the

Federal Government (See Figure 3-8). Manager indicated that if they fail to comply with the regulations, they may be subjected to fines or penalties. These financial penalties would be transferred to the public via taxes to cover the costs.

Chapter 4: Motivating Local Decision-Making in Light of Uncertainty

4.1 Decision-Making in Light of Uncertainty

My research found that the respondents perceive political jurisdiction and existing knowledge gaps as central barriers to developing and introducing ED policy. My respondents clearly recognized existing regulatory gaps and felt that increased policy-action could reduce the risks posed by EDs. However, Monitoring, Source Control, and Manager stated that local action was unlikely without very high standards of evidence coupled with political support and financial resources. This argument is aligned with the dominant perspective that has driven policy development through the twentieth century: science is a pre-requisite to policy (Metz & Ingold, 2017; Vogel, 2004). This perspective of evidence-based decision-making is intended to improve the quality of decisions and increase the success of policy implementation; however, it does not account for the limits of scientific proof and reinforces misunderstanding about the certainty science can provide. The result is delayed policy action (Metz & Ingold, 2017; Turnhout et al. 2019). These findings prompted my interest in the government resources required and the motivations that propel precautionary policy-action at the local level.

The solution to managing EDs cannot be easily calculated due to competing interests and disagreement of the risks and benefits of chemical use. The problem is defined by three related, but distinct challenges:

a) *Complexity: the difficulty of identifying and quantifying causal links between a multitude of potential candidates and specific adverse effects,*

b) *Uncertainty: lack of knowledge due to statistical variation, measurement errors, ignorance or indeterminacy, and*

c) *Ambiguity: variability of legitimate interpretations based on identical observations (Klinke & Renn, 2002, p. 1085)*

The management of EDs is further complicated because the benefits realized by one group may pose negative effects or cascading externalities within other contexts. For example, pharmaceutical users may benefit from direct use of a drug, however, long-term low dose exposure to non-target audiences (both human and aquatic life) may cause EDs to bioaccumulate in food sources impacting traditional fishing practices, recreational activities, and/or economic outputs. These interrelated and overlapping trade-offs are *"systemic risks"* (Klinke & Renn, 2006) defined as human and environmental risks embedded in *"larger contexts of social, financial and economic risks and opportunities"* (Klinke, & Renn, 2006, p. 2*).* The knowledge gaps and diverse opinions present a "*wicked problem*" (Rittel & Webber, 1973). Evaluating EDs as a wicked problem depends on how one perceives the risks and trade-offs and the priorities one wishes to pursue (Rittel & Webber, 1973). Turnhout et al. (2019) argue that in cases characterized by high uncertainty and poorly understood risks, action is necessary but cannot be made by calculating a solution. The authors argue that when scientific consensus is lacking or knowledge gaps persist, gathering more evidence alone cannot solve the issue. Rather, decision-makers must consider the short- and long-term costs and benefits of their actions (or inaction), and decisions must reflect local risk perceptions, political preferences, and community values.

Critical of my respondent's perspectives, the argument for evidence-based decision-making and the need to wait for salient, undisputed evidence is an impractical and flawed ideal (Klinke & Renn, 2002; Metz & Ingold, 2017; Vogel, 2004). Framing scientific evidence as a source of certainty to solve complex issues was coined the *"uncertainty paradox"* by Van Asselt and Vos (2006). This term describes a policy-maker's tendency to demand conclusive evidence prior to making a decision. The authors argue that knowledge alone cannot dispel uncertainty, and often when ideas are contested and disagreements persist, generating more data and inviting more

perspectives can have the opposite effect (McIlroy-Young, 2020; Turnhout et al., 2019; Van Asselt & Vos, 2006).

In cases of high risk and uncertainty, *the precautionary principle* has become central to guiding decision-makers on management challenges that pose high financial costs as well as risks of inaction. Particularly, the *precautionary principle* has been used to defend decisions pertaining to human and environmental health (Turnhout et al., 2019; Van Asselt & Vos, 2006). The precautionary principle states

> *where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. (United Nations, 1992)*

The principle intends to encourage precautionary approaches to policy issues that pose *"potentially serious or irreversible harm to the environment"* (Global Development Research Center, n.d.). It emphasizes that scientific uncertainty and knowledge gaps should not be the reason to delay decisions and can be used to legitimize policy-action when the risks are high, and data is unclear (Klinke & Renn, 2002; Metz & Ingold, 2017; Vogel, 2004). By accepting the inherent uncertainty, complexity, and ambiguity of a problem, the aim of this approach is to encourage governments to take responsibility for environmental risks rather than rely on reactive problem-solving measures after damages have been realized.

The *precautionary principle* is not new to Canadian legislation. It is defined within CEPA 1999, however, the implementation and application(s) to management is lacking (Boyd, 2016). As mentioned previously, Canada generally supports a risk-based approach to chemicals management and has been criticized for lack of enforcement and for taking a reactive approach (Standing Committee on Environment and Sustainable Development, 2017).

Each of the respondents in my study acknowledged the risks EDs pose and agree that insufficient policy-action has been taken. Source Control and Politician specifically highlighted that local decisions about *"tolerable risks"* already consider trade-offs using a triple-bottom-line approach and that mounting evidence suggests that policy-action is necessary. Specifically, Source Control highlighted the development of science over the past two decades and voiced support for regulatory action.

> *The science is getting better. The effects of these compounds are better understood, and they are detectable. [pause] And so, the question is when will they [EDs] reach the point when we should consider regulating them? – Source Control*

This recognition of the risks posed by EDs and the interest in pollution reduction is the motivation that could be channeled through precautionary policies.

My respondents' interest in increasing policy-action in light of existing uncertainties is aligned with the results from Doerr-MacEwen and Haight's (2006) study exploring perspectives on existing knowledge and preferred management strategies for active pharmaceuticals. They illustrated that even in the absence of complete scientific confidence, government action was deemed necessary. Nearly 70% of 27 expert informants felt it was *"very or somewhat important that their governments take management action to reduce the release of pharmaceuticals to the environment"* (p. 858). Their research also compared perspectives on preference and feasibility among eight management strategies ranging from policy-oriented solutions, end-of-pipe treatment, green chemistry, physician prescriptions, and public behaviour change. Based on their results, Doerr-MacEwen and Haight (2006) recommended seeking pollution prevention strategies that first target behaviour change and raise public awareness. Educational initiatives and medication return programs encouraging responsible use and disposal were concluded as the

most influential and effective approaches as they are able to evolve with changing priorities or easily target specific audiences. WWTP upgrades were also recommended to augment source control strategies and the authors recommended targeting advanced technologies to high-volume urban areas with the capacity of treating multiple contaminants (Doerr-MacEwen & Haight, 2006).

In support of taking a precautionary approach to water management, Metz and Ingold (2017) also investigated decision-makers' positions towards precautionary approaches. Their research investigated the case of micro-pollutants in Swiss water protection policies. Their findings concluded that *"most actors supported precautionary action as an appropriate policy strategy for dealing with remaining uncertainties"* (p. 729). Among the decision-makers supportive of precautionary policy, there was greater support for source control strategies aimed to incentivize reduction at the source as opposed to end-of-pipe solutions that treat water prior to discharge.

In light of the uncertainty posed by EDs, embracing the precautionary principle presents plausible and proactive policy-actions for local governments. Despite existing knowledge gaps and uncertainties, mounting evidence underscores the risk of low-dose long-term exposure to EDs (Boxall et al., 2004; Burkhardt-Holm, 2010; Fowler et al., 2012; Wilkinson et al., 2016). Rather than postponing policy-action and demanding more evidence prior to introducing regulations, local governments ought to leverage the momentum in support of pollution prevention.

Preventing ED exposure through source control strategies that specifically target EDs would reduce the threat of serious or irreversible human and ecological health risks and do so through proactive, cost-effective measures. Local governments are the interface of production,

consumption, and disposal; therefore, they are well equipped to negotiate solutions. Aligned with the findings from Doerr-MacEwen and Haight (2006) and Metz and Ingold (2017) I recommend that local governments impose reasonable and achievable policy-action inspired by the precautionary principle.

Since it is not currently a common practice for Canadian local governments to pursue bold policy action in advance of senior governments, it is valuable to learn from the motivations that inspire local policy-action within other environmental contexts such as climate change policy.

4.2 Local Motivations for Policy Action

This section discusses the motivations that prompt local governments to introduce voluntary regulations in advance of senior government directions. Understanding the motivations that compel local governments to advance policy and programs when senior government direction is absent helps to understand the resources that may support decision-making on topics such as ED management. The novelty of ED management presents challenges for regulators as there are few best practices to influence decision-making. As an emergent policy topic, ED management can learn from the progress of other environmental efforts such as climate change. Over the past two decades, local-level governments across the United States (U.S.) and Canada have adopted climate change policies and programs in advance of senior government direction. These cases offer lessons as to why local governments decide to voluntarily invest in local-level policy.

Similar to the scale of risks and uncertainties posed by EDs, climate change, and global warming are policy arenas where local- and state-level governments have shown leadership prior to Federal regulation. The lessons learned from past case-studies examining local and state-level

climate action help to understand the reasons local governments choose to act prior to receiving senior government mandates. Although local climate action differs from chemicals management there are many similarities in the challenges and jurisdictional authority between the two issues, thus exploring the motives and rationales offer comparable lessons.

The literature investigating local- and state-level climate action has developed an understanding of the motivations and leadership that prompts policy change and program adoption in the absence of senior government direction (Bedsworth & Hanak, 2013; Engel, 2009; Kousky & Schneider, 2003; Lambright et al.,1996; Zahran et al., 2008;). This research shows that local governments are well-positioned to understand existing public behaviour and are capable of influencing change through bylaws, taxes, and programs that target energy consumption, water use, and carbon emissions. These local-level policy initiatives are at the intersection of development, transportation, and consumer consumption, and they contribute to climate change targets such as achieving the International Panel on Climate Change (IPCC)'s goal of limiting the earth's temperature rise to 1.5*C (IPCC, 2018). However, such issues are classified as globally significant (Ostrom, 2010). Although individual actions to reduce carbon emissions can and do help achieve these global goals, individual efforts have been criticized as insignificant and thus warranted of *"collective action"* (Ostrom, 2010; Yi et al., 2017). From an economist's perspective, it is argued that globally significant issues suffer from what Hardin (1968) coined *"tragedy of the commons"* where communal resources are mutually destructed out of self-interest (Ostrom, 2010; Yi et al., 2017). Further, Ostrom (2010) claims that mis-matched efforts between jurisdictions can promote *"free riding"* (p. 555) where some participants do not contribute an appropriate share but reap the benefits of collective action. *"Leakages"* (p. 554) in the system can also occur where unfavorable activities relocate to jurisdictions with less stringent restrictions.

Global warming and chemicals management present good cases of this as individual actions do not change the global rates measurably and localized policies can discourage businesses that cannot meet the intended targets. According to Brennon (2009), this lens predicts that local governments hesitate to invest in policy initiatives as benefits are weighed against the financial costs. Rather than voluntarily adopting policies or programs, local governments prefer to wait for top-down directives and mandated policy responses (Sharp et al., 2011; Zahran et al., 2008). Sharp et al. (2011) elaborate on this concept explaining that although individual actions contribute to the goal, resistance is common when efforts cannot be measured, and benefits are diffused globally.

While there are economic arguments against engaging in local policy action, Ostrom (2010) explains that global issues need not wait for globalized approaches. She argues that agreements take a long time to achieve and even if agreements at the national level are made, they do not guarantee their implementation at local levels. Ostrom (2010) states that a *"think globally, act locally"* (p. 551) approach can be much more successful. Globalized issues call for what Ostrom (1999) terms "*polycentric governance"* or collective action. Taking a *"polycentric"* approach to environmental governance means that multiple independent governments are involved in addressing a problem, rather than a centralized *"monocentric"* government (Ostrom, 1999; 2010). This approach is beneficial as it provides the opportunity for multiple governments to voluntarily work together, learn from one another and adapt management practices over time (Ostrom, 2010).

Although authors have highlighted that it is economically irrational for local governments to voluntarily engage in globally significant issues, such as climate change, there are many cases across the U.S. and Canada where local and state governments have introduced climate action

policy surpassing senior government efforts. Researchers including, Bedsworth & Hanak (2013); Engel (2009); Kousky & Schneider (2003); and Lambright et al. (1996) and have investigated the motivations of Canadian and U.S. local and state governments. The lessons learned from these cases provide examples of the motivations and resources required for local governments to take leadership in the absence of senior government direction. In light of the uncertainty posed by EDs, embracing voluntary policy-action despite existing knowledge gaps and uncertainties would promote accountability and bring awareness to the risks posed by long-term ED exposure.

The motivations identified in the literature and the relationships to my research findings are discussed below:

4.2.1 Compel Senior Governments to Increase National Regulations.

In the case of climate change, Engel (2009) claims that U.S. state governments that are most vulnerable to the impacts of sea-level rise or dramatic temperature increases adopt restrictions with the hopes of compelling senior government action. States such as California that are vulnerable to increased natural disasters (such as forest fires and extreme weather) due to changing climate conditions recognize the benefit of collective participation. According to Engel (2009), a motive of the Government of California to adopt policies or pursuit legal action is the hope of encouraging their senior governments to replicate their initiatives at a national scale. The author also points to multiple lawsuits by U.S. states that compel national-level policy action. For example, *Massachusetts v. US EPA* to mandate nationwide emission reductions.

My respondents claimed that local policy-action for ED management requires stronger scientific evidence. However, as discussed above waiting for scientific consensus poses risks of inaction

and will further delay policy development. If a local government were to legitimize their decisions through the precautionary principle, they may compel senior governments to change their approach which is currently dominated by risk-based thresholds and single chemical assessments. During the interviews, Source Control stated that the local government has the authority and jurisdiction to adopt more stringent policies. Therefore, if ED policies were supported both politically and financially, a visionary approach defended by the precautionary principle could represent a cornerstone of chemicals management that the Federal government could recognize.

4.2.2 Political Interest

According to Engel (2009) and Lambright et al. (1996), past climate change initiatives demonstrate that political interest and leadership are key factors to progress policy action. Engel (2009) claimed that politicians choose to engage in certain political arenas to develop their identity, gain popularity among constituents, and help campaign for their re-election. For example, during the U.S. Bush administration, the Governor of California, Arnold Schwarzenegger, *"repeatedly bypassed the President on climate policy"* (Engel, 2009, p. 441) where the state entered into national-level agreements with the United Kingdom and hosted the Global Climate Summit (Engel, 2009). Typically, these types of events and agreements are hosted by Federal-level governments, however, state leaders such as California's Governor and other local and state leaders across the U.S. build their identity and attract media and political attention for their climate-focused activism. Engel (2009) argues that the sub-national governments' approach to *"tackle climate change"* showcases a *"David and Goliath appeal"* (p.441).

Lambright et al.'s (1996) comparative study of Toronto, ON, and Chicago, IL also highlighted the value of attracting decision-makers' attention. In response to global warming, the research emphasized the importance of heightened environmental consciousness among local government staff and decision-makers. In these cases, the researchers identified the government's shift in priorities and heightened interest after experiencing more above-average summer temperatures. According to Lambright et al.'s research, the government's political interest accelerated local-level policy and Toronto was the first municipality to implement local-level climate action policy (1996).

Complementary to my research findings, the climate-action literature highlighted the role of political interest in accelerating local-level policy action. I found that political leadership and framing policy changes as an "opportunity" helped advance progressive ideas. Politician's interests and excitement surrounding resource retention demonstrated the potential of capturing political momentum. Greater political knowledge and interest in EDs coupled with justification using the precautionary principle could progress local ED management.

4.2.3 Cost-saving and Co-benefits:

Investing in climate change solutions has the potential to reduce long-term energy costs and produce multiple short- and long-term benefits (Bedworth & Hanak, 2013; Engel, 2009; Kousky & Schneider, 2003). Engel (2009) and Kousky & Schneider (2003) claim that an *"important motivation"* (Engel, 2009, p. 442) of local government's interest in adopting climate change initiatives is the potential of saving energy costs and yielding multiple benefits from a single investment. According to Kousky & Schneider (2003), co-benefits can be leveraged by local governments to a) localize climate issues within cities, b) justify policies and programs to the

public, c) justify financial investments, and d) provide the opportunity to yield multiple benefits simultaneously. An example of this is Seattle's investment in public transportation which was intended to improve the walkability of neighborhoods and in turn, also reduced traffic congestion and vehicle carbon emissions, promoted affordable housing projects, and, overall, reduced urban sprawl (Engel, 2009).

Marketing the multiple benefits and potential cost-savings of a precautionary approach to ED management could yield greater interest and support for new policy initiatives. Raising awareness of the integrated and overlapping risks posed by ED exposure could generate commitment from decision-makers. Adopting precautionary policies and programs aimed to minimize the contaminant loading of wastewater prior to treatment could prompt investment in research and development, reduce or streamline long-term technology and infrastructure costs and improve human and environmental health. Reframing the investment in local-level ED management to highlight the co-benefits could motivate decision-makers to support precautionary policy-action and program development.

4.2.4 Policy Entrepreneurship:

Another motive highlighted by Engel (2009) is the opportunity for local and state governments to influence the design of new policy projects and become experts in the field. Those that are engaged from the start *"gain competitive advantages"* (Engel, 2009, p. 443). Their leadership can gain recognition and the opportunity to influence other jurisdictions both at the national and sub-national levels. An example of this is California's history of being the *"first-in-the-nation"* (p. 443) to lead climate-related projects, such as the U.S.'s first regional greenhouse gas emissions

trading scheme. This California initiative was adopted by other U.S. states including Florida and internationally by the European Union.

Similar to compelling senior governments to act, local governments could influence other jurisdictions to adopt and enforce precautionary policies and programs. Within a Canadian context, provinces such as British Columbia and municipalities within Ontario including Toronto and Hamilton have a history of progressive environmental practices. These are recognized leaders within Canada that could pioneer pollution prevention initiatives and serve as leaders for other local governments in Canada.

4.2.5 Network and Partnership Building:

Engaging in a new political area can prompt building professional networks across the state, country, or globe (Engel, 2009). Another motivation identified by Bedsworth and Hanak (2013) and Engel (2009) is the benefit of connecting and collaborating with other governments and stakeholders. Organized networks and collaborations help establish contacts, provide technical expertise, develop lobbying power and sometimes provide financial assistance (Engel, 2009). According to Bedsworth and Hanak (2013), in addition to government partners, collaborations with non-for-profits and community groups can also help to locate expertise to accelerate projects. An example of a successful network is the collaboration of municipalities across California's San Francisco Bay Area who partnered together to create community-level emissions inventories. The partnerships between local governments helped facilitate the progress and completion of over 100 local projects through knowledge and skills transfer.

Participation in international networks and associations such as the Cities for Climate Protection (CCP) Campaign hosted by the International Council for Local Environmental Initiatives (ICLEI) can also accelerate sustainability goals and enhance local job markets (Yi et al., 2013). ICLEI's local government campaign is an international network of over 1750 local governments across 100 countries that are committed to sustainable development (ICLEI, 2021). The program is designed to provide expert mentorship and peer-to-peer knowledge exchanges. Researchers such as Betsill (2000) investigated the rationale for municipal participation in the CCP and found that the greatest motive was economic interest.

As an emerging field, there are few best practices established for ED management. Leveraging the local government's existing connections and provincial networks to build a team dedicated to ED management would offer an opportunity for collaboration and knowledge exchange. According to Metz and Ingold, collaboration among government networks and experienced professionals leads to heightened support for precautionary policies (2017). Their study investigating the support for precautionary policy against micro-pollutants demonstrated the value of information sharing and the momentum of collective action. During the interviews, my respondents mentioned several existing academic and governmental networks. Enabling these networks to investigate and accelerate precautionary policy approaches could support increased ED management.

4.2.6 Market Development or Expansion

Another theme highlighted by Engel (2009) is the motivation to develop or expand emerging markets related to renewable energy or energy efficiency. California's progressive policies to cap greenhouse gas emissions and publicly fund solar energy are both examples where state policies

encouraged technological advances and the expansion of emerging markets. As noted above, participation in networks such as ICLEI's CCP campaign was also highly motived by the claims of job creation and economic development. Yi et al. (2013) confirmed these motives claiming that local governments with dedicated climate action policy were *"rewarded with increased number of "green jobs" compared to governments without local policy"* (p. 651).

Adopting precautionary policies for EDs would demand innovation in the chemical industry. Although there may be an opportunity for "green jobs" in this field, the government must also consider the potential consequences. Similar to the negative externalities raised by Ostrom (2010) about climate change, local precautionary policies could result in "leakages" where businesses relocate to neighbouring jurisdictions with less stringent restrictions. This could result in local job loss. Lessons from recent regulatory changes for BPA in baby products have also taught us about the potential harm of chemical-specific policies. In 2010, the Government of Canada opted to ban BPA from baby products resulting in substitutions to other plasticizers which have not been studied to the same degree and could lead to alternative problems (Government of Canada, 2017f).

4.2.7 Public Support

Alerting the public of local vulnerabilities and gaining their support can motivate policy change (Bedsworth & Hanak, 2013; Kousky & Schneider, 2003; Lambright et al., 1996). Researchers studying the motivations of local government decisions identified the importance of public support and the role of an *"issue champion"* (Kousky & Schneider, 2003, p. 361) *"Issue champions"* were identified as member(s) of the public who advocate for policy action and are leaders that voice public support for grassroots issues. The importance of leadership and broad

support was reinforced by both Kousky and Schneider (2003) and Bedsworth and Hanak's (1996) comparative studies that identified the importance of appealing to various public priorities that ranged from economic to environmental interests.

Demand from the public to increase abatement strategies could accelerate local support for ED management. Although Manager expressed hesitation toward investing in science communication, the climate-action case studies prove that public awareness and public advocacy incentivize governments to create public policy. Manager believed that ED science was too complex for public audiences and that translating the science into key messages for homeowners and business owners would be difficult and resource-intensive. As an emerging field, these cases-studies demonstrate that it is valuable to bring public awareness to the sources of pollution, the risks of ED exposure, and the possible management strategies.

4.3 Take-Aways

The motivations that prompted local climate-action policy demonstrate desirable leadership that can help local governments frame their interest in managing EDs. The novelty of ED management requires that local governments look to similar policy contexts to support voluntary and precautionary approaches. The case studies presented above highlight seven motivations that have been identified through the literature. Of these motivations, I recommend local governments begin by tailoring ones with the greatest impact and existing momentum: 1) public support, 2) political interest 3) cost-saving/ co-benefits, and 4) network and partnership building. I believe that mobilizing action through these motives would increase public awareness about the risks posed by ED exposure and help frame local government interests in precautionary policy-actions. Increasing the transparency about the local government's proactive role and enabling

policy maker's budding interest in chemicals management through collaborative networks would enable interested stakeholders to work together to generate local policy approaches.

Although respondents expressed hesitation toward exceeding Provincial and Federal Government mandates due to existing knowledge gaps, the literature in support of the precautionary principle promotes decisions in light of uncertainty. Local governments are at the intersection of production, consumption, and discharge of liquid wastes. This combined with their position to influence consumer and business behaviours supports local policy action.

Chapter 5: Conclusion

5.1 Contributions

This research investigated a local case study's perception of preferred management strategies, future challenges, and required resources to manage EDs. Through a combination of document review and semi-structured interviews, I gained an understanding of Canada's regulatory context that supports Canadian chemicals' management and local governments' preparedness to address future ED management. This work contributes novel, unexplored findings that capture a Canadian local government's perspectives on future ED management through a case study analysis. This work complements the research by authors Metz and Ingold (2014, 2017) and Doerr-MacEwen and Haight (2006) who have researched and described the available management strategies and investigated government, industry, and academic management preferences and their feasibility at national and international scales. Moreover, this case study contributes pragmatic recommendations and lessons to Canadian local governments, as well as insights to Provincial and Federal Governments who establish mandates and download responsibilities to Canadian local governments.

Interviews with local government staff and decision-makers aimed to understand the local government's perception of ED management and responses to the future regulatory scenario. The study findings highlighted that the respondents are aware and in favour of managing the risks posed by ED exposure, yet that the complexities, knowledge gaps, and uncertainties pose barriers to the local government's preparedness. The challenges identified by respondents were four-fold, first respondents perceived their jurisdictional authority as a limitation. Although respondents, specifically Source Control, acknowledged that they are permitted to exceed senior government requirements, they indicated that it was rare for their local government and that it would depend

on strong scientific evidence. Second, chemical complexities posed by EDs presented additional challenges for the following reason: 1) EDs are widely used and disposed of from everyday products and processes, 2) EDs are commonly present at trace levels close to or at instrumental detection limits, 3) It is difficult to associate cause and effect data, and 4) Chemical and physical changes can occur during WWTP processes and/or regular use. Communicating these complexities and uncertainties with the public and decision-makers was highlighted as a challenge by Manager who felt that these complexities exceed the general public's level of comprehension and that developing educational content would require considerable time and effort from staff. Third, the persistent knowledge gaps in ED science were recognized as a challenge as respondents were unclear how to engage with the scientific and academic communities to seek responses to unanswered questions and whether their participation in research studies would be mutually beneficial. Lastly, Politician identified evaluating environmental risks as a challenge due to competing interests and limited financial resources. Without clear direction from senior governments, voluntarily managing the risks posed by EDs was not policy-action that they generally felt was feasible.

Based on existing policy and programming, the respondents all had similar and aligned responses to the future regulatory scenario. Slight differences arose based on their roles and responsibilities, such as the order of the actions and priority considerations, yet the general alignment shows that the existing local management structure is supportive of responding to new regulations. While the structure to address the regulatory scenario is supportive, the exact management solutions remained unclear due to the uncertainties posed by EDs and WWTP technologies. The series of actions that this local government would pursue in response to new federal regulation of EDs would include: 1. Understanding federal policy and local government

expectations, 2. Performing local assessments to assess local influent, effluent, removal efficiencies, and to identify exposure sources, 3. Collaborating with partner jurisdictions and external organizations, 4. Designing management response(s) aligned with the source of exposure and 5. Administering and enforce the desired plan in order to comply with required regulation (See Figure 3-8). Local government staff and decision-makers are equipped with existing knowledge about EDs to begin to address future regulations, although due to knowledge gaps and technical limitations the exact source control or end-of-pipe solutions remain unclear.

5.2 Limitations

This research aimed to present preferred management strategies, future challenges, and required resources to manage EDs from one local government's perspective. I chose to investigate management strategies aimed to reduce contaminated wastewater as sewage is a major source of ED pollution as well as the responsibility of local governments in Canada. Framing ED exposure as a wastewater issue limited the scope of this study. Although wastewater is a major source of ED contamination, it is not the only source, therefore, additional research on other exposure routes could augment the findings of my research.

As a "*critical"* and *"extreme"* case (Flyvbjerg, 2006), this research presents lessons learned for other municipalities, however, the findings are not without limitations. According to Flyvbjerg's (2006) framework, cases defined by considerable experience and expertise offer lessons learned to communities with similar or less experience. Therefore, my findings provide insights to other Canadian local governments. However, the challenges and management strategies identified in this study are not exclusive. Replicating this study in a community with fewer resources or less experience in regard to wastewater management could conclude different results. It is important

to recognize that communities with less experience and expertise may perceive additional challenges and require additional resources based on the local context.

The selection of my case study and sampling techniques used to identify and recruit my respondents also reflected my analysis of the case and the inclusion criteria I evaluated to qualify participants. I recognize that these criteria could be evaluated differently by different researchers and that additional or alternative criteria could be applied to this type of case study research (Suri, 2011). My study population and sample size also present limitations as respondents' perspectives could have been influenced by factors other than just their role and responsibility in the local government; for example, their personal experiences, political history, and/or preconceptions may have impacted their opinions. More, my small, yet purposeful sample demonstrated knowledge of both source control and end-of-pipe treatment, however, expanding the sample to include dedicated wastewater treatment professionals could add to or elaborate on perspectives shared by the respondents.

Finally, this qualitative research is no doubt influenced by my lived experiences, world views, and personal and research biases (Baxter & Eyles, 1997; Maxwell, 2013). In presenting my research findings, my goal was to accurately represent the respondent's perspectives and realities; however, it is well documented that a research's world views influence study design, delivery, and analysis (Baxter & Eyles, 1997; Maxwell, 2013). As in all qualitative research, I acknowledge that this study and my claims reflect my perspectives and biases which have been shaped by my privilege, post-secondary education, gender, and background in urban and regional planning (Maxwell, 2013).

5.3 Future Directions

In light of the uncertainties, I claim that local governments ought to take voluntary policy-action. The scope and scale of the challenges posed by EDs parallel that of climate change and the lesson learned present motivations for local governments to embrace the precautionary principle. I recommend mobilizing local policy-action inspired by precautionary policies that aim to combine political momentum, collective action, and public education. ED management presents a novel, unexplored policy arena for local governments to learn from climate-action case studies and progress policy legitimized through the precautionary principle. To facilitate effective and efficient management strategies, future research investigating specific pollution prevention techniques would further guide local governments. Similar to the work completed by Doerr-MacEwen and Haight (2006), a comparative study investigating local government's preferences for different strategies and their expected feasibility could accelerate policy-action. Additionally, the study of additional case studies within Canada would expand the sample size and offer comparative data. Finally, expanding the research scope to include Provincial and Federal Governments would be interesting to learn from and compare senior governments' perspectives on ED management and gain an understanding of their approach to creating and responding to decision making in light of uncertainty.

5.4 Policy Recommendations

In Canada and around the world it remains debated whether EDs ought to be distinguished as a separate category due to the risks they pose and mechanisms by which they interact with the human body. At the Federal level, the debate and the critiques raised about CEPA 1999 by the SCESD are centered around the potential for EDs to demonstrate non-monotonic dose-response

curves due to heightened risks during critical development periods, latency periods between initial exposure and the realized adverse health effects which are commonly observed during critical periods of development and for EDs to pose compounding effects due to additive and/or synergistic properties. Due to these complexities, the most effective solution to this policy challenge is heavily debated. Some scientists and regulators argue for total reform of chemicals management in a way that would promote greater emphasis on a chemical's hazard classification and the potential for a chemical to cause adverse effects. The other argument is for incremental changes to existing risk-based assessment approaches whereby existing risk-based assessments would only be subjected to slight changes such as updated definitions or inclusion criteria.

Regardless of the debate at the national and international levels, my recommendation is for local governments to embrace the precautionary principle to justify local policy-action in light of existing uncertainties. The aim is for local governments to accept inherent uncertainties posed by EDs and to take responsibility for environmental and human health risks rather than rely on reactive problem-solving measures. Climate-action case studies demonstrate opportunities for local governments to introduce voluntary policies within their jurisdictional authority. The cases offer specific motivations that inspired decision-makers to advance policy prior to senior governments. I recommend local governments begin by tailoring motivations with the greatest impact and existing momentum: 1) public support, 2) political interest 3) cost-saving/ co-benefits, and 4) network and partnership building.

Local governments could implement voluntary actions to reduce exposure to EDs by building on existing pollution prevention mechanisms such as the source control regulatory policy and non-regulatory programming. This includes discharge policies enforced through the sewer use by-law

and business-specific codes-of-practice, and educational campaigns aimed to build knowledge and transparency. Local governments have the educational and regulatory tools in place, as well as the autonomy and authority to design local policies and programs. The next step forward is for decision-makers to accept the knowledge gaps surrounding ED science and choose to design more stringent policies and programs.

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