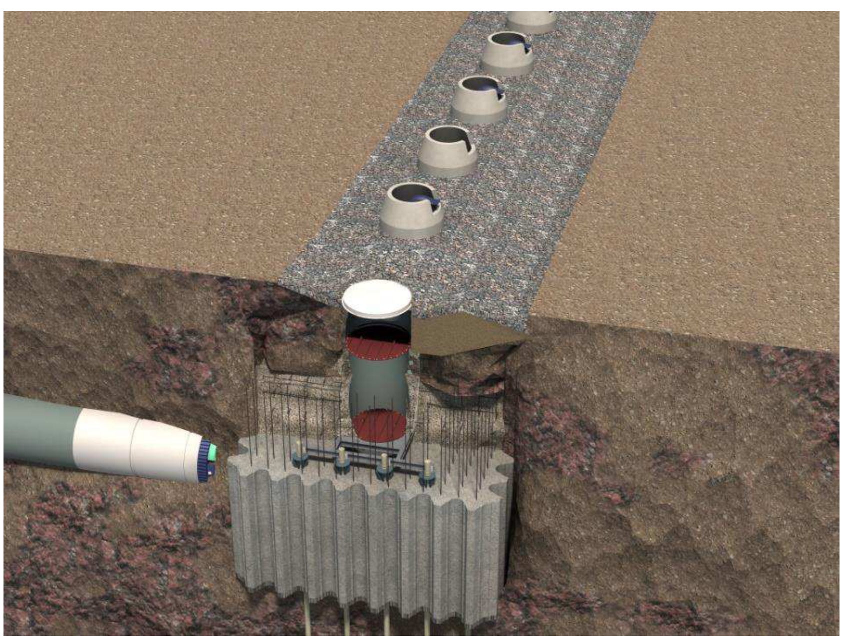
APPENDIX K
BC MINISTRY OF ENVIRONMENT EIS

Part A: Stage 2 EIS Report

Annacis Island WWTP New Outfall System

Vancouver Fraser Port Authority
Project and Environmental Review Application



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12 March 2018

ANNACIS ISLAND WASTEWATER TREATMENT PLANT TRANSIENT MITIGATION AND OUTFALL PROJECT

Stage 2 Environmental Impact Study

Submitted to:
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Metrotower Office Complex
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Report Number: 1525010-119-R-Rev0

Distribution:

1 copy Metro Vancouver
1 copy CDM Smith Canada ULC

REPORT

Golder Associates

Executive Summary

BACKGROUND

Metro Vancouver (MV), through the Greater Vancouver Sewerage and Drainage District, owns and operates three secondary wastewater treatment plants that discharge to the lower Fraser River. The largest plant, Annacis Island Waste Water Treatment Plant (AIWWTP) is located adjacent to the Fraser River on Annacis Island, Delta, British Columbia. The AIWWTP is being expanded by Metro Vancouver to increase secondary treatment hydraulic capacity to approximately 1.25 million people and is being upgraded to meet current seismic standards. Once complete, the AIWWTP Stage V upgrade will increase treatment capacity to accommodate the region's future population growth, provide additional reliability in maintaining sewage treatment capabilities in the event of a large earthquake, take advantage of green energy captured on-site, and better manage odour issues. A major component of the Stage V Expansion is the upgrade and replacement of the AIWWTP outfall in the lower Fraser River.

To discharge effluent from the new outfall, the project requires an amendment of Operational Certificate ME-00387 under the Integrated Liquid Waste and Resource Management Plan (ILWRMP) pursuant to the provincial *Environment Management Act* (EMA). As per the BC Municipal Wastewater Regulation (BC Reg 87/2012; OC 230/2012), (also pursuant to EMA), an Environmental Impact Study (EIS) of the effluent discharge is required to identify whether or not receiving water uses could be impaired by the hydraulic upgrade. The EIS is used by BC Ministry of Environment in their permitting decisions and is used by the discharger, in this case MV, as part of their due diligence to verify that they meet the requirements of EMA, the ILWRMP, and the federal *Fisheries Act* (R.S.C., 1985, c. F-14).

Golder Associates Ltd. was retained by CDM Smith Canada ULC on behalf of MV to prepare an EIS for the new outfall diffuser system, in support of the application to amend Operational Certificate ME-00387, in accordance with provincial guidance that specifies a staged EIS process. This report represents stage two of that process and is a refined evaluation of potential effluent-related impacts on the receiving environment and public health based on the final project design.

OBJECTIVES

This Stage 2 EIS is intended to provide a technical assessment of predicted water quality as a means to evaluate whether adverse effects on the receiving environment and public health might result from the Stage V Upgrade.

The objectives of the study are outlined below.

- Refine the receiving environment characterization of the Study Area to include additional information gathered since the Stage 1 EIS was submitted.
- Refine effluent plume modelling to include near-field plume modelling and far-field hydrodynamic water quality dispersion modelling.
- Determine the initial dilution of the effluent plume via modeling and estimate constituent concentrations in the near-field at the edge of the initial dilution zone (IDZ) and in the far-field within the Study Area. Assess the potential for adverse effects on aquatic life and impairment of other receiving environment uses identified for the Study Area, through a risk-based impact assessment of the predicted near-field and far-field concentrations.

- Identify uncertainties in the impact assessment.
- Provide recommendations to be considered in post-discharge monitoring for the AIWWTP outfall after the Stage V upgrade.

APPROACH

The Stage V upgrade is a hydraulic upgrade and does not involve any process changes that could change effluent quality. This EIS therefore assumes that effluent quality will remain the same as that most recently characterized between 2012 and 2016. Effluent quality reported for this period was assessed to determine if, after the Stage V upgrade, effluent quality would meet ILWRMP requirements and federal Wastewater Systems Effluent Regulation (WSER; SOR/2012-139) (WSER) limits. Although nutrient concentrations in effluent are not expected to change from those reported for the current discharge, nutrient loadings would be expected to increase under Stage V flows. The projected increase in nutrient loadings to the receiving environment was evaluated in the impact assessment with respect to the potential for nutrient enrichment in the lower Fraser River.

Consistent with provincial guidance, water quality predictions generated at the edge of the IDZ (near-field) and at areas of concern beyond the IDZ (far-field) were assessed to evaluate the potential for adverse effects on public health and water uses relevant to the Study Area: i.e., protection of aquatic life, secondary recreational contact, wildlife use, and agricultural uses (livestock and irrigation). For this assessment, the IDZ where mixing of the effluent and the receiving water occurs is defined as a cylindrical body of water around the outfall with a lateral radius of 100 m from the outfall and extending upwards to the surface of the water column. The Study Area is primarily located in an industrial area with no recreational beaches or drinking water intakes. Recreational areas are located further downstream and the Fraser River is not a drinking water source. The five areas of concern identified as far-field assessment nodes for this assessment therefore relate to the Corporation of Delta irrigation intake and sturgeon and salmonid rearing habitat identified in the Study Area. One far-field node was upstream of the AIWWTP, with the other four nodes located downstream.

Constituents that exceeded both ambient river concentrations at the edge of the IDZ and an applicable water quality objective or guideline were identified as preliminary near-field COPCs. Preliminary near-field COPCs were further evaluated by comparing predicted concentrations to measured concentrations at the edge of the IDZ for the currently approved AIWWTP discharge. This comparison was undertaken to evaluate if there was an expected incremental increase in IDZ concentrations due to the Stage V upgrade. Available toxicological information was also reviewed for preliminary COPCs to evaluate the potential for adverse effects on ecological and public health from the predicted Stage V IDZ concentrations. Concentrations of near-field COPCs were predicted at the far-field assessment nodes and screened against applicable water quality objectives and guidelines and ambient river concentrations.

Constituents assessed in the impact assessment included conventional parameters, metals, nutrients, and a range of organic constituents that included pesticides (herbicides, insecticides, and fungicides), alkylphenols, polychlorinated biphenyls, polybrominated diphenyl ethers, hormones and sterols, and polycyclic aromatic hydrocarbons. Approximately 140 constituents were assessed in the impact assessment. The receiving environment impact assessment also identified and evaluated persistent, bioaccumulative, and toxic constituents (PBTs) to evaluate the potential for adverse effects from fish consumption.

IMPACT STUDY CONCLUSIONS

Overall, the Stage 2 impact assessment presented in Section 7 indicates that pollution as defined by EMA is unlikely to occur as a result of the Stage V hydraulic upgrade to the AIWWTP. This conclusion is based on assessment of the receiving water quality predictions for approximately 140 constituents (Section 6) and in consideration of the uncertainty assessment (Section 8); specifically:

- Adverse effects are not expected on aquatic life, or impairment of other receiving environment uses identified for the Study Area, or public health. This conclusion is based on the assessment of predicted concentrations at the edge of the IDZ made for an effluent flow rate of two times the average dry weather flow (2xAWDF) and at lower effluent flow rates considered in the uncertainty assessment. This conclusion also applies to the assessment of predicted concentrations at far-field nodes in the Fraser River.
- No effect of the project on risk of adverse effects on wildlife and people consuming fish from the Fraser River is not expected because no change in effluent quality is anticipated and concentrations of PBT constituents at the IDZ are not predicted to increase with the Stage V upgrade. Fish tissue monitoring is recommended to confirm this conclusion.
- Secondary treated whole effluent at the point of discharge is not expected to be acutely lethal to aquatic life and conditions within the IDZ would likewise not be expected to be acutely lethal to aquatic life. When the new effluent outfall is commissioned, acute toxicity testing will be carried out to confirm these predictions and is expected to be a condition of the amended Operational Certificate.

The most recent characterization of effluent presented in the Stage 2 EIS (i.e., 2016) indicates that the AIWWTP effluent meets conditions of Section 6(1) of WSER, and as such its deposit is authorized under Section 36(4) of the *Fisheries Act*.

POST-DISCHARGE MONITORING

Post-Stage V monitoring is intended to confirm and verify the findings of the Stage 2 EIS and address identified uncertainties. Long term AIWWTP effluent monitoring and receiving environment monitoring programs are implemented by MV.

Sediment and fish tissue sampling to confirm the findings of the EIS is proposed for consideration by MV. This confirmatory work is not necessarily intended for long-term inclusion in the currently implemented receiving environment monitoring programs. Initially, it is intended to provide data to confirm whether the sediment quality is influenced by the Stage V upgrade and to confirm the findings of the assessment of PBT constituents. Sampling of sediment quality and fish tissues is recommended prior to and following commissioning of the Stage V discharge, with future recommendations to be made based on the findings of those studies.

Study Limitations

This report was prepared for the exclusive use of Metro Vancouver and CDM Smith Canada ULC. No other party may use or rely on this report or any portion thereof without Golder's express written consent. Golder will consent to any reasonable request by the Client to approve the use of this report by other parties as Approved Users. Regulators are considered Approved Users. Any use that a third party may make of this report, or any reliance on or decisions made based on it, is the responsibility of the third parties. Golder Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report. We disclaim responsibility for consequential financial effects on transactions or property values, or requirements for follow-up actions and costs.

In preparing this report, we have relied in good faith on information provided by others, notably CDM Smith Canada ULC and Envirowest Consultants Inc. We assume that the information provided is factual and accurate. We accept no responsibility for any deficiency, mis-statement or inaccuracy contained in this report as a result of omissions, misinterpretations or fraudulent acts of persons interviewed or contacted. As indicated in the report, Golder is responsible for the content of this report with the exception of Section 6.0 and Appendix A that was prepared by CDM Smith Canada ULC and Appendix D that was prepared by Envirowest Consultants Inc.

The services performed as described in this report were conducted in a manner consistent with the level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services. The content of this report is based on information compiled during preparation of the report, our present understanding of site conditions, the assumptions stated in this report, and our professional judgement in light of such information at the time of preparation of this report. This report provides a professional opinion and, therefore, no warranty is expressed, implied, or made as to the conclusions, advice and recommendations offered in this report. This report does not provide a legal opinion regarding compliance with applicable laws. With respect to regulatory compliance issues, it should be noted that regulatory statutes and the interpretation of regulatory statutes are subject to change.

The findings and conclusions of this report are valid only as of the date of the report. If new information is discovered in future work, or if the assumptions stated in this report are not met, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this report, and to provide amendments as required.

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APPENDIX E
Stage 2 EIS Screening Tables

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Supplemental Assessment: Water Quality Screening Tables

LIST OF ABBREVIATIONS AND ACRONYMS

AIWWTP	Annacis Island Wastewater Treatment Plant
ADWF	Average dry weather flow
AVS/SEM	Acid-volatile sulfides and simultaneously extracted metals
BAF	Bioaccumulation factor
BC	British Columbia
BC CDC	British Columbia Conservation Data Centre
BCCSN	British Columbia Cetacean Sighting Network
ENV	British Columbia Ministry of Environment and Climate Change Strategy
BCF	Bioconcentration factor
BOD	Biological oxygen demand
CBOD	Carbonaceous biological oxygen demand
CBOD5	Carbonaceous biological oxygen demand measured over five days
CCME	Canadian Council of Ministers of the Environment
CDII	Corporation of Delta Irrigation Intake
CDM Smith	CDM Smith Canada ULC
CEAA	Canadian Environmental Assessment Act
CEPA	Canadian Environmental Protection Act
CFD	Cumulative frequency distribution.
COPC	Constituents of potential concern
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CRA	Commercial, recreational, and aboriginal
DDT	Dichlorodiphenyltrichloroethane
Delta	Corporation of Delta
DFO	Fisheries and Oceans Canada
DI	Don Island
DIN	Dissolved inorganic nitrogen
DP	Dissolved phosphorus
ECCC	Environment and Climate Change Canada
E.coli	*Escherichia coli*
EDC	Endocrine disrupting compound
EE2	17α-ethinyl-estradiol
EIS	Environmental impact study
EMA	Environment Management Act
EMC	Environmental Monitoring Committee
FRAP	Fraser River Action Plan

FRAMP	Fraser River Ambient Monitoring Program
FREMP	Fraser River Estuary Management Program
FRO	Fraser River Objective
FRWQO	Fraser River Water Quality Objective
FRSQO	Fraser River Sediment Quality Objective
FSC	Food, social and ceremonial (purposes)
Golder	Golder Associates Ltd.
GVS&DD	Greater Vancouver Sewerage and Drainage District
HQ	Hazard quotient
IBA	Important Bird Area
IDZ	Initial dilution zone
ILCR	Incremental lifetime cancer risk
ILWRMP	Integrated Liquid Waste and Resource Management Plan
ISQG	Interim Sediment Quality Guideline
LC50	Median lethal concentration resulting in mortality to 50% of a test group
LWMP	Liquid Waste Management Plan
MCA	Marine conservation analysis
MDL	Method detection limit
MELP	Ministry of Environment, Lands, and Parks
MoE	Ministry of Environment
MV	Metro Vancouver
MWR	Municipal Wastewater Regulation
NAR	Not at Risk
NH3	Ammonia
NH3-N	Un-ionized ammonia as nitrogen
NH4+	Ionized ammonia
NO3-	Nitrate
NO2-	Nitrite
NWA	National Wildlife Area
PAH	Polycyclic aromatic hydrocarbon
PBDE	Polybrominated diphenyl ether
PBT	Persistent, bioaccumulative, and toxic
PCB	Polychlorinated biphenyl
PCDD	Polychlorinated dibenzodioxins
PCDF	Polychlorinated dibenzofurans
PFOS	Perflourooctane Sulfonic Acid
the Port	the Port of Vancouver

PPCP	Pharmaceutical and personal care product
QA/QC	Quality assurance/quality control
QP	Qualified professional
RDLs	Reported detection limits
REM	Receiving Environment Monitoring Program
RSL	Regional screening levels
SAR	Species at Risk
SARA	Species At Risk Act
SC	Special Concern
TB	Timberland basin
TEQ	Toxic equivalency quotient
TN	Total nitrogen
TI	Tilbury Island
TOC	Total organic carbon
TOR	Terms of reference
TP	Total phosphorus
TRC	Total residual chlorine
TSMP	Toxic Substances Management Policy
TSS	Total suspended solids
US EPA	US Environmental Protection Agency
v/v	Volume by volume
WAI	Western Annacis Island
WHO	World Health Organization
WHSRN	Western Hemisphere Shorebird Reserve Network
WQG	Water quality guidelines
WMA	Wildlife Management Areas
WSER	Wastewater Systems Effluent Regulation
WWTP	Wastewater treatment plant

UNITS

%	percent
<	less than
°C	degrees Celcius
d	days
h	hours
kg/d	kilograms per day
kg/y	kilograms per year
km	kilometres
L3/T	cubic litre per tonne
m	metres
m3	cubic metres
m3/day	cubic metres per day
m3/s	cubic metres per second
m3/year	cubic metres per year
mg-N/L	milligrams of nitrogen per litre
µg/L	micrograms per litre
mg/L	milligrams per litre
ML/d	million litres per day
ng/L	nanograms per litre
pH	acidity units
pg/L	picograms per litre

1.0 INTRODUCTION

Metro Vancouver (MV), through the Greater Vancouver Sewerage and Drainage District (GVS&DD), owns and operates three secondary wastewater treatment plants that discharge to the lower Fraser River. The largest plant, Annacis Island Waste Water Treatment Plant (AIWWTP; 1299 Derwent Way, Delta, British Columbia [BC]), currently provides secondary treatment of wastewater to more than one million people in the Greater Vancouver region. The plant is currently being expanded to increase treatment hydraulic capacity to approximately 1.25 million people and is being upgraded to meet current seismic standards. Once complete, the AIWWTP Stage V upgrade will increase treatment capacity to accommodate the region's future population growth, provide additional reliability in maintaining sewage treatment capabilities in the event of a large earthquake, take advantage of green energy captured on-site, and better manage odour issues. A major component of the Stage V Expansion is the upgrade and replacement of the AIWWTP outfall in the lower Fraser River. The final design for the replacement outfall consists of a tunnel system to convey treated effluent from the plant to a diffuser structure to be constructed in the Fraser River downstream of the existing outfall and the Alex Fraser Bridge. CDM Smith Canada ULC (CDM Smith) was retained by MV to provide consulting engineering services for the AIWWTP Transient Mitigation and Outfall Project (henceforth referred to as the Project).

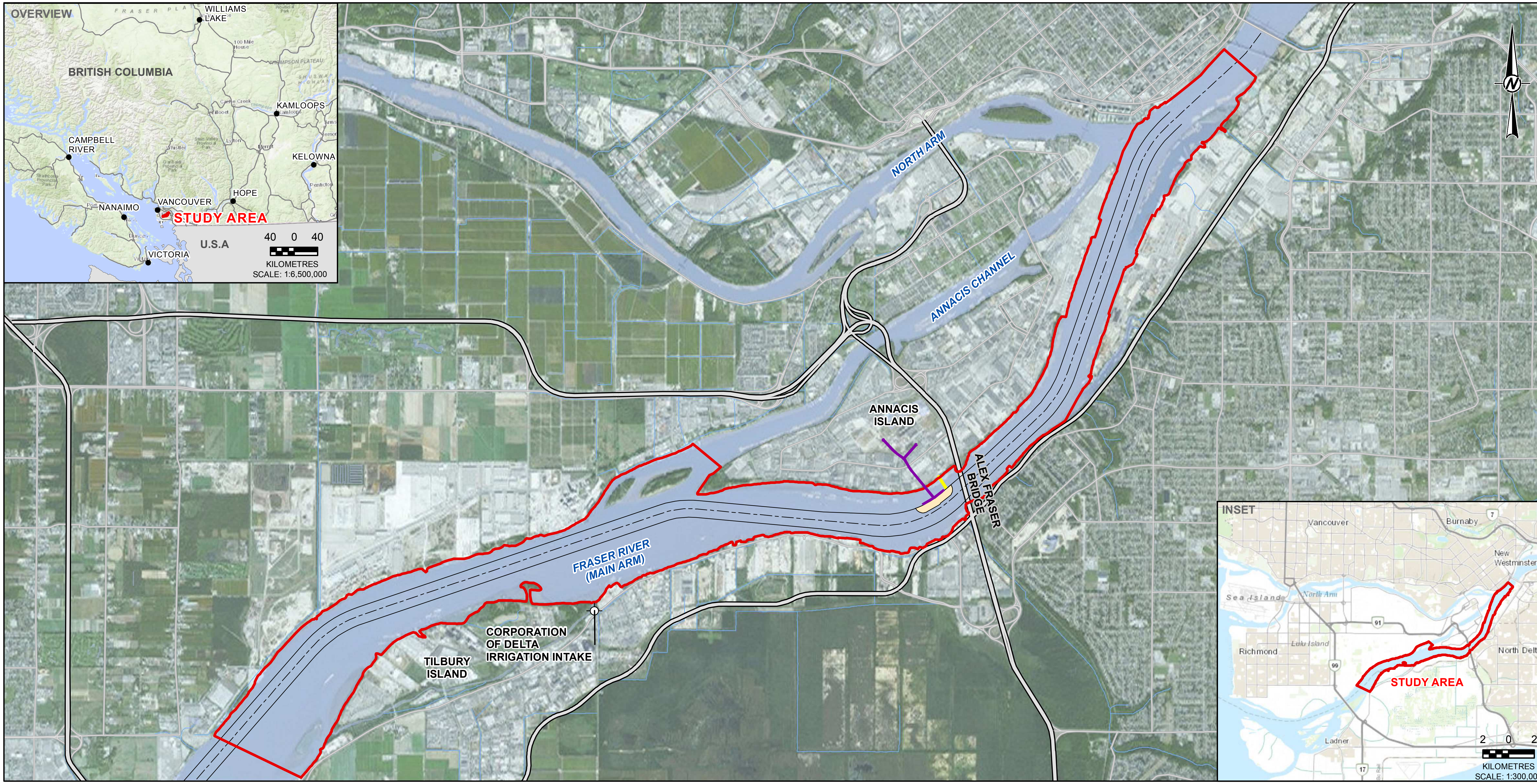
To discharge effluent from the new outfall diffuser, MV requires an amendment of Operational Certificate ME-0387 that authorizes MV to discharge effluent from the AIWWTP under MV's Integrated Liquid Waste and Resource Management Plan (ILWRMP) pursuant to the provincial *Environment Management Act* (EMA) ([SBC 2003] Chapter 53). As per the BC Municipal Wastewater Regulation (MWR) (BC Reg 87/2012; OC 230/2012), (also pursuant to EMA), an Environmental Impact Study (EIS) of the effluent discharge is required to identify whether or not receiving water uses could be impaired by the hydraulic upgrade. The EIS is used by BC Ministry of Environment (ENV) in their permitting decisions and is used by the discharger, in this case MV, as part of their due diligence to verify that they meet the requirements of EMA, the ILWRMP, and the federal *Fisheries Act* (R.S.C., 1985, c. F-14).

Golder Associates Ltd. (Golder) was retained by CDM Smith on behalf of MV to prepare an EIS for the new outfall diffuser system, to support the application to amend Operational Certificate ME-00387 in accordance with provincial guidance (BC Ministry of Environment, Land and Parks [MELP] 2000). Generic provincial guidance in BC MELP (2000) specifies a staged EIS process that typically comprises a Stage 1 assessment of the preliminary design and available data, a pre-discharge monitoring program (if required), and a Stage 2 EIS. The Stage 2 EIS represents a refined evaluation of potential effluent-related impacts on the receiving environment and public health based on the final project design. This report presents the Stage 2 EIS for the Project.

1.1 Project Description

The AIWWTP is the largest of the three secondary wastewater treatment plants owned and operated by MV that discharge to the lower Fraser River. The AIWWTP is located on Annacis Island, Delta, BC (Figure 1). This plant discharges an approximate average 490 million litres per day (ML/d) or 5.7 cubic metres per second (m^3/s) of secondary treated effluent into the Annieville Channel of the Main Arm of the Fraser River through three pipes to a distance of about 160 metres (m) from the north shore, immediately downstream of the Alex Fraser Bridge (ENKON 2015a) (Figure 1). The AIWWTP treats wastewater generated by over 1 million residents within in the Fraser Sewerage Area that consists of all or portions of Burnaby, Coquitlam, Delta, Langley, Maple Ridge, Richmond, New Westminster, Pitt Meadows, Port Coquitlam, Port Moody, Surrey, White Rock, and a small portion of the City of Vancouver. The sewage treated at the AIWWTP is comprised of industrial, commercial, and domestic wastewaters and surface run-off/stormwater.

The AIWWTP is currently being expanded by MV to increase the secondary treatment hydraulic capacity and a new outfall is required to augment or replace the existing outfall facilities. Metro Vancouver is currently implementing Stage V improvements to increase the peak wet weather capacity of the plant from 12.6 m^3/s to 18.9 m^3/s, and future Stage VIII plans are also being made to further increase the peak wet weather capacity to 25.3 m^3/s. A new outfall diffuser system is required because the current AIWWTP is not able to provide sufficient dilution to the effluent, particularly at times of slack water and low flow in the river, and lacks sufficient hydraulic capacity to discharge the planned flow increases at high river levels (CDM Smith 2017) (Appendix A).



LEGEND

- STUDY AREA
- INITIAL DILUTION ZONE
- EXISTING WWPT OUTFALL
- PROPOSED WWPT OUTFALL
- WATER
- WATERCOURSE
- FRASER RIVER SHIPPING CHANNEL
  - CENTRE OF CHANNEL
  - OUTER CHANNEL BOUNDARY
- HIGHWAY
- MAJOR ROAD
- CORPORATION OF DELTA IRRIGATION INTAKE

0 0.5 1 1.5 2

1:45,000 KILOMETRES

REFERENCES

1. SHIPPING CHANNEL SUPPLIED BY BLACK & VEATCH
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COORDINATE SYSTEM: NAD 1983 UTM ZONE 10N

CLIENT
CDM SMITH CANADA ULC AND METRO VANCOUVER

PROJECT
ANNACIS ISLAND WWTP TRANSIENT MITIGATION & OUTFALL UPGRADE
DELTA, B.C.

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-09-27
DESIGNED	PM
PREPARED	JP/MH/CC
REVIEWED	ECI
APPROVED	ECI

TITLE
ANNACIS ISLAND WWPT STAGE 2 ENVIRONMENTAL IMPACT ASSESSMENT STUDY AREA

PROJECT NO.	CONTROL	REV.	FIGURE
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25mm

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1.2 Company Information

The main contact information for the company is:

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Burnaby, BC, V5H 0C6

1.3 Stage 2 EIS Objectives

This Stage 2 EIS is intended to provide a technical assessment of predicted water quality as a means to evaluate whether adverse effects on aquatic and public health might result from the Stage V Upgrade based on the replacement outfall diffuser design described by CDM Smith (2017) in Appendix A as well as existing effluent and receiving environment data.

The objectives of the study are outlined below.

- Refine the receiving environment characterization of the Study Area provided in the Stage 1 EIS based on additional information gathered since the Stage 1 EIS was submitted.
- Refine effluent plume modelling to include near-field plume modelling and far-field hydrodynamic water quality dispersion modelling.
- Determine the initial dilution of the effluent plume via modeling and estimate the concentration of constituents of potential concern (COPCs) at the edge of the initial dilution zone (IDZ) for an effluent flow rate of 2xAWDF. The IDZ is the three-dimensional zone around the point of discharge where mixing of the effluent and the receiving water occurs. For a large waterbody such as the lower Fraser River, the IDZ is commonly defined as a cylindrical body of water around the outfall with a lateral radius of 100 m from the outfall and extending upwards to the surface of the water column.
- Conduct an assessment of expected impacts to water quality in the receiving environment and a risk-based evaluation of potential impacts to ecological and public health and agricultural use based on predicted water quality in the near-field at the IDZ for an effluent flow rate of 2xAWDF and in the far-field at several assessment nodes.
- Identify uncertainties in the impact assessment.
- Provide recommendations to be considered for an AIWWTP outfall post-discharge monitoring program.

1.4 Consultation with Ministry of the Environment

Golder prepared a draft terms of reference (TOR) for the Stage 2 EIS based on BC MELP (2000) guidance for preparing EIS documents, as well as input provided by ENV in their review of the Stage 1 EIS. ENV subsequently approved the draft TOR for the Stage 2 EIS dated 22 March 2017.

The consultation noted here was of a technical and regulatory nature. In addition, MV has been engaged in consultation with First Nations, municipalities, other stakeholders, and MV citizens on broader issues relating to upgrades in sewage treatment infrastructure. Consultation with regulators and key stakeholders on this effluent discharge permit amendment has been an ongoing process.

1.5 Report Overview

Consistent with the suggested scope outlined in BC MELP (2000), this Stage 2 EIS is comprised of tasks grouped under the following general headings:

- Characterization of the Receiving Environment (Sections 2.1 to 2.3)
- Receiving Environment Use (Section 2.4)
- Regulatory Setting (Section 3.0)
- Impact Study Scope and Spatial Boundaries (Section 4.0)
- Effluent Assessment (Section 5.0)
- Receiving Water Quality Predictions (Section 6.0)
- Receiving Environment Impact Assessment (Section 7.0)
- Uncertainty Assessment (Section 8.0)
- Impact Conclusions (Section 9.0)
- Recommendations for AIWWTP outfall post-discharge monitoring program (Section 10.0)

The EIS was undertaken by Qualified Professionals (QPs) as shown in Table 1-1.

Table 1-1: Stage 2 Environmental Impact Study: Authorship and Professional Certification

Section #	Section Title	Company[a]	Name	Accreditation
Section 1	Introduction	Golder	Elaine Irving Lilly Cesh	RPBio RPBio
Section 2	Receiving Environment Characterization and Use			
Section 3	Regulatory Setting			
Section 4	Boundaries of Impact Assessment			
Section 5	Effluent Assessment			
Section 6	Receiving Water Quality Predictions	CDM Smith	Kapila Pathirage	PEng
Section 7	Receiving Environment Impact Assessment	Golder	Elaine Irving Lilly Cesh Cristina Quinn	RPBio RPBio PChem
Section 8	Uncertainty Assessment	Golder CDM Smith	Elaine Irving Kapila Pathirage Lilly Cesh Cristina Quinn	RPBio PEng RPBio PChem
Section 9	Impact Conclusions	Golder	Elaine Irving Lilly Cesh Cristina Quinn	RPBio RPBio PChem
Appendix A	Multiport Diffuser Design and Dilution Modeling Report	CDM Smith	Kapila Pathirage	PEng
Appendix B	Lower Fraser River Ambient Water Quality Summary	Golder	Elaine Irving Cristina Quinn	RPBio PChem
Appendix C	Stage V Pre-Upgrade Sediment Characterization Report	Golder	Elaine Irving	RPBio
Appendix D	Description of Ecological Attributes	Envirowest	Rolf Sickmuller	RPBio
Appendix E	Water Quality Screening Tables	Golder	Lilly Cesh Cristina Quinn	RPBio PChem
Appendix F	Supplemental Assessment	CDM Smith Golder	Kapila Pathirage Elaine Irving Cristina Quinn	PEng RPBio PChem

a. Golder Associates Ltd. (Golder); CDM Smith Canada ULC (CDM Smith); Envirowest Consultants Inc. (Envirowest)

2.0 RECEIVING ENVIRONMENT CHARACTERIZATION AND USE

2.1 Background and Study Area

The Fraser River is one of the largest unregulated rivers in North America with a catchment area that encompasses approximately 232,000 square kilometres, the majority of which is located east of the Lower BC Mainland. The lower Fraser River extends from the City of Hope to its confluence with the Strait of Georgia.

The AIWWTP is located within the Corporation of Delta (Delta) on Annacis Island in the Fraser River Main Arm, downstream of the New Westminster 'trifurcation' where the river splits into three channels or arms. The North Arm extends from New Westminster Quay past Sea Island and receives about 10 to 15 percent (%) of the Fraser River flows. The Main Arm (referred to as South Arm in Fraser River Estuary Monitoring Program [FREMP]) is larger, conveying 80 to 85% of Fraser River flows, and serves as the main navigation channel for the Fraser River (FREMP 2006). A portion of the Main Arm splits around Annacis Island, with the Annacis Channel located on the north side of the island and the Annieville Channel on the south side. The mouth of the Fraser River joins the Strait of Georgia along a 37 kilometres (km) delta-front from Point Grey to Point Roberts.

The Environmental Management Strategy for Dredging in the Fraser River Estuary developed by FREMP (2006) divided the Main Arm of lower Fraser River into four channel segments. These segments were developed based on differences in channel morphology, water quality, tidal influences, and dredging requirements:

- **Sand Heads Channel**—Located west of Steveston to the end of the Steveston Jetty and provides the main access to the Fraser River for shipping.
- **Main Arm Tidal Channel**—Located between Steveston and Deas Island. The main shipping channel runs along the north side of the channel, while the south side has estuarine wetlands and an island complex.
- **Main Arm Meso-Tidal Channel**—Runs from Deas Island along the main shipping channel on the north side of Annacis Island to the eastern tip of the island. Most of this section has industrial activity along its shorelines and is confined by bank protections and training structures.
- **Annacis Channel**—Located along the northern bank of Annacis Island. This section contains combination industrial and residential sections, with extensive channel training works to maintain velocities and minimize dredging requirements.

The proposed outfall location is in the Main Arm Meso-Tidal Channel in a stretch of the river named Annieville Channel (Figure 1). Most of the Main Arm Meso-Tidal Channel has industrial activity along its shorelines and is confined by bank protections and training structures, including the New Westminster trifurcation training structure that serves to split Fraser River flows down multiple channels, reducing sedimentation and the need for dredging. This segment also includes Gunderson Slough and Tilbury Slough that are characterized by their shallow bar mouths, and Deas Slough that is a popular recreational boating area (FREMP 2006). The main shipping channel runs from Gravesend Reach through to St. Mungo's Bend on the south side of Annacis Island and continues upriver through Annieville Channel.

The land area around the new and existing AIWWTP outfalls is mixed commercial and industrial in nature with adjacent sites being Turning Point Brewery and a Sea Span loading area. The new outfall diffuser is proposed to be placed at the edge of the navigational channel to minimize impacts on dredging and shipping.

The proposed Stage 2 EIS project study area represents an extension of the preliminary study area adopted for the Stage 1 EIS as shown in Figure 1. For the Stage 2 assessment, the Study Area located within the Main Arm Meso-Tidal Channel is proposed to extend 5.5 km upstream of the outfall, where MV has their reference location for the AIWWTP Receiving Environment Monitoring (REM) program, to 8 km downstream to the southern extent of Tilbury Island. Existing ambient river conditions within the Study Area were characterized based on a compilation of available data and information. Receiving environment uses within the Study Area were documented, as well as current discharges and water withdrawals.

2.2 Physical Setting

2.2.1 Hydrology

The Main Arm of the Fraser River, where the Study Area is located, carries 80 to 85% of the river flow (FREMP 2006), with flows since 2008 ranging from 605 to 11,700 m^3/s (Environment and Climate Change Canada's [ECCC] Pacific Water Quality Monitoring & Surveillance Program; see CDM Smith [2017] Appendix A for hydrograph depiction of flow rates). Low flows typically occur between September and March, while peak flows occur between April and August in response to freshet and runoff of precipitation (Bull 2004).

The river system in the vicinity of the proposed outfall location is a complex estuarine environment due to tidal influences and the encroachment of saline water from the ocean. Flows in the vicinity of the proposed discharge location are subject to tidal influence that affects water velocity, water depth, and vertical mixing. Salt water migrates up the Fraser River as a result of a combination of density differences between salt and fresh water and rising tides in the Strait of Georgia, and exists as a saline "salt wedge" along the bottom of the river. Fresh water is less dense than salt water and will typically flow out over top of the denser saline waters. The rising tide causes the wedge of salt water to migrate upstream underneath the outflowing freshwater of the Fraser River. Salt water intrusion at Annacis Island is reported to occur only at lower flows (Milliman 1980), as the salt wedge extends upstream to New Westminster during low flows on the Fraser River. During freshet, the salt wedge only migrates up the Fraser River channel as far as Steveston Bend and does not reach the Study Area.

2.2.2 Water and Sediment Quality

Within the Fraser River Basin, natural sources of metals such as weathering of the mineral constituents of sediment substrates, are mobilized and sediment is transported downstream to the lower reaches of the Fraser River and further into the Fraser River estuary towards the Strait of Georgia (FRAP 1999a, Bull et al 2004). Flows are highest during the freshet season and thus a large proportion of sediment movement occurs during this period. Both the hydraulic regime of the Fraser River and natural geological sources of sediment within the catchment influence water and sediment quality in the lower Fraser River.

Industrial activities such as manufacturing, shipping, and pulp and paper milling have historically occurred and continue to occur on the Fraser River, although manufacturing and shipping are more prominent in the lower reaches (Swain et al. 1998). Other than the AIWWTP, there are two other municipal waste water treatment plants (WWTPs) in operation on the lower Fraser River (i.e., Lulu Island and Northwest Langley WWTPs) but the AIWWTP is the largest. Runoff from urban areas in the greater Vancouver area may also influence Fraser River water and sediment quality because the storm water system discharges directly into the lower Fraser River.

Water Quality

Receiving environment water quality for the Project was defined as ambient water quality within the Study Area, with the term 'ambient' referring to water quality outside the direct influence of effluent discharges, consistent with terminology used by the Fraser River Ambient Monitoring Program (FRAMP) (ENKON 2016a).

Ambient water quality data obtained from regional and federal data sources were compiled and statistics calculated for the period from January 2012 to September 2016, to characterize ambient water quality in the lower Fraser River (Appendix B). The statistics, presented in tabular format in Tables B2 to B9, were screened against applicable receiving environment water quality guidelines as identified in Section 2.4.6. A characterization of ambient water quality within the EIS Study Area shown in Figure 1 is provided below based on interpretation of the screening results presented in Appendix B. These statistics were used as inputs to represent ambient river concentrations in the generation of short-term and monthly water quality predictions as described in Section 6.0.

Conventional Parameters, Nutrients, and Metals

The lower Fraser River within the Study Area tends to be slightly alkaline and well oxygenated, with soft to moderately soft water hardness (Tables B2 to B4). Upstream migration of the salt wedge from the Strait of Georgia under certain low flow conditions as described in Appendix A influences water quality; notably by increasing levels of salinity, conductivity, and total dissolved solids.

Under high flow conditions from April to August, total suspended solids (TSS) concentrations are naturally high due to the downstream transport of sediment from natural geological sources. Elevated total concentrations of metals such as aluminum, chromium, copper, iron, manganese, and zinc, that can exceed Fraser River Water Quality Objectives (FRWQOs) as well as federal and provincial water quality guidelines (WQGs), are evident during these months due to the increased transport of particulate metals to the lower Fraser River during freshet (Tables B2 to B4). In contrast, dissolved concentrations of these metals are considerably lower, indicating that only a proportion of total metal concentrations are potentially available for uptake by aquatic biota. The same disparity between total and dissolved concentrations is observed for phosphorus during freshet, where total concentrations increase by an order of magnitude but dissolved concentrations are lower and more consistent throughout the year.

The Fraser River can also be naturally turbid under low flow conditions although to a lesser degree than during freshet. Thus suspended sediments present in the water column continue to exert some influence on total metal and nutrient concentrations in the Study Area throughout the year (Tables B2 to B4).

Organic Constituents

Of the subset of organic constituents identified in Section 5.5 to be carried through the Stage 2 EIS assessment, polychlorinated biphenyls (PCBs) and 17α-ethinyl-estradiol (EE2) were the only organic constituents reported above applicable guideline values under ambient conditions (Tables B5 to B7). EE2 values were derived from a dataset where all reported values were less than the method detection limits (MDLs) reported by the analytical laboratory and the majority of reported MDLs were higher than the short-term BC WQG for the protection of aquatic life (0.75 nanograms per litre [ng/L]). As discussed in Section 7.0, the EE2 data available for the Fraser River through the AIWWTP REM program have uncertainty associated with them due to the limited ability of analytical laboratories to measure EE2 at MDLs lower than the BC WQG. As described in Section7.0, there is also uncertainty regarding PCB data included in the ambient dataset due to detected concentrations in quality assurance/quality control (QA/QC) blank samples, including laboratory blank samples.

Bacteriological Parameters

The 2012-2016 geometric mean values for fecal coliforms and *Escherichia coli* (E. coli) calculated for the AIWWTP 'disinfection season' from April to October were below their respective FRWQOs and in the case of *E. coli* below the water quality guideline for recreational use (Tables B8 and B9). The corresponding geometric mean value for *Enterococus* was above the FRWQO but below the water quality guideline for recreational use.

Sediment Quality

In the lower Fraser River, fine sediments are transported more readily because less energy is required to mobilize them. Depositional areas of these fine sediments can form where the current is reduced as a result of the morphology of the river or a physical obstruction to the river flow. The center of the lower Fraser River channel where current and flow are highest tends to be scoured and substrate predominantly comprises sand with a small quantity of silt. Areas closer to shore or where eddies in the current form tend to accumulate finer sediment such as clay-silt with a higher proportion of organic matter. As confirmed by a sediment characterization study initiated in 2016 to support this EIS provided in Appendix C, the Study Area is similarly structured in that the proportion of fine material in sediment tends to decrease from the near-shore towards the center of the channel. Finer sediment material, both clay and organic, has a higher surface area in comparison to coarser sediment material, and therefore more binding sites that contaminants can adsorb to.

Sediment sampling in the lower Fraser River as a component of the FRAMP to monitor ambient sediment quality focusses on depositional areas with finer sediments where contaminant loads are expected to be the highest. To date FRAMP has surveyed ambient sediment quality in 2006, 2011 and 2016 (Enkon 2007, Keystone 2011, ENKON 2016b). Prior to 2006, sediment quality had been surveyed in the lower Fraser River by a number of initiatives, including the FREMP surveys, the Fraser River Action Plan (FRAP) in the 1990s, as well as monitoring by ENV (FREMP 1996, FRAP 1999b, Bull 2004).

2016 Sediment Characterization Survey

Prior to 2016, the most recent sediment sampling program specific to the AIWWTP (Thomas 2007) concluded that sediment substrates in the vicinity of the existing AIWWTP outfall comprised coarse hard-packed sand that proved challenging to sample. To support this EIS, a study was initiated in 2016 to provide a characterization of sediment conditions in the vicinity and downstream of the planned location for the new AIWWTP outfall, as well as at upstream reference stations. Methods, results, and conclusions from this study are provided in Appendix C with a summary below.

The EIS sediment characterization study involved the collection of nine sediment grab samples from near-shore and mid-channel locations upstream and downstream of the AIWWTP. These samples were analyzed for grain size distribution, moisture, total organic carbon (TOC), polycyclic aromatic hydrocarbons (PAHs), metals, acid-volatile sulfides and simultaneously extracted metals (AVS/SEM), fecal coliforms, *E. coli* and enterococci. Trace organics analysis was conducted on a subset of five stations, mostly in near-shore areas. Samples were analyzed for alkyl phenols, sterols, hormones, pesticides, PCBs, polychlorinated dibenzo-p-dioxins and furans (PCDD/Fs), and polybrominated diphenyl ethers (PBDEs).

Stations sampled upstream and downstream of the AIWWTP had sediment characteristics depending on proximity to the Fraser River shore. Mid-channel stations located close to the dredged navigational channel in higher flow areas were comprised predominantly of coarse sand with low TOC. Concentrations of metal and organic constituents at these stations were below applicable Fraser River Sediment Quality Objectives (FRSQOs) and BC and federal sediment quality guidelines, with the exceptions of nickel and chromium. These observations are consistent with ambient monitoring of sediments along the lower Fraser River, where similar exceedances have been reported for these metals, suggesting that these metals are related to natural geological conditions.

Sandy or silty loam sediments were present at stations in lower flow areas located closer to shore. These sediments had a higher proportion of fines compared to those from the mid-channel. Concentrations of metals, organic, and biological constituents reported at these stations tended to be higher than those reported at mid-channel stations, but were generally still below available FRSQOs, BC lower SWQGs, and Canadian Council of Ministers of the Environment (CCME) Interim Sediment Quality Guideline (ISQG) values. Where exceedances were observed, they were relatively small and were consistent with those reported by FRAMP for sediment sampled along the length of the lower Fraser River.

Sediments from near-shore stations upstream and downstream of the AIWWTP had higher concentrations of fecal coliforms, *E. coli*, and enterococci compared to mid-channel stations where concentrations were at or near MDLs. Concentrations of bacteriological parameters reported at the upstream reference station in Annacis Channel were within the reported range for the co-located ambient station sampled by FRAMP in late winter 2016.

The near-shore station closest to the existing outfall (NF-3) had the highest concentration of *E. coli* and fecal coliforms. The coprostanol/ (coprostanol+cholestenol) ratio calculated for this station suggested an influence of human waste on sediment quality. The other eight stations sampled had ratios within the range reported by ENKON (2016a) for stations along the Main Arm of the lower Fraser River that did not indicate an influence of human waste on sediment quality.

2.3 Ecological Resources

Ecological resources in the lower Fraser River have been the subject of numerous studies and initiatives including the FREMP and the FRAP, as well as other monitoring or research initiatives by government, industry, and academia. Ecological resource information, with respect to the physical habitat characteristics and aquatic resources relevant to the Study Area, was accessed from information sources that included but were not limited to the following:

- FREMP, an organization jointly established by the provincial and federal governments in the 1980s that disbanded in 2013
- FRAP
- FRAMP
- Fisheries and Oceans Canada, Pacific Region website
- BC Conservation Data Centre (BC CDC)
- Government of Canada, *Species At Risk Act* (SARA) Public Registry

- Committee on the Status of Endangered Wildlife in Canada (COSEWIC) status reports for listed marine mammal species
- British Columbia Cetacean Sighting Network (BCCSN)
- British Columbia Species and Ecosystems Explorer
- British Columbia Marine Conservation Analysis (MCA) atlas and public database
- iMapBC (DataBC)
- Relevant peer-reviewed scientific literature and government data reports

2.3.1 Fish and Fish Habitat

Fish Habitat

Habitat along the shorelines of the Annieville Channel where the Study Area is located have been highly modified. Most habitats along this section of the river comprise either a narrow riparian fringe woodland, intermitted marsh, or mudflat. High river flows combined with rock armouring of the South Surrey Interceptor and channel restrictions associated with the Alex Fraser Bridge have resulted in a diverse bathymetry in proximity to the Project (Appendix A). The most notable bathymetric feature includes a deep scour hole extending downstream of the South Surrey Interceptor and past the Project. Other notable bathymetric features include sand waves established in the downstream extent of the scour hole that become increasingly mobile during high freshet flows.

The former FREMP classified the shorelines of the Fraser River based on the relative value of the habitat features (FREMP 2006). The FREMP (2006) colour-coded system classified the overall habitat value of the estuarine shoreline and identified development constraints associated with each classification. The definition of habitat was limited to functional habitat values provided by estuarine environments for fish and wildlife. The FREMP (2006) classification system comprised a three tiered colour-coded system:

- Red-coded shorelines sustained highly productive fish and wildlife habitats
- Yellow-coded shorelines sustained moderately productive habitats
- Green-coded shorelines were characterized by habitats of low productivity

The FREMP classification system applied only to intertidal habitat and riparian habitat extending up to 30 m landward of the shoreline. Habitats below local low water, hence below the intertidal zone, were not addressed by the system. This is particularly relevant, as the new outfall will not encounter habitats above local low water (i.e., within the intertidal or upland zones). Fish habitat information regarding shoreline, intertidal, and sub-tidal habitats in the vicinity of the proposed location for the new outfall is provided in Appendix D, including a description of ecological attributes to support this Stage 2 EIS.

The FREMP habitat classifications of the south shoreline of Annacis Island are predominantly high (red) productivity or moderate (yellow) productivity. The high and moderate productivity classifications are largely a function of riparian vegetation and intermittent fringe marsh establishment along the shoreline. Low (green) productivity habitat is present in the footing protection structure of the Alex Fraser Bridge north support structure immediately upstream of the Project, and the ship docks at the upstream extent of Annacis Island.

The south shoreline of the Main Arm (i.e., Corporation of Delta shoreline) includes all three habitat classifications. Moderate productivity shoreline is generally more prevalent, interspersed with low productivity shoreline and occasional high productivity habitat. High productivity habitat is more prevalent along the Tilbury Island shoreline.

Fish

An estuarine fish assemblage occupies the lower Fraser River to the upper limits of tidal influence at Mission (McPhail 2007). The river sustains nationally important commercial, recreational, and aboriginal fisheries, as regulated by the federal *Fisheries Act* and fish species of management concern in the context of commercial, recreational, or Aboriginal fisheries and species at risk.

The lower river contains a number of euryhaline species that are adaptable to a range of salinities, (e.g., lampreys, sturgeon, smelts, salmon, and trout); however, there are also purely freshwater species (McPhail 2007). Freshwater species include five minnows [brassy minnow (*Hybognathus hankinsoni)*, peamouth chub (*Mylocheilus caurinus)*, northern pikeminnow (*Ptychocheilus oregonensis)*, longnose dace (*Rhinichthys cataractae*), and leopard dace (*R. falcatus)*)] and three sucker species [bridgelip sucker (*Catostomus columbianus)*, largescale sucker (C. *macrocheilus)*, and mountain sucker (*C. platyhyncus)*].

The fish community of the lower Fraser River is dominated by cyprinids, salmonids, and catostomids (Richardson et al. 2000).The Fraser River is a salmonid-bearing system. Salmonid use of the Main Arm from Steveston to New Westminster is largely upstream adult migration in the fall and downstream juvenile migration and rearing in the spring to midsummer (FREMP 2006). Seven species of salmonids (*Oncorhynchus* spp.) occur within the lower Fraser River: chinook salmon (*O. tshawytscha*); chum salmon (*O. keta*); coho salmon (*O. kisutch*); cutthroat trout clarkii subspecies (*O. clarkii clarkii*); pink salmon (*O. gorbuscha*); rainbow trout; and sockeye salmon (*O. nerka*) (Water and Land Use Committee 2006). Adult salmon migrate upriver annually to spawn and hundreds of millions of juveniles migrate downstream to and through the estuary and ultimately to the sea (Rosenau and Angelo 2007).

The Main Arm also supports eulachon (*Thaleichthys pacificus*) during their migration to upstream spawning habitats as close to the Project as New Westminster and sustains white sturgeon (*Acipenser transmontanus*). In recent years, juvenile sturgeon have been captured along the south shore of Annacis Island. Despite having special conservation assessment status (COSEWIC 2003) and provincial conservation priority (BC CDC), the lower Fraser River white sturgeon population is not included in Schedule 1 of the *SARA.*

Out-migrating juvenile salmonids utilize intermittent intertidal marshes established along the Main Arm. The marshes provide rearing habitat for juvenile chinook salmon, chum salmon, coho salmon and white sturgeon (Healey 1991, Salo 1991, Cohen 2012, Nelson et al. 2004). Specific occurrences of species identified by the BC CDC and iMapBC adjacent to the Project are limited to juvenile white sturgeon. The absence of other documented occurrences in proximity to the outfall is not indicative of species absence, as salmon and coarse fish species have been captured in reaches of the Fraser River upstream and downstream of the outfall.

More detailed information on the ecological attributes of species of management concern that are the subject of provincial and or federal management policies and/or programs is provided in Appendix D. Species of management concern include salmon (*Oncorhynchus* spp.), eulachon, sturgeon (*Acipenser* spp.), and char (*Salvelinus* spp.).

2.3.2 Fish Health and Tissue Concentrations

Fish health and contaminant tissue concentrations in the lower Fraser River have been the subject of several monitoring initiatives undertaken since the 1990s, including the FRAP in the 1990s, a study by BC MoE in 2003, and more recently monitoring studies in 2004, 2007 and 2012 by FRAMP (Raymond et al. 1999, FRAP 1999b, Bull 2004, ENKON 2009, ENKON 2014). These studies monitored resident Fraser River species with a focus on small-bodied fish that are more likely to show site fidelity compared with other more mobile fish species (i.e., peamouth chub [*Mylocheilus caurinus*], large scale sucker [*Catostomus macrocheilus*]). Studies have also been undertaken to determine contaminant concentrations in white sturgeon in the Fraser River and anadromous salmon species that utilise the Fraser River as they migrate between freshwater and marine environments.

A summary of the main findings of these programs and studies with relevance to the Main Arm of the lower Fraser River is provided below.

Monitoring of Fish Health and Contaminant Tissue Residues in the Lower Fraser River

In a synthesis of fish health information available for the Fraser River, FRAP (1999) concluded that concentrations of legacy contaminants like dichlorodiphenyltrichloroethane (DDT), organochlorines, dioxins/furans, and metals measured in fish collected from the Fraser River had decreased from the 1970's to the late 1990's. The synthesis incorporated the results of both historical studies and a study specifically undertaken for FRAP by Raymond et al. (1999). Although PCB concentrations in fish sampled from the Fraser River were below the provincial guideline for human consumption at that time, FRAP (1999) identified the potential for effects of dioxin-like PCBs on wildlife consumers of fish.

Fish tissue monitoring by ENV in 2003 reported that concentrations of dioxins and furans in starry flounder (*Platichthys stellatus*) sampled close to the Fraser River mouth met the Fraser River Objective (FRO) to protect human health (Bull 2004). A similar comparison to FROs for PCBs in starry flounder was inconclusive because the detection limit for fish tissue was higher than the objective derived to prevent biomagnification in the food web and protect wildlife from the consumption of whole fish. Historically, concentrations in starry flounder from the same location have been below the FRO for PCBs in fish tissue (surveys in 1994 and 1995). In 1988, five unspecified fish species were sampled by ENV from this location and concentrations in all five species were below the PCB FRO (Bull 2004).

The most recent monitoring of fish health and contaminants in tissues collected from the lower Fraser River was undertaken for the FRAMP in 2004, 2007, and 2012 (ENKON 2009, 2014). A summary is provided below of findings from the most recent 2012 survey, in which sentinel fish species largescale sucker (*Catostomus* macrocheilus) and peamouth chub were sampled in the Main Stem upstream of the AIWWTP, in the Main Arm close to Steveston, and in the North Arm.

- Health metrics measured in peamouth chub from three study areas in the lower Fraser River showed few among-area differences. Lengths, weights, condition factors, and relative reproductive organ size did not significantly differ between areas. These findings contrasted with the findings of the 2007 and 2004 surveys reported by ENKON (2009), where both sexes of peamouth chub collected from the Main Arm were significantly longer and heavier than chub collected from the other two areas.

- Health metrics measured in largescale sucker from three study areas in the lower Fraser River showed some significant differences among the three study areas related to length, weight, and condition factor. Suckers collected from the Main Arm were longer and heavier than those collected from the other two areas. In contrast, suckers collected from the Main Stem were shorter and lighter than the two other areas. Male fish from the Main Arm had the highest condition factor and males from the Main Stem had the lowest condition factor. These findings were consistent with those reported by ENKON (2009) for the 2007 survey.

- Tissue concentrations of dioxins and furans, PCBs, and benzo[a]pyrene reported for the three study areas in 2012 met FROs for dioxins/furan toxic equivalency quotients (TEQs), total PCBs, and benzo[a]pyrene. Concentrations of methylmercury in the three areas were above the CCME fish tissue guideline for the protection of wildlife consumers. Most other constituents measured in fish met applicable provincial or federal guidelines. Where concentrations exceeded guideline values, they did so by a margin essentially equal to the guideline within the limits of analytical precision.

- Concentrations of arsenic, PCBs, and PBDEs measured in composite liver and whole body samples from peamouth chub and largescale sucker whole body samples collected from the Main Stem were lower than those collected further downstream in the Main Arm and in the North Arm. A similar spatial pattern for PCBs was observed in the 2004 and 2007 surveys.

- Since the FRAMP fish monitoring was initiated in 2004, a decrease in total PCB concentrations in peamouth chub livers has been observed. Overall, total PCB concentrations reported in peamouth chub muscle and liver were substantially lower in the 2012 and 2007 surveys compared to historically reported concentrations (1971-1995).

- With respect to total mercury, concentrations in fish tissue appear to have decreased from historical tissue concentrations reported for the lower Fraser River (i.e., 1973-1995). FRAMP first measured methylmercury in fish collected from the lower Fraser River in 2012 and concentrations in peamouth chub and largescale sucker whole body samples were highest in the Main Stem and lowest in the North Arm.

- Concentrations of dioxins and furans and copper did not significantly differ between the three areas in 2012, similar to the findings of the 2004 and 2007 surveys.

- Analysis of stable carbon and nitrogen isotopes in muscle tissue to confirm site fidelity of largescale sucker and peamouth chub indicated that these fish species sampled from the Main Arm showed site fidelity and did not move into other sampling areas. While largescale suckers also showed site fidelity in the Main Stem and North Arm sampling areas, there was an indication that peamouth chub may have moved between the North Arm and the Main Stem.

With specific reference to the AIWWTP, historical sampling of peamouth chub in the vicinity of Annacis Island by EVS (1996) documented that cadmium, copper, iron, lead, and zinc were detected in fish tissue but there was no apparent pattern of contamination associated with the AIWWTP.

Fish Contaminant Tissue Studies in the Lower Fraser River

Both Cullon et al. (2009) and Kelly et al. (2011) sampled adult salmon for tissue analysis during their upstream migration from the Strait of Georgia to upstream spawning grounds, either close to the mouth of the Fraser River or from the lower Fraser River.

Cullon et al. (2009) determined concentrations of persistent organic compounds in adult chinook salmon and compared concentrations to those determined in chinook smolts collected from the central Strait of Georgia prior to ocean migration. The authors concluded from this comparison that 97 to 99% of PCB, dioxin and furan, DDT, and hexachlorocyclohexane concentrations reported in returning adult chinook were accumulated by the fish in the marine environment as opposed to the Fraser River and its tributaries. In a desktop study to investigate PCB accumulation by Pacific salmon in Washington State, US, Hope (2012) also concluded that the majority of PCB accumulation by the salmon likely occurred in the marine environment as opposed to the freshwater environment.

In a subsequent study of Fraser River salmonids, Kelly et al. (2011) determined concentrations of PCBs, dioxins and furans, PBDEs, organochlorine pesticides, and metals in the muscle and eggs of adult sockeye and chinook salmon. The salmon were sampled from the lower Fraser River while migrating upstream in 2007. Mercury and arsenic concentrations were below applicable human health consumption guidelines. Concentrations of PCBs, dioxins and furans, PBDEs, and organochlorine pesticides were detected in muscle and the authors concluded that concentrations of these lipophilic compounds can be magnified in adult salmon as they migrate upstream but that the maternal transfer to eggs is slow relative to less hydrophobic constituents. Mean TEQs of PCBs and dioxins and furans in eggs sampled from female sockeye and chinook salmon sampled by this 2007 study were below a TEQ benchmark in salmonid eggs associated with 30% egg mortality. Reported 2007 TEQs were also substantially lower than TEQs reported in eggs from salmonids sampled from the Great Lakes region between 1986 and 1997.

A study in the early-1990s by McDonald et al. (1997) reported that concentrations of metals, PCBs, dioxins and furans, and chlorophenols in muscle and liver tissues sampled from adult white sturgeon from the lower Fraser River were lower than concentrations measured in sturgeon muscle and liver samples from the upper Fraser River. At that time, pulp mills were a source of organic contaminants in the upper Fraser River.

2.3.3 Benthic invertebrates

A characterization of benthic invertebrate communities in the Main Arm was provided by Swain et al. (1998) based on a study by Northcote et al. (1976). In this historical study, benthic invertebrates were sampled at stations located along the lower Fraser River in late summer/fall of 1972 and 1973, when the river was characterized by average to high flows and the salt wedge was located closer to the river mouth. The benthic invertebrate community assessment was based on comparison of benthic metrics such as abundance and diversity between stations. The average number of taxa collected from mud and sand substrates in the Main Arm was lower than that estimated for the North Arm; however, diversity was similar between the two arms for both substrate types. Benthic communities present at the most upstream station in the Main Arm located near Tilbury and Deas islands were composed of oligochaetes, leeches, *Pisidium* clams, crustaceans such as amphipods and isopods, and dipteran insect larvae (chironomids, a type of non-biting midge). At that time of year (late summer/fall), Swain et al. (1998) suggested that it would be reasonable to expect more freshwater organisms in the Main Arm compared to earlier in the year when salinity intrusion extends farther upstream in the lower Fraser River.

More recently in 2016, a preliminary benthic survey as part of the sediment characterization study to support this EIS confirmed that benthic communities downstream of the AIWWTP were dominated by oligochaetes and chironomids. Invertebrates were more abundant at stations closer to shore compared to the mid-channel where higher flows prevailed and the navigational channel is subject to periodic dredging. One mid-channel station in the navigational channel was devoid of a benthic invertebrate community. Invertebrate density at the other mid-channel station outside of the navigational channel was less than 5% of the mean density of the two near-shore stations. The two nearshore stations had comparable invertebrate densities. The absence of a benthic invertebrate community within the mid-channel at the proposed outfall location was confirmed by an evaluation of three samples collected in February 2017 (Appendix D).

2.3.4 Mammals

Marine and non-marine mammals expected to occur in the Study Area and a description of their habitat use and diet is provided in Appendix D; a brief summary is provided in this section.

With respect to marine mammals, Steller sea lions (*Eumetopias jubatus*) and Harbour seals (*Phoca vitulina*) are expected to occur in the Study Area. California sea lions (*Zalophus californianus*) congregate at Sandheads near Steveston, Richmond, and may occasionally travel up the lower Fraser River to proximity of the Project during adult salmon migrations. Stellar sea lions are considered to be a species of special concern both provincially and federally (Section 2.3.6). They spend the majority of time in marine waters or at terrestrial rookeries and haul-out sites, but occasionally enter freshwater environments (COSEWIC 2013). Use of the lower Fraser River by Steller sea lions includes feeding congregations in the river during spring eulachon runs (Bigg 1985) and occasional rafting behaviour up to 35 km upstream of the mouth of the river (Olesiuk unpublished data, cited in COSEWIC 2013). There are no known haul-outs within the Study Area and presence would largely be transient in nature. Harbour seals are found in coastal waters, some lakes, and many rivers including the lower Fraser River upstream to Hell's Gate. Preferred haul-out sites include tidal mud flats, sand bars, reefs, and log booms. They are considered to be year-round residents in the lower Fraser River, but move around locally in association with tides, food, reproductive behaviour, and season.

Ten (10) native mammal species likely occur within and in proximity to the proposed new outfall location. These include North American river otter (*Lontra canadensis*), mink (*Neovison vison*), American beaver (*Castor canadensis*), common muskrat (*Ondatra zibethicus*), and coyote (*Canis latrans*). Habitat use by these species is primarily limited to terrestrial areas and/or portions of the river proximal to the riverbank.

2.3.5 Birds

The Study Area overlaps with the Boundary Bay – Roberts Bank – Sturgeon Bank Important Bird Area (IBA) designated because of its importance for large congregations of overwintering waterfowl and shorebirds, colonial waterbirds, and seabirds, as well as numerous species at risk (IBA 2016). This IBA consists of a complex of marine, estuarine, freshwater and agricultural areas and extends from Boundary Bay to the City of Surrey, west to the Fraser River estuary. The IBA covers most of the Study Area with the exception of the stretch of river between Annacis Island and the Alex Fraser Bridge.

A portion of the IBA (45%) located downstream of the Study Area is protected in conservation management areas such as parks and wildlife management areas. The majority of protected areas are situated around inter- and sub-tidal areas. Two provincial Wildlife Management Areas (WMAs; South Arm Marshes WMA and Roberts Bank WMA), one national wildlife area (Alaksen National Wildlife Area [NWA]), and one national migratory bird sanctuary (George C. Reifel Migratory Bird Sanctuary) occur southwest of the Study Area on the Fraser River-Pacific Ocean delta. These areas were established to protect congregations of overwintering birds, waterfowls, shorebirds, and seabirds. They support critical numbers of North American dunlin (*Calidris alpina*), North American trumpeter swan (*Cygnus buccinator*), North American black-bellied plover (*Pluvailis squatarola*), and also provide habitat for migrating and overwintering bird species like the migrating snow goose (*Chen caerulescens*) and dabbling ducks (e.g., American widgeon [*Anas americana*], northern pintail [*Anas acuta*]; Environment Canada 2016).

A discussion of terrestrial and aquatic birds observed or expected to occur in the Study Area is provided in Appendix D, including potential foraging and nesting areas. In summary, many songbirds, waterbirds, raptors, seabirds, and shorebirds are present in riparian areas, along the shoreline, or on the river within the Study Area. Typical birds found within the riparian areas include eagles, ducks, crows, woodpeckers, hummingbirds, sparrows, warblers, and finches. Typical birds in the open areas of the shoreline include spotted sandpipers (*Actitis macularius*) and killdeer (*Charadrius vociferus*). Birds that nest in marsh vegetation along the riverbank include marsh wren (*Cistothorus palustris*) and red-winged blackbird (*Agelaius phoeniceus*). River foraging birds include raptors (e.g., eagles), dabbling ducks (e.g., mallard, wigeon), diving ducks (e.g., mergansers, goldeneyes), geese, seabirds (e.g., gulls and cormorants), herons, and shorebirds (e.g., sandpipers). The primary raptor expected to fish within the vicinity of the Project is the bald eagle (*Haliaeetus leucocephalus*) and several bald eagle nests are established on Annacis Island. A number of swallow species are found within the Study area that would forage on aerial insects over the river surface.

2.3.6 Species at Risk

Federal and provincial environmental agencies have separate systems to classify Species at Risk (SAR), as described below. Background information was used to compile a list of SAR which could potentially occur in the Study Area (Appendix D; Table D-1). Focal SAR included those listed on Schedule 1 of the federal SARA Public Registry and/ or provincially Blue-listed or Red-listed species that have been documented near the Study Area, or are expected to occur in the Study Area based on site and habitat conditions.

Federal Rank – COSEWIC and SARA

Federally, species ranking is the responsibility of COSEWIC established under Section 14 of the SARA. Below is a listing of the status categories used by COSEWIC to rank or list a species:

- **Extinct** - a species that no longer exists
- **Extirpated** - a species no longer existing in the wild in Canada, but occurring elsewhere
- **Endangered** - a species facing imminent extirpation or extinction
- **Threatened** - a species likely to become endangered if limiting factors are not reversed
- **Special Concern** - a species that is particularly sensitive to human activities or natural events, but is not an endangered or threatened species

- **Data Deficient** - a species for which there is inadequate information to make a direct, or indirect, assessment of its risk of extinction
- **Not at Risk** - a species that has been evaluated and found to be not at risk

The SARA Public Registry is the official depository and source of data and information relating to federally listed species at risk. Schedule 1 on the Public Registry is the official list of wildlife species at risk receiving legal protection under the SARA.

Provincial Rank – BC CDC

In BC, the BC CDC assigns a provincial rank to a species, which is based solely on its status within the province. In order to simplify interpretation of species ranks in BC, three categories have been created: Red, Blue, and Yellow, which provides a foundation for managing and protecting SAR in the province. The provincial listing categories are described below:

- **Red** - any indigenous species, subspecies or plant community that is Extirpated, Endangered, or Threatened in BC. Extirpated elements no longer exist in the wild in BC, but do occur elsewhere. Endangered elements are facing imminent extirpation or extinction. Threatened elements are likely to become endangered if limiting factors are not reversed.
- **Blue** - any indigenous species, subspecies or community considered to be Vulnerable (Special Concern) in BC. Vulnerable elements are of special concern because of characteristics that make them particularly sensitive to human activities or natural events.
- **Yellow** – any indigenous species in BC which appear to be secure and not at risk of extinction. Yellow-listed species may have subspecies which are Red-listed or Blue-listed. Yellow-listed species are not discussed in this assessment, unless they have federal designation under SARA.

Species Review

Based on the SAR search documented in Appendix D, two mammals, seven birds, five fish, three invertebrates, and thirteen plants were identified as focal SAR for the Study Area. Table 2-1 provides a summary of the focal SAR with the potential to occur in aquatic or riverbank areas of the Study Area or have been documented within 2 km of the centreline of the Fraser River along the length of the Study Area (prepared by Envirowest; Appendix D).

Table 2-1: Species at Risk with Potential to Occur in Aquatic or Riverbank Areas within the Study Area

Scientific Name	Common Name	Provincial Listing	COSEWIC Ranking[a]	SARA Designation[b]	Nearby Occurance[c]
Mammals					
Eumetopias jubatus	Steller sea lion	Blue	SC	1 - SC	No
Myotis lucifugus	Little brown myotis	Yellow	E	1-E	No
Birds					
Ardea herodias fannini	Great blue heron *fannini* subspecies	Blue	SC	1-SC	Yes
Butorides virescens	Green heron	Blue	No Ranking	No Designation	Yes

Scientific Name	Common Name	Provincial Listing	COSEWIC Ranking[a]	SARA Designation[b]	Nearby Occurance[c]
Falco peregrinus anatum	Peregrine falcon, anatum subspecies	Red	SC	1-SC	Yes
Hirundo rustica	Barn swallow	Blue	T	No Designation	Yes
Hydroprogne caspia	Caspian tern	Blue	Not at Risk	No Designation	Yes
Phalacrocorax auratus	Double-crested cormorant	Blue	Not at Risk	No Designation	Yes
Progne subis	Purple martin	Blue	Not at Risk	No Designation	Yes
Fish					
Acipenser medirostris	Green sturgeon	Red	SC	1-SC	No
Acipenser transmontanus pop.4	White sturgeon (lower Fraser River population)	Red	T	No Designation	Yes
Oncorhynchus clarkii	Cutthroat trout, *clarkii* subspecies	Blue	No Ranking	No Designation	Yes
Salvelinus confluentus coastal lineage	Bull trout South Coast Lineage	Blue	SC	No Designation	No
Thaleichthys pacificus	Eulachon	Blue	E	No Designation	No
Invertebrates					
Galba dalli	Dusky fossaria	Blue	No Ranking	No Designation	No
Physella virginea	Sunset physa	Blue	No Ranking	No Designation	No
Sphaerium striatinum	Striated fingernail clam	Blue	No Ranking	No Designation	No
Plants					
AA29:F41nagallis minima	Chaffweed	Blue	No Ranking	No Designation	Yes
Bidens amplissima	Vancouver Island beggarticks	Blue	SC	1-SC	Yes
Carex feta	Green-sheathed sedge	Blue	No Ranking	No Designation	No
Callitriche heterophylla var. heterophylla	Two-edged water-starwort	Blue	No Ranking	No Designation	Yes
Carex interrupta	Green-fruited sedge	Blue	No Ranking	No Designation	No
Elatine rubella	Three-flowered waterwort	Blue	No Ranking	No Designation	Yes
Juncus oxymeris	Pointed rush	Blue	No Ranking	No Designation	Yes
Lilaea scilloides	Flowering quillwort	Blue	No Ranking	No Designation	Yes
Lindernia dubia var. anagallidea	False-pimpernel	Blue	No Ranking	No Designation	Yes
Lindernia dubia var. dubia	Yellowseed false pimpernel	Red	No Ranking	No Designation	No
Lupinus rivularis	Streambank lupine	Red	E	1-E	Yes
Sidalcea hendersonii	Henderson's checker-mallow	Blue	No Ranking	No Designation	Yes
Verbana hastata var. scabra	Blue vervain	Blue	No Ranking	No Designation	No

a – E= Endangered, T = Threatened, SC = Special concern, NAR = Not at Risk

b – 1-E1 = Endangered Schedule 1, 1-T = Threatened Schedule 1, 1-SC = Special concern Schedule 1.

c – Nearby occurrences indicate whether a species has been documented to occur within 2 km of the centreline of the Fraser River along the length of the Study Area

2.4 Receiving Environment Uses and Relevant Water Quality Guidelines

A desktop review of online databases and websites was undertaken to search for information on known human and environmental uses of the Fraser River relevant to the EIS. Information sources included:

- Fisheries and Oceans Canada, Pacific Region website
- ENV - Water Licences Query database
- MV website
- Recreation Sites and Trails BC website
- BC Parks website
- FREMP website

2.4.1 Protected Areas and Parks

Within the Study Area, Don Island (also known as Oikawa Island) and Lion Island (also known as Sato Island) are designated by Metro Vancouver as regional parks. The shoreline on the north side and the downstream tip of Annacis Island is designated as municipal parkland. The upstream tip of Tilbury Island is also designated a municipal park (Metro Vancouver 2015). An inventory of regional and municipal parks located within the Study Area is provided in Table 2-2.

Table 2-2: Parks Located in the Vicinity of the Study Area

Park Name	Area
Regional Parks	
Lion (Sato) Island	Mid-stream Fraser River main channel
Don (Oikawa) Island	Mid-stream Fraser River main channel
Municipal Parks	
Annacis Channel Inlet on North East Side of Annacis Island	Shoreline of Annacis Island
West Patrick Island Development	North Shoreline of Annacis Island
Grosvenor Habitat Park	South-Western Shoreline of Annacis Island
New Westminster Pier Park	Northern shoreline of Fraser River main channel
Tilbury Island Municipal Park Space	Northern tip of Tilbury Island

Downstream of the Study Area, closer to the mouth of the Fraser River, there are several provincial and federal ecological reserves.

- Two federal management zones, Alaksen NWA and George C. Reifel Migratory Bird Sanctuary, are protected under the Migratory Birds Convention Act.
- Three provincial wildlife management areas, South Arm Marshes WMA, Sturgeon Bank WMA, and Roberts Bank WMA, are protected under the Ecological Reserve Act.

These protected areas provide wetland habitat for waterfowl and other species and support scientific research and education (IBA 2016). The value of the Fraser River Estuary area downstream of the Study Area that encompasses Burns Bog, Sturgeon Bank, South Arm Marshes, and Boundary Bay is recognized through several international designations. This area is designated a Hemispheric Site under the Western Hemisphere Shorebird Reserve Network (WHSRN) and most of the area is a Ramsar Wetland of International Significance.

Several parks are present downstream of the Study Area, including Deas Island, a regional park, and a number of municipal parks. A new regional greenway called the Delta-South Surrey Regional Greenway is also in development, which will connect natural areas for both wildlife and people, from Annacis Island to Mud Bay.

2.4.2 Fisheries

Fraser River stocks support several Commercial, Recreational, and Aboriginal fisheries, and salmon in particular continue to be important to First Nations for food, social, and ceremonial purposes (DFO 2015a). Along with commercial activities, Tsawwassen First Nation, Musqueam Indian Band, and other Aboriginal group members may be engaged in activities that have cultural importance in the Study Area.

Aboriginal fisheries are authorized by communal licences issued to individual First Nations organizations by Fisheries and Oceans Canada (DFO) under the Aboriginal Communal Fishing Licences Regulations. First Nations are licenced for Food, Social, and Ceremonial (FSC) fisheries and fisheries with a sales component, including economic opportunity, demonstration, and harvest agreement fisheries. Communal commercial licences issued annually for First Nations participation in the commercial fishery provide detail on fishing areas, methods, allocation, and times (DFO 2013a,b).

Tsawwassen First Nation, Sechelt First Nation, Q'ul-Lhanumutsun Aquatic Resources Society, Tsleil-Waututh Nation, Cowichan Tribes, Snuneymuxw First Nation, Tseycum First Nation, and Musqueam Indian Band hold general commercial licences in Management Area E. As such, they are permitted to conduct salmon gillnetting activities in a section of the lower Fraser River encompassing the Study Area: i.e., from the Port Mann Bridge to the Strait of Georgia, a distance of about 35 km (DFO 2013b). The Tsawwassen First Nation and Musqueam First Nation have the most active fisheries on the lower Fraser River (DFO 2014). The preferred location of commercial fishing activity changes depending on seasonal trends and daily movements of salmon within the Fraser River; therefore, specific information regarding fishing activity in the Study Area was not available for the approximately 15.6 km length of the Study Area within this fishing zone. A summary of total reported salmon numbers caught and kept in the 2014[1] First Nations fisheries in the lower Fraser River below the Port Mann Bridge is provided in Table 2-3.

There are no shellfish harvesting areas within the Study Area or in the South Arm of the river. Shellfish areas along the outer estuary are currently closed to shellfish harvesting and closure is considered permanent (DFO 2016).

[1] 2014 is the most recent publically available series of catch reports for the Lower Fraser River at the time of publication.

Table 2-3: 2013 First Nations Kept Catches in the Lower Fraser River (below Port Mann Bridge)

Species	Opening	Kept Catch by Band[a]			Total
		Musqueam	Tsawwassen	Other	
Chinook	May - Oct	2,169	1,060	141	3,370
Sockeye	June - Sept	193,199	94,452	10,379	298,030
Chum	Sept - Nov	20,249	8,452	30	28,731
Coho	Sept - Nov	242	159	3	404
Pink	July - Oct	0	7	0	7
Steelhead	-	0	0	0	0

Catch represented as number of individual fish
a – Includes FSC and economic opportunity fisheries (DFO 2015b)

2.4.3 Recreational Activities

The lower Fraser River, situated in the urban environment of the Greater Vancouver area, provides many recreational opportunities for the Greater Vancouver population. Day use is often associated with designated parks, wildlife areas, and trails. The broader Fraser River area offers opportunities for hiking, walking, biking, picnicking, wildlife viewing, and nature study (Metro Vancouver 2014). Sport fishing for salmon, trout, and other species is also popular in these areas (Forbes 2015). There is minimal swimming activity in the Fraser River, with swimming more prevalent in its smaller tributaries where conditions are more suitable (Swain et al. 1998). No recreational hunting is permitted within the Study Area; however, hunting is permitted on the Fraser River downstream of Deas Island with some restrictions. Hunting is also permitted in designated agricultural areas within Richmond west of Annacis Island if a hunting permit is secured from the local rod and gun club (BC MFLNRO 2016). Waterfowl targeted for hunting in these areas include duck species, Canada geese, snow geese, and brant geese (BC MFLNRO 2016).

The Study Area is located in a predominantly industrial and commercial use area of the lower Fraser River with recreational boating and fishing the most probable recreational activities. Although public access to the Annacis Island shoreline is possible in some areas along paved roads in the commercial/industrial area of the island, accessible shoreline is marshy and not generally suitable for recreational use. There is currently no formal trail network along Annacis Island, but the Delta-South Surrey Regional Greenway will cross this island in the future (Metro Vancouver 2009).

Fishing

The lower Fraser River tidal water area provides fishing opportunities for angling and is popular for sport fishing, particularly since this activity can be carried out from the shoreline and from boats. Areas commonly used for recreational fishing include Deas Island Park, Steveston area, the termini of shore-line roads in Richmond, the South Arm Marshes, and Dow Delta Bar Fishing Park, located at the eastern tip of Tilbury Island (Moffat and Nichol 2012, Hsu 2014, City of Richmond 2015). The area encompassing the Project, from Deas Island Park to the Port Mann Bridge, is a primarily industrial and commercial area of the Fraser River, and is reported to be unappealing for anglers, with limited public access to the shoreline (Forbes 2015).

Major recreational fish species include salmon, trout, and sturgeon. Sturgeon and wild trout are catch and release, but the recreational fishery for these species is open year-round (DFO 2015c). Of the salmon species, sockeye and coho are reported to be the most popular within the Fraser River, although chum fishing is reported to be increasing. Peak fishing season is between July and early September, although fishing does occur year-round. During odd-numbered years, the pink salmon fishery is active in September (Hsu 2014).

The federal government sets specific fishing regulations and catch quotas for Fraser River recreational fisheries. Current recreational fishing restrictions in the project area (DFO sub-region 29-13) allow for the retention of a specified number of chinook, chum, and coho of a specified size. Retention of wild coho, pink, and sockeye salmon of any size is not permitted for recreational fishing witihin the project area.

Boating

Recreational boating occurs year-round, with highest levels of activity occurring between May and September and lowest levels of activity occurring December to February. Recreational boaters generally exit and enter the Main Arm near Steveston owing to general ease of navigation, but experienced recreational boaters may exit and enter the Main Arm by Canoe Passage. Most recreational boaters limit their movements downstream of the Study Area and remain outside of the main shipping channel, but crossings of the main shipping channel within the Study Area and recreational boating activities do occur.

One marina and boat launch exists within the Study Area: Shelter Island Marina & Boatyard, located near the southern tip of Annacis Island, can accommodate up to 300 vessels and provides additional boatyard and ancillary services (Shelter Island Marina & Boatyard Inc. 2015). Additional marinas are located in Delta and Richmond outside of the Study Area.

2.4.4 Other Uses

The lower Fraser River is used for industrial, commercial, and residential purposes. Seven fish processing plants, a fleet of over 850 fishing boats, five deep sea port terminals, a ferry terminal, and over 250 industrial operations are situated within the Fraser River estuary (FREMP 2003). The river provides an important means of transportation for movement of raw materials, including logs, fish, and construction aggregates, as well as finished products (FREMP 2003).

A summary of current and reasonably foreseeable projects or activities located on or near the lower Fraser River within 17 km of the proposed AIWWTP new outfall was provided in the Stage 1 EIS (Golder 2016).

2.4.5 Withdrawals and Discharges

Withdrawals

A summary of licensed Fraser River water withdrawals located within the Study Area is presented in Table 2-4. In comparison to average daily flow (average of 3,888,000 cubic metres per day (m^3/day) at Hope for the duration of monitoring efforts over a period of over 100 years) the maximum total withdrawals from within the Study Area represent 3% of the total discharge of the Fraser River.

Table 2-4: Withdrawal Rates to the Fraser River Main Channel between Pattullo Bridge and Tilbury Island

Company[a]	License No.	Purpose	Maximum Withdrawal
Beedie (Huston Road) Holdings ltd. 3030 Gilmore Diversion Burnaby BC V5G 3B4	C115426	Cooling	4,546.09 m^3/day
Corporation of Delta 4500 Clarence Taylor Cres Delta BC V4K 3E2	C116994	Land Improvement	0 m^3/day total flow (no diversion from the Fraser River)
Corporation of Delta 4500 Clarence Taylor Cres Delta BC V4K 3E2	C116994	Irrigation	29,603,520 m^3/year[b]
Lafarge Canada Inc 7611 No 9 Rd Richmond BC V6W 1H4	C124518	Fire Protection	454.61 m^3/day
Lehigh Hanson Materials Limited PO Box 2300 Vancouver BC V6B 3W6	C052514	Fire Protection	9,819.55 m^3/day
Lehigh Hanson Materials Limited PO Box 2300 Vancouver BC V6B 3W6	C052514	Cooling	19,639.11 m^3/day
Maybog Farms Ltd c/o John Ronald May 15411 Cambie Road V6V 1T3	C127913	Frost Protection	236,828 m^3/year
Maybog Farms Ltd c/o John Ronald May 15411 Cambie Road V6V 1T3	C126396	Flood Harvesting	177,621 m^3/year
Maybog Farms Ltd c/o John Ronald May 15411 Cambie Road V6V 1T3	C126396	Irrigation	118,414 m^3/year
Maybog Farms Ltd c/o John Ronald May 15411 Cambie Road V6V 1T3	C126396	Storage-Non Power	24,670 m^3/year

a – Government of British Columbia Water Lot Lease Query, Accessed April 4, 2016 at http://www.env.gov.bc.ca/wsd/wrs/query/licences/
b – cubic metres per year

Discharges

A summary of permitted discharges to the Fraser River located within the Study Area is provided in Table 2-5. These discharges are located downstream of the proposed outfall location. There are no discharges within the Study Area located upstream of the proposed outfall location, with the exception of the current Annacis outfall (maximum 1,050,000 m^3/day) and two low volume discharges from Westminster Marine Services Ltd. and Cipa Lumber Co. Ltd. (<30 m^3/day).

Table 2-5: Discharge Rates to the Fraser River Main Channel between Pattullo Bridge and Tilbury Island

Company Name[a]	Permit Number	Authorization Type	Volume of Discharge m³/day (max)	Average Discharge (m³/day)	Monitoring Requirements		
					5-day BOD[b] (mg/L[c])	TSS (mg/L)	Grease and mineral oil (mg/L)
Westminster Marine Services Ltd.	PE-3154	Permit	-	1.14	45	60	-
Cipa Lumber Co. Ltd.	PE-00182	Permit	28	0.8	-	-	-
Greater Vancouver Sewerage and Drainage District	ME-00387	Operational Certificate	1,050,000	-	45	45	-
RMC Ready-mix Ltd.	PE-11217	Permit	15	5	-	-	-
Rempel Bros. Concrete Ltd.	PE-12181	Permit	35	-	-	-	-
Lafarge Canada Inc.	PE-00042	Permit	6,050	1,500	-	75	10
Lafarge Concrete a Division of Lafarge Canada Inc.	PE-2439	Permit	-	1.37	-	75	-
Armtec holdings limited	PE-02976	Permit	120	-	45	60	-
Shearer Fish Company Limited	PE-7785	Permit	4.6	-	-	-	-
Lehigh northwest cement limited	PE-04513	Permit	18,200	-	-	-	-

a – ENV Permit Search, Accessed April 4, 2016 at https://j200.gov.bc.ca/pub/ams/Default.aspx?PossePresentation=DocumentSearch
b- biological oxygen demand
c- milligrams per litre
"-" not applicable

2.4.6 Applicable Water Quality Objectives and Guidelines

Water quality guidelines are typically intended to be protective of all situations and incorporate multiple conservative assumptions such as safety factors and conservative exposure conditions. Therefore, comparison to guidelines represents a conservative evaluation of the potential for predicted concentrations to result in adverse effects (BC MoE 2013a). Water quality guidelines have been developed to be protective of different water uses in both freshwater and marine/estuarine environments, including aquatic life, wildlife, drinking water sources, recreational contact, and agriculture (livestock and irrigation). The following environmental uses were identified for the AIWWTP receiving environment:

- Commercial, recreational, and aboriginal (CRA) fisheries with the exclusion of shellfish harvesting
- Recreational activities such as boating
- Irrigation or livestock watering
- Ecological resources, including fish and other aquatic life and wildlife

To determine whether the receiving environment uses identified for the Project could potentially be impaired as a result of the Project, predicted concentrations were compared to various screening values for the protection of ecological and public health and agricultural use in Section7.0. A summary of those screening values is provided below.

Ecological Health and Agriculture Use: Aquatic Life, Wildlife, Livestock and Irrigation

The following objectives and guidelines were considered in the evaluation of potential adverse effects on ecological health and agricultural use:

- FRWQOs applicable to the lower Fraser River from the New Westminster Trifurcation to the Banks (Swain et al. 1998)
- Approved BC WQGs for the most sensitive water use; working BC WQGs were used for constituents without approved WQGs (BC MoE 2017)
- Federal WQGs for the most sensitive water use (CCME 2016)
- Federal Environmental Quality Guidelines for PBDEs (Environment Canada 2013)

Aquatic life WQGs were typically the most sensitive guidelines. These guidelines are conservative environmental quality benchmarks with built-in safety factors that represent concentrations that will not result in adverse effects on aquatic resources. Both freshwater and marine/estuarine aquatic life guidelines were considered because the Study Area is within the Main Arm Meso-Tidal Channel and both freshwater and estuarine conditions may be present depending on the location of the salt wedge (Appendix A). As such, the lowest of the freshwater and estuarine/marine guidelines for the most sensitive water use was conservatively applied.

The guidelines protective of aquatic life are divided into short-term maximum guidelines and long-term average guidelines as described below.

- Short-term maximum guidelines are intended to protect against severe effects such as lethality to the most sensitive species over a defined short-term exposure period in the receiving environment (e.g., up to 96 hours [h]). For the purposes of the Stage 2 EIS, short-term exposure has been characterized as concentrations over 24 h, which is shorter (more conservative) than the standard acute toxicity test durations for *Daphnia magna* (48 h) and rainbow trout (96 h) and is consistent with short-term WQGs for turbidity (24 h) (BC MoE 2017a).
- Long-term average guidelines reflective of a 30-d exposure are intended to be protective against sub-lethal and lethal effects on the most sensitive species and life stage indefinitely (Meays 2012, BC MoE 2013a).

Predicted concentrations were compared against both short-term and long-term screening values.

Public Health: Recreational Use

The following objectives and guidelines were considered in the evaluation of potential adverse effects on public health:

- Approved BC WQGs (BC MoE 2017a)
- Guidelines for Canadian Drinking Water Quality (Health Canada 2017)
- United States Environmental Protection Agency (US EPA) Regional Screening Levels (RSL) for tapwater (US EPA 2017)

The approved BC WQGs for recreational use were selected as the primary screening criteria, when available. For some constituents, the recreational guidelines have been categorized as either primary or secondary contact guidelines. Primary contact includes swimming and other high contact activities whereas secondary contact includes fishing and boating activities with a lower potential for direct contact. Secondary contact guidelines were selected preferentially because primary contact activities do not occur in the Study Area.

Recreational guidelines were only available for a subset of constituents. Therefore, when a recreational guideline was not available a conservative screening value was derived by multiplying the drinking water guideline by a factor of 10 as recommended by the World Health Organization's (WHO) Guidelines for Recreational Water Environments (WHO 2003). The WHO (2003) adjustment of 10% of potable water intake is based on a swimming scenario, and is therefore conservative for recreational secondary contact where the recreational user would not be fully submerged in water. Drinking water guidelines were obtained from the approved BC WQGs and Health Canada (2014) with preference given to the most conservative health-based value. Drinking water guidelines based on aesthetic (non-health) considerations (e.g., colour, taste, odour) were not adjusted. When guidelines were unavailable from these sources, they were obtained from the US EPA (2017) RSLs. The US EPA tapwater RSLs are risk-based screening criteria that were derived based on an acceptable hazard quotient (HQ) of 1 for non-carcinogens, and an acceptable incremental lifetime cancer risk (ILCR) of 10^{-6} for carcinogens. Health Canada considers an HQ of 0.2 and ILCR of 10^{-5} to be acceptable thresholds for risk. Therefore, the US EPA RSLs were adjusted (i.e., RSL multiplied by 0.2 for non-carcinogens and RSL multiplied by 10 for carcinogens) to reflect acceptable target risk levels in Canada. US EPA RSLs were then further adjusted by a factor of 10 to convert drinking water guidelines to recreational water use screening values.

3.0 REGULATORY SETTING

For effluent discharges to aquatic receiving environments in BC, applicable legislation includes the federal *Fisheries Act* that contains a general prohibition against the deposit of a deleterious substance into waters frequented by fish (Section 36), and the provincial EMA that contains a general prohibition against causing pollution. Under the general provisions of the *Fisheries Act*, what constitutes a deleterious substance is a matter of expert opinion; however, for municipal discharges, what constitutes a deleterious substance and when it can be discharged is specifically defined in the Federal Wastewater Systems Effluent Regulation (WSER; SOR/2012-139). The definition of pollution under EMA is discussed below in Section 3.1.2.

To discharge effluent from the new outfall diffuser, MV requires an amendment of Operational Certificate ME-00387 that authorizes MV to discharge effluent from the AIWWTP under the ILWRMP pursuant to EMA. As per the MWR (also pursuant to EMA), an EIS of the effluent discharge is required to identify whether or not receiving water uses could be impaired by the hydraulic upgrade. The EIS is used by the ENV in their permitting decisions and is used by the discharger, in this case MV, as part of their due diligence to verify that they meet the requirements of EMA and the ILWRMP.

3.1 Integrated Liquid Waste and Resource Management Plan

Within BC, Liquid Waste Management Plans (LWMPs) developed by local governments are authorization mechanisms under EMA. In the absence of an LWMP approved by ENV, discharges to the environment within the local jurisdiction may be authorized through other mechanisms that include the MWR (Metro Vancouver 2010).

The LWMP for the GVS&DD the Integrated Liquid Waste and Resource Management Plan (ILWRMP) authorizes water, air, and land discharges associated with the management of liquid waste in Metro Vancouver. Discharges are authorized according to discharge criteria specified in the site specific Operational Certificates for each facility, including the AIWWTP (Metro Vancouver 2010). In May 2011, the integrated plan was approved by the Minister of Environment subject to conditions under the provisions of EMA and has since guided liquid waste management decisions at the AIWWTP.

MV has committed to meeting requirements of the Canada-wide Strategy for the Management of Municipal Wastewater Effluent (CCME Strategy; CCME 2009) in its ILWRMP. The CCME Strategy requires that treated municipal effluent discharged into the environment meets the National Performance Standards for wastewater effluent (carbonaceous biochemical oxygen demand [CBOD] and TSS) and that ambient environmental conditions of relevant receiving environments in the region be monitored. The CCME Strategy also requires risk assessment of other wastewater discharge constituents to determine if environmental discharge objectives are required.

3.2 Environmental Management Act and the Municipal Wastewater Regulation

EMA is BC’s principal pollution control statute with regulations made pursuant to that Act for more specific regulatory purposes such as the discharge of municipal effluent. EMA prohibits causing pollution, and provides for authorization mechanisms for discharge of waste into the environment. One such authorization mechanism for municipal facilities that discharge treated effluent is an operational certificate. Other authorization mechanisms under EMA may include regulations.

The relevant subordinate regulation for the Project is the MWR that specifies requirements for the discharge of municipal wastewater, including reclaimed water, to receiving environments within BC. The MWR superseded the Municipal Sewage Regulation in 2012 (BC Reg 129/99; OC 507/99). However, as described in Section 3.1.1, BC MoE allows local governments to develop LWMPs as part of local liquid waste discharge authorization through EMA. As such, discharges within local jurisdictions are regulated though LWMPs and Operational Certificates for each facility, not the province-wide MWR. In the case of the AIWWTP, the approved ILWRMP has been in place since May 2011.

Under EMA, pollution is defined as “the presence in the environment of substances or contaminants that substantially alter or impair the usefulness of the environment”. Common expectations under EMA are two-fold:

- Acutely lethal conditions should not exist within the IDZ or the effluent. The IDZ is the three-dimensional zone around the point of discharge where mixing of the effluent and the receiving water occurs. For a large water body, the IDZ is commonly defined as a cylindrical body of water around the outfall, with a lateral radius the lesser of 100 m from the outfall or 25% the width of the body of water and extending upwards to the surface of the water column.
- Chronic sublethal effects should not occur outside of the IDZ. A lack of chronic sublethal effects is (conservatively) predicted when the constituent of concern has a concentration lower than approved WQGs (BC MoE 2017a).

3.3 Fisheries Act and the Federal Wastewater Systems Effluent Regulation

With respect to the *Fisheries Act*, a deleterious substance is a substance that, if added to water, would degrade or alter or form part of a process of degradation and would likely be rendered deleterious to fish or fish habitat, or the use by man of fish that frequent that water. The specific properties defining a substance as being deleterious under the parent act are left to interpretation by experts, except where sector-specific regulations have been developed, such as the federal WSER that came into effect July 2012. This works-specific regulation was written under the authority of subsection 36(5) and paragraphs 43(g.1), (g,2), and (h) of the *Fisheries Act*.

Under the WSER, the following classes of substances are prescribed as deleterious substances and their discharge into the environment is authorized in concentrations below the specified limits: CBOD, TSS, TRC (total residual chlorine), and un-ionized ammonia. Discharge can also only occur if the effluent is shown not to be acutely lethal to rainbow trout in accordance with specified standard test methods specified in the regulation.

3.4 Port of Vancouver Project Review Process

Under the *Canada Marine Act*, the Vancouver Fraser Port Authority (the Port) is responsible for the administration, management, and control of land and water within its jurisdiction. The Port requires that developments meet applicable standards and minimize environmental and community impacts. New developments are also expected to support the Port’s land use objectives as described in the Port’s land use plan.

The Port is a federal agency that is subject to Section 67 of the *Canadian Environmental Assessment Act* (CEAA) with respect to projects on lands under their administration. The Port has established a review process to address potential effects to environmental and Aboriginal resources as described in the CEAA. The review process is based on a system of four project categories. In this system, Category A projects are simple, minor works that do not require review by the Port and Category D projects are large complex undertakings that may require extensive review and stakeholder consultation

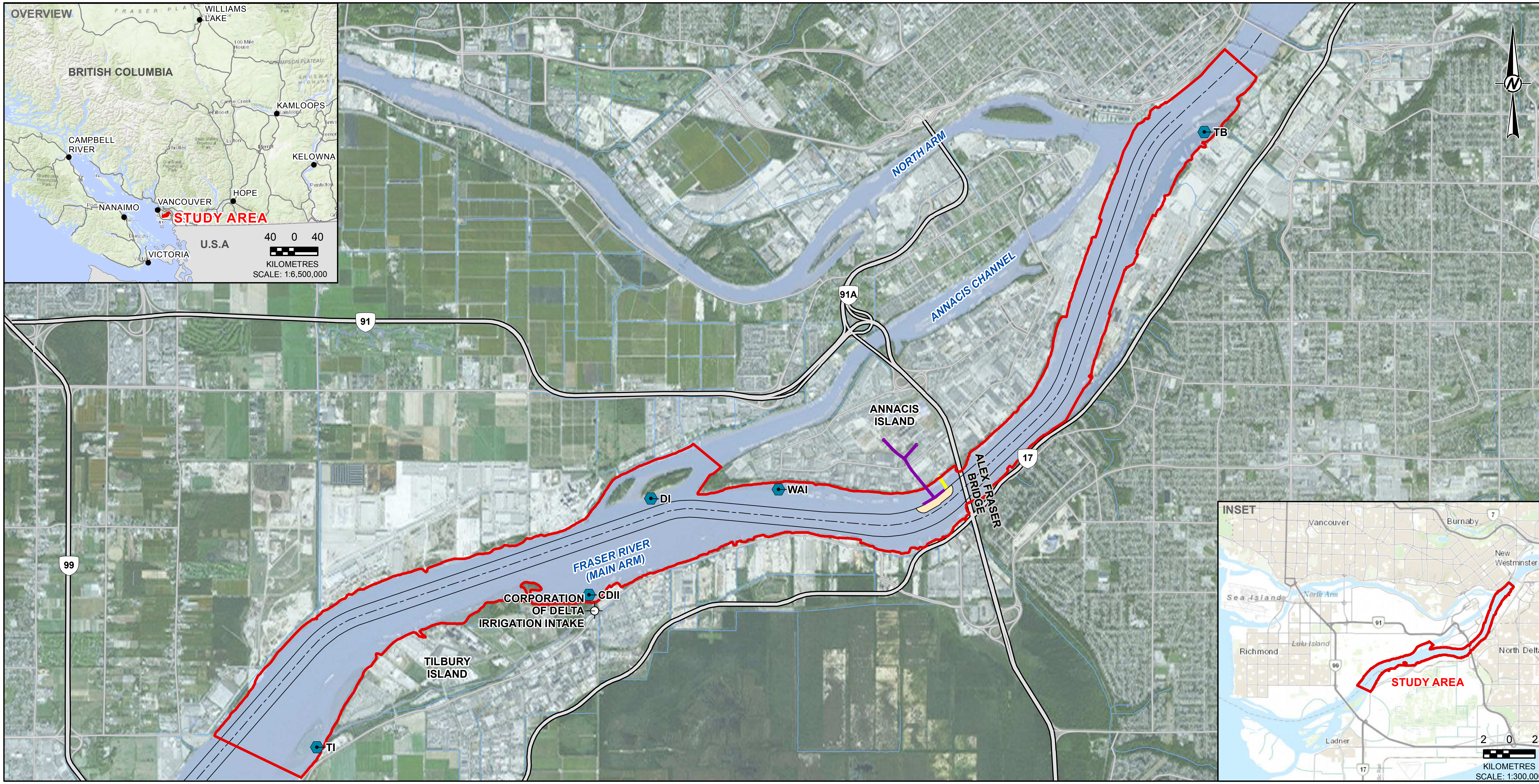
4.0 IMPACT STUDY SCOPE AND SPATIAL BOUNDARIES

Guidance provided by ENV for a municipal effluent discharge EIS (BC MELP 2000) recommends that the Stage 2 impact assessment assess effluent quality of the proposed discharge at end-of-pipe and assess nutrient loadings from the discharge to the receiving environment. The scope of Section 5 of this EIS for the proposed Stage V hydraulic upgrade addresses these recommendations and meets the approved Stage 2 EIS TOR for project.

The EIS guidance also recommends that water quality predictions, generated at the edge of the IDZ and at 'areas of concern' beyond the IDZ, be assessed to determine the potential for the proposed project to have adverse effects on public health or the receiving environment. For this assessment the IDZ, where mixing of the effluent and the receiving water occurs, is defined as a cylindrical body of water around the outfall with a lateral radius of 100 m from the outfall and extending upwards to the surface of the water column. Potential 'areas of concern' are defined in BC MELP (2000) as shellfish harvesting areas, beaches, water intakes, and fish spawning and rearing habitat areas. As discussed in Sections 2.3.1 and 2.4.2, there are no fish spawning habitats or shellfish harvesting areas within the Study Area. The Study Area is primarily located in an industrial area with no recreational beaches or drinking water intakes. Recreational areas are located further downstream and the Fraser River is not a drinking water source. The five areas of concern identified as far-field assessment nodes for this assessment therefore relate to the Corporation of Delta irrigation intake and sturgeon and salmonid rearing habitat identified in the Study Area based on information provided in Appendix D.

The five assessment nodes shown on Figure 2 were selected to support an evaluation of potential impacts in the far-field beyond the IDZ where sensitive aquatic habitat or resources were identified. One of the far-field assessment nodes is located upstream of the outfall at Timberland Basin and the other four nodes are located downstream of the AIWWTP.

- **Timberland Basin (TB)**: located along the south shore immediately upstream of the trifurcation of the Main Stem of the Fraser into Annacis Channel, Main Arm, and the North Arm. Vancouver Fraser Port's fish habitat bank is located within the blind end of the basin. Riparian woodland, intertidal marsh, intertidal mudflat, and intertidal channels are represented by the bank. Shallow subtidal river bottom surrounds the bank.
- **Western Annacis Island (WAI)**: located along the northern shoreline of the Main Arm, upstream of the confluence of Annacis Channel and the Main Arm. This area is characterized by intertidal flats and shallow nearshore subtidal river bottom within the hydraulic shadow of tethered inactive barges. The inactive barges have been tethered at this location since at least 2002 (google earth; 9 Feb 2017). The flats are comprised predominantly of fine sediments, with a narrow band of marsh along the landward margin.
- **Don Island (DI)**: located along the northern shoreline of the Main Arm, at the confluence of the Annacis Channel and the Main Arm. Don Island is part of a two island complex that includes Lion Island. The island complex is characterized by relatively extensive intertidal mudflat.
- **Corporation of Delta Irrigation Intake (CDII)**: the inlet-outlet channel of the Corporation of Delta's 80th Street Pump Station at River Road. The pump station discharges drainage to Tilbury Slough. It also draws water from the Fraser River for agricultural purposes.
- **Tilbury Island (TI)**: located along the southern shoreline of the Main Arm, along the margin of Tilbury Island near its downstream end. The site encapsulates part of an intertidal shoal that includes marsh and mudflat, with shallow subtidal river bottom partly demarcating the shoal from Tilbury Island.



LEGEND

- STUDY AREA
- INITIAL DILUTION ZONE
- EXISTING WWPT OUTFALL
- PROPOSED WWPT OUTFALL
- WATER
- WATERCOURSE

FRASER RIVER SHIPPING CHANNEL

- CENTRE OF CHANNEL
- OUTER CHANNEL BOUNDARY
- HIGHWAY
- MAJOR ROAD
- CORPORATION OF DELTA IRRIGATION INTAKE
- WATER QUALITY ASSESSMENT NODE

CDII: CORPORATION OF DELTA IRRIGATION INTAKE
DI: DON ISLAND
TB: TIMBERLAND BASIN
TI: TILBURY ISLAND
WAI: WESTERN ANNACIS ISLAND

0 0.5 1 1.5 2
1:45,000 KILOMETRES

REFERENCES
1. SHIPPING CHANNEL SUPPLIED BY BLACK & VEATCH
2. ROADS, WATERCOURSE AND WATERBODY DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED
3. IMAGERY COPYRIGHT © 20090925 ESRI AND ITS LICENSORS. SOURCE:DIGITALGLOBE WV01. USED UNDER LICENSE, ALL RIGHTS RESERVED.
COORDINATE SYSTEM: NAD 1983 UTM ZONE 10N

CLIENT
CDM SMITH CANADA ULC AND METRO VANCOUVER

PROJECT
ANNACIS ISLAND WWTP TRANSIENT MITIGATION & OUTFALL UPGRADE
DELTA, B.C.

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-11-09
DESIGNED	LC
PREPARED	JP/MH
REVIEWED	ECI
APPROVED	ECI

TITLE
ANNACIS ISLAND WWTP WATER QUALITY ASSESSMENT NODE LOCATIONS

PROJECT NO.	CONTROL	REV.	FIGURE
1525010	702 - 702.4	0	02

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
25mm

The receiving environment impact assessment presented in Section 7 evaluated water quality predictions at the edge of the IDZ in the near-field and at far-field assessment nodes, as described in a synthesis of relevant information from Appendix A in Section 6. This section also includes an assessment of persistent, bioaccumulative and toxic constituents (PBTs) where PBT constituents were identified and evaluated to determine the potential for adverse effects to people and wildlife consuming fish from the Fraser River. The conclusion of the EIS and an assessment of uncertainties noted in Sections 5 through 7 are provided in Section 8.

Guidance provided by BC MELP (2000) indicates that following the Stage V upgrade and commencement of the discharge, effluent and receiving environment monitoring results should to be evaluated to:

- determine whether water quality guidelines are being met outside the IDZ
- confirm that sediment biota, chemistry, and toxicity are not adversely affected
- confirm previous modeling and predictive assessments findings

The potential need for refinement of monitoring currently being conducted for the existing discharge or additional monitoring or confirmatory studies was considered during preparation of the impact assessment. Recommendations to be considered for Stage V post-discharge monitoring and confirmatory studies are provided in Section 10.

5.0 EFFLUENT ASSESSMENT

The objectives of the effluent assessment were to characterize effluent quality assumed for the Stage V hydraulic upgrade including comparison to relevant limits and standards, assess the potential for acute toxicity based on toxicity testing results for the current discharge, and assess nutrient loadings to the Fraser River under Stage V flows. This section also includes a summary of the selection procedure employed to compile a short-list of organic constituents to be assessed in the receiving environment impact assessment provided in Section 7.

In summary, the Stage V effluent assessment includes the following:

- A general overview of the main constituents regulated or of interest in municipal wastewater effluent discharges (Section 5.1).
- A summary of effluent criteria applicable to the AIWWTP (Section 5.2) and a summary of effluent chemistry and toxicity testing results from 2012 to 2016 (Section 5.3.1).
- Ammonia is further discussed in Section 5.3.2 with respect to the maximum allowable limit back-calculated from the BC total ammonia WQG for the purpose of the impact assessment.
- An assessment of the potential for Stage V effluent to be acutely lethal based on toxicity testing results for the current discharge (Section 5.3.3).
- An assessment of nutrient loadings to the receiving environment with reference to the assimilative capacity of the lower Fraser River downstream of the AIWWTP (Section 5.4).
- The process for selecting organic constituents to be assessed in the impact assessment is described in Section 5.5.

The content of this section addresses relevant guidance provided by BC MELP (2000) for a Stage 2 EIS, relevant requirements of the ILWRMP approved for the GVS&DD, and the WSER as described in Section 5.2.

5.1 Summary of Effluent Constituents

In Metro Vancouver, municipal wastewater is primarily comprised of domestic wastes and surface run-off/stormwater but also includes industrial and commercial inputs. With respect to environmental significance, municipal effluent may contain oxygen-depleting constituents, ammonia and other nutrients, pathogenic microorganisms, metals, surfactants, organic compounds and other potentially harmful constituents, such as endocrine disrupting compounds. Although municipal effluent is a complex mixture, there are certain constituents and properties that have been associated with known adverse effects or conditions in aquatic environments.

Some of the key constituents found in municipal effluent and their potential environmental effects on organisms in aquatic receiving environments are discussed below. Whether or not these potential impacts might occur will depend on the specific characteristics of the effluent discharge and the receiving environment, in addition to exposure conditions encountered by aquatic life in the Fraser River. An evaluation of potential environmental impacts on aquatic life in the Fraser River is presented in Section 7.0 of this report.

5.1.1 pH

pH is an environmental factor that affects physiological processes including enzyme activity, ionic regulation, and the chemical speciation of constituents present in water. pH is an important exposure and toxicity modifying factor affecting the bioavailability and toxicity of metals and nutrients. In freshwater systems, pH is typically in the range of 6.5 to 9, and values outside this range can disrupt the processes of waste excretion and oxygen uptake across fish gills (McKean and Nagpal 1991). Metals are typically more bioavailable to aquatic organisms under low pH (acidic) conditions and less bioavailable under higher pH (alkaline) conditions.

5.1.2 Total Suspended Solids

There are several reviews on the effects of suspended sediments in freshwater ecosystems (e.g., Birtwell 1999, Caux et al. 1997, EIFAC 1964, Newcombe and Jensen 1996, Newcombe and MacDonald 1991). Suspended solids are not usually associated with lethal effects on fish except when the TSS concentration is very high. In studies on the acutely lethal concentrations of TSS on juvenile salmon, it was found that 31,000 mg/L and 17,600 mg/L caused mortality to 50% of juvenile chinook and sockeye salmon respectively over a 96-h test period (Servizi and Gordon 1990, Servizi and Martens 1987). These concentrations are not commonly encountered in waterbodies except under rare circumstances. Suspended sediment also can cause changes in behaviour such as avoidance (Bisson and Bilby 1982, Robertson et al. 2006) and physiological trauma such as gill damage, which has been observed at TSS concentrations on the order of hundreds to thousands of mg/L (Birtwell 1999, Muck 2010, Servizi and Martens 1987).

5.1.3 Carbonaceous Biochemical Oxygen Demand (CBOD)

Municipal effluent contains constituents that can cause depletion of oxygen from surrounding water. Various types of microorganisms degrade the constituents of the effluent, converting them into energy. This process requires oxygen from the surrounding environment, thereby leading to reductions in oxygen available for aquatic organisms. Oxygen can also be removed from the surrounding environment by direct chemical reaction with constituents in the waste via a process known as chemical oxidation.

The oxygen-depleting potency of a municipal effluent is measured as CBOD over a 5-d period (i.e., $CBOD_5$) in a laboratory in which the contribution from nitrogenous bacteria has been suppressed. The extent to which oxygen is removed from receiving waters depends on the dynamics of this process in relation to dispersion and re-oxygenation of the receiving waters through contact with the atmosphere. Waters that are confined and stagnant are more prone to oxygen depletion than waters that are unconfined and well flushed.

5.1.4 Ammonia

Ammonia is a waste product that is produced by fish and other aquatic organisms to dispose of nitrogenous wastes. Nitrogenous wastes produced by humans and other mammals are excreted in the form of urea. Ammonia can result from the breakdown of urea or the amine portion of amino acids, which make up proteins. Ammonia is a naturally occurring constituent and its concentration in unpolluted waters is typically low and not of toxicological concern. However, it can be introduced into the aquatic environment through the discharge of wastewaters at concentrations that can potentially result in toxicity, depending on the specific characteristics of the discharge and the receiving environment.

Ammonia in water exists as two distinct chemical species, un-ionized ammonia (NH_3) and ionized ammonia (NH_4^+, also known as the ammonium ion), in an equilibrium that is influenced by pH, temperature, and in marine waters, salinity (CCME 2010, US EPA 2013). As pH increases, the amount of the more toxic un-ionized form increases. Increased water temperature and decreased salinity also favour increases of the un-ionized form. Water quality guidelines in Canada are set on the basis of pH, temperature, and (for marine WQGs) salinity because of the influence of these environmental factors on the toxicity of ammonia.

5.1.5 Nutrient Enrichment

In aquatic systems, plant productivity can respond to increases in nutrient concentrations (Environment Canada 2004). The associated increase in plant biomass can in turn potentially affect water quality and invertebrate and fish communities. Aquatic biota initially respond to mild enrichment with an increase in productivity that may not necessarily result in adverse effects on water quality or resident biota. However, beyond a certain point in nutrient limited systems, increased productivity due to nutrient inputs can result in changes to water quality and aquatic life through a process called eutrophication (Nordin 1985). Changes can include but are not limited to the following:

- Increases in plant and animal biomass and/or productivity. Excessive nutrient enrichment can cause increased phytoplankton production and result in an in an “algal bloom”. Algal blooms can influence water quality and cause negative impacts to other aquatic organisms via production of toxins (i.e., from cyanobacteria) or from depletion of dissolved oxygen following death and decomposition of algal cells, as well as during diurnal respiration.
- Decreases in biodiversity and changes in dominant biota, and/or declines in ecologically sensitive species and increases in tolerant species.
- Increases in turbidity and organic matter, leading to sedimentation, or potential detritus and/or algal build up on substrates.

Algae take up mineral elements such as nitrogen, phosphorus, silicate, iron, and trace metals that they use to convert light energy into organic material via the process of photosynthesis. Any one of these elements, if in short supply, could potentially limit algal biomass. Conversely, an enrichment of nutrients that are limiting could result in increased algal productivity. In freshwater systems phosphorus is typically the limiting nutrient but in marine waters nitrogen forms generally limit algal growth (Nordin 1985, Environment Canada 2004).

5.1.6 Pathogens

Contact with domestic waste has long been recognized as a potential source of infectious disease-causing organisms such as bacteria, viruses, and protozoans (Dadswell 1990). A group of bacteria known as fecal coliforms are present in municipal effluent and are commonly used as an indicator of the presence of effluent and the associated risk of pathogens. *Enterococci* bacteria are also used as an indicator of municipal effluent because they survive longer in freshwater environments than fecal coliforms.

Human health risk from pathogens requires that there be contact with the source of pathogens and humans or harvestable shellfish resources. As noted in Section 2.4, existing and proposed outfall areas are not located adjacent to harvestable shellfish resources, and due to plume trapping the likelihood for significant contact between the plume and human users is low.

5.1.7 Metals

Metals occur naturally in the environment and may enter the aquatic environment from natural weathering processes and anthropogenic sources, such as those related to fossil fuel combustion, industrial emissions, discharge of municipal wastewaters, and stormwater runoff from paved surfaces. Certain metals are essential for maintaining good health because of their importance as components of enzymes or proteins, and a shortage of those metals can result in adverse effects. Excess concentrations of essential or non-essential metals can result in toxicity (Chapman and Wang 2000, Campbell et al. 2006). The toxicity of metals to aquatic organisms ranges widely from slight reductions in growth rates to mortality, and may be acute (after a short-term exposure) or chronic (over a longer term). Metal accumulation and toxicity is dependent on metal bioavailability that is influenced by exposure conditions and toxicity modifying factors, such as pH, water hardness, and dissolved organic carbon (DOC), as well as physiological and biological characteristics of aquatic organisms.

5.1.8 Organics

Organic compounds range from simple molecules to long-chained, multi-ringed, halogenated structures that vary in persistence and effects on aquatic organisms. The fate and transport of organic compounds in environmental systems is controlled by partitioning between surface water, suspended particulates and sediment, associated organic matter, and biota. The extent to which organic compounds are associated with organic matter is related to a number of factors including molecular weight and the number and position of chlorine atoms in the case of chlorinated compounds.

Organic compounds can have a wide range of effects on aquatic organisms, from reproductive impairment such as reduced fecundity and viability of offspring, developmental impairment such as brain and skeletal deformations and reduced growth, to acute mortality of both adults and juveniles. Of particular concern are persistent, bioaccumulative, and toxic constituents that are hydrophobic and can accumulate in fatty tissues unless the organism has a mechanism for metabolizing and excreting the compound. Organic compounds may be biomagnified up the food chain, resulting in higher concentrations in higher trophic level organisms such as carnivorous marine mammals. Examples of persistent organic compounds present in municipal effluents include PAHs, PCBs, and PBDEs.

5.1.9 Endocrine Disrupting Compounds

Municipal wastewater contains constituents known or suspected to be endocrine disrupting compounds (EDCs), which include some parameters in the following groups: surfactants, plasticizers, and pharmaceutical and personal care products (PPCP) (Anderson 2005, Environment Canada 2007b). EDCs interfere with the endocrine (hormonal) system of animals and may cause reproductive abnormalities.

The presence and ecological significance of EDCs is an area of emerging international science, with ongoing research being conducted on the fate and behaviour of EDCs in the environment and the effectiveness of various wastewater treatment methods (Anderson 2005). In Canada, the need for research and policy directions regarding EDCs such as PPCPs has been recognized and priorities in the areas of effects research and risk management for PPCPs have been identified (Environment Canada 2007b). Research includes the development of analytical methods, assessment of the efficiency of treatment of various EDCs, and evaluation of the presence and effects of EDCs in the aquatic environment (Environment Canada 2008b). One of the compounds that has received attention is EE2, the synthetic hormone in the birth-control pill, and it is the only PPCP for which there is a BC WQG.

5.1.10 Sterols

Sterols are steroid derivatives found naturally in animals, plants and fungi. A number of sterols measured in the aquatic environment originate from fecal matter such as coprostanol, while others such as cholestanol are formed naturally by bacteria and do not have a fecal origin. Coprostanol is a reduced metabolite of cholesterol produced in the gut of humans along with most other higher animals. Cholesterol can be transformed to coprostanol in municipal effluents and sludges that contain elevated levels of fecal bacteria. Elevated concentrations of coprostanol downstream of municipal wastewater treatment plants are therefore frequently used as a biomarker or indicator for the presence of human fecal matter in the environment.

5.2 Effluent Criteria Applicable to the AIWWTP

Under the CCME Strategy (CCME 2009) and the WSER, the following National Performance Standards exist as minimum performance requirements for effluent quality:

- average concentration of $CBOD_5$ does not exceed 25 mg/L
- average concentration of TSS does not exceed 25 mg/L
- average concentration of TRC does not exceed 0.02 mg/L if chlorine or one of its compounds is used in the treatment process
- maximum concentration of un-ionized ammonia is less than 1.25 mg/L as ammonia nitrogen (NH_3-N) at 15 ± 1 degrees Celsius (°C)

As discussed in Section 3.1, the ILWRMP approved for the GVS&DD commits MV to meeting National Performance Standards for CBOD and TSS in their wastewater effluents prior to discharge to the aquatic receiving environment.

Compliance limits specified in the Operational Certificate - ME00387 (23 April 2004) for the AIWWTP effluent are:

- maximum concentration of $CBOD_5$ does not exceed 45 mg/L
- maximum concentration of TSS does not exceed 45 mg/L
- concentration of TRC to remain below 0.1 mg/L (the required minimum detection limit)

There is also a requirement under the WSER that effluent is not acutely lethal to rainbow trout (median lethal concentration causing mortality in 50% of test organism, LC_{50} ≥100% volume by volume (v/v)), determined on a monthly basis in accordance with Reference Method EPS 1/RM/13 or EPS 1/RM/50 (Environment Canada 2007a, 2008a).

The federal and provincial limits discussed above are minimal compliance requirements, and the assessment of potential impacts carried out herein has been broader, as necessitated by the general provisions of provincial legislation and the CCME strategy as indicated in the ILWRMP which is a provincial instrument.

5.3 Summary of Effluent Chemistry and Toxicity Testing

The Stage V upgrade is a hydraulic upgrade, and does not involve any process changes that could change the quality of effluent. Therefore, this EIS assumes that effluent quality will remain the same as that characterized between 2012 and 2016 in Appendix A. A summary is provided below of expected effluent chemistry and toxicity, based on a review of data characterizing effluent currently being discharged.

5.3.1 Effluent Chemistry

AIWWTP effluent has been analyzed for wide range of constituents including those described in Sections 5.1.1 to 5.1.10; a list of constituents can be found in Appendix A. Physical parameters, major ions, nutrients, metals, and bacteriological constituents are routinely monitored. Organic constituents in AIWWTP effluent have been more comprehensively monitored since 2013 with respect to the parameter suite and frequency of sampling.

For the purpose of this EIS, AIWWTP effluent quality was characterized based on operational plant data, monthly comprehensive monitoring, data reported from the 2012-2016 AIWWTP IDZ boundary monitoring programs (ENKON 2013a,b; 2015b; and unpublished MV data), and data summarized by Tri-Star (2015). Summary statistics were calculated and reported by CDM Smith (2017) in Appendix A for effluent constituents for which there are National Performance Standards, municipal regulations, and/or receiving environment WQGs.

Based on the effluent characterization by CDM Smith (2017) in Appendix A for the period 2012 to 2016, federal and operational certificate effluent limits were met for $CBOD_5$, TSS, TRC, and un-ionized ammonia (Table 5-1).

Table 5-1: Annacis Island WWTP Effluent Quality Compared to National and Operational Certificate Effluent Limits

Constituent[a]	Units	National Performance Standards	Operational Certificate Limits	Mean Effluent Concentration (2012-2016)[b]	Max Effluent Concentration (2012-2016)[b]	2016 Max Concentration (Reported in GVS&DD [2017])
$CBOD_5$	mg/L	≤25 (average)	45 (max)	6.9	20	12 (Table 3.1)
TSS	mg/L	≤25 (average)	45 (max)	8.0	36	34 (Table 3.1)
TRC	mg/L	≤0.02 (average)	0.1	<0.02 (median)[c]	<0.1	<0.02 (Table 3.1)
Un-ionized ammonia	mg-N/L	1.25 (max) at 15°C	-	0.52	0.93	0.81 (Table 3.7)

nm – not measured

a – $CBOD_5$ – 5-day carbonaceous biochemical oxygen demand; TSS – total suspended solids; TRC – total residual chlorine;- not applicable

b –summary statistics reported by CDM Smith (2017) in Appendix A

c- a mean value was not calculated because all concentrations were below the detection limit

Bold values exceed federal or operational certificate effluent limits

Annual summaries of AIWWTP effluent quality and results from annual compliance assessments were summarized in the 2011 to 2016 annual wastewater reports issued by GVS&DD (GVS&DD 2012-2017). In these reports, compliance constituent effluent quality from 2012 to 2016 was characterized as follows:

- Operational Certificate ME00387 limits for CBOD, TSS, and TRC were met each year.
- Monthly average concentrations of $CBOD_5$ and TSS met WSER limits each year (i.e., National Performance Standards).
- Monthly maximum concentrations of un-ionized ammonia met the WSER limit from 2013 to 2016; data were not reported for 2011 and 2012.
- Annual maximum concentrations of TRC in 2011 to 2013 were reported as <0.1 mg/L (the minimum method detection limit of the operational certificate) that is above the WSER limit. However, as a result of an analytical instrument change in 2014, a lower detection limit was achievable from 2014 onwards which meant that the annual maximum concentration of TRC met the federal limit in 2014, 2015, and 2016.
- The estimated concentration[2] of fecal coliforms at the edge of the IDZ met the FRWQO, for each reported month (May through October) of each year.

Based on the most recent characterization of effluent (i.e., 2016, GVS&DD 2017), the AIWWTP effluent met WSER limits (as summarized above) and was not acutely toxic (Section 5.3.3). Thus, the AIWWTP effluent meets conditions of Section 6(1) of WSER, and as such its deposit is authorized under Section 36(4) of the *Fisheries Act*. Because the Stage V upgrade is a hydraulic upgrade and effluent quality is assumed to remain the same as that characterized between 2012 and 2016, it is expected that effluent quality after the Stage V upgrade will meet the requirements of the ILWRMP and WSER limits.

5.3.2 Ammonia

The AIWWTP is regulated under the ILWRMP and Operational Certificate ME-00387. The Operational Certificate does not specify an effluent discharge limit for ammonia but the ILWRMP specifies that the National Performance Standard for un-ionized ammonia in wastewater effluent be met (equivalent to the WSER limit: maximum of 1.25 milligrams of nitrogen per litre [mg-N/L] unionized ammonia at 15°C). An assessment of predicted concentrations of total and unionized ammonia at the edge of the IDZ as a result of the Stage V hydraulic upgrade is presented in Section 7.0.

As discussed in Section 3.0, this EIS has been prepared following the MWR and associated guidance from BC MELP (2000). Both the MWR and BC MELP (2000) specify that a maximum allowable limit for total ammonia should be calculated to meet the Environmental Quality Objective for total ammonia at the edge of the IDZ, which is the BC WQG for total ammonia. A summary is provided in Section 6.3.5.2 of the procedure used to calculate maximum allowable limits for total ammonia by month. Monthly maximum allowable limits calculated for this EIS are presented in Table 6-4.

[2] Maximum 30-day geometric mean value multiplied by a minimum dilution factor of 40:1 for the IDZ

Total ammonia concentrations measured in AIWWTP effluent between 2012 and 2016 (Appendix A) are lower than the calculated maximum allowable limits. The minimum calculated limit for August (37.61 mg-N/L) is similar to the 2012-2016 effluent 95th percentile concentration (38.7 mg-N/L) and is higher than the 2012-2016 mean concentration (31.4 mg-N/L). The maximum calculated limits range from 37.61 mg-N/L in August to 63.84 mg-N/L in June (Table 6-4). These maximum allowable limits are intended to represent upper (maximum) concentrations in the effluent that result in concentrations at the IDZ that meet the BC WQG for total ammonia. The allowable limits are therefore intended to be protective of aquatic life and other water uses at the edge of the IDZ but are not intended to represent effluent discharge limits.

As discussed in Section 5.1.4, ammonia toxicity is dependent on the proportion of total ammonia that exists in the more toxic unionized form. The proportion of un-ionized ammonia is primarily determined by effluent pH and temperature. Effluent discharged from AIWWTP between 2012 and 2016 was not acutely toxic to rainbow trout and the maximum unionized ammonia effluent concentration was 0.93 mg-N/L, which is lower than the National Performance Standard of 1.25 mg-N/L at 15°C. As per the ILWRMP and the WSER, ammonia in the AIWWTP effluent will continue to be regulated by the National Performance Standard of 1.25 mg-N/L at 15°C. In addition to monitoring ammonia in both effluent and the receiving environment and undertaking routine effluent toxicity testing, MV has conducted ammonia spiking studies as summarized in AECOM (2015). In these studies, AIWWTP effluent was spiked with ammonia to further evaluate the dose response relationship between acute toxicity in rainbow trout to exposure of ammonia in the AIWWTP effluent. The findings of these studies have been considered in ongoing evaluation of the AIWWTP ammonia removal system implemented through secondary effluent treatment (AECOM 2015).

5.3.3 Effluent Toxicity

Annual summaries of AIWWTP effluent quality and results from annual compliance assessments were summarized in the 2012 to 2016 annual wastewater reports issued by GVS&DD (GVS&DD 2013-2017). From 2012 to 2016, reported monthly acute toxicity tests with rainbow trout all passed (i.e., 96-h LC_{50} >100% v/v) and met the National Performance Standard for toxicity testing. Standard acute toxicity testing of the effluent with *Daphnia magna* during this time period also all passed (i.e., 48-h LC_{50} >100% v/v). Acute toxicity testing followed ECCC's standard test protocols[3] and all conditions of the protocols were met. Because the Stage V upgrade is a hydraulic upgrade and effluent quality will remain the same as that characterized between 2012 and 2016, it is expected that effluent quality after the Stage V upgrade will meet the requirement that the effluent not be acutely toxic to rainbow trout. This expectation will be confirmed by continuation of the acute toxicity testing program currently implemented for the existing AIWWTP discharge following the Stage V upgrade.

MV has also undertaken chronic toxicity testing of the AIWWTP effluent with *Ceriodaphnia dubia* and fathead minnow (*Pimephales promelas*) since 2008, consistent with the CCME Strategy to evaluate the potential for toxicity in the receiving environment (GVS&DD 2017). Tests have been conducted using ECCC standard toxicity testing protocols; i.e., 7-d Fathead Minnow Larval Survival and Growth Test Method: Reference Method EPS 1/RM/22 (Environment Canada 20111) and 7-d *Ceriodaphnia dubia* Survival and Reproduction Test Method: Reference Method EPS 1/RM/21 (Environment Canada 2007c).

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[3] Reference Method EPS 1/RM/13 or EPS 1/RM/50 for rainbow trout (Environment Canada 2007a, 2008a) and EPS 1/RM/14 for *D. magna* (Environment Canada 2000).

Tri-Star (2015) evaluated chronic toxicity test results from 2009 to 2012. They reported that exposure to the effluent only rarely reduced *C. dubia* survival over 7 days but that fathead minnow survival tended to be lower when exposed to effluent for 7 days. An evaluation of toxic units calculated from these data by Tri-Star (2015) indicated that chronic toxicity based on IC_{25} concentrations only appeared to be a concern outside the IDZ on one occasion from 2009 to 2012.

More recent data are generally consistent with these findings. The most recent annual wastewater report issued by GVS&DD (2017) reported that test results for chronic toxicity testing with *C. dubia* and fathead minnow in 2016 varied with AIWWTP effluent quality, timing of sample collection, and test organism. Overall GVS&DD (2017) concluded that '*periodically some toxicity was observed at an effluent concentration that may predict it to persist at the IDZ boundary, especially considering that some toxicity has also been observed in the Fraser River*'. To address this finding GVS&DD (2017) committed to further investigation of the chronic toxicity test results.

5.4 Nutrient Loading Assessment

5.4.1 Factors Affecting Primary Productivity in the Lower Fraser River

Because the Fraser River is predominantly freshwater at Annacis Island (even though there is salt water intrusion along the river bottom under low flow conditions), it is expected that phosphorus would be the limiting nutrient for algal growth close to the AIWWTP (Environment Canada 2004). In general, the relationship between nutrient concentrations and periphyton biomass is weaker in rivers and streams than in lakes (Dodds et al. 2002, Wetzel 2001). In rivers and streams, primary productivity is influenced to a greater degree by a number of factors other than nutrient concentrations, that include but are not limited to light availability, flow velocities, stability and type of substrate, length of the growing season, suspended sediment load, invertebrate grazing, flood and drought frequencies, time since the last freshet, and water temperature (Allen 1995, Dodds et al. 2002, Tank and Dodds 2003, Lewis and McCutchan 2010, Wetzel 2001).

As discussed in Section 2.2.2, total phosphorus (TP) concentrations reported for the lower Fraser River, although higher than the BC WQG derived to protect against eutrophication in lakes, have not resulted in substantial algal growth (Nordin 1985, FRAP 1999a). Algal communities are not as well established in the lower Fraser River compared to upper reaches due to the influence of sediment transport downstream through the estuary to the Strait of Georgia (FRAP 1999a, Johannessen et al. 2015). Primary productivity is more likely limited by the turbid conditions characteristic of the lower reaches that reduce light penetration through the water column, rather than by nutrients (Sylvestor 1998). Benthic algal communities are further constrained by unstable, soft bottom, sandy substrates characteristic of the lower reaches. River conditions are particularly turbid during the freshet season from April to August that encompasses most of the growing season for algae in BC defined by Nordin (1985). Outside of this growing season, algal growth continues to be limited by turbid and light-limiting conditions in the river as well as colder temperatures.

5.4.2 Predicted Nutrient Loadings under Stage V Flows

Although concentrations of phosphorus and nitrogen in effluent are not expected to change from those reported for the current discharge, nutrient loadings would be expected to increase under Stage V flows. Predicted mean nutrient loadings are shown in Table 5-2 along with current mean loading estimates. Both current and predicted loadings were compared to ambient loadings in the Fraser River from upstream sources calculated for the period September/early October based on AIWWTP REM data from 2012 to 2016. This time period represents the end of the growing season in BC after freshet ends in August, when the river is less influenced by loads of terrestrial phosphorus with surface run-off.

Table 5-2: Stage AIWWTP Upgrade: Predicted Phosphorus and Nitrogen Loadings to the Lower Fraser River Receiving Environment in Early Fall (September/Early October)[1]

Loading Scenario	Total Phosphorus		Total Nitrogen	
	Mean Loading (kg/d)	**Contribution of Effluent to Respective Total Load (%)**	**Mean Loading (kg/d)**	**Contribution of Effluent to Total Load (%)**
Ambient Fraser River Loading from Upstream Sources[2]	4,725	n/a	37,020	n/a
Current Effluent Loading	1,126	19%	14,926	29%
Current Total Fraser River Load downstream of the AIWWTP	5,851	n/a	51,946	n/a
Predicted Stage V Effluent Loading [3]	1,522	24%	20,176	35%
Predicted Total Fraser River Load downstream of the AIWWTP	6,247	n/a	57,196	n/a
Predicted Absolute Incremental Change	*396*	*5% increase*	*5,250*	*6% increase*

Notes

n/a = not applicable; kg/d = kilograms per day

1 – Provided by CDM Smith. Loading calculations were based on date paired river and effluent quality and flow data.

2 – Calculated from phosphorus and total nitrogen concentrations reported by the AIWWTP REM program in September/October (2012 to 2016)

3 – 2 times Average Dry Weather Flow (ADWF)

Total downstream loadings of phosphorus and nitrogen in the Fraser River were calculated for current and predicted scenarios as the sum of the AIWWTP contribution and the ambient upstream load. Percent contributions of the current or predicted effluent discharges to the respective total loads in the river downstream of the AIWWTP were then calculated.

With the Stage V upgrade, loadings from the AIWWTP will represent 24% of the TP load in the Fraser River, which is an increase of 5% (in absolute terms) relative to the current AIWWTP discharge contribution of 19% of the total load. AIWWTP. Nutrient enrichment has not been documented downstream of the AIWWTP where the river is well oxygenated and no excessive algal growth has been reported (ENKON 2016a). Consequently, a 5% incremental increase in TP loads to the river is not expected to result in increased algal growth.

In the marine environment of the Strait of Georgia, primary productivity is expected to be limited by light availability and nitrogen. In a recent study, Johannessen et al. (2015) estimated that wastewater from the upstream GVS&DD municipal WWTPs, including the AIWWTP, contributed ≤1% of the nitrogen, organic carbon, and oxygen demand in the Strait of Georgia. The authors concluded that the total contribution from the WWTPs was unlikely to cause eutrophication in the Strait of Georgia. The total loading of all dissolved inorganic nitrogen (DIN) sources to the

Strait was 721,000,000 kilograms per year (kg/y) and the estimated loadings from all five WWTPs was 8,580,000 kg/y, with the AIWWTP contributing 3,780,000 kg/y. Therefore, the predicted 6% (in absolute terms) increase in nitrogen loading under Stage V flows is not expected to result in eutrophication in the Strait of Georgia.

5.5 Selection of Organic Constituents for the Receiving Impact Assessment

A variety of organic constituents in the effluent have been analyzed by MV between 2012 and 2016. The EIS focused on assessing those constituents with the most potential to cause adverse effects on public health and the receiving environment. Priority was therefore given to the selection of constituents that met the following criteria:

- Constituents for which environmental water quality criteria were available.
- Constituents for which 2012 to 2016 data reported by the Annacis REM program or the FRAMP water quality component suggested that river concentrations might be showing increasing temporal trends within or downstream of the Study Area.

Organic constituents selected for the impact assessment based on these selection criteria include select pesticides (herbicides, insecticides, and fungicides), alkylphenols, PCBs, PBDEs, hormones and sterols, and most PAHs (see Appendix E).

6.0 RECEIVING WATER QUALITY PREDICTIONS

This section was authored by CDM Smith. This section describes the selected diffuser design concept (Section 6.1) and the methodology (Sections 6.2 and 6.3) and results (Section 6.4) of predicted concentrations at the edge of IDZ to support receiving water quality assessments for the Stage 2 EIS. Details of analyses to develop the multiport diffuser design concept and assessment of its hydraulics and mixing characteristics in the Fraser River are provided by CDM Smith (2017) in Appendix A and summarized below.

6.1 Multiport Diffuser Design Concept

The multiport diffuser design concept has the following features:

- The ability to discharge Stage V flows (18.9 m^3/s) at a river level of 103.18 m geodetic datum—the conditions for which this EIS is being evaluated—by gravity without impacting the hydraulic gradeline of the treatment plant. For flows above Stage V, an effluent pump station will be needed to discharge to future design flow (Stage VIII) of 25.3 m^3/s peak wet weather flow. The diffuser was designed to accommodate Stage VIII flows by opening additional diffuser ports.
- A 240-m long diffuser manifold located just outside the edge of the navigation channel just downstream of the existing outfall (Figure 3). The manifold connects to the main vertical riser from the outfall tunnel at its center.
- The manifold has 24, 0.75-m diameter risers leading to 0.75-m diameter ports discharging horizontally via variable orifice valves with an equivalent diameter of 0.525 m toward the center of the river. For Stage V flows, 6 of the ports would be blocked off to aid in increasing dilution leaving 18 active ports. All 24 ports would be open at Stage VIII when peak wet weather flow is 25.3 m^3/s.
- The Stage V ports are fitted with variable orifices (e.g., Tideflex® diffuser valves) to increase exit velocities at low effluent flows. These valves also reduce sediment entering the diffuser system. The remaining ports are capped until needed for increased Stage VIII flows.
- The diffuser ports are surrounded by a concrete conical sleeve (diffuser protective structure) to protect them from anchors, ship strikes, and submerged debris. The sleeve accommodates access to the port terminus to permit maintenance of the variable orifices.
- The ends of the manifold are fitted with bulkheads to facilitate internal access and/or cleaning.

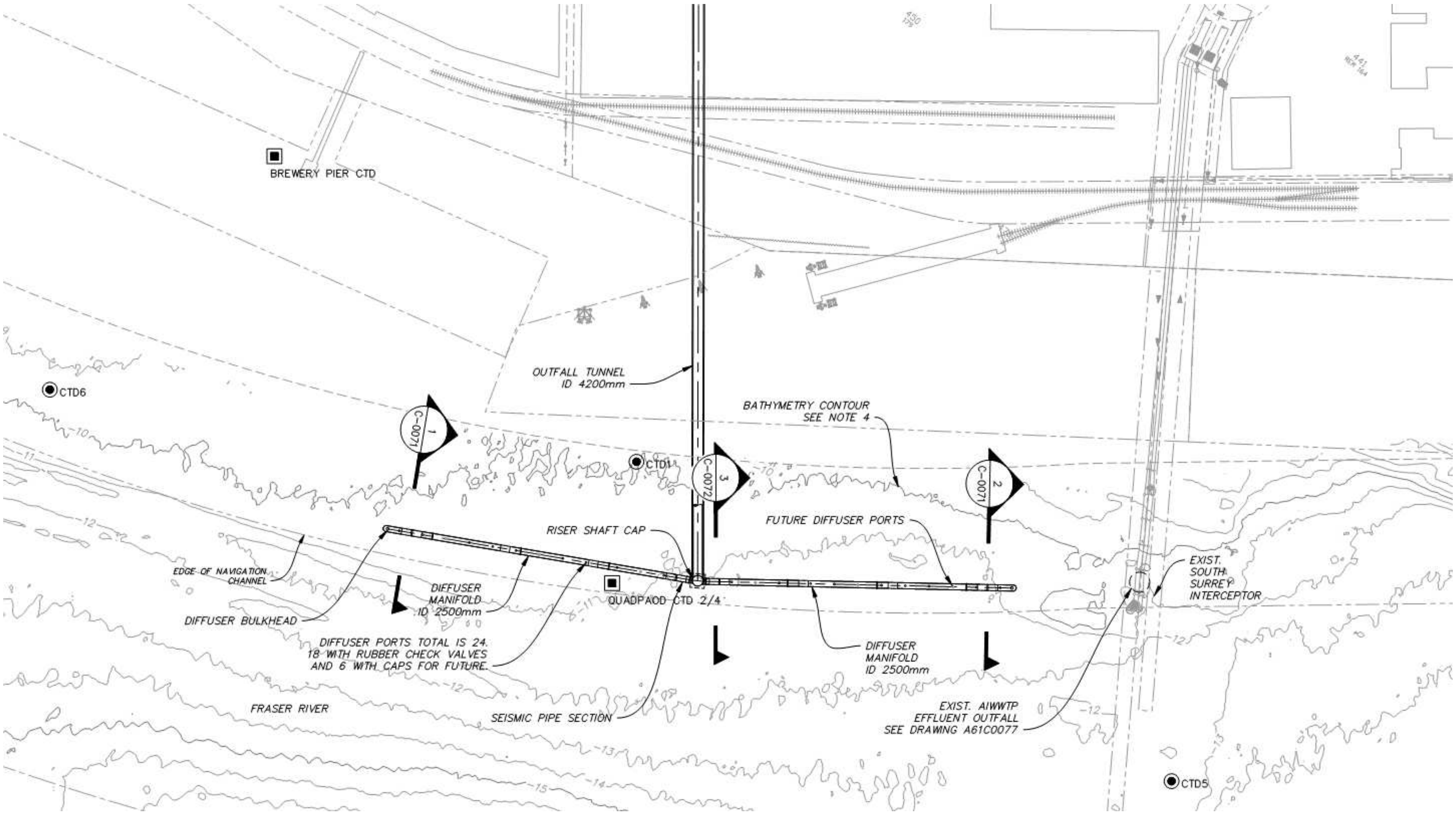

Figure 3: Proposed Diffuser Location

The proposed location for the diffuser manifold is in the deepest water available in the Study Area (outside of the navigation channel), which improves initial dilution. The design of the diffuser in this location results in the top elevation of the diffuser protective structures at 8.7 m water depth below Chart Datum. The MWR specifies that the water depth at the shallowest port should be 10 m below Chart Datum. Thus, the proposed diffuser configuration will require a variance of the MWR diffuser depth requirement.

The MWR allows for consideration of mixing with ambient waters in determining compliance with BC WQGs. The MWR define an IDZ as described in Section 1.3. The IDZ boundaries for the proposed diffuser for the AIWWTP are shown in Figure 4.

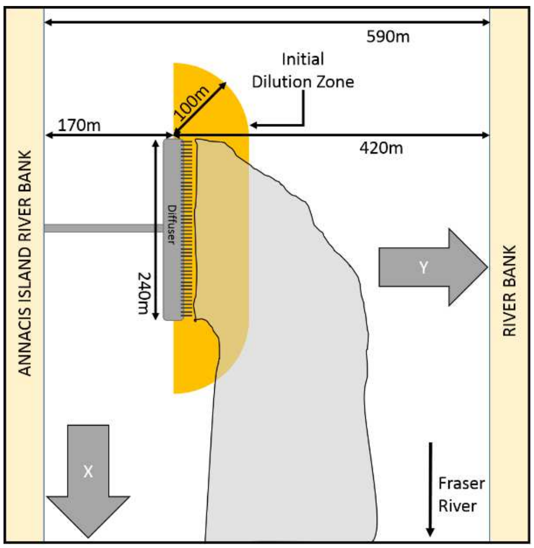

Figure 4: Conceptual IDZ

6.2 Input Data for the Analysis

The key input data for the prediction of concentrations at the edge of the IDZ are listed below; detailed information is provided in Appendix A.

- **Effluent Flow**—Daily maximum instantaneous flows from the AIWWTP from 2012-2016 were used as the basis for estimating the future flow distribution; 2012-2016 flows range from 5.5 m^3/s to 13.7 m^3/s. During periods of high flow into the plant, the influent flow is manually throttled and allowed to bypass the plant to prevent the plant from reaching its design capacity of 12.6 m^3/s. The distribution of flows was scaled from present day to Stage V using a future minimum flow of 7.4 m^3/s and a peak flow of 18.9 m^3/s, while maintaining the proportional shape of the distribution.

  For determinations of compliance with WQGs, initial dilution predictions were only performed at the compliance effluent flow of 14.75 m^3/s, which is two times average dry weather flow (2xADWF). A supplemental screening analysis was performed using future monthly average effluent flows as a sensitivity test for comparison to long-term WQGs; these results are presented in Section 8.

- **Effluent Concentrations**—Effluent data were compiled from 2012-2016 records (along with samples collected for selected constituent in 2017) and taken primarily from annual summaries of monthly operating data and effluent samples collected during IDZ monitoring. Selected constituents (fecal coliform bacteria, TRC, and $CBOD_5$) were taken from daily plant operational records. Statistical summaries of the effluent data are reported in Appendix A; these calculations used the full detection limit when constituents were flagged as either less than a method detection limit or a maximum possible concentration.

- **Fraser River Flows**—Due to the complexity of the Fraser River estuary, flows measured at the ECCC monitoring station at Hope (BC08MF0001) were used to define five river 'flow classifications' that describe when the river has uni- or bidirectional currents, is freshwater, or has the possibility of various degrees of salinity stratification at the Study Area. The five Fraser River flow classifications are Q >6,000 m^3/s (high flow, unidirectional); 6,000 m^3/s > Q >2,000 m^3/s (moderate flow, bidirectional); 2,000 m^3/s > Q >1,500 m^3/s (low flow, bidirectional, weak salinity) 1,500 m^3/s > Q >800 m^3/s (lower flow, bidirectional, moderate salinity), and Q <1,000 m^3/s (lowest flow, bidirectional, highest salinity).

- **Fraser River Water Depth**—Data from the tide gauge at New Westminster (#7654) were used to define typical low and high water levels at the Study Area.

- **Fraser River Current**—Current speed is a key input to the initial dilution models. Data on current speed were taken from a year-long (representing 2013) simulation using the H3D hydrodynamic model of the proposed diffuser discharging at the compliance flow of 14.75 m^3/s (2xADWF) at a location in the center of the river about 1 km downstream from the proposed diffuser.

- **Fraser River Salinity**—River salinity data were taken from a variety of sources and used to define three river flow conditions (described above under Fraser River flows) when notable salinity stratification can be present at the Project Study Area. The shapes of the assumed vertical profile for low and high water levels are shown in Appendix A. The characterization of salinity accounted for both the strength and vertical distribution of salinity and also the likelihood of its being present.

- **River-Effluent Seasonal Temperature Differences**—Contemporaneous Fraser River temperature data from the Gravesend Reach buoy and effluent temperature were used to define average temperature difference for the five river flow classifications.

Predictions for ammonia required characterization of two additional constituents in the effluent and Fraser River ambient: pH and alkalinity.

- **pH**—Fraser River pH values were taken from available data from the Gravesend Reach buoy from 2012-2016; the data were screened to remove extreme outliers. Annacis effluent pH values were taken from the grab samples of effluent from the 2012-2016 plant operational data reports.

- **Alkalinity**—Fraser River alkalinity from the FRAMP or ECCC sampling program at Tilbury Island from 2012-2016 was used to characterize ambient alkalinity, while effluent alkalinity from the same time period was gathered from the AIWWTP operational data reports.

6.3 Predicting Concentrations at the Edge of the IDZ

Modeling is used to determine the concentrations of discharged effluent at various locations in the Fraser River. The main objectives of the model tasks are to:

- Understand the factors affecting the fluid dynamics of the mixing of the effluent and ambient river waters; and parametrize them for use in the modeling.
- Model the instantaneous dilution process of contributing concentration of effluent under a wide range of ambient river conditions to determine dilution at the edge of the IDZ.
- Model the mixing of the effluent beyond the IDZ to understand the movement of the effluent beyond the IDZ, provide predictions at other far-field receptors locations, and to define background buildup concentration from tidal forces when bilateral currents are present.
- Characterize effluent mass loads to be used with (1) entrained flux from the instantaneous dilution analysis to determine near-field concentrations and (2) far-field model dilutions to determine the far-field concentrations.
- Provide modeled results of near- and far-field dilutions for assessment in the receiving environment impact assessment in Section 7.0.

6.3.1 Methodology: Predictions at the IDZ Boundary

Determining the extent to which each constituent in the treated effluent meets applicable WQGs requires predicting the concentration of that constituent at the edge of the IDZ.

The concentration at the edge of the IDZ (C_{IDZ}) can be broken into separate components:

- The instantaneous contribution from the effluent plume that has just undergone initial dilution (C_n).
- Ambient (background) concentration (C_{amb}); the ambient background water quality data used in the analysis are described in Section 2.1.2.
- Long-term background buildup as the concentration in the river due to the discharge of the treatment plant itself (C_{bb}).

Another component that needs to be considered is the contribution from other sources that would contribute to the ambient river concentrations between the location where the ambient background is measured and the discharge of effluent. For the AIWWTP project, this was investigated and there are no additional discharges between these locations, therefore, there is no need for another source term in the IDZ equation.

A series of equations were developed to account for the different near- and far-field concentrations to develop a total concentration at the edge of the IDZ. Neglecting other sources, the far-field dilution (S_f) and the near-field dilution (S_n) are defined as:

$$S_f = (C_{eff} - C_{amb})/(C_{bb} - C_{amb}) \quad (1)$$

$$S_n = (C_{eff} - C_{bb})/(C_n - C_{bb}) \quad (2)$$

Where the total dilution (St) is defined as:

$$\mathrm{S_t} = (\mathrm{C_{eff}} - \mathrm{C_{amb}})/(\mathrm{C_n} - \mathrm{C_{amb}}) \tag{3}$$

And is approximately the harmonic sum of the near-field and far-field dilution.

$$1/S_t \approx 1/S_f + 1/S_n \tag{4}$$

To determine the concentration at the edge of the IDZ, using the definition of the far-field, near-field and total dilutions, the equation yields:

$$\mathrm{C_{IDZ}} \;=\; \mathrm{C_{amb}} + \underbrace{\left[\frac{(\mathrm{C_{eff}}-\mathrm{C_{amb}})}{\mathrm{S_f}}\right]}_{\text{Far-field}} + \underbrace{\left[\frac{(\mathrm{C_{eff}}-\mathrm{C_{bb}})}{\mathrm{S_n}}\right]}_{\text{Near-field}} \tag{5}$$

Equation 1 can be solved for $\mathrm{C_{bb}}$ and substituted into Equation 5 to yield:

$$\mathrm{C_{IDZ}} \;=\; \mathrm{C_{amb}} + \left[\frac{(\mathrm{C_{eff}}-\mathrm{C_{amb}})}{\mathrm{S_f}}\right] + \mathrm{C_n} - \left[\frac{\mathrm{C_{amb}}}{\mathrm{S_n}}\right] - \left[\frac{(\mathrm{C_{eff}}-\mathrm{C_{amb}})}{\mathrm{S_n}*\mathrm{S_f}}\right] \tag{6}$$

Where:

$$\mathrm{C_n} = \frac{\mathrm{M_e}}{\mathrm{E}} \tag{7}$$

and: $\mathrm{M_e}$ = constituent mass flux (M/T)

E = entrained flux (the product of the initial dilution factor and the associated effluent flow rate cubic litres per tonne (L^3/T)

Predicted dilutions may be combined with effluent flow rates to estimate entrained flux, which is a measure of the volume of water in which the constituent mass flux is diluted per unit time. The independence of each component used to calculate entrained flux (including the many used to derive the predicted dilution) is important because each may be assigned appropriate probabilities of occurrence. Provided these probabilities are independent, they can be combined in what is called a “joint probability” analysis. The probabilities of several independent but concurrent events can be multiplied together to determine the overall probability of that combination of events.

Given that the frequencies of occurrence, or probability distributions, for each of the individual components, the edge of the IDZ concentration can be predicted through a statistical analysis. The basic approach depends on the type of WQGs being assessed in the impact assessment presented in Section 7.0.

- For constituents with short-term maximum WQGs, the available data is used to model input constituents statistically. Representative values from each probability distribution are selected and interval of occurrence is assigned to each value. Individual near-field model runs representing each combination of representative values are run (64 runs at 2xADWF effluent discharge rate representing different river characteristics: current speed, water depth, temperature, and salinity structure)), and the joint probability of the predicted dilution is calculated. The distribution of instantaneous dilutions and their joint probabilities is used in combination with mass loads (Section 6.3.3) to determine the 95th percentile high concentrations for comparison to short-term guidelines. This was then added to the other components of Equation 6 (e.g., ambient concentration as mean unless there were fewer than 10 samples, and then as median values, and 95th percentile far-field concentration when bi-directional river conditions exist), and compared to determine if the short-term WQG is met.

- For constituents with long-term average (30-d) WQGs, the available data is used to develop monthly average values for each ambient river model input constituent at the 2xADWF compliance flow of 14.75 m^3/s to allow calculation of dilution monthly. For months when salinity can be present, two simulations (stratified and unstratified) are made and then are combined based on the probability of salinity being present. Then, the monthly predicted dilution is applied to the average effluent loading and the compliance flow rate of 14.75 m^3/s to determine the instantaneous concentration representing the near field. This is added to the monthly average ambient background concentration and monthly average far-field concentration to determine the monthly average predicted concentrations to compare to long-term average WQGs.

6.3.2 Far-field Dilution

TetraTech Canada Inc. was engaged to employ their existing hydrodynamic model H3D of the Lower Fraser River to simulate far-field mixing of the AIWWTP effluent through the proposed diffuser to provide input into:

- Background buildup concentrations that are part of the predictions of concentrations at the edge of the IDZ where background buildup represents typical tidal return flow concentrations for evaluating compliance with maximum (95th percentile), and 30-d average (calendar month average) WQGs and FRWQOs, and
- Concentrations at other far-field assessment points.

6.3.2.1 H3D Model Structure and Inputs

The details of the model's structure and setup for the AIWWTP application are described in Appendix A, Attachment G. Some key features of the H3D implementation are described below:

- **Bathymetry** – The model used bank-to-bank bathymetry from 2012.
- **Model grid** – A nominal grid of 50 m longitudinally (upstream-downstream) and 20 m laterally (across stream) was used. The model has nominal 1.5 m thick layers, resulting in 9-12 active layers in most locations in the model depending on the tide.
- **Upstream boundary** – River flow as recorded at Hope, augmented with Harrison River flows, was used as the upstream boundary condition.
- **Downstream boundary** – TetraTech's 1-km resolution Strait of Georgia-Juan de Fuca Strait model was used to establish the downstream boundary conditions using predictions for water level, temperature and salinity at Sands Head.
- **Time step** – A nominal 6-second timestep was used in the H3D model.
- **Near-field Inputs** – The initial dilution model UM3 was used at each timestep to represent the location of the end of the initial mixing for each of the 18 diffuser ports. The diffuser configuration is as shown in Figure 3. The mass, temperature and salinity associated with the discharge at 2xADWF (the compliance flow of 14.75 m^3/s, which was held constant through the year-long simulation) was then added to the appropriate grid cell in H3D representing the end of individual mixing from each of the 18 ports of the diffuser.
- **Parameter type** – Both a conservative and first-order decay parameter were simulated. The first-order decay parameter used a US EPA algorithm represent the decay of bacteria in ambient waters.

The near-field to far-field coupling described above has limitations. To date, no single hydrodynamic model has been able to simultaneously represent the turbulence of the initial mixing process as well as the general, large-scale circulation typifying the receiving environment. Consequently, various model approximations are required to provide a practical estimate of the performance of a new diffuser. In this case, the near-field model, UM3, does not function well when limited by the proximity to the bottom or water surface; that is its numerically-modelled plume diameter expands faster than it would in the real world. In the real world, and if the plume were not restrained by top and bottom boundaries, the plume diameter would grow at a rate governed by entrainment processes and by the plume diameter, which determines the area available for entrainment. Since the UM3 implementation in H3D does not adjust the amount of surface available for entrainment, allowing it to be overestimated, the plume acquires the ambient velocity quicker that it would in the real world. Thus, the UM3 plume does not travel as far before it releases its effluent to the H3D model as it would in reality, likely resulting in higher modelled concentrations of effluent. For this reason, effluent momentum (Figure 4) may continue across the river farther than UM3 simulates, particularly when ambient currents are low. The boundary issues in UM3 are implemented in the H3D model coupling by only using UM3 to determine the location to insert mass into the three-dimensional model and thus constraining the modelled plume expansion, as discussed above. The overestimate of effluent concentration will be greatest when ambient velocities are small, such as at low flow, high tide slack conditions. The UM3-H3D coupling provides reasonable results at distance from the diffuser (as one would expect from a far-field model), but likely represents higher concentrations than are present at certain low velocity tidal conditions both within the IDZ (where far-field models are not representative) and the region immediately adjacent to it.

6.3.2.2 H3D Results: Background Buildup

The background buildup concentration is associated with the presence of previously diluted effluent within the Fraser River because of the tidal processes in the Fraser River. The background buildup concentration can be considered as a steady-state average process wherein re-entrainment of previously discharge effluent occurs after tidally reversing currents over many cycles. For the AIWWTP discharge, background buildup only needs to be considered when the currents at the site are bidirectional.

The *Annacis Island Wastewater Treatment Plant Pre-Discharge Monitoring Dilution/Dispersion Study* (LWMP Environmental Monitoring and Assessments Technical Committee, 1997) provides a description of the mixing processes at the existing outfall based on analysis of a dye study conducted in the mid-1990s; the mixing processes were found to vary with river velocity. When currents were moderate to high (e.g., flood/ebb periods of tidal cycle), the effluent rapidly dispersed due to jet velocity and (temperature-driven only) buoyancy. Then vertical diffusivity mixed the effluent field over the entire vertical section. When there was little current (e.g., slack tide periods), the effluent field rose rapidly to the surface, where it spread slowly incorporating additional dilution through gravitational spreading. Residual current (the net downstream flow when tides are removed) carried the effluent field away from the discharge point. At the lower current velocities, the study concludes “there is little or no opportunity for previously discharged, diluted effluent to be re-entrained in the forming effluent field. The effect of multiple dosing thus is not significant.” The study does not provide a conclusion about the effect of multiple dosings during moderate and high currents.

Previous initial dilution studies of the AIWWTP discharge accounted for background buildup either through using CORMIX's tidal reversal conditions to account for transient recirculation and re-entrainment of the discharge plume remaining from the previous tidal cycle (Seaconsult 1995) or using a far-field model (RMA) to obtain a 14-day average of the background buildup (Black and Veatch 2015).

The present study includes consideration of background buildup for the following reasons.

- Dye study data confirm that the effluent field can be found throughout the water column, which will be located upriver of the outfall during flooding tides; thus, the return flow during ebbing tide has the potential to return a portion of the effluent field in the entrainment water used for dilution during ebbing tides.
- The diffuser design being evaluated discharges horizontally and not vertically, and this will result in altered mixing dynamics versus that observed in the dye study; horizontally discharging ports improve instantaneous dilution over vertical ports, and should minimize, if not avoid, the expression of the rising plume as boils on the river's surface. Further, the singular direction of the ports will push the plume to the middle of the river and the river flow being entrained into newly discharging effluent will come from behind the diffuser.

The presence of background buildup in the Fraser River will reduce the available potential dilution at the edge of the IDZ.

Using the results of the year-long simulation of the H3D model, a depth-averaged, year-long time history of dilution is calculated for a conservative contaminant assuming a constant effluent flow of 14.75 m^3/s. The dilution time-series is based on an H3D model node located approximately in the center of the Fraser River and 1 km downstream of the proposed diffuser location. Based on initial model test runs, this distance seemed adequate in allowing for far-field processes to mix the plume without any direct impact of near-field processes from the coupling location of the UM3-H3D near-field to far-field model, but was close enough to the proposed diffuser location that the plume could wash back over itself near the diffuser during periods of reversing tidal conditions.

A cumulative frequency distribution (CFD) of the depth-averaged dilution was developed, and the 5% exceedance value was selected to represent the risk of background buildup for maximum WQGs. The 5% exceedance background buildup dilution is approximately 58:1. This background buildup dilution will be used for maximum WQGs. Background buildup concentrations are only considered when bidirectional flow in the Fraser River flow exists (i.e., when $Q_a < 6,000$ m^3/s).

For long-term average endpoints, a CFD was developed for each of the monthly instantaneous background buildup dilutions at the same H3D model node, and the 50% exceedance value was used to develop estimates of background buildup monthly and listed in Table 6-1. This background buildup dilution is used for WQGs with long-term average endpoints.

Table 6-1. Monthly Background Buildup Dilution for Use in Long-term Average Assessments

Month	Monthly Average Background Buildup Dilution
January	160:1
February	137:1
March	158:1
April	317:1
May	772:1
June	932:1
July	726:1
August	354:1
September	277:1
October	244:1
November	191:1
December	175:1

6.3.2.3 H3D Results: Concentrations at Far-Field Assessment Nodes

The H3D model was used to predict concentrations of effluent COPCs at five far-field assessment node locations in the project Study Area (Figure 2). From the year-long H3D simulation, time histories were developed at these locations for every model layer at a 15-minute step. Using a unit concentration at the discharge point, to determine short-term effects, a water column average, 24-h daily average time-series was developed for each node. The 5th percentile dilution was calculated for a conservative and non-conservative pollutant. To determine long-term effects, a water column average, calendar monthly average time-series was also developed for both types of pollutants at each of the nodes of interest. This information is used in the Stage 2 EIS assessment in Section 7.

6.3.2.4 H3D Results: Behavior of the Effluent Plume in the Far Field

In addition to evaluating concentrations at far-field assessment nodes in the impact assessment (Section 7.0), concentrations and corresponding dilutions at cross-river transects near the discharge location were created to demonstrate transport of the effluent in the Fraser River throughout a year. Figure 5 depicts the transect locations denoted by the row number in the H3D model where data in Figures 6-8 are displayed; the transects are located relative to the ends of the diffuser 200 m upstream, 200 m downstream, 500 m downstream and 1,000 m downstream.

The model data was processed for different timeframes: water column average hourly, running 24-h average, and running 30-d average. The data was processed by taking the water column average concentration over either an hour, 24-h, or 30-d for each model node (purple dots in Figure 5, which were spaced nominally at 20 m), and then the maximum value along the transect was selected for data display. Figures 6 through 8 shows the maximum value for the appropriate time averaging period (hourly, 24-h and 30-d, respectively), along with the Fraser River flow at Hope for 2013, and the lines representing a 10:1 and 20:1 dilution of the effluent.

Each figure depicts the time history for all four transect locations. Salient observations on this analysis include:

- On a 24-h and 30-d moving average basis, the maximum water column concentration along each transect always corresponded to a dilution greater than 25:1 and 35:1, respectively. These time frames match those used for comparison to WQGs and FRWQOs in the impact assessment presented in Section 7.0 (that are described in Section 2.4.6).
- Across the entire simulated year (2013), there were 16 instances when the maximum hour concentration along one of the four transects had a corresponding dilution less than 10:1. Typically these are single hour spikes and suggest fleeting low dilution concentrations, mostly likely associated with a strong tidal asymmetry. Nearly all occur at transect 597 located 200 m downstream of the downstream end of the diffuser. As discussed in Section 6.3.1.1, the coupling of the UM3-H3D model can yield less dilution than occurs in the intermediate region outside the IDZ, and this numerical process conservatism cannot be discounted here. As is expected, hourly concentrations drop significantly during freshet, when flow in the river is unidirectional and higher flows create greater mixing.

With respect to the impact assessment, understanding of plume behaviour is more meaningful on the 24-h and 30-d time scales rather than the 1-h time scales. As discussed in Section 2.4.6, short-term exposure has been defined for the purpose of the Stage 2 EIS as 24 h. This time period is shorter than the standard acute toxicity test durations for *D. magna* (48 h) and rainbow trout (96 h) and is consistent with short-term WQGs for turbidity specified for 24 h (BC MoE 2017a).

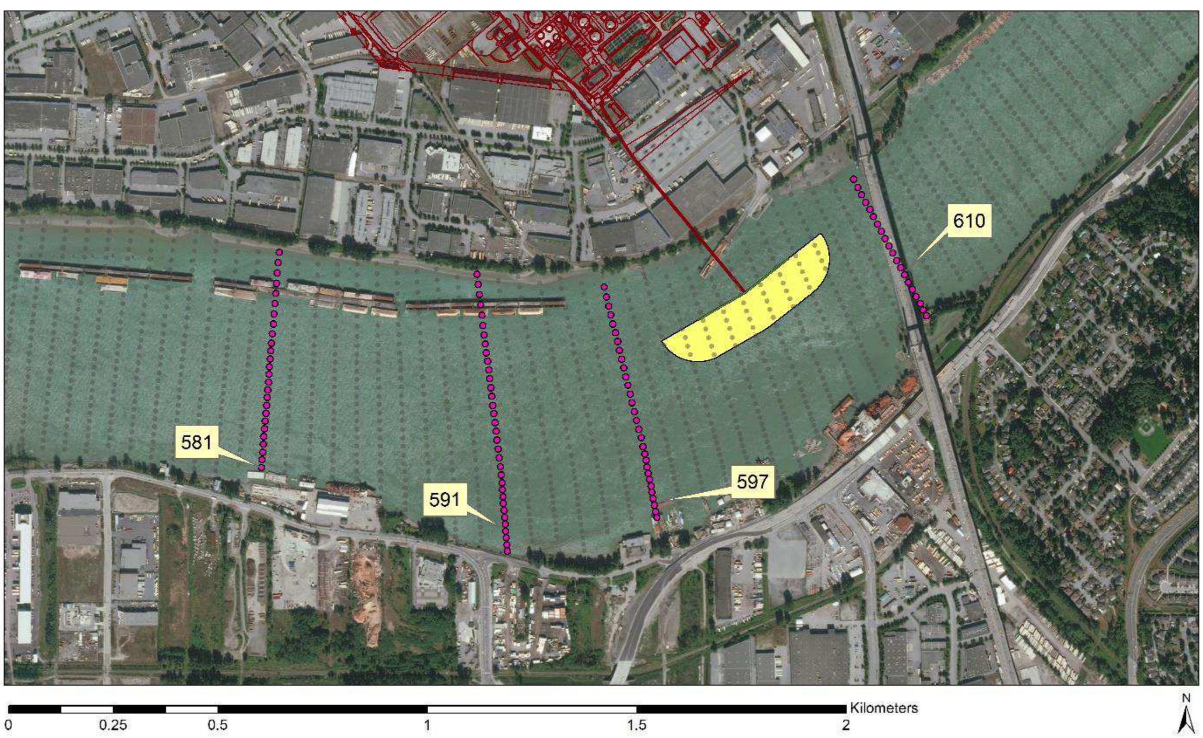

Figure 5. Transect Locations (by model row number) in H3D Model Grid that Correspond to Figures 6-8.

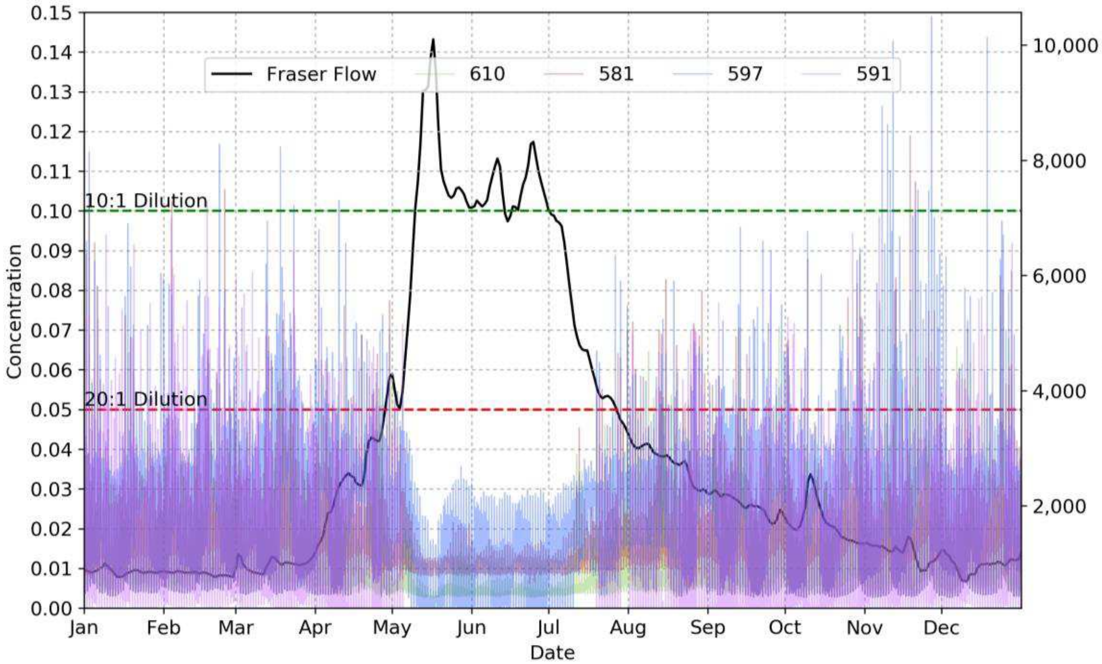

Figure 6. Maximum Water Column Average Concentration (hourly). The concentrations are taken along the transect locations shown in Figure 5.

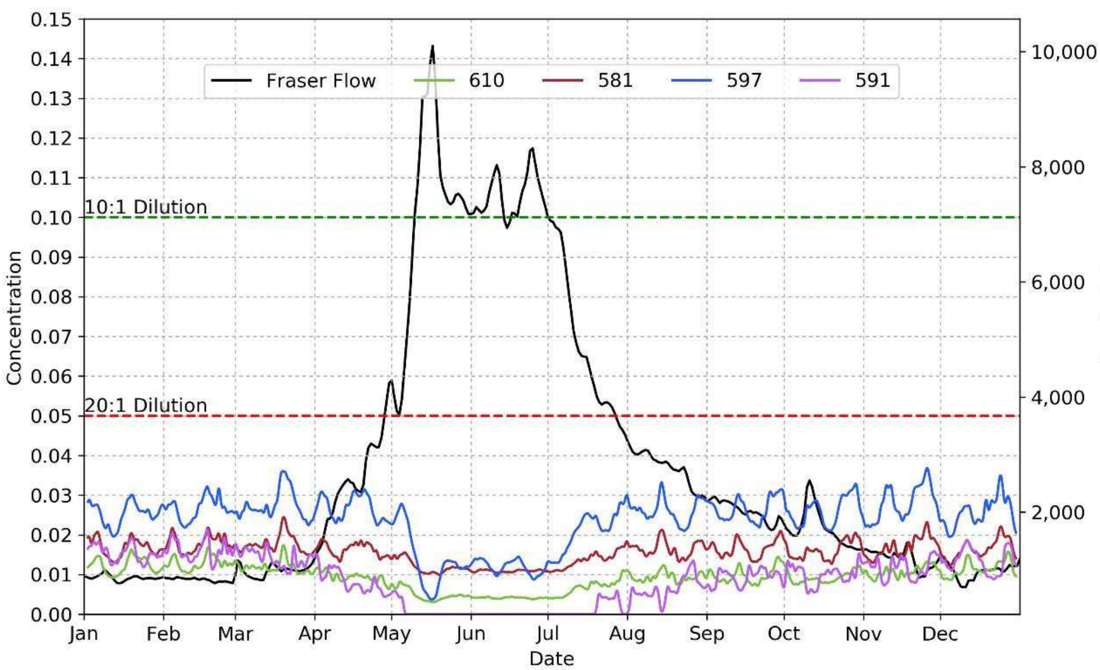

Figure 7. 24-h Moving Average of Maximum Water Column Average Concentration. The concentrations are taken along the transect locations shown in Figure 5.

Figure 8. 30-d Moving Average of Maximum Water Column Average Concentration. The concentrations are taken along the transect locations shown in Figure 5.

6.3.3 Instantaneous Dilution in the Near-field

Instantaneous dilution at the edge of the IDZ was determined using either the revised Shrivastava-Adams equation (Appendix A; Section 6.2.2) when river conditions were unstratified or the CORMIX2 program (Jirka et al. 1996) for stratified conditions.

For constituents with short-term maximum WQGs, instantaneous dilution was determined for 64 individual model runs using the effluent compliance flow of 14.75 m^3/s (2xADWF) and a range of constituents for water depth, effluent-ambient temperature difference, current speed, and presence/magnitude of stratification to represent the spectrum of ambient river conditions as shown in Table 6-2.

Table 6-2: Number of Monthly Effluent and Ambient Model Input Parameters

Fraser River Flow Classification	Water Depths	Effluent Flows	Current Speed	Temperature Difference	Density Profile
High flow: Current unidirectional $Q_a \geq 6{,}000$ m^3/s	2	1	4	1	1
Moderate flow: Current bidirectional 6,000 $m^3/s > Q_a \geq 2{,}000$ m^3/s	2	1	4	1	1
Low flow: Current bidirectional 2,000 $m^3/s > Q_a \geq 1{,}500$ m^3/s Weak stratification possible at high tide only	2	1	4	1	2
Lower flow: Current bidirectional 1,500 $m^3/s > Q_a \geq 800$ m^3/s Moderate stratification possible at high tide only	2	1	4	1	2
Lowest flow: Current bidirectional; Q_a <800 m^3/s Strong salinity possible at high tide, lesser strength at low tide	2	1	4	1	3

Representative values for each parameter in Table 6-2 were selected and the percent of time the value occurs was assigned (details of these values and percentages are described in Appendix A). The joint probability of the predicted dilution was calculated from the probabilities of each parameter in Table 6-2. Section 6.3.4 presents the method for calculating mass loads from effluent data, which were combined with the distribution of dilutions to predict the instantaneous dilution component of the IDZ concentration.

For constituents with long-term average WQGs, the available data were used to develop monthly average values for each model input parameter to permit calculation of dilution on a monthly basis. For months when salinity can be present, two simulations (stratified and unstratified) were performed and then combined based on the probability of salinity being present. The monthly predicted dilution was then applied to the average effluent mass load to determine the instantaneous component of the concentration at the edge of the IDZ.

6.3.4 Calculating Mass Loads from Effluent Sampling Data

Near-field concentrations were calculated on a mass loading basis to preserve the independence of all constituents used to calculate C_{IDZ}. Mass loads were statistically developed and divided by entrained fluxes, developed from the near-field model, to yield near-concentrations. The methodology and statistical rational used to develop the mass loads and from them the near-field concentrations is discussed below.

Section 4.4 of Appendix A describes the available effluent quality data. Effluent daily mass loads were calculated as the product of the sampling concentrations and the estimated Stage V average daily effluent flow rate on the day of sampling. Stage V flows were determined using the actual flow on the day and translating them to Stage V flows using the relationship presented in Section 6.2. The daily mass loads for each constituent were then fit to one of three continuous statistical distributions:

- Normal
- Unbounded Johnson
- Bounded Johnson

Johnson distributions were considered to account for observed skewness (a measure of a distribution's asymmetry) and kurtosis (a measure of the weight of a distribution's tails relative to the whole) in daily load datasets. Both the bounded and unbounded Johnson distributions are transformations of the normal distribution, and can account for nearly any skewness and kurtosis.

Some constituents were deemed unsuitable for Johnson distribution fitting due to either low sample counts or a high percent of non-detected values and were consequently assumed to be normally distributed. Because algorithmically fitting loads to a Johnson distribution would account for some skewness and kurtosis in the data, it is important to have a high level of confidence in those data characteristics. If, for example, a constituent is 100% non-detect, there is typically no variation in the data since the only value measured is that of the detection limit (some constituents have multiple detection limits). However, when the concentrations are converted to loads based on the average daily effluent flow rate on the date of sampling, variation in the loads arises due to the variation in those daily flow rates. Because such flow induced variation in loads cannot be confirmed as real, due to the uncertainty of the concentrations, we cannot be confident in any skewness or kurtosis it may exhibit. If a constituent was greater than 50% non-detect values, its loads were fit to a normal distribution since we could only be confident in less than 50% of the variation in the loads. Additionally, if a constituent had less than 10 samples total, the loads were assumed to be normally distributed due to the limitations of Johnson distribution fitting algorithms with small datasets.

Percentile mass loads were calculated for each constituent using the percent point function (ppf) of the selected distribution with the best-fit constituents produced by the fitting algorithms.

$$M_e = \xi + \left[\left(1 + e^{-(z-\gamma)/\delta}\right)^{-1} * \lambda\right] \quad \text{Bounded Johnson Distribution ppf} \quad (8)$$

$$M_e = \xi + \left[\sinh\left(\frac{z-\gamma}{\delta}\right) * \lambda\right] \quad \text{Unbounded Johnson Distribution ppf} \quad (9)$$

$$M_e = \mu + z * \sigma \quad \text{Normal Distribution ppf} \quad (10)$$

Where: ξ = Johnson location parameter

λ = Johnson scale parameter

δ = Johnson shape parameter

γ = Johnson shape parameter

μ = Arithmetic mean

σ = Standard deviation

z = Standard normal variable (z-score)

100 mass loads were calculated for each constituent each with an occurrence probability of 0.01. The mass loads for constituents using a Johnson distribution were inspected to ensure the loads were reasonable and in agreement with engineering judgment.

6.3.5 Temperature and Ammonia

6.3.5.1 Comparison of the Effect of Effluent Temperature on Ambient Water Temperature

A separate analysis was conducted to assess the BC WQG for temperature protective of aquatic life that limits the temperature change to a +/- 1°C temperature variation at any time, location, or depth in marine and estuarine waters. A conservative analysis was undertaken to evaluate this guideline using the minimum dilutions associated with each Fraser River flow classification using contemporaneous 2011-2015 data on effluent temperature and ambient river temperature measured at the Gravesend Reach buoy. The difference in temperature was then divided by the 5th percentile (low) dilution.

The differences between effluent and ambient temperature range between -0.49°C to 14.3°C. Based on the 95th percentile predicted dilution for the low flow classification, the predicted impact in temperature is 1.06°C which is slightly above the allowable change in the interim guideline.

6.3.5.2 Ammonia Predictions

There are six regulations relevant to the discharge of ammonia dissolved in wastewater effluent. The ammonia predictions in relation to each of those regulations is discussed in Section 7.5 of Appendix A. summary of the compliance assessment is provided in Table 6-3.

Table 6-3. Ammonia Compliance Summary

	Regulation	Rule	Result
End-of-Pipe	WSER Un-Ionized Ammonia	Un-ionized ammonia must be <1.25 mg-N/L at 15°C ± 1°C	100% Met; Maximum predicted value = 0.35 mg-N/L
End-of-Pipe	CEPA Total Ammonia	Maximum Allowable Total Ammonia (mg-N/L) $= 306{,}132{,}466.34 * 2.7183^{(-2.0437*\mathrm{pH_{eff}})}$	100% Met; Of 835,200 cases examined, the highest predicted effluent concentration occurs at the estimated 99th percentile mass load of 26,120 kg/day resulting in an effluent concentration of about 20.5 mg-N/L at the compliance flow rate of 14.75 m^3/s.
End-of-Pipe	British Columbia Environmental Management Act	Maximum Allowable Total Ammonia is the concentration necessary to meet provincial long-term water quality objectives	100% Met; The method is discussed below and the predictions are included in Table 6-4.
Receiving Environment	British Columbia Provincial Water Quality Objectives for Fraser River from Hope to Sturgeon Banks	Maximum concentration of total ammonia (mg-N/L) at the edge of the IDZ is less than the values listed in Table J-1 in Attachment J to Appendix A	100% Met; Of 835,200 cases examined, the case closest to non-compliance has the minimum difference between the predicted concentrations and the maximum objectives of -2.60 mg-N/L
Receiving Environment	British Columbia Provincial Water Quality Objectives for Fraser River from Hope to Sturgeon Banks	Average 30-day nitrogen concentration of total ammonia (mg-N/L) at the edge of the IDZ is less than the values listed in Table J-2 in Attachment J to Appendix A	100% Met; The monthly predictions are presented in Table 7-5 of Appendix A. The difference between the predicted concentrations and the average objectives ranged from 0.8 to 1.4 mg-N/L.
Receiving Environment	WSER & Canadian Water Quality Guidelines for the Protection of Aquatic Life	Unionized ammonia concentration at the edge of the IDZ is less than or equal to 0.016mg-N/L	99% Met*; Of 835,200 cases examined, 65,853 do not meet the guidelines. All have a very low instantaneous probability of occurrence, totaling 0.92 percent of the time. Duration of exceedances cannot be determined from the analysis. Details of the method and result are presented below.

*This regulation is contingent on effluent being acutely toxic due to the concentration of unionized ammonia (<1.25 mg-N/L at 15°C ± 1°C)"

Back-Calculated Maximum Allowable Monthly Limits

As described in Section 5.3.2, this EIS has been prepared following the MWR and associated guidance from BC MELP (2000). Both the MWR and BC MELP (2000) specify that a maximum allowable limit for total ammonia should be calculated to meet the Environmental Quality Objective for total ammonia at the edge of the IDZ (i.e., the BC WQG for total ammonia). The following is a summary of the procedure used to calculate maximum allowable limits for total ammonia (by month).

Because the MWR references the provincial long-term average WQGs, the back calculation was done on an average monthly basis. For each month, the ammonia guideline was calculated using the blending pH and temperature at the edge of the IDZ. The effluent concentration necessary to achieve each month's guideline was calculated by solving the initial dilution equation (Section 6.3.1) for effluent concentration. Table 6-4 shows the predicted monthly average effluent ammonia concentrations, the guideline at the edge of the IDZ, and the corresponding maximum allowable effluent concentration. The maximum allowable effluent ammonia limit is always well higher than the predicted effluent concentration. It should be noted that effluent concentrations are low compared to historical data due to nature of a mass loading based analysis. Because the 2xADWF compliance flow rate of 14.75 m^3/s is in the 96th percentile of Stage V effluent flow (Figure 6-8 of Appendix A), ammonia mass loads are diluted more than they would be for most other flow rates.

Table 6-4. Predicted Monthly Average Effluent Ammonia Concentrations

Month	Monthly Average Near-Field Dilution	Monthly Average Blended Temperature (C)	Monthly Average Blended pH	Provincial Long-term Average Total Ammonia Guideline at Edge-of-IDZ (mg-N/L)	Future Predicted Effluent Total Ammonia Concentration (mg-N/L)	Back Calculated Maximum Allowable Effluent Concentration (mg-N/L)
January	28.4	3.45	7.45	1.99	15.50	46.65
February	30.0	4.02	7.51	1.97	16.15	47.15
March	31.4	5.27	7.57	1.94	15.98	49.55
April	32.2	7.37	7.62	1.90	16.43	54.20
May	36.8	10.51	7.62	1.85	16.37	63.23
June	37.7	13.28	7.69	1.81	15.94	63.84
July	35.3	16.82	7.63	1.56	14.90	51.03
August	32.5	19.28	7.67	1.31	14.35	37.61
September	31.8	16.65	7.62	1.58	14.83	43.79
October	32.0	11.94	7.60	1.82	15.12	50.16
November	31.7	7.20	7.43	1.90	15.44	50.24
December	30.0	4.24	7.42	1.97	15.64	49.04

WSER Receiving Water Unionized Ammonia

The WSER indicates that if "effluent deposited via its final discharge point is acutely lethal because of the concentration of unionized ammonia", the discharger may apply to receive temporary authorization to continue discharging given that un-ionized ammonia "at any point that is 100 m from the point of entry where effluent is deposited in that water via the final discharge point is less than or equal to 0.016 mg/L, expressed as nitrogen (N)". Compliance was assessed by calculating the effluent unionized ammonia concentration according to Section 14 of the WSER, which is summarized in the WSER end-of-pipe regulation in Table 1; if the effluent unionized ammonia concentration is greater than 1.25 mg-N/L, effluent acute toxicity can be attributed to unionized ammonia concentration. Although, as previously shown in Table 6-3, predicted future effluent unionized ammonia concentration do not exceed 1.25 mg-N/L, compliance with the WSER receiving environment regulation for unionized ammonia is evaluated. Unionized ammonia concentrations at the edge of the IDZ are calculated using the equation published in WSER (34)(3) with the total ammonia concentration, blended pH and blended temperature for each case.

Figure 9 shows the CDF of predicted unionized ammonia at the edge of the IDZ. The predicted unionized ammonia concentration at the edge of the IDZ exceeds 0.016 mg-N/L in 65,853 out of the total 835,200 cases. Although this is over 7% of the total cases considered, when the probability of each case is included, unionized ammonia is predicted to exceed the objective about 0.92% of the time. Out of the cases that do exceed the objective, more than 90% of the time they are less than 0.005 mg-N/L over. These predictions are discussed further in the receiving environment impact assessment (Section 7.0).

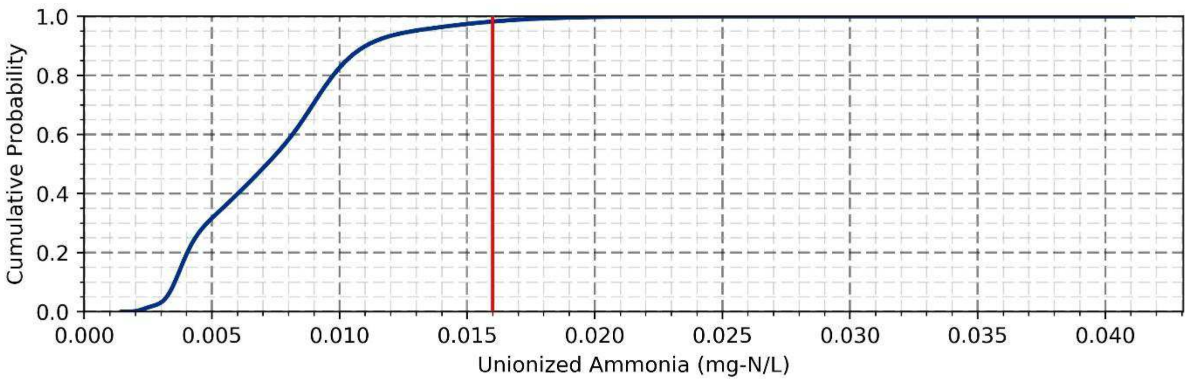

Figure 9. Predicted Unionized Ammonia at the Edge of the IDZ

6.4 Results of Predicted Concentrations at the Edge of the IDZ

Appendix A provides the results of the predicted concentration at the edge of the IDZ applying the methodology described above. These concentrations were carried forward into the receiving environment impact assessment in Section 7.0.

7.0 RECEIVING ENVIRONMENT IMPACT ASSESSMENT

The receiving environment impact assessment considered water quality predictions at the edge of the IDZ (near-field; Section 7.2) and at far-field nodes shown on Figure 2 (Section 4.0). The potential for adverse effects on ecological and public health and agricultural uses as a result of the proposed effluent discharge was evaluated by comparing predicted 95th percentile (or maximum) short-term (24-h average) and long-term (monthly average) water quality against applicable FRWQOs and WQGs and ambient river concentrations as described in Section 7.1.

Constituents that exceeded applicable screening criteria and ambient river concentrations at the edge of the IDZ were identified as preliminary near-field COPCs. Preliminary near-field COPCs were further evaluated by comparing predicted concentrations to measured concentrations at the edge of the IDZ for the currently approved AIWWTP discharge. This comparison was undertaken to evaluate if there was an expected incremental increase in IDZ concentrations due to the Stage V upgrade. Available toxicological information was also reviewed for preliminary COPCs to evaluate the potential for adverse effects on ecological and public health from the predicted Stage V IDZ concentrations. Concentrations of near-field COPCs were predicted at the far-field assessment nodes and screened against applicable FRWQOs and WQGs and ambient river concentrations (Section 7.4). The potential for nutrient enrichment in the Study Area was evaluated separately, taking into consideration receiving environment characteristics and nutrient loadings to the receiving environment (Section 5.4).

The approach taken for this impact assessment addressed guidance provided in BC MELP (2000) and a requirement of the MWR to evaluate whether the proposed hydraulic upgrade to the existing AIWWTP discharge will result in adverse effects to public or ecological health (BC MELP 2000). Guidance provided by the CCME Strategy (CCME 2008) further recommends that dilution should not be allowed for persistent, bioaccumulative and toxic constituents (PBTs) and that conditions within a mixing zone should not result in the bioconcentration of constituents to levels that are harmful to human health or ecological health. For this assessment, PBT constituents were identified and evaluated to determine the potential for adverse effects to people and wildlife consuming fish from the Fraser River (7.4).

7.1 Methods

7.1.1 Data Sources

The receiving environment impact assessment relied on measured and predicted water quality information from the following sources:

- Ambient, effluent, and IDZ concentrations previously measured as part of AIWWTP effluent monitoring by MV, the REM program, the FRAMP water quality program, and the federal water quality monitoring program (Section 2.2.2 and Appendices A and B).
- Water quality statistics for the ambient river concentrations derived by Golder (Appendix B).
- Water quality statistics for the effluent concentrations derived by CDM Smith (Appendix A).
- Water quality statistics at the edge of the near-field IDZ for the currently approved AIWWTP discharge calculated by Golder from measured concentrations (Appendix E).

- Predicted water quality at the edge of the near-field IDZ derived by CDM Smith for an effluent flow 2xADWF (Appendix A).
- Predicted water quality at far-field assessment nodes derived by CDM Smith (Appendix A).

7.1.2 Data Review

The impact assessment relied on the quality assurance and quality control (QA/QC) programs of the source authors, which can be found in the original sources. Notwithstanding reliance on the original data sources, data quality was reviewed for ambient, effluent, and IDZ concentrations of a subset of organic constituents that can be challenging to measure in water. Constituents that received a supplemental review of data quality were total PCBs, PBDE-47, PBDE-99, PBDE-100, alpha-endosulphan, hexachlorobenzene, hexachlorobutadiene, alpha-chlordane, and EE2.

The following sources of data quality uncertainty were identified in that review.

Detected Concentrations in Method Blanks, Field Blanks, and Trip Blanks

Method blanks, field blanks, and trip blanks are used as indicators of sources of contamination that could interfere with data interpretation, i.e.

- Method blanks are indicators of laboratory contamination.
- Trip blanks are indicators of shipping (volatiles only) and laboratory contamination.
- Field blanks are indicators of ambient sources of contamination during sampling and shipping (volatiles only) in addition to laboratory contamination (US EPA 2009).

Method blanks were available for each of the samples reviewed, whereas trip and field blanks were only available for some of the samples reviewed.

Available method blanks, trip blanks, and field blanks were above the method detection limit for most of the PCB and PBDE samples reviewed, indicating the presence of contamination. Given the ubiquitous nature of PCBs and PBDEs in natural environments, it is not surprising that they were detected in blanks; however, the magnitude of detected concentrations can indicate elevated uncertainty in reported sample concentrations. For example, the method blanks associated with measurements of the BDE-47, BDE-99, and BDE-100 from Winter 2013 were 3 to 25 times greater than the ambient and IDZ measured concentrations. Several IDZ and reference samples for total PCBs, BDE-47, BDE-99, and BDE-100 collected from Winter 2014 and Winter 2016 were within five times the method blanks, trip blanks, and/or field blanks, indicating that these samples are not distinguishable from the blank concentrations (BC MoE 2013b).

In consideration of the findings of the data review, a high level of uncertainty was associated with the PCB and PBDE effluent and river water data that was used to generate water quality predictions to be assessed in the impact assessment.

Variable Method Detection Limits

Most organic constituents in the ambient dataset (Appendix B) were below the method detection limit (MDL) in 100% of the samples collected and approximately one third of the organic constituents in the effluent dataset (Appendix A) were 100% below the MDL.

For constituents that were 100% below the MDL, the impact assessment conservatively assumed that the concentration was equal to the full MDL. For organic constituents, the MDL is often sample dependent and therefore there is a range of MDLs for a given constituent. The MDL range spanned up to one order of magnitude for PCBs, PBDEs, pesticides, and hormones and sterols. For example, EE2 was not detected in any effluent or ambient sample. The ambient dataset for EE2 (n = 30) ranged from <0.37 to <3.1 ng/L and the effluent dataset (n = 32) ranged from <2.4 to <49.9 ng/L. Unusually high MDLs in these datasets were identified as values greater than 1.5 times the interquartile range (i.e., analogous to outlier data). Removing these unusually high MDLs, the ambient dataset ranged from <0.37 to <1.7 ng/L and the effluent dataset ranged from <2.4 to <35.5 ng/L. The resulting ambient and effluent EE2 MDLs were used in IDZ predictions.

7.1.3 Screening of Near-Field and Far-Field Predictions

The short and long-term predictions were generated as described in Section 6.3 for approximately 140 consituents. In brief, the short term concentrations represents the upper-bound (i.e. 95th percentile or maximum) concentration for a 24-h period and the monthly concentrations represent the central tendency (i.e. average or median) concentration for a given month.

A stepwise screening approach was used to identify COPCs in the near field at the edge of the IDZ and at the five far-field nodes for the short term and monthly concentrations as shown in Figure 10 and described further below.

- **Step 1:** Compare short-term and monthly water quality predictions at the edge of the IDZ against applicable screening criteria identified in Section 2.4.6. Constituents with predicted concentrations above a screening criterion were further evaluated to assess whether predicted concentrations reflected a potential Project-related change in environmental quality relative to current ambient river concentrations.
- **Step 2**: For constituents with predicted concentrations above a screening criterion, compare against the ambient river concentration plus 20%. In consideration of temporal variability and variability in sampling and laboratory methods, a predicted increase of less than 20% above the ambient river concentration was considered unlikely to reflect a measurable and ecologically meaningful Project-related change in environmental quality. A predicted difference of less than or equal to 20% is within the limits of precision associated with water quality modelling and water quality monitoring. This screening criterion is consistent with guidance in BC MoE (2013b), where a relative percent difference less than 20% between two duplicate water quality values is not considered to indicate a distinguishable difference between the two values. Constituents with predicted concentrations above a screening criterion and the ambient river concentration were identified as preliminary COPCs. These preliminary COPCs were further evaluated to determine if predicted concentrations reflected a Project-related increase relative to current IDZ water quality conditions.

- **Step 3:** Compare preliminary COPCs against the current IDZ concentration. Constituents with predicted concentrations above a water quality screening criterion and ambient and current IDZ river concentrations were identified as near-field COPCs.
- **Step 4:** COPCs identified in the near-field were carried through to the far-field assessment where predicted concentrations at far field nodes were compared to relevant water quality screening criteria.
- **Step 5:** As in the near-field assessment, constituents with predicted concentrations above water quality screening criteria were further evaluated by comparison against ambient river concentrations. Constituents with concentrations above a water quality screening criterion and the ambient river concentration at one or more far-field nodes were identified as far-field COPCs.

Exceeding a screening criterion does not necessarily indicate a potential for unacceptable impairment of water uses, but rather that the potential for adverse effects and water use impairment might be increased and should be investigated further. Near-field and far-field COPCs identified by the screening methodology described above were retained for further evaluation to assess the potential for adverse effects to identified receiving environment water uses (Sections 7.2.1 and 7.3.1) and public health (Sections 7.2.2 and 7.3.2).

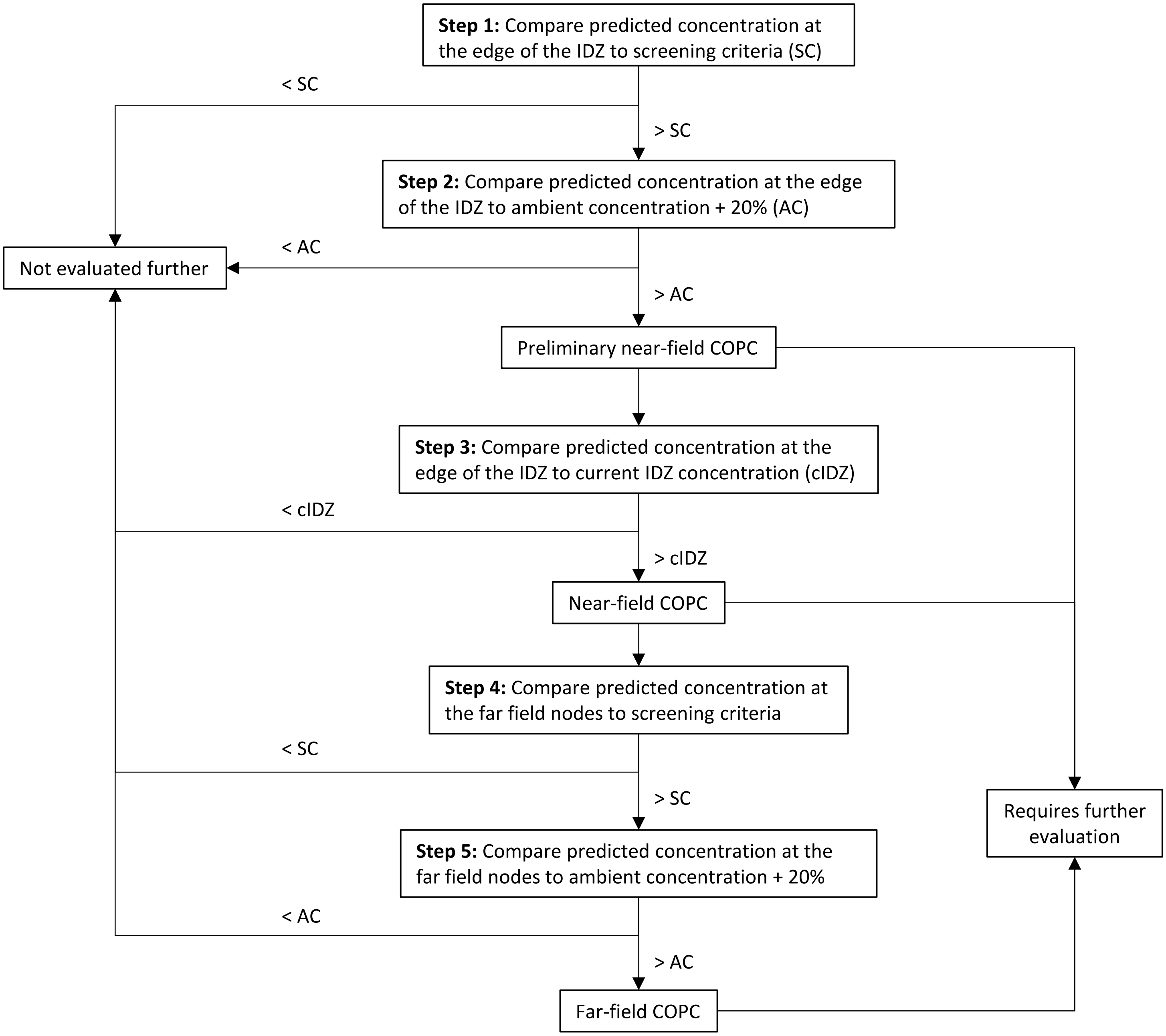

Figure 10: Flow chart of screening methodology used to determine near-field and far-field COPCs

7.1.4 Assessment of PBT Constituents

An evaluation of PBT constituents was undertaken to assess the potential for adverse effects on wildlife and people consuming fish from the Fraser River in response to technical guidance provided by CCME (2008) for the CCME Strategy. The PBT assessment included the following steps:

- Identification of PBT constituents
- Review of current and predicted future effluent concentrations
- Assessment of the incremental change in water concentrations at the edge of the IDZ due to the Project by comparing predicted IDZ water concentrations against current IDZ water concentrations
- Review of uncertainty associated with analytical measurements of PBT constituents

7.2 Near-Field Assessment Results

Screening results of short-term and monthly concentrations predicted at the edge of the IDZ as described in Section 6.0 are provided in Appendix E. The following subsections present screening of upper bound predicted short-term and monthly average concentrations at the edge of the IDZ, to evaluate potential impacts on aquatic life, wildlife, livestock and irrigation uses (Section 7.2.1) and public health (Section 7.2.2). The exception was ammonia where a specific approach was taken in predicting total and un-ionized ammonia concentrations, as described in Section 6.3.5.1, that considered blended pH and blended temperature for each of the 835,200 predicted cases. From this analysis, monthly total ammonia predictions were provided by CDM Smith (as summarised in Appendix A) for inclusion in Appendix E Table E-3, however, short-term predicted concentrations of total ammonia and the unionized ammonia predictions were directly referenced from the analysis of the 835,200 predicted cases by CDM Smith in Section 6.3.5.1 and Appendix A.

7.2.1 Aquatic Life, Wildlife, Livestock and Irrigation Uses

For most of the approximately 140 constituents, predicted short-term and monthly concentrations were below applicable FRWQOs, BC WQGs, and CCME WQGs, and/or did not represent a measurable or ecologically meaningful increment over ambient river concentrations (i.e., predicted concentrations were within 20% of current upstream concentrations). Thus, for most of the constituents assessed in the EIS, the Project is not expected to contribute to an incremental change in potential adverse effects to aquatic life or potential impairment of wildlife and agriculture environmental uses (Appendix E, Tables E-1 to E-5). The relatively small number of constituents that were identified as exceptions are discussed below. Inorganic constituents that do not have water quality guidelines but are predicted to be greater than 20% over ambient river concentrations are also discussed below.

Constituents discussed below are: un-ionized ammonia; phosphorus; nitrogen; temperature; sodium; copper; lithium; permethrin; total PCBs; EE2; and sterols. Predicted concentrations at the edge of the IDZ were compared to current concentrations at the edge of the IDZ to characterize the predicted relative change in water quality due to the Stage V upgrade. The current IDZ concentration represented water quality at the IDZ boundary under low flow conditions because the characterization was based on data collected by the AIWWTP REM program that sampled river water and effluent in late winter and late summer from 2012 to 2016.

Nutrients and Conventional

Un-ionized Ammonia

The maximum un-ionized ammonia concentration at the edge of the IDZ of 0.041 mg-N/L predicted by CDM Smith in Section 6.3.5.1, was above the CCME guideline of 0.016 mg-N/L by a factor of 2.5 and the current maximum IDZ concentration of 0.025 mg-N/L by a factor of 1.6. The ammonia compliance summary undertaken by CDM Smith in Appendix A and summarized in Table 6-3 indicates that exceedance of the CCME guideline was expected to be infrequent, with predicted concentrations above the WQG occurring in less than 1% of the 835,200 modelled cases.

Toxicity data summarized by Environment Canada (2001) and considered by CCME (2010) in the WQG derivation, indicated that the maximum predicted un-ionized ammonia concentration of 0.041 mg-N/L would be associated with potential chronic, sublethal effects (e.g., a 20% reduction in growth or reproduction) on the most sensitive 5% of fish and invertebrate species. Due to the infrequent predicted occurrence of concentrations exceeding the CCME short-term guideline (<1%), the relatively small percentage of fish and invertebrate species that would potentially be affected (5%), and the associated low magnitude of potential effects (chronic, sublethal effects) it was considered unlikely that maximum predicted concentrations of un-ionized ammonia would result in adverse effects to aquatic life at the edge of the IDZ.

Total Phosphorus and Total Nitrogen

The BC nutrient WQG for rivers is an algal biomass-based BC WQG for streams of 100 mg/m^2 chlorophyll *a* (Nordin 1985). As discussed in Section 5.4.1, the unstable, soft bottom, sandy substrates characteristic of the lower Fraser River are not suitable to support the establishment of benthic algal communities and thus no benthic algal biomass data are available for these lower reaches. As a surrogate for screening purposes, predicted IDZ concentrations were compared to the BC TP WQG that was derived to protect against eutrophication in lakes (0.005-0.015 mg/L; Nordin 1985).

As discussed in Section 2.2.2, TP concentrations reported for the lower Fraser River were above the BC WQG derived to protect against eutrophication in lakes, but these concentrations have not resulted in substantial algal growth because of site-specific riverine conditions and the general lower sensitivity of rivers to phosphorus relative to lakes (Nordin 1985, FRAP 1999a). Algal growth is primarily light limited in the lower Fraser River, particularly during the growing season defined by Nordin (1985) that overlaps with high river flows and associated elevated sediment transport downstream.

There is no total nitrogen (TN) WQG available in Canada. Monthly TN concentrations across all months were lower than the mean TN concentration reported at the IDZ between 2012 and 2016. The same is true for predicted TP concentrations during winter prior to the onset of early freshet in April and then after freshet in September. . For the higher flow months from April to August it was more appropriate to compare to ambient concentrations under higher flow conditions than to a low flow IDZ concentration. The mean predicted IDZ concentration was only 1.4 times the mean high flow phosphorus concentration measured upstream and approximately half the 95th percentile upstream concentration. Given the variability in TP concentrations during freshet due to variability in both aquatic and terrestrial inputs of particulate phosphorus during this time (Appendix B), the predicted IDZ concentration was within the range of variability expected during freshet. As discussed in Section 5.4.1 -primary productivity is primarily limited by the elevated sediment loadings in the river during freshet and reduced light penetration through the water column.

Monthly TN and TP predictions were the most relevant to the assessment of the potential for adverse effects on aquatic life due to eutrophication because effects due to eutrophication are realized over longer time periods and plant growth is influenced by conditions over the entire growing season (Environment Canada 2004). Actual effects are likely best represented by the average concentration over the growing season from May to September however for the purpose of this assessment, monthly predictions were assessed. Short-term flow-based predictions were provided, but these are less relevant because they represent a time period of 24 hours instead of weeks or months.

Temperature

BC and CCME WQGs state that any change in water temperature should be within ±1°C from natural ambient background in marine and estuarine waters (BC MoE 2017a, CCME 2016). These guidelines are intended to maintain temperatures to which organisms have adapted through evolutionary processes (BC MoE 2017a). Although many biological processes in marine and estuarine waters are sensitive to temperature changes, the variability in exposure conditions experienced in these dynamic systems by biota means that a temperature alteration of ±1°C is likely minor compared to overall variability in the system (CCME 1999). The exposure environment in the lower Fraser River is similarly dynamic, influenced by tidal cycles, upstream intrusion of the salt-wedge, and variable upstream freshwater flows.

At the edge of the IDZ, temperature was predicted to be within 1°C of the ambient background temperature for 199 out of 200 predicted cases (>99% of modelled cases) using matched effluent and ambient data from 2011 to 2016 (Section 6.3.5, Appendix A). For the one exception, a slight increase in temperature of 1.06°C was predicted to occur in December. This temperature increase one day during the winter when temperatures were well below the upper tolerance thresholds of resident fish species, was not expected to result in adverse effects to aquatic life. For example, according to Levy (1992) and Oliver and Fidler (2001), the upper thermal tolerance (i.e., lethal level) for juvenile and migrating adult salmonids was on the order of 21°C for the most sensitive species.

Sodium

There is no WQG for sodium in Canada. Maximum predicted concentrations of sodium were not distinguishable from ambient concentrations with the exception of the short-term sodium concentration during high flows. Given that sodium is a major ion incorporated into salinity and conductivity measurements, predicted concentrations of these constituents were reviewed and salinity predictions were compared to the CCME WQG. There are no exceedances of this guideline and predicted conductivity was within the range of concentrations found in the Fraser River, which indicates negligible potential for adverse effects on aquatic life at the IDZ.

Metals

Predicted short-term concentrations of total and dissolved aluminum, iron, manganese, and nickel were above the FRWQO or the lowest short-term WQG, but were not distinguishable from ambient river concentrations. Predicted short-term concentrations of these constituents were therefore not evaluated further in the impact assessment. Predicted monthly concentrations of dissolved and total aluminum, total chromium, copper, iron, and mercury were greater than FRWQOs or the lowest long-term WQG but also were not distinguishable from ambient river concentrations. Predicted monthly concentrations of these constituents were therefore not evaluated further in the impact assessment.

Predicted short-term and monthly lithium concentrations at the IDZ were greater than the ambient river concentration, and no WQG is available for lithium in Canada. However, maximum predicted short-term and monthly lithium concentrations were equal to or less than IDZ concentrations reported for the current discharge. Therefore, no incremental change in concentrations at the IDZ or associated potential for adverse effects would be predicted due to the Stage V upgrade and lithium was not evaluated further. An assessment of lithium would also have been limited by paucity in toxicity information available for this metal.

Predicted short-term total copper concentrations were above the FRWQO under low flows and distinguishable from the ambient concentration and current conditions at the IDZ. Therefore, predicted short-term total copper concentrations were evaluated further.

Copper

The predicted short-term total copper concentration during low flow (3.4 µg/L) was 1.1 times the FRWQO and BC WQG of 3 µg/L for estuarine/marine environments, but lower than the freshwater BC WQG for total copper of 12.7 µg/L that accounts for a predicted water hardness during low flow of 114 mg/L as $CaCO_3$. Given that the AIWWTP is located close to the upper extent of salt-water intrusion into the lower Fraser River, biota are only exposed intermittently to estuarine conditions when the salt-wedge is present and are exposed to freshwater conditions proportionally more of the time (Section 2.2, Appendix A). Therefore, the small exceedance of the estuarine/marine WQG is not expected to reflect a potential for adverse effects to aquatic life in the Fraser River. As noted above, predicted monthly copper concentrations at the IDZ were not distinguishable from ambient river conditions.

Notwithstanding this conclusion, total copper predictions were conservatively evaluated at the far-field nodes (Section 7.3.1).

Organics

Predicted short-term concentrations of methoprene, deltamethrin, PCB 126, phenanthrene, pyrene, and aniline were above the FRWQO or the lowest short-term WQG, but were not distinguishable from ambient river concentrations and were not evaluated further. Maximum predicted monthly concentrations of endosulphan, deltamethrin, phenanthrene, aniline, and EE2 were above the FRWQO or the lowest long-term WQG, but were not distinguishable from ambient river concentrations and were not evaluated further.

Constituents identified for further evaluation were:

- **Permethrin**. A short-term WQG is not available for permethrin. Predicted short-term permethrin concentrations were above the long-term WQG and are more than 20% over ambient concentrations. Based on this conservative screening, permethrin was evaluated further.
- **Total PCBs and EE2**. Predicted total PCB concentrations were above the short-term BC WQG for all flows but were not distinguishable from ambient river concentrations during moderate and high flows. Predicted concentrations of total PCBs during low flows and EE2 during all flows were above the BC short-term WQG and more than 20% over ambient water concentrations.

- **Sterols**. There are no WQGs for a number of sterols, including cholestanol, cholesterol, coprostanol, desmosterol, and epicoprostanol; however, predicted short-term and monthly concentrations were above ambient river concentrations. As mentioned in Section 5.1.10, a number of sterols originate from fecal matter and are often associated with WWTPs. Given that FRAMP has reported an increase in sterols in the lower Fraser River in recent years and EIS predictions were above ambient river concentrations, sterols were carried forward for further evaluation.

Permethrin

Predicted short-term concentrations of permethrin ranged from 1.3 to 1.5 ng/L. Predicted short-term permethrin concentrations were above the CCME long-term WQG of 1 ng/L, were more than 20% over ambient concentrations, and were higher than the current IDZ concentration. However, the short-term predicted permethrin concentrations were based on non-detect concentrations in effluent and the full detection limit was used in the model; therefore, there is uncertainty in the predicted concentrations and they are likely an overestimate. The use of the full detection limit in the model resulted in higher predicted IDZ concentrations compared to the current IDZ concentration.

A summary of available acute toxicity data by CCME (2006) concluded that fish 96-h LC_{50} values ranged from 620 ng/L to 540,000 ng/L and invertebrate LC_{50} values ranged from 170 ng/L to 940,000 ng/L. The predicted short-term concentrations of permethrin were below the lowest acute LC_{50} values for fish and invertebrates and so the potential for adverse effects to aquatic life is considered to be negligible. Notwithstanding this conclusion, permethrin was carried forward into the far-field assessment (Section 7.3.1).

Total PCBs

Predicted short-term concentrations of total PCBs ranged from 292 to 311 picograms per litre (pg/L), depending on the flow scenario. Predicted total PCB concentrations were above the BC short-term WQG (100 pg/L) during all flows but not distinguishable from ambient river concentrations during moderate and high flows. Total PCB concentrations during low flows were above the BC short-term WQG and more than 20% over ambient water concentrations, but below the current IDZ concentration of 377 pg/L. Therefore, no incremental change in concentrations at the IDZ or associated potential for adverse effects would be predicted due to the Stage V upgrade.

As mentioned in Section 7.1.2, there is high uncertainty in ambient, current IDZ, and predicted IDZ total PCB concentrations due to concentrations detected in field and laboratory blank samples that indicated contamination during sample collection and analysis. To address the noted uncertainty in the total PCB data, it is recommended that consideration be given to the collection of additional effluent, ambient, and IDZ water sample data be collected subject to a review of field sampling and laboratory analysis procedures.

Hormones

17α-ethinyl-estradiol (EE2), a synthetic derivative of the natural hormone estradiol, is the only hormone for which there is a regulatory guideline (BC WQG; BC MoE 2017a). Predicted short-term concentrations of EE2 ranged from 2.3 to 2.4 ng/L. These values were above the short-term BC WQG (0.75 ng/L) and more than 20% over the ambient river concentration (2.0 ng/L) but below the current IDZ concentration of 3.6 ng/L. Therefore, no incremental change in concentrations at the IDZ or associated potential for adverse effects would be predicted due to the Stage V upgrade.

Predicted EE2 concentrations also have elevated uncertainty because no detected concentrations of EE2 were available to inform predictions. EE2 predictions were based on non-detect values with a wide range of MDLs (<2.4 to <35.5 ng/L in effluent; <0.37 to <1.7 ng/L in ambient data). Predicted short-term concentrations are therefore expected to be overestimates of true concentrations. Using standard analytical methods for the EE2 analysis, commercial and government laboratories in Canada are not currently able to achieve MDLs lower than the BC WQG. There are particular challenges for effluent samples with more complex matrices; M. Servos, University of Waterloo, personal communication, 22 August 2016). Predicted short-term EE2 concentrations are within the range of potential effects to aquatic life (Caldwell et al. 2008). However, it is not possible to evaluate the potential for adverse effects of EE2 at this time due to the high uncertainty in the predicted concentrations.

Sterols

Predicted short-term concentrations of sterols (cholestanol, cholesterol, coprostanol, desmosterol, and epicoprostanol), which do not have WQGs, were more than 20% over the ambient river concentrations but below the current IDZ concentration. Therefore, no incremental change in concentrations at the IDZ or associated potential for adverse effects would be predicted due to the Stage V upgrade.

7.2.2 Public Health

Predicted short-term and monthly concentrations at the edge of the IDZ were below the recreational screening criterion or within 20% of ambient concentrations for most constituents, indicating that adverse effects of these constituents on public health are not expected (Appendix E, Tables E-8 to E-10). The predicted short-term sodium concentration during low flow was greater than the recreational screening criteria, but predicted concentrations were not distinguishable from ambient river concentrations. Constituents that were above both the recreational screening criterion and the ambient water concentration (where ambient water concentrations are available), or inorganic constituents (i.e. conventional constituents, nutrients and metals) that do not have water quality guidelines but were predicted to be greater than 20% over the ambient water concentration were considered to be preliminary near-field COPCs. The preliminary near-field COPCs for public health include the following:

- total residual chlorine
- total nitrogen
- TP
- dissolved phosphorus (DP)

- EE2
- cholestenol
- cholesterol
- coprostanol
- desmosterol
- epicoprostanol

Preliminary COPCs were carried forward for further evaluation and are discussed below. Predicted concentrations at the edge of the IDZ were compared to current IDZ concentrations to characterize the expected change in water quality due to the Project. Preliminary near-field COPCs with predicted water quality concentrations at the edge of the IDZ that are greater than the current IDZ concentration were considered to be Project-related near-field COPCs. Sterols were included as preliminary COPCs because they are increasing in the Fraser River, predictions were above ambient river concentrations, and they are of particular interest to regulatory agencies.

Total Residual Chlorine

An active treatment system is in place to remove chlorine in the effluent prior to discharge such that the National Performance Standard for TRC in municipal effluent is met (see Section 5.3.1). The effluent is also monitored and the effluent database consists of 1100 TRC measurements that were all below the method detection limits of 0.02 to 0.1 mg/L. The short-term and monthly predicted TRC concentrations were based on non-detect concentrations in this effluent database and the full detection limit was used in the model. As a result, there is uncertainty in the predicted concentrations and they are likely an overestimate as they are based on method detection limits. Ambient river and current IDZ data are not available for TRC.

Predicted short-term (0.0019 – 0.0028 mg/L) and monthly (November to March; 0.00062 – 0.00070 mg/L) IDZ concentrations for TRC were above the selected recreational screening criterion (0.0006 mg/L; Table E-8). The screening criterion for TRC is based on the US EPA RSLs for tap water. The US EPA tap water RSLs are risk-based thresholds that are protective of ingestion of water, dermal contact, and inhalation of volatiles. As chlorine is a volatile constituent, its RSL (0.6 µg/L after adjusting for an HQ of 0.2 and a factor of 10 for recreational use) is largely driven by the inhalation pathway. However, the inhalation pathway considered for tap water is based on exposure to chlorine vapour while showering. This pathway is not relevant for secondary contact recreational use of the Fraser River which does not occur in an enclosed environment. The RSLs protective of ingestion of water and dermal contact is more relevant to the site-specific scenario. The US EPA provides an RSL of 4 mg/L for ingestion and 920 mg/L for dermal contact (after adjusting to HQ=0.2 and applying a factor of 10 for recreational use).The maximum predicted concentration of TRC (0.0028 mg/L) is below the RSLs for both of these pathways. In addition, Health Canada (1999) and the WHO (2006) guidance for safe swimming pool use have reported acceptable levels of TRC in swimming pools in the 1 to 3 mg/L range, which indicates that the predicted TRC concentrations are unlikely to be associated with adverse health effects. Therefore, short–term and monthly predicted concentrations of TRC are not expected to pose a risk to human health in the near-field. Because there were no ambient or current IDZ concentrations of TRC available, TRC was retained for evaluation in the far-field assessment.

Total Nitrogen

A recreational screening criterion for total nitrogen was not available; however, predicted short-term (1.3 – 2.0 mg-N/L) and monthly concentrations (0.82 – 0.99 mg-N/L) were more than 20% over the ambient concentration. In the absence of a screening criterion for TN, a surrogate screening values was selected. A health-based screening criterion for ammonia was not available. In healthy individuals, ammonia is both produced and metabolized in the body and levels in the human body typically exceed those found in drinking water (HC 2013). The Health Canada drinking water guideline for ammonia is based on protection of the water supply against nitrification. The health-based screening criterion for nitrate-nitrite is based on the protection of infants from methaemoglobinemia, a blood disorder. Therefore, predicted short-term and monthly concentrations were compared against the recreational screening criterion for nitrate as nitrate-nitrite. The predicted short-term and monthly concentrations are below the nitrate (as nitrate-nitrite) screening criterion (10 mg-N/L). Current total nitrogen concentrations at the IDZ range from 1.0 to 2.3 mg-N/L which are equal to or greater than the predicted total nitrogen concentrations that range from 0.82 to 2.0 mg-N/L. Therefore, total nitrogen concentrations are remaining consistent or decreasing due to the Project. Given that total nitrogen concentrations are predicted to be less than the nitrate (as nitrate-nitrite) screening criterion and below the current IDZ concentrations, total nitrogen is not expected to pose a risk to human health.

Total and Dissolved Phosphorus

Predicted short-term (during low and moderate flows) and monthly concentrations of TP were above the selected recreational screening criterion (0.01 mg/L) and more than 20% over the ambient concentration. Predicted concentrations of TP were also greater than the current IDZ concentration for the short-term moderate and high flow scenarios and the monthly concentrations for April through August. Predicted short-term concentrations of TP ranged from 0.18 to 0.42 milligrams of phosphorus per liter (mg-P/L) and monthly concentrations of TP ranged from 0.075 to 0.14 mg-P/L.

A recreational screening criterion for DP is not available, therefore the screening criterion for TP was applied. The predicted short-term and monthly concentrations of DP were above the TP screening criterion (0.01 mg/L) and more than 20% over the ambient concentration. Current DP concentrations at the IDZ are not available. The predicted short-term concentrations of DP ranged from 0.095 to 0.13 mg-P/L and monthly concentrations ranged from 0.045 to 0.064 mg-P/L.

The recreational screening criterion for TP is based on an aesthetic objective specific to the protection of water clarity in lakes (BC MoE 2001). There is no recreational screening criterion for TP for streams or rivers. The BC WQG also provides a drinking water guideline for TP of 0.01 mg-P/L for lakes used as a source of drinking water. The BC drinking water guideline is also an aesthetic objective which is intended to reduce taste and odour associated with algae. Health-based screening criteria are not available. Excess phosphorus in lakes has been shown to cause toxic algal blooms and therefore phosphorus is used as an indicator of potential algae problems. However, no clear relationship between phosphorus and algal blooms exists for streams, therefore water quality guidelines for phosphorus are not directly applicable to algae growth in streams and rivers. Direct measurements of algae biomass are recommended for stream environments (BC MoE 2001). Given that the guideline for phosphorus as an indicator of algae blooms is not applicable to streams (and therefore rivers) and there is no health-based screening criteria for the effects of phosphorus, the predicted concentrations of total and dissolved phosphorus are not expected to pose a risk to human health in the near-field. However, because predicted IDZ concentrations of TP are higher than the current IDZ concentrations and there were no current IDZ concentrations of DP, both total and dissolved phosphorus were retained for evaluation in the far-field assessment.

Hormones

Recreational screening criteria are not available for EE2. Predicted short-term EE2 concentrations were more than 20% over the ambient concentration but less than current IDZ concentrations under all flow scenarios and seasons. Therefore, no incremental change in concentrations at the IDZ would be predicted due to the Stage V upgrade.

Although screening criteria for EE2 are not available from the BC WQG, Health Canada, or US EPA, the Minnesota Department of Health (MDH) recently released a health-based screening value of 0.5 ng/L for short-term exposure and 0.2 ng/L for long-term exposure to EE2 in drinking water (MDH 2016). Drinking water values of 0.5 ng/l and 0.2 ng/L are equivalent to recreational screening value of 5.0 ng/L and 2.0 ng/L for short-term and long-term exposure, respectively, after the factor of 10 adjustment (see Section 2.4.6; WHO 2006). Predicted short-term EE2 concentrations at the IDZ range from 2.3 to 2.4 ng/L which is less than the MDH-based short-term recreational value of 5.0 ng/L. Predicted long-term EE2 concentrations at the IDZ range from 1.0 to 1.1 ng/L which is less than the MDH-based long-term recreational value of 2.0 ng/L. Kolpin et al. (2002) measured hormones in 70 streams in the US between 1999 and 2000. The maximum observed EE2 concentration was 831 ng/L with a median of 73 ng/L. The predicted EE2 concentrations at the IDZ are well below both the median and maximum concentrations reported by Kolpin et al (2002). As discussed in Section 7.2.1, the IDZ predictions for EE2 are expected to be overestimates of true concentrations given that they are based on variable non-detect values in the effluent and ambient river data (i.e., <2.4 to <35.5 ng/L in the effluent; <0.37 to <1.7 ng/L in the ambient data). Therefore, the predicted EE2 concentrations at the IDZ are likely overestimated but still below the MDH-based recreational screening values as well as below the concentrations found in US streams. Given that predicted EE2 concentrations are decreasing due to the Stage V upgrade and are below available health-based screening values, EE2 is not expected to pose a risk to human health.

Sterols

Recreational screening criteria are not available for sterols (i.e. cholestanol, cholesterol, coprostanol, desmosterol, and epicoprostanol). Predicted short-term and monthly sterol concentrations were more than 20% over the ambient concentration but less than current IDZ concentrations under all flow scenarios and seasons. Therefore, no incremental change in concentrations at the IDZ would be predicted due to the Stage V upgrade.

Health-based screening values for the sterols are not available. The sterols are inter-related as they are all products along the same reaction pathway. Desmosterol is an intermediate in the synthesis of cholesterol and coprostanol, epicoprostanol and cholestenol are hydrogenation products of cholesterol. Limited human health toxicity information is available for desmosterol, coprostanol, epicoprostanol and cholestenol. High blood cholesterol is associated with increased risk of heart attacks and heart disease. The National Institute of Health (NIH 2005) recommends a diet of less than 200 mg of cholesterol per day for an individual wishing to lower their blood cholesterol levels. The predicted IDZ concentrations of cholesterol range from 939 to 2527 ng/L. Therefore, a conservative exposure estimate for adults exposed to 0.15 L of water per day is 140 to 379 ng per day or less than 0.0002% of the recommended daily dietary intake. Given that predicted sterol concentrations are decreasing due to the Stage V upgrade and the low contribution of cholesterol to the total daily exposure of an adult, the sterols are not expected to pose a risk to human health.

7.3 Far-Field Assessment Results

Near-field COPCs were modelled at five far-field nodes extending from upstream of the AIWWTP to downstream at Tilbury Island. These nodes are described further in Section 4.0. Screening of short-term and monthly concentrations of near-field COPCs at far-field nodes are provided in Appendix E (Tables E-9 to E-11). The following subsections present screening of predicted short-term and monthly concentrations at far-field nodes to evaluate potential impacts on aquatic life, wildlife, livestock and irrigation uses (Section 7.3.1) and public health (Section 7.3.2).

7.3.1 Aquatic Life, Wildlife, Livestock, and Agricultural Uses

Total and dissolved phosphorus, copper, and permethrin were identified as near-field COPCs and were evaluated at the far-field nodes shown in Figure 2 (see Section 4.0). Screening results of predicted far-field concentrations for these constituents are provided in Appendix E, Table E-9 and E-10.

Total and Dissolved Phosphorus

As discussed in the near-field assessment and Section 5.4, total phosphorus concentrations reported for the lower Fraser River are above the BC WQG derived to protect against eutrophication in lakes, but these concentrations have not resulted in substantial algal growth because of site-specific riverine conditions and the general lower sensitivity of rivers to phosphorus relative to lakes (Nordin 1985, FRAP 1999a). Algal growth is primarily light limited in the lower Fraser River, particularly during the growing season defined by Nordin (1985) that overlaps with high river flows and associated elevated sediment transport downstream.

Total phosphorus monthly predictions from April to September are not distinguishable from ambient river conditions during these higher flow months and so adverse effects on aquatic life due to the Stage V upgrade would not be expected. From October to April, a period that does not encompass the growing season in BC, monthly predictions were distinguishable from ambient river conditions for the five assessment nodes for some months between November and March, depending on the assessment node. When the five nodes are considered, predicted low flow concentrations were up to 1.4 (TP) or 1.5 (DP) times mean values calculated for the river upstream of the AIWWTP (2012 to 2016; TP = 0.031 mg/L; DP = 0.019 mg/L; Appendix B). The maximum monthly total and dissolved concentrations are predicted at Tilbury Island in February (i.e., TP = 0.044 mg/L; DP = 0.030).

These instances, where monthly concentrations at two of the five assessment nodes are predicted to be slightly above ambient river concentrations, occur during the fall/winter months when conditions for algal growth is sub-optimal in BC. Further, turbidity in the lower Fraser River continues to persist through these months resulting in reduced light penetration through the water column. It is therefore unlikely that there would be an increase in algal growth at the Western Annacis Island and Tilbury Island downstream assessment nodes as a result of the mean monthly concentrations predicted in the far-field and adverse effects on aquatic life due to eutrophication are not expected in this well oxygenated river.

Monthly phosphorus predictions are the most relevant to the assessment of the potential for adverse effects on aquatic life due to eutrophication because effects due to eutrophication are realized over longer time periods and plant growth is influenced by conditions over the entire growing season (Environment Canada 2004). Actual effects are likely best represented by the average concentration over the growing season from May to September however for the purpose of this assessment, monthly predictions have been assessed. Short-term flow-based predictions have been provided but these are less relevant because they represent a time period of 24 hours instead of weeks or months.

Copper

Low flow short-term concentrations predicted at the far-field nodes were below the FRWQO. As described for ambient conditions in Section 2.2.2, the lower Fraser River experiences turbid conditions year-round but to a greater degree under moderate and high flows compared to low flows. Both ambient and predicted short-term total copper concentrations under moderate and high flows were above the FRWQO, indicative of the increased influence of downstream sediment transport under higher flows. The influence of resultant suspended sediment levels under higher flows is reflected in the proportion of the predicted total copper concentration measured as dissolved copper at these far-field nodes, under low (35-36%), moderate (25%), and high flows (15%). Flow based short-term total copper concentrations predicted at the five far-field nodes are also not distinguishable from ambient river conditions.

Monthly copper concentrations predicted at the five far-field nodes were also not distinguishable from ambient river conditions consistent with the corresponding screening result for copper in the near-field IDZ assessment. From September to March outside of the high flow season, predicted monthly concentrations were lower than the FRWQO, but during and just after the freshet total copper concentrations increased to above the FRWQO, as was shown for ambient concentrations.

Given that both total and dissolved copper concentrations predicted at the far-field nodes were within the range of concentrations reported in the Fraser River under ambient conditions, the potential for adverse effects on aquatic life at these locations was considered to be negligible.

Permethrin

Predicted short-term concentrations of permethrin at the far-field nodes ranged from 0.91 to 1.0 ng/L (Table E-9). These values were below or equal to the conservatively applied CCME long-term WQG of 1 ng/L. Furthermore, predicted short-term concentrations of permethrin at all far-field nodes were not distinguishable from ambient river concentrations, and therefore concentrations were not predicted to increase due to the Project. Monthly permethrin concentrations at far-field nodes were also lower than the CCME long-term WQG of 1 ng/L.

7.3.2 Public Health

Three near-field IDZ COPCs were identified for public health: TRC, TP, and DP. The short-term and monthly predicted concentrations of these constituents were modelled at the five far-field nodes (Section 4.0). Screening of the predicted concentrations are provided in Appendix E (Table E-11).

Total Residual Chlorine

Predicted short-term TRC concentrations ranged from 0.044 to 0.57 µg/L and monthly concentrations ranged from 0.017 to 0.18 µg/L. Predicted short-term and monthly concentrations of TRC were below the selected recreational screening criterion (0.6 µg/L, or 0.0006 mg/L) at each of the five far-field nodes. Therefore, predicted concentrations of TRC are not expected to pose a risk to public health.

Total and Dissolved Phosphorus

Predicted short-term and monthly concentrations of TP were above the selected recreational screening criterion (0.01 mg/L) at all far-field nodes. Predicted short-term concentrations were approximately 20% over the ambient concentration during daily low flow scenarios at four of the five far-field nodes (Corporation of Delta Irrigation Intake, Don Island, Tilbury Island, and Western Annacis Island). Predicted monthly concentrations of TP were approximately 20% over the ambient concentration from January to March at the Corporation of Delta Irrigation Intake, in January and February at Don Island, in February at Timberland Basin, and from October to March at Tilbury Island and Western Annacis Island.

A recreational screening criterion for DP was not available; therefore, the screening criterion for TP was applied. Predicted short-term and monthly concentrations of DP were above the selected recreational screening criterion (0.01 mg/L) at all far-field nodes. Each of the five far-field nodes was approximately 20% over the ambient concentration during low and moderate daily flows but not during high flows. The Corporation of Delta Irrigation Intake, Don Island, and Timberland Basin were predicted to be approximately 20% over the ambient concentration for most of the low flow season but not during the high flow season; whereas Tillbury Island and Western Annacis Island were predicted to be approximately 20% over the ambient concentration for most of the year.

As discussed in Section 2.4.6, the recreational and drinking water screening criterion from BC MoE (2001) are based an aesthetic objectives. Health-based screening criteria are not available. Phosphorus in lakes is used as an indicator of potential algae problems, but, no clear relationship between phosphorus and algal blooms exists for streams (BC MoE 2001). Given that the guideline for phosphorus as an indicator of algae blooms is not applicable to streams (and therefore rivers) and there is no health-based screening criteria for the effects of phosphorus, the predicted concentrations of total and dissolved phosphorus are not expected to pose a risk to public health.

7.4 Assessment of PBT Constituents

7.4.1 Identification of PBT Constituents

The selection of constituents to be evaluated as PBT was intended to identify constituents that are known to bioaccumulate in fish tissue, are persistent in the aquatic environment, and are of potential toxicological concern in the Fraser River. Federal policy (i.e., the Toxic Substances Management Policy [TSMP]) and site-specific monitoring programs (i.e., FRAMP) were consulted to identify PBT constituents of concern in the Fraser River.

In Canada, the TSMP (EC 1995) defines criteria for classifying which constituents are PBT. In order for a constituent to be classified as PBT, the constituent must meet specific criteria for persistence, bioaccumulation, and toxicity. If a constituent does not meet the criteria for all three characteristics, the constituent cannot be classified as PBT. The TSMP criteria are:

- A constituent is defined as persistent if any of the following criteria are met: half-life in air ≥ 2 days; half-life in water ≥ 182 days; half-life in sediment ≥ 365 days; half-life in soil ≥ 182 days.
- A constituent is defined as bioaccumulative if the bioaccumulation factor (BAF) ≥ 5000, or bioconcentration factor (BCF) ≥ 5000, or the log of the octanol-water partition coefficient (log K_{OW}) ≥ 5.0, where BAFs are preferred over BCFs and log K_{OW} is used in the absence of BAFs or BCFs.

- A constituent is considered toxic if it meets the *Canadian Environmental Protection Act* (CEPA) definition of toxic (i.e., CEPA-toxic or CEPA toxic equivalent). CEPA (Government of Canada 1999a; Section 64) states that “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) constitute 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”.

The TSMP classifies a substance as Track 1 if it meets the criteria for all three characteristics (i.e. persistent, bioaccumulative, and toxic) and is predominantly anthropogenic. Track 1 constituents are targeted by the federal government for virtual elimination from the environment. The PBT criteria identified above are consistent with international approaches, including those of the Stockholm Convention (UNEP 2009) and the European Union (ECHA 2017). For the purposes of identifying PBT constituents in the AIWWTP Stage 2 EIS, constituents that are Track 1 constituents under the TSMP (EC 2017a,b) were considered PBT constituents.

The FRAMP monitoring program has analyzed fish tissue for organic constituents of concern in the Fraser River due to either their potential to bioaccumulate in fish tissue or potential toxicological effects to fish and fish consumers. Inclusion of constituents measured in the FRAMP fish tissue monitoring program was intended to supplement the Canada-wide TSMP list with site-specific information.

A constituent was considered in the PBT assessment if:

- The constituent is listed as a Track 1 substance under the TSMP (EC 2017a, b); and/or
- The constituent is one of the organic or organometallic constituents measured in fish tissue as part of the 2012 FRAMP fish health survey (ENKON 2014).

Based on these criteria, the constituents listed in Table 7-1 were included in the PBT assessment in the Stage 2 EIS.

Table 7-1: Constituents considered in the PBT Assessment of the AIWWTP Stage 2 EIS

- Aldrin
- Chlordane
- Dichlorodiphenyltrichloroethane (DDT)
- Dieldrin
- Endrin
- Heptachlor
- Hexachlorobenzene
- Hexachlorobutadiene
- Methyl mercury
- Mirex
- Polybrominated Diphenyl Ethers (PBDEs)
- Polychlorinated Biphenyls (PCBs)
- Polychlorinated Dibenzodioxins (PCDDs)
- Polychlorinated Dibenzofurans (PCDFs)
- Perflourooctane Sulfonic Acid (PFOS)
- Polycyclic Aromatic Hydrocarbons (Benzo[a]pyrene only)
- Toxaphene

7.4.2 Evaluation of Near-field PBT Water Concentrations

The potential incremental effect of the Project on exposure of wildlife and people consuming fish from the Fraser River to PBT constituents was evaluated in two steps. The first step was to evaluate potential effects of the Project on conditions at the end-of-pipe by comparing current and Stage V effluent concentrations. The second step was to evaluate potential effects of the Project on conditions at the IDZ by comparing IDZ water concentrations predicted for Stage V flows to current water concentrations measured at the IDZ for the AIWWTP discharge.

The Stage V upgrade involves an expansion of the effluent discharge capacity of the plant from 12.6 m^3/s to 18.9 m^3/s. The upgrade is a hydraulic upgrade where the effluent discharge capacity is increased but the effluent quality is expected to be the same. Given that the effluent concentrations are not expected to change, there is no incremental effect of the Stage V upgrade on concentrations at the end of the pipe, and therefore no incremental change in exposure of wildlife and people consuming fish from the Fraser River to PBT constituents. Therefore, the Stage V upgrade is not expected to result in a change to the potential for adverse effects from PBT constituents on aquatic and public health.

The potential of increased loadings of PBT constituents to result in adverse effects on wildlife and people consuming fish from the Fraser River was assessed by comparing predicted maximum monthly average IDZ concentrations against the currently measured average IDZ concentrations (Table E-12, Appendix E). Loadings of PBT constituents to the receiving environment were considered in the generation of near-field predictions, as described in Section 6.3 and Appendix A.

Predicted maximum monthly average concentrations at the edge of the IDZ are less than current average IDZ concentrations for approximately half of the PBT constituents for which current IDZ concentrations were available (Appendix E, Table E-12). Therefore, the Stage V upgrade is not expected to result in a change to the potential for adverse effects from these PBT constituents on aquatic and public health. This conclusion applies to DDT, dieldrin, hexachlorobenzene, PBDEs, and benzo[a]pyrene.

For the remaining PBT constituents for which current IDZ concentrations were available (i.e., PCBs, aldrin, chlordane, endrin, heptachlor, and mirex), predicted concentrations were higher than current conditions. However, predicted concentrations of these constituents are affected by additional sources of uncertainty. As discussed in Section 7.1.2, there is high uncertainty in the effluent, ambient, and current IDZ concentrations of PCBs due to elevated concentrations of the blanks. Aldrin, chlordane, endrin, heptachlor, and mirex were affected by elevated detection limits where the MDL range difference between the minimum and maximum MDL ranged from a factor of 14 to 160. Therefore, predicted concentrations are expected to be overestimates. Given that the effluent concentration is not increasing, it is more likely that these constituents would show the same decrease at the IDZ following the Stage V upgrade as the PBT constituents with relatively reliable predictions based on higher-quality data. PCBs, aldrin, chlordane, endrin, heptachlor, and mirex are discussed in more detail below.

Current IDZ concentrations were not available for PCDD/Fs, hexachlorobutadiene, toxaphene, methyl mercury and PFOS, and therefore a comparison with predicted IDZ concentrations could not be made. However, it is expected that IDZ concentrations of these constituents would also decrease following the Stage V upgrade, as shown for the PBT constituents with relatively reliable predictions based on higher-quality data.

Overall, the modelling results indicate that the Stage V upgrade is unlikely to cause adverse effects to wildlife and people consuming fish from the Fraser River, but, given the uncertainty associated with the modelling results, confirmatory monitoring of PBT constituents in fish tissue is warranted (see Section 10.0).

Polychlorinated Biphenyls (PCBs)

Predicted maximum monthly average IDZ concentrations of PCB-114, PCB-123, PCB-126, total PCBs (Mammalian Health TEQ), total PCBs (Avian Health TEQ), and total PCBs (Public Health TEQ) were greater than current average IDZ concentrations by up to a factor of 2. As discussed in Section 7.1.2, there is high uncertainty in the effluent, ambient, and current IDZ concentrations due to analytical-related issues. Recommendations to address this uncertainty through the current monitoring program are provided in Section 8.

For the purpose of this assessment, the current PCB effluent and river water data were used to evaluate the relative contribution of the AIWWTP to total PCB loadings downstream from the AIWWTP. For both the current AIWWTPAIWWTP discharge and the predicted Stage V discharge, relative contributions to total PCB loads in the Fraser River downstream of the AIWTTP were calculated using median effluent and river loads in a similar way as described for nutrients in Section 5.4 (Table 7-2). The comparison indicated that Stage V loadings from the AIWWTP will represent 7% of the PCB load in the Fraser River, which is an increase of 2% (in absolute terms) relative to the current AIWWTP discharge contribution of 5% of the total load. In both cases the upstream river loading was dominant and this is reflected in the significant contribution from the ambient Fraser River (median total PCB concentration of 166 pg/L) to the predicted IDZ concentration (monthly total PCB concentration of 190 pg/L).

Table 7-2: Stage V AIWWTP Upgrade: Predicted Polychlorinated Biphenyl (PCB) Loadings to the Lower Fraser River Receiving Environment [1]

Loading Scenario	Total PCB [4]	
	Median Loading (kg/d)	**Contribution of Effluent to Respective Total Load (%)**
Ambient Fraser River Loading from Upstream Sources[2]	0.01530	n/a
Current Effluent Loading	0.00088	5%
Current Total Fraser River Load downstream of the AIWWTP	0.01620	n/a
Predicted Stage V Effluent Loading [3]	0.00120	7%
Predicted Total Fraser River Load downstream of the AIWWTP	0.01650	n/a
Predicted Absolute Incremental Change	*0.00032*	*2% increase*

Notes

n/a = not applicable; kg/d = kilograms per day

1 – Provided by CDM Smith (Frannie Bui, CDM Smith, personal communication, 29 November 2017). Loading calculations were based on date paired river and effluent quality and flow data.

2 – Calculated from total PCB concentrations reported by the AIWWTP REM program (2012 to 2016)

3 – 2 times Average Dry Weather Flow (ADWF)

4 – Total PCB concentrations were calculated by the analytical laboratories by summing the detected PCB congeners.

As PBT substances, PCBs are hydrophobic and are preferentially taken up from the water column by suspended matter, sediments on the river bottom, and aquatic biota. It was therefore appropriate to consider current sediment and fish tissue concentrations in the lower Fraser River in the evaluation of potential adverse effects from the Stage V upgrade. When the following lines of evidence were considered, the relatively small contribution from the AIWWTP to the overall PCB loading in the lower Fraser River and the 2% incremental increase in that contribution from the Stage V upgrade suggests that the upgrade would not be expected to have the potential for adverse effects to fish, fish consuming wildlife and public health.

- PCB concentrations were below the FRSQO, BC lower SWQGs, and CCME ISQG values in mid-channel sediments within the vicinity of the proposed outfall and in near-shore sediments located downstream of the proposed outfall location (Section 2.2.2; Appendix C). Total PCB concentrations measured in sediments downstream from the existing outfall were more than ten times lower than the total PCB FRSQO of 20,000 pg/g, with the exception of one near-shore location in the near-field where a concentration of 3,259 pg/g was reported and one far-field location where a concentration of 16,336 pg/g was reported.
- PCBs bioaccumulate in fish tissue from water and food consumption so fish tissues represent the environment to which they are exposed. As discussed in Section 2.3.2, tissue concentrations of PCBs reported for the three study areas in 2012 including the Main Arm at Steveston met the PCB tissue FRO and there appears to have been a decrease in both fish muscle and liver concentrations over time in sentinel fish species. Salmon have been shown to accumulate a large proportion of their PCB body burden while at sea and not during time spent in the lower Fraser River (Section 2.3.2).

To address uncertainty in the PCB water data and to confirm fish tissue PCB concentrations upstream and downstream of the AIWWTP, a confirmatory monitoring study is recommended (see Section 10.0). Sediment quality monitoring has also been recommended in Section 10 following the Stage V upgrade.

Aldrin

The predicted maximum monthly average IDZ concentration for aldrin (0.013 ng/L) was greater than the current average IDZ concentration (<0.011 ng/L). However, both predicted and current values were derived from non-detect values with variable MDLs, and do not reflect a comparison of actual concentrations. The current IDZ concentration is based on a limited dataset of six measurements that were all below MDLs varying from <0.010 to <0.023 ng/L. Predicted IDZ concentrations were based on seventeen measurements of the effluent that were all below MDLs varying from <0.010 to <0.98 ng/L. The apparent predicted increase in Aldrin concentration simply reflects a higher MDL in effluent data compared to ambient data.

Chlordane

The predicted maximum monthly average IDZ concentration for chlordane (0.031 ng/L) was greater than the current average IDZ concentration (<0.011 ng/L). However, both predicted and current values were derived from non-detect values with variable MDLs, and do not reflect a comparison of actual concentrations. The current concentration is based on a limited dataset of twelve measurements that were all below MDLs varying from <0.010 to <0.094 ng/L. The predicted IDZ concentrations were based on a limited dataset of sixteen measurements of effluent that were all below MDLs varying from <0.030 to <0.42 ng/L. The apparent predicted increase in chlordane concentration simply reflects a higher MDL in effluent data compared to ambient data.

Endrin

The predicted maximum monthly average IDZ concentration for endrin (0.027 ng/L) was greater than the current average IDZ concentration (<0.023 ng/L). However, both predicted and current values were derived from non-detect values with variable MDLs, and do not reflect a comparison of actual concentrations. The current concentration is based on a limited dataset of six measurements that were all below MDLs varying from <0.012 to <0.33 ng/L. The predicted IDZ concentrations were based on a limited dataset of seventeen measurements of effluent with one value above the MDL (0.03 ng/L) and the remainder below MDLs varying from <0.010 to <0.72 ng/L. The apparent predicted increase in endrin concentration simply reflects a higher MDL in effluent data compared to ambient data.

Heptachlor

The predicted maximum monthly average IDZ concentration for heptachlor (0.011 ng/L) was marginally greater than the current average IDZ concentration (<0.010 ng/L). However, both predicted and current values were derived from non-detect values with variable MDLs, and do not reflect a comparison of actual concentrations. The current concentration is based on a limited dataset of six measurements that were all below MDLs varying from <0.010 to <0.044 ng/L. The predicted IDZ concentrations were based on a limited dataset of seventeen measurements of effluent with only one sample above the MDL (0.03 ng/L) and the remainder below MDLs varying from <0.010 to <0.72 ng/L. The apparent predicted increase in heptachlor concentration simply reflects a higher MDL in effluent data compared to ambient data.

Mirex

The predicted maximum monthly average IDZ concentration for mirex (0.011 ng/L) was marginally greater than the current average IDZ concentration (<0.010 ng/L). However, both predicted and current values were derived from non-detect values with variable MDLs, and do not reflect a comparison of actual concentrations. The current concentration is based on a limited dataset of six measurements that were all below MDLs varying from <0.010 to <0.013 ng/L. The predicted IDZ concentrations were based on a limited dataset of seventeen measurements of effluent with one sample above the MDL (0.066 ng/L) and the remainder below MDLs varying from <0.010 to <0.30 ng/L. The apparent predicted increase in mirex concentration simply reflects a higher MDL in effluent data compared to ambient data.

8.0 STAGE 2 EIS UNCERTAINTY ASSESSMENT

The Stage 2 EIS conducted herein was a predictive exercise, with the objective of identifying whether the proposed effluent discharge could potentially result in adverse effects on aquatic life or impairment of other uses identified for the receiving environment. Accordingly, it is not possible to make direct environmental measurements in the receiving environment and assess impact directly. Assessing impact before discharge requires the use of various predictive tools, such as effluent dilution modeling. For an assessment based on predicted water quality, it is appropriate to identify the main uncertainties associated with the assessment and to consider the implications of these uncertainties on predictions made and the estimate of impact. Identification of these uncertainties also assists in the development of the post-discharge Stage V monitoring program.

Uncertainties in the Stage 2 assessment that were identified in Sections 5, 6, and 7 are summarized in Table 8-1.

Table 8-1: Identified Uncertainties in the Stage 2 EIS for the AIWWTP Outfall Diffuser Proposed to Provide Capacity for Stage V flows

Assumption or Limitation	**Section**	**Uncertainty**	**Under/ Over Estimate of Impact**	Rationale
Use of full detection limits to calculate both ambient and effluent concentrations	Sections 2, 5, and 6	Low for most constituent; Moderate for others such as organic constituents	Over	The use of full detection limits in statistically characterizing ambient and effluent water quality resulted in predicted concentrations at the edge of the IDZ that were conservative. The degree of conservatism depended on the percentage of samples for each constituent that had non-detected values (more non-detects resulted in greater over-prediction of true values).
Use of limited data (sample size) and data reported at varying detection limits equal to or higher than WQGs	Sections 2, 5, and 6	Low for most constituent; Moderate to high for others like organic constituents (EE2, PCBs, pesticides)	Over	The ability to adequately characterize effluent and ambient conditions was limited for some organic constituents by sample size, varying detection limits, and detection limits equal to or higher than corresponding WQGs. This resulted in uncertainty in the inputs to the IDZ predictions and therefore uncertainty in predicted IDZ concentrations.
Use of effluent, ambient, and current IDZ PCB and PBDE data with contamination issues (contaminated method, field, and trip blanks)	Sections 2, 6, and 7	Moderate to High	Over	Detection of PCBs and PBDEs in the method, trip, and field blanks collected alongside the effluent, ambient and IDZ data indicated that the actual concentrations in the samples were lower than the measurements indicated. This resulted in an overestimate of predicted concentrations.
Use of recently measured IDZ concentrations (at the existing outfall) to compare to predicted IDZ concentrations	Section 7	Low	Over	Recent IDZ concentrations reported for the current outfall were not available for all constituents. When unavailable, predicted concentrations were only compared to ambient river concentrations. This likely resulted in an overestimate of the potential for adverse effects from the Stage V upgrade for these constituents.

Assumption or Limitation	Section	Uncertainty	Under/ Over Estimate of Impact	Rationale
The mass loading method used the 2xADWF compliance flow of 14.75 m^3/s and average mass loadings to predict monthly IDZ concentrations for comparison against long-term average WQGs	Appendix A, Section 7.2.3	Moderate	Under	In their comments on the Stage 1 EIS, ENV requested that water quality modelling for the Stage 2 EIS focus on an effluent flow scenario of 2xADWF (14.75 m^3/s) to make predictions of concentrations at the edge of the IDZ. Monthly predictions can be sensitive to the effluent flow rate used, where lower effluent flow rates can result in higher predictions at the edge of the IDZ. To test whether a change in effluent flow rate would affect the impact conclusions, a supplemental set of predictions was made at future average monthly flows, resulting in a predicted concentration for each month (see Section 7.3.2 of Appendix A). The predicted concentrations at the edge of the IDZ changed from -3% to +40% relative to the 2xAWDF scenario. Over 50% of the more than 2,000 parameter-month combinations changed less than 5%. Section 8.1 provides additional details on the supplemental screening.
The coupling of the models UM3 and H3D to input mass from initial dilution processes into the far-field model	Appendix A, Section 6.4.2 and Attachment G	Low	Over, but only in the region, in and adjacent to the IDZ	Near-field models should be, and for this project were, used to assess mixing processes in the region adjacent to a discharge. Far-field models are best suited for predictions well beyond that region. The far-field model is reasonable for use to determine background buildup concentrations and predictions at other sensitive receptor locations as was done in this EIS, but should not be used to look in the region where near-field mixing processes are still active. Any near-field to far-field coupling described has limitations. To date, no single hydrodynamic model has been able to simultaneously represent the turbulence of the initial mixing process as well as the general, large-scale circulation typifying the receiving environment. Consequently, various model approximations are required to provide a practical estimate of the performance of a new diffuser. In this case, the near-field model, UM3, does not function well when limited by the proximity to the bottom or water surface; that is its numerically-modelled plume diameter expands faster than it would in the real world. In the real world, and if the plume were not restrained by top and bottom boundaries, the plume diameter would grow at a rate governed by entrainment processes and by the plume diameter, which determines the area available for entrainment. Since the UM3

Assumption or Limitation	Section	Uncertainty	Under/ Over Estimate of Impact	Rationale
				implementation in H3D does not adjust the amount of surface available for entrainment, allowing it to be overestimated, the plume acquires the ambient velocity quicker than it would in the real world. Thus, the UM3 plume does not travel as far before it releases its effluent to the H3D model as it would in reality, likely leading to higher modelled concentrations of effluent. For this reason, effluent momentum (Figure 6-2, Appendix A) may continue across the river farther than UM3 simulates, particularly when ambient currents are low. The boundary issues in UM3 are implemented in the H3D model coupling by only using UM3 to determine the location to insert mass into the three-dimensional model and thus constraining the modelled plume expansion, as discussed above. The overestimate of effluent concentration will be greatest when ambient velocities are small, such as at low flow, high tide slack conditions. The UM3-H3D coupling provides reasonable results at distance from the diffuser (as one would expect from a far-field model), but likely represents higher concentrations than are present at certain low velocity tidal conditions both within the IDZ (where far-field models are not representative) and the region immediately adjacent to it.
The far-field model, H3D, generated predictions for a one year period based on the 2xADWF compliance effluent flow of 14.75 m^3/s.	Appendix A, Section 6.4.2 and Attachment G	Low	Over	ENV requested that water quality modelling for the Stage 2 EIS focus on an effluent flow scenario of 2xADWF (14.75 m^3/s). Effluent flows at Stage V are anticipated to vary from 7.7 to 18.9 m^3/s. The compliance flow represents a very high (96th percentile) flow.
Interaction of constituent mixtures will not result in effects greater than estimated through the use of FRWQOs and provincial and federal WQGs.	Section 7	Low	Under	The impact assessment has examined constituents individually; however, in reality they are discharged in a mixture. Although additive interactions among constituents are more common, it is possible that more-than-additive (synergistic) or less-than additive (antagonistic) interactions may occur. The conservative derivation of receiving environment FRWQOs and WQGs accounts for the potential for these interactions through the use of safety factors (Meays 2012).

Moderate or moderate-to-high uncertainty was identified in Table 8.1 in relation to the following assumptions or data limitations:

- *Use of full detection limits to calculate both ambient and effluent concentrations*. Moderate uncertainty may have resulted in an over-estimation of predictions for organic constituents not detectable in effluent or ambient river water. In many cases there was a wide range of detection limits considered for these organic constituents that may have contributed to an over-estimation of predictions.
- *Use of limited data (sample size) and data reported at varying detection limits equal to or higher than WQGs.* Moderate to high uncertainty may have resulted in an over-estimation of predictions for some organic constituents such as EE2, PCBs, pesticides. This limitation is discussed further in Section 10 with respect to monitoring of the upgraded outfall.
- *Use of effluent, ambient, and current IDZ PCB and PBDE data with contamination issues (contaminated method, field, and trip blanks).* Moderate to high uncertainty may have resulted in an over-estimation of predictions for these organic constituents. This limitation is discussed further in Section 10 with respect to monitoring of the upgraded outfall.
- *The mass loading method used the 2xADWF compliance flow of 14.75 m^3/s and average mass loadings to predict IDZ concentrations for comparison against long-term average WQGs.* Moderate uncertainty may have resulted in an under-estimation of predicted monthly concentrations for some constituents at the edge of the IDZ (but not in the far-field).

  To address this uncertainty, a supplemental near-field assessment was undertaken in Appendix F to evaluate whether the impact assessment of monthly IDZ concentrations for an effluent flow of 2xADWF might under-estimate potential impact for a range of lower effluent flows. The focus of this sensitivity analysis was on long-term monthly IDZ predictions because they were more sensitive to changes in effluent flow rate compared to the short-term predictions that were considered to be more robust.

  Evaluation of predicted monthly average COPC concentrations in the supplemental assessment supported the same conclusion as the assessment in Section 7. Specifically, the supplemental assessment concluded that for the Stage V monthly scenario, no adverse effects on aquatic life or impairment of other receiving environment uses or public health would be expected at the edge of the IDZ. Therefore, the same impact conclusion was reached for Stage V monthly average flows as for the 2xAWDF effluent flow scenario. With respect to the study area as a whole, as documented in Table 8-1, there is conservatism in the far-field assessment of potential impact that spans the entire study area upstream and downstream of the AIWWTP.

9.0 IMPACT CONCLUSIONS

Overall, the Stage 2 impact assessment presented in Section 7 indicates that pollution as defined by EMA is unlikely to occur as a result of the Stage V hydraulic upgrade to the AIWWTP. This conclusion is based on assessment of receiving water quality predictions for approximately 140 constituents (Section 6) and in consideration of the uncertainty assessment (Section 8); specifically:

- Adverse effects are not expected on aquatic life or impairment of other receiving environment uses identified for the Study Area or public health. This conclusion is based on assessment of predicted concentrations at the edge of the IDZ made for an effluent flow rate of two times the average dry weather flow (2xAWDF) and at lower effluent flow rates considered in the uncertainty assessment. This conclusion also applies to the assessment of predicted concentrations at far-field nodes in the Fraser River.
- No effect of the project is expected on risk of adverse effects to wildlife or people consuming fish from the Fraser River because no change in effluent quality is anticipated and concentrations of PBT constituents at the IDZ are not predicted to increase with the Stage V upgrade. Fish tissue monitoring is recommended to confirm this conclusion.
- Secondary treated whole effluent at the point of discharge is not expected to be acutely lethal to aquatic life and conditions within the IDZ would likewise not be expected to be acutely lethal to aquatic life. When the new effluent outfall is commissioned, acute toxicity testing will be carried out to confirm these predictions and is expected to be a condition of the amended Operational Certificate.

The most recent characterization of effluent presented in the Stage 2 EIS (i.e., 2016) indicates that the AIWWTP effluent meets National Performance Standards (i.e., WSER limits and it is not acutely toxic). Thus, the AIWWTP effluent meets conditions of Section 6(1) of WSER, and as such its deposit is authorized under Section 36(4) of the Fisheries Act.

10.0 STAGE V POST-DISCHARGE MONITORING AND CONFIRMATORY MONITORING

The potential need for post-discharge monitoring was evaluated in consideration of provincial EIS guidance by BC MELP (2000). This generic guidance indicates that following commencement of the discharge, effluent and receiving environment monitoring results are to be evaluated: (1) to determine whether water quality guidelines are being met outside the IDZ; (2) to confirm that sediment biota, chemistry, and toxicity are not adversely affected; and, (3) to confirm previous modeling and predictive assessments findings.

Post-Stage V monitoring is intended to confirm and verify the findings of the Stage 2 EIS and address uncertainties identified in the EIS. Long-term monitoring is already in place for the lower Fraser River and these programs are currently under internal review. Recommendation from the review process are considered and discussed with the Environmental Monitoring Committee (EMC) before being incorporated into ongoing programs as appropriate and as opportunities arise. The EMC is a technical committee with representatives from member municipalities, Metro Vancouver, senior governments, and the academic community. Thus, the following recommendations are intended to inform review of the long-term monitoring program and recommend additional monitoring specifically to confirm Stage 2 EIS findings and address uncertainties identified in the EIS.

10.1 Summary of Current Long-Term Monitoring Relevant to the Stage V Upgrade

The proposed project represents a hydraulic upgrade to an existing outfall already subject to annual monitoring of the receiving environment at the edge of the initial dilution zone (REM program) and ambient conditions within the wider Main Arm receiving environment (FRAMP). The term ‘ambient’ refers to water quality outside the direct influence of effluent discharges to the Fraser River. In undertaking both programs MV has endeavoured to use the best commercially available analytical methods within BC, where possible. A synthesis of results from the REM and FRAMP programs considered relevant to the Stage 2 EIS is provided in Section 2. These programs are briefly described below:

- The REM program is focussed on water quality monitoring of a wide range of water quality constituents at the edge of IDZ, including conventional parameters, metals, nutrients, bacteriological parameters and organic constituents such as pesticides (herbicides, insecticides, and fungicides), alkylphenols, PCBs, PBDEs, hormones and sterols, and PAHs. Water samples taken at a reference location in the Fraser River Main Stem downstream of the skytrain bridge and at the edge of the AIWWTP IDZ, are submitted to CALA certified laboratories for analysis. The program currently incorporates the best analytical methods currently available from commercial analytical laboratories within the region as determined by MV, particularly with respect to organic parameters.
- The REM program has been implemented by MV at the AIWWTP since 2004 and the design of the program has evolved over time since the original design by Gartner Lee (2003). Currently water quality is monitored up to two times per year and the data are subject to annual reporting and review by the EMC.
- The FRAMP was designed in 2002 to meet a Liquid Waste Management Plan commitment to undertake ambient monitoring of the lower Fraser River within Metro Vancouver (i.e., North Arm, Main Arm and Main Stem up to and including Langley/Maple Ridge). The program has operated on a five year cycle since 2003 with water quality monitored once per year and sediment quality and fish health and tissue monitored about every five years. To date, water quality has been monitored for fourteen consecutive years; three separate sediment quality studies and three separate fish health and tissue studies have been conducted to date.

Both the REM and FRAMP monitoring program designs are currently under review by MV and recommendations will be considered and discussed with the EMC and incorporated into ongoing monitoring programs as appropriate and opportunities arise, with the overall objective of monitoring the potential influence of discharges from MV WWTPs to the lower Fraser River receiving environment.

10.2 AIWWTP Effluent Sampling Program and the REM Water Quality Program

The considerations outlined below are provided for Stage V post-discharge monitoring through the long term AIWWTP effluent monitoring and receiving environment monitoring programs currently implemented by MV.

- Constituents evaluated in the Stage 2 EIS impact assessment should be considered for inclusion in monitoring of AIWWTP effluent and river water at the edge of the IDZ and upstream of the Annacis outfall, to assess attainment of FRWQOs and applicable WQGs, and confirm the findings of the EIS. Where methods are available to achieve MDLs below applicable guidelines and no uncertainties in the data were identified in the Stage 2 EIS, monitoring of these constituents in effluent and river water should continue.
- Consistent with the current approach for the REM program, organic constituents do not need to be routinely monitored; however, over the longer-term, organic constituents evaluated in the Stage 2 EIS impact assessment including PBT constituents should be characterized in effluent and river water as appropriate to assess attainment of FRWQOs and applicable WQGs, and confirm the findings of the EIS.
- Where methods are not commercially available to achieve MDLs below applicable guidelines for the AIWTTP effluent and river water submitted for analysis, the monitoring program review should consider how meaningful interpretation of these data could be conducted, given this constraint. With the continued development of analytical technologies by research, government, and commercial laboratories, MDLs for constituents such as EE2 are expected to improve over time; however, for now MDLs remain a constraint for the assessment of several organic constituents in effluent and river water. As improved analytical methods become available, supplementary sample collection and analysis is recommended for AIWWTP effluent, river water for select constituents evaluated in the Stage 2 EIS impact assessment that have been subject to these constraints.
- For constituents where uncertainty in the current dataset that affected data interpretation was identified, sampling and laboratory procedures should be reviewed as part of the overall monitoring program review, with the objective of reducing uncertainty in the effluent and water quality data reported. For example, both sampling and laboratory procedures should be reviewed for PCBs and PBDEs to address the noted issues related to elevated concentrations in field and laboratory blank samples.
- Continue to undertake acute 96-hour rainbow trout toxicity testing of the effluent as required by the ILWRMP, amended Operational Certificate, and WSER.
- The re-evaluation of the REM program will need to develop a revised monitoring strategy for use once the new multiport diffuser operational. As the diffuser is oriented parallel to the river flow and discharges across the main flow (which is the opposite of the existing diffuser), the location of the plume will change with changing tide conditions. Thus, a revised monitoring strategy will need to be more robust and should consider averaging strategies for sample collection (e.g., compositing samples along the IDZ boundary over all or a portion of the tidal cycle, or depth composite sampling) to obtain representative samples of plume conditions at the edge of the IDZ.

10.3 Confirmatory Sampling

Sediment and fish tissue monitoring to confirm the findings of the EIS is proposed below. The proposed confirmatory sampling is not necessarily intended for long-term inclusion in the programs currently implemented by MV. Initially, sampling is intended to provide data to confirm whether the sediment quality is influenced by the Stage V upgrade and to confirm the findings of the EIS assessment of PBT constituents. Sampling of sediment quality and fish tissues is recommended prior to and following commissioning of the Stage V discharge, with future recommendations to be made based on the findings of those studies.

- Sediment sampling is recommended downstream and upstream of the proposed AIWWTP outfall prior to and following commissioning of the Stage V discharge to determine if the Stage V upgrade has influenced sediment quality. This sampling objective could potentially be achieved by conducting supplemental sampling during the existing sediment quality program, providing that the frequency of sampling in the revised design will address this sampling objective. The sediment monitoring program currently implemented by MV is focussed on sampling near-shore sampling areas with slower flows and finer sediments. Preliminary sampling of benthic invertebrate communities in 2016 and 2017 documented in Appendices C and D suggest that, consistent with the findings of Gartner Lee (2003), there would be substantial challenges in being able to detect meaningful change in benthic invertebrate communities located within the receiving environment downstream of the AIWWTP due to the dynamic, unstable physical characteristics of the receiving environment. Sampling of sediment quality would likely be a more effective way of assessing potential impact to sediment dwelling biota.
- Collection of fish tissues to be analyzed for PBT constituents is recommended to confirm the findings of the EIS assessment of PBT constituents. Fish tissue collection should focus on small-bodied and sentinel species with site-fidelity that could be used to evaluate the potential for risks to wildlife consumers of fish and used as a surrogate for fish consumed by people (peamouth chub is a potential candidate species). MV currently monitors both fish tissue and fish health in the lower Fraser River as part of the FRAMP. As part of the review of this program, consideration should be given to incorporating suitable locations upstream and downstream of the AIWWTP for sampling of fish tissue prior to and following commissioning of the Stage V discharge. Provisionally target species could align with the current FRAMP design to allow for comparison to historical data but the final selection of sentinel species should be evaluated further during the monitoring program review.
- As in existing programs, sediment and fish tissue samples should continue to be analyzed using the best commercially available analytical methods with the objective of achieving MDLs below applicable sediment and tissue FROs and guidelines.

11.0 CLOSURE

We trust that this report provides sufficient information for your present needs. If you have any questions, please do not hesitate to contact the undersigned at 604-296-4200.

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