

Joint Utility Board Sewage Treatment Plant – Stage 2 Environmental Impact Study REMP (Receiving Environment Monitoring Program)

Submitted to:

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LIST OF ACRONYMS

ADWF	Average Dry Weather Flow
AET	Apparent Effect Threshold
AVS	Acid Volatile Sulphides
Axys	Axys Environmental Consulting Ltd.
BC	British Columbia
BCG	British Columbia Government
BCAWQG	BC Approved Water Quality Guidelines
BCWWQG	BC Working Water Quality Guidelines
BCMOE	British Columbia Ministry of Environment
BOD	Biochemical Oxygen Demand
CALA	Canadian Association of Laboratory Accreditation
CBOD ₅	5-Day Carbonaceous Biochemical Oxygen Demand
CCLT	Cowichan Community Land Trust
CCME	Canadian Council of Ministers of the Environment
CEC	Contaminants of Emerging Concern
CEEMC	Cowichan Estuary Environmental Management Committee
CEEMP	Cowichan Estuary Environmental Management Plan
CFIA	Canadian Food Inspection Agency
CFU	Colony Forming Units
CHR	Canadian Heritage River
C:N	Carbon to Nitrogen Ratio
CoC	Chain of Custody
COD	Chemical Oxygen Demand
CSLWMP	Central Sector Liquid Waste Management Plan
CVRD	Cowichan Valley Regional District
DFO	Fisheries and Oceans Canada
DNC	District of North Cowichan
DO	Dissolved Oxygen
DQO	Data Quality Objectives
D&K	Dayton & Knight Consulting
EIS	Environmental Impact Study
EMA	<i>Environmental Management Act</i>
FEQG	Federal Environmental Quality Guidelines
FF	Far-Field
FLNRORD	Forest, Lands, Natural Resource Operations and Rural Development
G3	G3 Consulting Ltd.
GC	Government of Canada
GPEE	Great Pacific Environmental and Engineering
IBA	Important Bird Area
IDZ	Initial Dilution Zone
ISQG	Interim Sediment Quality Guidelines
JUB	Joint Utility Board
LC ₅₀	Median Lethal Concentration
LWMP	Liquid Waste Management Plan
MDF	Maximum Daily Flow
MF	Mid-Field
MOE CCS	Minister of Environment Climate Change Strategy
MPN	Most Probable Number

<i>MWR</i>	<i>Municipal Wastewater Regulation</i>
NA	Not Applicable
NF	Near-Field
NOAA	National Oceanic and Atmospheric Administration
OP	Orthophosphate
PAH	Polycyclic Aromatic Hydrocarbon
PBDE	Polybrominated Diphenyl Ether
PCB	Polychlorinated Biphenyl
PEL	Probable Effects Level
PHF	Peak Hourly Flow
PSA	Particle Size Analysis
PSU	Practical Salinity Units
QA/QC	Quality Assurance and Quality Control
RCA	Rockfish Conservation Area
REMP	Receiving Environment Monitoring Program
SEM	Simultaneously Extracted Metals
SoG	Strait of Georgia
SOP	Standard Operating Procedures
STP	Sewage Treatment Plant
TC	Total Carbon
TEL	Threshold Effect Levels
TERM	Terminus
TOC	Total Organic Carbon
TSS	Total Suspended Solids
TP	Total Phosphorus
TRC	Total Residual Chlorine
USEPA	United States Environmental Protection Agency
VP	Visual Plumes UM3
WQG	Water Quality Guideline
<i>WSER</i>	<i>Wastewater Systems Effluent Regulations</i>
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

G3 Consulting Ltd. (G3) was retained by the District of North Cowichan (DNC) to design a Receiving Environment Monitoring Program (REMP) for the proposed relocation of the Duncan/North Cowichan Joint Utility Board (JUB) Sewage Treatment Plant (STP) effluent outfall to marine waters of Satellite Channel. Registration and changes to registered wastewater treatment plant facilities require an Environmental Impact Study (EIS), including a REMP, as prescribed by the *Municipal Wastewater Regulation* (MWR) under the *Environmental Management Act*. An EIS for the proposed outfall relocation was completed in two (2) stages, Stage 2 of the EIS is comprised of three (3) studies: an assessment of ambient ecological conditions in Cowichan Bay and Satellite Channel and potential changes and impacts associated with STP wastewater discharge at the relocated outfall; an assessment of marine pipeline routes; and, a pre and post discharge REMP (as reported herein).

The JUB STP REMP was designed as an iterative program with four (4) primary objectives: 1) ensure compliance with the *Municipal Wastewater Regulation*; 2) ensure the protection of human health and the environment; 3) inform owners of the JUB STP of potential impacts of effluent discharge to the receiving environment and to guide decision-making in discharge operations; and, 4) to inform First Nations, the public and other stakeholders of environmental quality in the receiving environment.

REMP monitoring objectives were selected based on information obtained during the Stage 2 EIS. The REMP is to include effluent, water and sediment quality in addition to biological assessments. The REMP considered First Nations concerns and traditional ecological knowledge to design the most appropriate study with specific sampling location and depth, time for sample collection, frequency of sampling, type and number of samples to be collected and type of analyses to be performed.

Specific objectives for the REMP include, but are not limited to, monitoring for the purpose of: 1) ensuring preservation of the ecological integrity of the receiving environment Cowichan Bay/Satellite Channel; 2) ensuring that water quality conditions outside the Initial Dilution Zone (IDZ) will not impede the use of fisheries resources by First Nations, recreational and commercial users (i.e. geoduck); and, 3) maintaining water quality suitable for safe recreational use in Cowichan Bay/ Satellite Channel.

Monitoring of water quality where effluent is discharged is prescribed under the *MWR* to ensure that bacteria levels meet limits at the edge of the IDZ. Under the *MWR*, monitoring must ensure that the effluent discharge “does not cause water quality parameters outside the initial dilution zone, to fail to meet water quality guidelines.” Water quality guidelines are defined under *MWR* as those “published under the authority of the Minister” or in the absence of BC water quality guidelines or objectives “any other water quality standard acceptable to the minister.” Compliance with *BC Approved or Working Water Quality Guidelines* for the Protection of Aquatic Life ensures that aquatic organisms will not be affected by discharge outside the IDZ. Federal environmental quality guidelines will also be applied where no provincial guidelines are available.

A radial gradient design is proposed for the REMP where sampling stations are located over spatial gradients extending outward from the outfall where the extent of effects can be determined. The proposed radial design from the JUB STP outfall diffusers ports (central point herein referred to as terminus station) extends to Near-Field (NF) stations at the edge of the IDZ (100 m), Mid-Field (MF; 300 m from IDZ) and Far-Field (FF; 1 km from IDZ) stations. MF and FF stations were selected based on major current directions into and out of Cowichan Bay and Sansum Narrows. Biological resources use (e.g., harvesting at shellfish beds) and other activities (e.g., recreational activities, swimming, diving etc.) were also considered when assigning sampling stations. FF stations are intended to represent ambient conditions, with stations located outside the predicted influence of the effluent outfall.

Water samples are to be collected near surface to assess levels to which human and animals could come into contact with in the upper water column; at predicted trapping depth in an effort to capture the effluent plume in the receiving environment; and just above the bottom to assess water quality near-bottom.

Pre-discharge monitoring would likely be in summer 2020 and winter 2020/21 collecting water, sediment and aquatic organisms in summer and water in winter. After the outfall begins discharging, sampling is to be conducted annually during the winter rainy season and summer low flow period to assess water quality.

Sediment sampling and benthic invertebrate community surveys are recommended once every three years after discharge commences, to assess longer-term trends and potential for bioaccumulation effects in the receiving environment. Sediment sampling and benthic invertebrate communities are recommended to be undertaken two years after discharge commences.

Benthic invertebrate community surveys provide information on aquatic environmental conditions and the amount of bioavailable energy to fish. Benthic invertebrate community surveys are used for assessing other STP receiving environment (e.g., Metro Vancouver, Regional District of Nanaimo) and therefore responses can be compared. Benthic invertebrates are recommended to be collected for taxonomy identification to determine benthic community structure around the proposed outfall location. The study is to be done concurrent with sediment assessments to aid in interpretation of results.

Bioaccumulation in tissue of shellfish (i.e. clams) is to be evaluated to ensure that the JUB STP discharge does not cause an increase in concentration of potential contaminants associated with wastewater. Clams were selected given their relevance as a local food resource valued by First Nations.

Parameters recommended for the REMP include parameters with regulatory limits under the *MWR*, parameters associated with wastewater effluent for which *BC Approved Water Quality Guidelines* are available (e.g. bacteria, ammonia, some metals) and parameters known or suspected to be present in the JUB STP effluent which could have the potential to cause deleterious effects on human health or aquatic organisms. Organic parameters and contaminants of emerging concern (CECs) are generally low or not detected in the receiving environment (i.e., PAHs, PCBs, PBDEs, alkylphenols), as such these CECs are to be tested in the receiving environment only when levels are evaluated in final effluent.

The REMP should be re-evaluated after the post-discharge first three (3) year cycle and amended as necessary. Modifications will likely occur to the REMP's duration, frequency, sampling stations, parameters and matrices tested based on the pre- and post-discharge monitoring results.

1.0 INTRODUCTION

G3 Consulting Ltd. (G3) was retained by the District of North Cowichan (DNC) to design a Receiving Environment Monitoring Program (REMP) for the proposed relocation of the Duncan/North Cowichan Joint Utility Board (JUB) Sewage Treatment Plant (STP) effluent outfall to marine waters in Satellite Channel just beyond the entrance to Cowichan Bay from its current location in Cowichan River. The proposed relocation is part of Amendment No. 3 to the *Central Sector Liquid Waste Management Plan* (CSLWMP; D&K, 1999; CVRD, 2015) currently under review by the British Columbia Government (BCG). Registration and changes to registered wastewater treatment plant facilities require an Environmental Impact Study (EIS) and REMP as prescribed by the *Municipal Wastewater Regulation* (MWR; BCG, 2018) under the *Environmental Management Act* (EMA; BCG, 2017).

An EIS for the proposed outfall relocation was completed in two (2) stages with the first stage completed in 2015 (GPÉE, 2015) and the second stage completed by G3 Consulting Ltd (G3) in 2018 and 2019. Stage 2 of the EIS is comprised of three documents: an assessment of ambient conditions in Cowichan Bay and Satellite Channel and potential changes and impacts associated with wastewater discharge at the relocated outfall (Stage 2 EIS; G3, 2020); a biophysical assessment of pipeline routes in the estuarine and marine environment (G3, 2020a); and a REMP (report herein). The pre- and post-discharge REMP, as presented herein, continued with the other reports to fulfill mandatory requirements under MWR and completes the Stage 2 EIS.

This chapter presents background information and a description of the proposed relocated outfall, regulatory framework, study area and receiving environment characteristics. The REMP rationale, components and schedule are provided in Chapter 2 and proposed methodologies are provided in Chapter 3. References (Chapter 4) and Figures (Appendix 1) are presented at the back of this report.

1.1 Background

The JUB STP is co-owned by the City of Duncan and Municipality of North Cowichan and currently provides service to approximately 26,000 residents within parts of the Cowichan Valley Regional District (CVRD), City of Duncan, southern part of the District of North Cowichan (DNC), parts of Electoral Areas D and E, and parts of the Cowichan Tribes reserve land (Reitsma, 2018). Detailed information on the JUB STP, Cowichan Bay study area and regulatory framework is provided in the EIS reports (GPÉE, 2015; G3, 2020 and 2020a) and summarized herein.

The JUB STP provides secondary treatment using a conventional aerated lagoon facility (screening/degritting followed by oxidation and settling) with seasonal chemical phosphorus removal using alum and disinfection with chlorination followed by de-chlorination prior to release to the environment. Effluent from the JUB STP currently discharges into the Cowichan River through a multiport diffuser adjacent to the JUB facility, approximately 5 km upstream from the braided mouth of the river that enters Cowichan Bay. Substantial upgrades to the facility have occurred including screening/degritting facilities and a new completed mixed aeration system were installed in spring of 2000. In 2002/2003, a new phosphorus removal system was constructed to reduce phosphorus discharge into the Cowichan River (Reitsma, 2018).

In August 2011, a new lease agreement between DNC/Duncan (JUB) and Cowichan Tribes included the continued use of the land for the JUB STP for the next 49 years, with an option to renew and a commitment to make reasonable effort to remove the JUB STP outfall from the Cowichan River over the next 10 years (by 2021). Population growth in the region has resulted in increased effluent discharge levels. In addition, extended low flow periods in the Cowichan River have resulted in poor effluent mixing and diffusion and have increased the risk of exceeding the assimilative capacity (i.e. discharge rate) of the Cowichan River. The outfall also causes erosion in the Cowichan River in the area of STP discharge. An assessment of the relative risk of the existing river outfall and proposed marine outfall was discussed in the EIS reports (GPÉE, 2015 and G3, 2020).

The provincial EMA (BCG, 2017) enables local government to develop a Liquid Waste Management Plan (LWMP) for approval by the BC Minister of Environment Climate Change Strategy (MOE CCS). The

CSLWMP submitted by the CVRD (D&K, 1999) was approved in May 2000, with two subsequent amendments approved in June 2002. The JUB outfall relocation was proposed as part of Amendment No. 3 to CSLWMP, currently under review by the BC provincial government (CVRD, 2015; GPPE, 2015a).

The JUB STP operates under the Operational Certificate ME-01497 (June 2002) which sets authorized discharge limits and requirements for monitoring. A revised or new Operational Certificate will be required for the relocation of the outfall to the marine environment.

1.2 Regulatory Framework

Under the federal *Fisheries Act* (GC, 2019), the federal *Wastewater Systems Effluent Regulations* (WSER; SOR/2012-139; GC, 2015) provides mandatory effluent quality standards and effluent reporting requirements for wastewater system operators. Effluent must not be acutely toxic and must meet limits set for carbonaceous biochemical oxygen demand (CBOD), suspended solids, total residual chlorine and un-ionized ammonia.

At the provincial level, the *Environmental Management Act* (EMA; SBC 2003; BCG, 2017) governs the management of waste in BC and the *Municipal Wastewater Regulation* (MWR; B.C. Reg. 87/2012; BCG, 2018), pursuant to the EMA, regulates the discharge of municipal wastewater. The EMA provides the authority for introducing wastes into the environment through the use of permits (i.e. Operational Certificate ME-01497 issued for JUB STP), regulations and codes of practice while protecting public health and the environment. The MWR prescribes registration requirements for owners of wastewater treatment facilities, which includes the need to follow sound outfall design criteria, conduct EISs, meet minimum effluent quality, comply with water quality guidelines at the edge of the initial dilution zone (IDZ) and provide implement a REMP. The IDZ is defined in the MWR as a 3-dimensional zone around the point of discharge where mixing of municipal effluent and receiving waters occurs. In marine waters, the IDZ is a cylinder with the following dimensions: the height from the seabed to the water surface and a 100 m radius measured from the first and last diffuser ports (Part 6, MWR; BCG, 2018).

1.2.1 Operational Certificate

As discussed above, the JUB STP operates under the Operational Certificate ME-01497 (June 2002), which sets authorized discharge limits and requirements for monitoring effluent and receiving environment. It is anticipated that a revised or new operational certificate will be issued following approval of Amendment No.3 by the BC provincial government. Current effluent quality requirements of the Operational Certificate are listed in Table 1-1 along with provincial and federal effluent criteria.

1.2.2 Cowichan Estuary Environmental Management Plan (EMP)

The Cowichan Estuary is subject to the Cowichan Estuary Environmental Management Plan (CEEMP; BCMOE,1987), which limits detrimental impacts and further habitat loss and dictates the type of activities acceptable and designated areas in which to practice them (e.g., industrial/commercial, log handling, recreation, etc.). All new project proposals for the estuary must be reviewed by the Cowichan Estuary Environmental Management Committee (CEEMC), which makes a recommendation to the Minister of Forest, Lands, Natural Resource Operations and Resource Development (FLNRORD) for approval before a project can proceed.

Potentially two of the four proposed effluent pipeline route options assessed for the proposed outfall relocation (G3, 2020a) would involve placement of the effluent pipeline within the CEEMP area; therefore, if one of those options are selected a review by the CEEMC and approval by the Minister of FLNRORD would be required before the project could proceed. Routing of the pipelines through aquatic habitats to the outfall location, including a biophysical survey and risk assessment was provided in a separate report “Joint Utility Board Sewage Treatment Plant Outfall Environmental Impact Study Stage 2 Piping Routing Risk Assessment” (G3, 2020a).

Table 1-1: Effluent Quality Requirements for Provincial, Federal & JUB Operational Certificate

Parameter	Units	MWR Criteria				WSER Criteria	JUB Operational Certificate (ME-01497)
		Rivers		Embayed/Open Marine			
		<2x ADWF	≥2x ADWF	<2x ADWF	≥2x ADWF		
Maximum Discharge	m³/day	NA	NA	NA	NA	NA	49,000
Toxicity (96-h rainbow trout test)	% survival	>50% in 100% effluent	>50% in 100% effluent	>50% in 100% effluent	>50% in 100% effluent	>50% in 100% effluent	LC50 ≥ 100% effluent
CBOD ₅	mg/L	≤ 45	≤ 130	≤ 45	≤ 130	< 25 ²	≤ 30
TSS	mg/L	≤ 60 ¹	≤ 130	≤ 60 ¹	≤ 130	< 25 ²	≤ 40
pH	pH	6.0 – 9.0	NA	6.0 – 9.0	NA	NA	6.0 – 9.0
TP	mg/L	≤ 1	NA	NA	NA	NA	18 kg/day in July, Aug, Sept
OP	mg/L	≤ 0.5	NA	NA	NA	NA	Monitor monthly
Ammonia	mg/L	Calculate final effluent ammonia level required to achieve: At edge of IDZ, ≤ ammonia chronic WQG based on ambient temp, pH and salinity				< 1.25 un-ionized maximum at 15°C ± 1°C	Monitor monthly
Fecal Coliforms	CFU/100ml	At edge of IDZ: Shellfish bearing waters: ≤14 MPN/100 mL median or geometric mean; and, Recreational use waters: ≤ 200 MPN/ 100mL geometric mean					≤ 200 median of 7 consecutive samples ≤ 800 max any sample
TRC	mg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.01

Notes: ADWF: average dry weather flow; CBOD₅: 5-day carbonaceous biochemical oxygen demand; CFU: colony forming units; IDZ: initial dilution zone; JUB: Duncan-North Cowichan Joint Utility Board; LC₅₀: Median Lethal Concentration ;MPN: most probable number; MWR: *Municipal Wastewater Regulation* (BCG, 2018); NA: Not applicable; OP: orthophosphate as (P);TP: total phosphorous; TRC: total residual chlorine; TSS: total suspended solids; WQG: water quality guidelines; WSER: *Wastewater System Effluent Regulations* (GC, 2015).

¹ For lagoon systems.

² Average.

1.3 Study Area

Cowichan Bay is located along the east coast of Vancouver Island. The Cowichan and Koksilah rivers confluence and discharge at the west end of Cowichan Bay. The Cowichan River originates from Cowichan Lake and the Koksilah River begins at Waterloo Mountain, south of Cowichan Valley (CCLT, 2004). The Cowichan Estuary ecosystems form where freshwater of the Cowichan and Koksilah rivers meets the marine environment of Cowichan Bay (Figure A1-1, Appendix 1). To the south east, Cowichan Bay opens to Satellite Channel, Sansum Narrows and Saanich Inlet. Both Satellite Channel and Sansum Narrows are channels between Vancouver Island and Salt Spring Island. Satellite Channel runs south of Salt Spring Island and Sansum Narrows runs west of Salt Spring Island, both connecting to the Strait of Georgia (SoG).

In 2003, Cowichan River was designated as a Canadian Heritage River (CHR, 2003) given its natural, cultural and recreational value. Cowichan Bay, including its estuary, is ecologically important and provides habitat for numerous flora and fauna including species at risk. The Cowichan/Koksilah River Estuary conservation land and Satellite Channel Ecological Reserve are provincial protected areas associated with the Cowichan Bay and Cowichan Estuary. The Cowichan River Provincial Park is also located 12 km upstream of Cowichan Bay. Other environmentally sensitive or important areas include Cowichan Estuary Important Bird Area (IBA; BC048; IBA Canada, 2019); Saanich Inlet; and, Fisheries and Oceans' (DFO) rockfish conservation areas (RCAs; Patey Rock Point, Mable Bay, Burgoyne Bay; Figure A1-2, Appendix 1). More detailed information on these areas is provided in the EIS reports (GPPE, 2015; G3, 2020 and 2020a).

Cowichan Bay and Cowichan River are traditional territory of First Nations (Cowichan Tribes, WSAWEC, Malahat and others) and play an important part of food, social and ceremonial practices. Cowichan Bay and Estuary are also an important place for recreation, fisheries and industry. Other anthropogenic influences in the Cowichan Estuary, Cowichan Bay and surrounding area include: Cowichan Bay Village, Western Forest Products Cowichan Bay Sawmill, Western Stevedoring operations on the Cowichan Bay Terminal, Pacific Industrial Marine, Lambourn Wastewater Treatment Plant, JUB STP, marinas, vessel traffic (including anchorage points), various fisheries, agricultural operations and recreational activities.

1.4 Receiving Environment Characteristics

1.4.1 Bathymetry

Bathymetry (water depth) within Cowichan Bay is relatively uniform, measuring approximately 60 m depth throughout the center of the bay, with shallower depths closer to shore. Separation Point has depths up to 135 m and shallow depths (10 m) around Boatswain Bank. Depths become greater (>80 m) again within Satellite Channel (Figure A1-1, Appendix 1).

1.4.2 Hydrology

Tides

Cowichan Bay exhibits mixed semi diurnal tides, consisting of two high tides and two low tides each day. Within a day, one high tide and one low tide exceeds the other. The largest monthly tidal range in 2018 was in July, with lowest low tide (lowest low water) recorded at 0.1 m and highest high tide (higher high water) recorded at 3.7 m (DFO, 2019). Tidal conditions are described as flood tide when water is moving into the Bay resulting in rising seawater levels, and an ebb tide when water is flowing out of the Bay resulting in lower water levels.

Currents

Water circulation within Cowichan Bay is unique and complex due to freshwater inputs from Cowichan River at surface, tidal influences and Coriolis effect, where currents veer towards the south side of the bay (Axys, 1991). At the mouth of Cowichan Bay, flood tides primarily bring currents into the bay with a proportion deviating northwest to Sansum Narrows and, on ebb tide, flowing either into Satellite Channel or as a back eddy off Cherry Point (Axys, 1991).

Around Cowichan Bay circulation is also complex with Separation Point on the north side of the embayment line and Boatswain Bank to the south going into Satellite Channel. In historical studies, complex eddies were shown to form at various depths. Separation Point contained back eddies on ebb tide and Boatswain Bank had eddies on flood tide. Due to these eddies, waters flowing south from Sansum Narrows and north from Saanich Inlet toward Satellite Channel created a clockwise eddy at the mouth of Cowichan Bay, southwest of Separation Point (Axys, 1991).

Ocean currents were characterized by G3 (2020) using depth, temperature, magnitude and direction data collected at multiple stations over three [3] seasons (spring, summer and winter). Averages for current magnitude and current direction were calculated for each depth layer (deep, middle and surface), tidal phase (flood, ebb and slack), season and station. Current magnitude, during each season and tidal phase, was faster in the surface layer (1 m to 20 m) compared to middle (20 m to 40 m) and bottom (40 m to 60 m) layers. Complex current patterns were noted and likely due to eddies historically noted to form near Separation Point, Boatswain Bank and the mouth of Cowichan Bay. In general, water flow at the proposed outfall would be predicted, during flood tide, to be directed into the Bay with a portion moving northwest into Sansum Narrows and out of the Bay, into Satellite Channel, during ebb tides.

Freshwater Input

Freshwater discharge from the Cowichan and Koksilah rivers into the Cowichan Estuary generates estuarine circulation into Cowichan Bay. The amount and timing of the freshwater inputs influence

overall water quality in Cowichan Bay. The Cowichan River watershed drains approximately 940 km² from its origin in Cowichan Lake to its mouth in the Cowichan Estuary (47 km; McKean, 1989). Cowichan Rivers mean monthly discharge near Duncan (Station 08HA011; 48° 46' 23" N, 123° 42' 52" W) from 1960 to 2018 ranged from approximately 6 m³/s in August to 113 m³/s in December (GC, 2018). Discharge is lowest in summer (August/September) and highest in fall (November/December), coinciding with precipitation levels.

Water levels in Cowichan River have decreased over the last decade, attributed in part, to climate change and industrial and human uses (GPPE, 2015). Koksilah River (approximately 44 km long) originates south of the Cowichan Valley, on the slope of Waterloo Mountain, and drains a watershed of approximately 300 km² before discharging into Cowichan Estuary (McKean, 1989). Koksilah River mean monthly flows as recorded at Cowichan Station (Station 08HA003; 48° 43' 40" N, 123° 40' 14" W) from 1960 to 2018 ranged from <1 m³/s in July, August and September to 22 m³/s in January and December (GC, 2018a).

1.4.3 Climate

Average daily temperatures and total daily precipitation from January 2015 to June 2019 was recorded at Shawnigan Lake station (48°38'49" N, 123°37'35" W; GC, 2019). Daily mean temperatures were highest in the summer (July [19°C] and August [20°C]) and lowest in the winter (December [-3°] and January/February [-4°C]). Mean total monthly precipitation was highest in fall/winter (November [237 mm], December [215 mm], January [210 mm]) and lowest in summer (July [14 mm], August [11 mm]; GC, 2019).

1.4.4 Ecosystems

Biophysical surveys conducted as part of Stage 2 EIS in 2018 and 2019 (G3, 2020a), identified several ecosystems potentially affected by installation of the JUB STP pipeline, depending on routing, including eelgrass (*Zostera marina*) beds, tidal marsh, mudflats, riparian areas, nearshore intertidal and marine subtidal. Tidal marsh and mudflat ecosystems are located in the Cowichan Estuary, riparian areas were restricted to the mouth of the Koksilah River and eelgrass beds were recorded along the subtidal nearshore zone of Cowichan Bay. These shoreline ecosystems can be highly productive and also provide a valuable role in sheltering coastlines from erosion, filtering nutrients and sediment from the water column and provide nursery and foraging habitats for many crustaceans, fish and migratory birds (Batzer and Sharitz, 2014; BC MOE, 2006; Butler *et al.*, 1996; Gebauer and Moul, 2001).

The proposed outfall relocation would be within the marine subtidal environment, away from the intertidal shoreline ecosystems. Results from the biophysical survey (G3, 2020a) saw no flora within the marine subtidal environment (>10 m depth), likely absent given the depth of benthic environment and limited number of fauna species present. Plumose anemones (*Metridium* sp.) were the most common species recorded, though other sessile species recorded included sea pens and tube anemones (*Pachycerianthus fimbriatus*). Mobile fauna including crabs, fish, amphipods with spot prawn (*Pandalus platyceros*) occasionally noted.

1.5 Effluent Characterization

During the Stage 2 EIS, JUB STP effluent characterization was conducted to assess potential impacts of the outfall on the receiving environment and presented in the EIS reports (G3, 2020). Effluent data for JUB STP was characterized from 1996 to 2018 and compared to the Operational Certificate (ME-01497) to assess both previous (1996 to 2017) and current (2018) compliance. In previous years (1996 to 2017), effluent occasionally exceeded total suspended solids (TSS), 5-day carbonaceous biochemical oxygen demand (CBOD5), pH, fecal coliforms, toxicity and total residual chlorine (TRC). Most exceedances were prior to the STP upgrades completed in 2003. In 2018, all stipulated operational limits were met, except for one exceedance of TRC due to a flooding event.

Overall average effluent flow in 2018 (11,398 m³/d) was comparable to the two previous years (12,176 m³/d and 12,746 m³/d; 2017 and 2016, respectively). In 2018, minimum effluent flow was measured in July (6,381 m³/d) and August (6,266 m³/d), during the dry season, and was highest in December (22,695 m³/d; mean monthly flow) during the wet season. Flow rate is affected by infiltrating groundwater and is highest during the rainy season (Nov to Feb) and lowest during the dry season (Jun to Aug). Effluent maximum daily flow ranged from 6,687 m³/d to 32,052 m³/d in 2018 and 7,230 m³/d to 41,775 m³/d from 1996 to 2017. Effluent daily flow rates were well below the JUB Operational Certificate (ME-01497) authorized maximum daily limit (49,000 m³/day; G3, 2020).

1.5.1 Existing Cowichan River Outfall

Currently, the JUB STP outfall discharges into the Cowichan River, approximately 5 km upstream of the Cowichan Estuary and flows into Cowichan Bay. The JUB Operational Certificate (ME-01497) requires two receiving environment monitoring stations in the Cowichan River. One station is located approximately 50 m upstream of the point of discharge and a second approximately 200 m downstream of the point of discharge. Samples are collected at each station during the first 10 days of August each year. Parameters measured include total phosphorous, ortho phosphorous, total nitrogen, ammonia nitrogen, pH and temperature.

The location of the outfall in the Cowichan River increases the risk of exceeding the assimilative capacity of the Cowichan River (i.e., discharge rate of effluent that can enter the system without deleterious effects). Increased effluent discharge levels (related to population growth in the region) and extended low flow periods in the Cowichan River which have resulted in poor effluent mixing and diffusion are hindering the rivers capacity. Low flow conditions in early 2019 further exacerbated the concerns related to discharges to the Cowichan River.

1.5.2 Proposed Outfall

The outfall is proposed to be relocated to marine waters from the current location in the Cowichan River. Originally, a proposed outfall was situated in the middle of Cowichan Bay, defined in the Stage 1 EIS (GPEE, 2015); however, based on discussions with local First Nations, the outfall was relocated further east, to just beyond the line of embayment (i.e. entrance of the bay). The proposed outfall location is located near the embayment line, approximately 900 m southeast of Separation Point. Proposed discharge would be through a multiport diffuser with an estimated length of 100 m and a termination depth of approximately 60 m. The proposed wastewater pipeline route has not yet been determined; however, any minor alterations in the diffuser direction or configuration were also assessed in the Stage 2 EIS and did not substantially affect modelling outcomes.

1.6 Plume Dilution Modelling for Proposed Outfall

During the Stage 2 EIS (G3, 2020 and 2020a), a model was used to predict wastewater effluent dilution and water quality at the 100 m edge of the potential initial dilution zone (IDZ). Current and water profiles were measured in 2018 at several sites and the United States Environmental Protection Agency (USEPA) modelling application Visual Plumes UM3 (VP) was used to complete initial dilution modelling (G3, 2020). The effluent plume was predicted to remain trapped below the surface for all effluent discharge scenarios and ambient conditions assessed. Minimum trapping depth was predicted to be 27.5 m below the surface in winter, under slack tide conditions (Table 1-2). Under average current conditions and maximum daily flow (2014-2018), trapping depth was predicted at approximately 47 m depth in spring and summer and 36 m in winter. Minimum dilution was predicted at the 100 m IDZ boundary and was noted to be very high under the maximum effluent discharge scenarios assessed. Plume direction was also modelled, and found to be variable based on location, season and tide.

Table 1-2: Summary of Minimum and Maximum Predicted Trapping Depth							
Effluent Discharge (m ³ /day)	Current Strength	Trapping Depth Ranges					
		Spring		Summer		Winter	
		Min	Max	Min	Max	Min	Max
41,800 (2014 to 2018 Maximum Daily Flow)	Slack	46.0	46.9	44.1	49.9	29.3	42.3
	Average	45.7	47.0	46.7	48.1	31.3	42.6
	Max	46.4	48.1	50.0	51.1	43.7	45.4
44,000 (2014 to 2018 Peak Hourly Flow)	Slack	46.1	46.7	43.8	49.8	29.3	42.2
	Average	45.4	46.9	46.4	47.8	31.2	42.5
	Max	47.9	48.1	49.9	51.1	43.5	45.4
57,100 (2058 Projected Maximum Daily Flow)	Slack	45.1	46.1	42.8	49.2	29.0	39.4
	Average	43.6	46.3	45.3	46.8	30.7	39.5
	Max	47.7	48.0	49.3	50.9	36.8	44.9
101,000 (2058 Projected Peak Hourly Flow)	Slack	37.5	43.4	40.5	47.3	27.5	32.6
	Average	32.0	44.1	42.2	44.4	28.6	32.7
	Max	47.1	47.3	47.4	50.1	31.3	43.7

Notes: shaded cells represent minimum trapping depth for each effluent discharge scenario; trapping depth is considered from the surface; MDF (Maximum Daily Flow); PHF (Peak Hourly Flow).

Using a conservative approach, the lowest predicted dilution ratio was used to calculate estimated worst-case concentrations of bacteria and chemicals of interest at the 100 m edge of the IDZ based on effluent concentrations. Fecal coliforms were predicted to be well below the *Municipal Wastewater Regulation (MWR)* limits and *BC Approved Water Quality Guideline (BCAWQGs; BCMOE, 2018)*. Predicted ammonia levels also met the most stringent site-specific *BCAWQGs* (0.44 mg/L). Metal levels were generally low in JUB STP effluent and also predicted to meet applicable water quality guidelines (WQGs) at the edge of the IDZ. Contaminants of emerging concern (CEC) were also assessed and parameters tested would meet available WQGs at the IDZ. In the unlikely scenario where there is a complete malfunction of the JUB STP and chlorination ceases, fecal coliforms were predicted to exceed the *MWR* limit and *BCAWQGs* for shellfish waters (14/100mL) at the edge of the IDZ; however, would meet the *MWR* limits and *BCAWQGs* for recreational waters (200/100 mL).

Modelling limitations at the proposed outfall location include, predicting plume direction and trapping depth in the spring and summer season, as current and water profiles at the proposed outfall location were only assessed in winter. Although trapping depth is likely similar given comparable depth profiles of temperature and salinity (hence water density) at stations in the middle of the Bay and Satellite Channel in April/May 2018 and July/August 2018, analyzing plume direction at increasing distances from the proposed outfall location can still have inherent limitations. Main tidal currents were noted to flow in towards Cowichan Bay during flood tides and out during ebb tides; however, conditions could change rapidly within a small area, especially near Separation Point. In addition, modelling was also predicted at the maximum effluent discharge flow rates (41,800 m³/day to 101,000 m³/day) to assess worst-case scenarios which are not reflective of current average effluent flow (approximately 15,000 m³/day); at decreased flow rates the plume could potentially be deeper in the water column than predicted at maximum effluent discharge flow rates.

1.7 Pre-Discharge Conditions in Cowichan Bay

A baseline evaluation of ambient ecological and biophysical conditions in Cowichan Bay, and an assessment of how potential discharge might affect those conditions, was conducted during the Stage 2 EIS and presented in the EIS reports (G3, 2020). Pre-discharge ambient assessments for the Stage 2 EIS were conducted throughout 2018 in different seasons and flow conditions, based on Stage 1 EIS report recommendations. Water and sediment quality, invertebrate tissue concentrations (benthic invertebrates and Pacific oysters [*Crassostrea gigas*]) and benthic invertebrate communities within Cowichan Bay were assessed. A summary of results is presented below.

1.7.1 Water

During the EIS Stage 2 (G3, 2020), depth profiles for physical parameters (e.g., temperature, dissolved oxygen (DO), pH, salinity and turbidity) were undertaken and completed concurrently with water quality at sampling stations within Cowichan Bay. In April/May (2018) and at select stations in December (2018), temperature and salinity depth profiles revealed a distinct thermocline and halocline close to the surface (5 m to 10 m depth).

Bacteria levels throughout Cowichan Bay and Satellite Channel were generally low in 2018, with the exception of near surface (1 m depth) stations in December and levels were comparatively higher in Cowichan Estuary (except May). Influences were likely runoff from upstream sources, which could include wildlife, agriculture runoff, industry and septic sources. Total ammonia and total nitrate results were below the *BCAWQG* (BCMOE, 2018). Total metals met short-term *BCAWQGs*, except for copper, which slightly exceeded at one station in April. Total metals met applicable long-term *BCAWQGs*, except for boron in April/May and July; however, boron was within the range of values considered typical for Canadian coastal marine waters (G3, 2020).

1.7.2 Sediment

Sediment quality was assessed in 2018 (G3, 2020). Particle size percent (%) distribution in sediment was generally comparable between stations and characteristic of muddy sediment (>90% silt-clay content) at all stations, with the exception of sandier sediment at Station S5, which was located in Satellite Channel and most subject to strong currents. Lower total organic carbon (TOC) and total carbon (TC) was noted in coarser sediment (S5) and higher carbon content in finer sediments closer to the estuary. Copper exceeded the Canadian Council of Ministers of the Environment's (CCME) Interim Sediment Quality Guidelines (ISQGs) at all stations sampled. Arsenic and copper levels were above the CCME ISQGs; however, were below CCME Probable Effect Levels (PEL). Arsenic slightly exceeded the CCME ISQGs at four (4) stations in April and one (1) station in July. Nickel exceeded Threshold Effect Levels (TEL) at all stations. Barium slightly exceeded Apparent Effect Threshold (AET) guidelines at four (4) stations in April and one station in July; cobalt at two stations in April and manganese and vanadium at all stations in April and July. Several metals concentrations were correlated to sediment characteristics (i.e., particle size percent [%] distribution). Bacteria levels in sediment were low or non-detect. Carbon isotope results were indicative of sediment found in marine environments. Metal exceedances were attributed to various natural and anthropogenic sources.

1.7.3 Benthic Invertebrates Communities

Total abundance and species richness (number of taxa) of benthic invertebrates sampled in Cowichan Bay generally demonstrated a spatial gradient, with increasing abundance with distance from the Cowichan Estuary primarily due to an increased abundance of larger particle sizes (i.e. sand). The top five dominant species in the study area were: *Axinopsida serricata* (suspension feeder bivalve); *Macoma carlottensis* (bivalve surface deposit feeder); *Lumbrineris cruzensis* (subsurface deposit feeder polychaete); *Protomedia* sp. (suspension feeding amphipods); and, *Heterophoxus oculatus* (carnivorous predator). Benthic invertebrate communities in Cowichan Bay were indicative of a healthy diverse population in a typical stable marine environment (G3, 2020).

1.7.4 Invertebrates Tissue Concentrations

Concentration of chemicals in invertebrate tissue was assessed in subtidal benthic invertebrates collected in April (2018) and intertidal Pacific Oysters (*C. gigas*), which were collected from three (3) locations within the Cowichan Estuary in September (2018). Metal concentrations met applicable tissue residue guidelines, except for a marginal exceedance of *British Columbia Approved Tissue Residual Guideline* for lead in the benthic invertebrate sample. Bacteria was also measured in the oysters collected in the estuary (September 2018) and were well below the *BCAWQGs* for shellfish.

1.7.5 Potential Impacts Assessed in Environmental Impact Study

Potential impacts to human health and receiving environment from discharged effluent at the proposed JUB STP outfall location were assessed during the Stage 2 EIS (G3, 2020), based on ambient study results, effluent characterization and plume modelling. Key parameters assessed had limits specified in the *MWR* (i.e. fecal coliforms) or with water quality guidelines available (i.e., bacteria, nutrients, metals, CEC, etc.).

As described above, water quality at the edge of the IDZ was predicted using effluent data and the Visual Plume modeled effluent dilution ratio and results were compared to *MWR* criteria and applicable *BCAWQGs* (BCMOE, 2001; 2018). Fecal coliforms were predicted to be <2 colony forming units [CFU]/ 100 mL), well below the *MWR* limits and *BCAWQGs* (≤ 14 CFU/100 mL for shellfish waters). Ammonia, metals and CECs were also predicted to meet *WQGs* at the IDZ. Given the high dilution rate and extended distance away from many of the potential sensitive areas identified by traditional ecological knowledge (TEK) from First Nations (i.e., Cowichan Estuary, shellfish beds, marinas, dive sites, herring spawning grounds, rockfish conservation areas, important fishing areas, Saanich Inlet, Satellite Channel Ecological Reserve), potential impacts associated with the proposed JUB STP effluent outfall are unlikely. Effluent would be at a minimum of 27.5 m below the surface, preventing contact with recreational users in most circumstances (except diving; closest known dive site was 3.6 km from the proposed outfall).

Under a very unlikely complete JUB STP malfunction (loss of chlorination), predicted fecal coliform would exceed the *MWR* limit and *BCAWQGs* for shellfish water (≤ 14 CFU/100 mL); however, would be well below the *MWR* limit and *BCAWQGs* for recreational waters (≤ 200 CFU/100 mL). Cumulative effects were predicted to be low or negligible under JUB STP operational scenarios.

2.0 STUDY DESIGN

This chapter provides rationale, components and schedule for the Receiving Environment Monitoring Program (REMP). The REMP for the relocated Duncan/North Cowichan Joint Utility Board (JUB) Sewage Treatment Plant (STP) effluent outfall to marine waters at the Cowichan Bay embayment line is a requirement under the *Municipal Wastewater Regulation* (MWR; BCG, 2018) as discussed in Chapter 1. The REMP is divided into two phases: **pre-discharge** and **post-discharge** monitoring.

2.1 Introduction

An effective monitoring program should be designed to integrate monitoring results into a decision-making framework to guide managers and undergo an adaptive management framework with periodic re-assessment and any appropriate changes included into the program (CCME, 2015). This ensures better use of resources and implementation of cost-effective programs for owners and managers. In addition, policy makers in regulatory agencies also benefit from access to monitoring results to assess the effectiveness of legislations and make changes to legislations and programs, when required. Finally, First Nations, public and other stakeholders have an interest in being properly informed on environmental quality in their region.

The JUB STP REMP was designed as an iterative program with four (4) overall goals:

- 1) to ensure compliance with the *Municipal Wastewater Regulation* (MWR; BCG, 2018);
- 2) to ensure the protection of human health and the environment;
- 3) to inform owners of the JUB STP of potential impacts of effluent discharge to the receiving environment to guide sound decision-making in the operation of the JUB STP; and,
- 4) to inform First Nations, the public and other stakeholders of environmental quality in the receiving environment.

In addition, specific JUB STP REMP monitoring objectives below were determined based on information obtained during the Stage 2 EIS (G3, 2020). Specific objectives for the REMP include, though not limited to, monitoring for the purpose of:

- 1) ensuring preservation of the ecological integrity of the Cowichan Bay and Satellite Channel receiving environment and adjacent areas;
- 2) ensuring that water quality conditions in Cowichan Bay and Satellite Channel outside the initial dilution zone (IDZ) will continue to support use of fisheries resources by First Nations, recreational and commercial users (i.e. geoduck);
- 3) maintaining water quality suitable for safe recreational use in the Cowichan Bay and Satellite Channel area; and,
- 4) determining spatial and temporal trends in environmental quality.

2.1.1 Sanitary Closure

First Nations have expressed a desire to see the sanitary closure in Cowichan Bay lifted in the future. An annual closure for shellfish harvesting is currently in effect within waters and intertidal foreshore of Cowichan Bay, including Genoa Bay and Boatswain Bank (Figure A1-2, Appendix A).

Sanitary closure for shellfish harvesting (for any purpose) is permanently closed within 300 m around industrial, municipal and sewage treatment plant outfall discharges from any wastewater treatment plant discharge and within 125 m around a marina, ferry wharf, floating living accommodation or any finfish net pen (DFO, 2020). This closure is imposed by the federal government for protection of public health. The relocated outfall just beyond the embayment line of Cowichan Bay is further than 300 m from any intertidal areas.

2.1.2 Conceptual Model for REMP

Information on the receiving environment in the Cowichan Bay and Satellite Channel, quality of the JUB STP effluent and potential responses of receptors in the receiving environment to stressors associated with wastewater discharges is summarized for a conceptual model to guide the study design for the monitoring program (Table 2-1).

Table 2-1: Conceptual Model Components for the REMP	
Component	Description
1. Statement of monitoring goals	- Ensure compliance with the <i>MWR</i>; - Ensure the protection of human health and the environment; - Inform owners of the JUB STP of potential impacts of effluent discharge to the receiving environment to guide sound decision-making; and, - Inform the public, stakeholders and First Nations of environmental quality in the receiving environment.
2. Statement of monitoring objectives	- Ensure preservation of the ecological integrity of the Cowichan Bay/ Satellite Channel receiving environment and adjacent areas; - Ensure that water quality conditions in Cowichan Bay and Satellite Channel outside the IDZ will continue to support use of fisheries resources by First Nations, recreational and commercial users (i.e. geoduck); - Ensure that water quality is suitable for safe recreational use in the Cowichan Bay and Satellite Channel area; and, - Determining spatial and temporal trends in environmental quality.
3. Identification of the ecological and human receptors in the receiving environment	- Fish, shellfish, marine mammals and other forms of aquatic life; - Recreational users; and, - First Nations traditional and ceremonial use.
4. Identification of the human activity of interest that may place stress on the receptors	The release of treated municipal wastewater through a submerged diffuser at the JUB STP effluent outfall.
5. Identification of other stressors on the receiving environment that must be considered	- Lambourn Wastewater treatment plant outfall; - Marine vessels; - Marinas; - Upland non-point sources including runoff from agricultural, commercial, residential and industrial activities and septic fields; - Contaminants in Cowichan/Koksilah rivers from point sources, such as discharge from the Town of Lake Cowichan Wastewater Treatment Plant, and non-point sources from runoff entering the Cowichan/Koksilah rivers; and, - Climate change
6. Identification of processes that reduce exposure to potential receptors	- Exposure unlikely outside the IDZ given high quality of wastewater treatment and very high dilution rate predicted; - At the IDZ boundary, bacteria levels predicted to be <2 CFU/ 100 mL and other parameters of interest (e.g. nutrient, metals) to meet available water quality guidelines; - Predicted trapping depth well below the water surface (>27.5 m deep), which will limit contact with recreational users and shellfish beds; and, - Sanitary closure for bivalve shellfish in effect in Cowichan Bay.
7. Identification of the pathways by which receptors may be exposed to stressors	- Dissolved chemicals or particulate material in the treated effluent discharge; - Potential ecological pathways include direct toxicity, eutrophication, reduced dissolved oxygen and elevated turbidity; and, - Potential human health effects pathways include direct contact or ingestion of fecal coliforms through recreational use or through ingestion of shellfish contaminated by bacteria and chemicals
8. Identification of the specific endpoints to be assessed (monitoring variables)	- Water quality at IDZ, mid-field and far-field stations to meet <i>MWR</i> and <i>WQG</i>; - Sediment quality assessed against sediment <i>WQG</i>; - Benthic invertebrate community indices and indicators relating to sediment and water quality; and, - Assessment of bioaccumulation in shellfish (i.e. clams) tissue.

Note: Adapted from AE, 2018.

2.2 Program Design Rationale

The REMP was developed considerate of the most appropriate study design including First Nations and local concerns in regard to sampling locations, sampling depth, timing and frequency of sample collection, type and number of samples to be collected and type of analyses to be performed. The rationale for each component is presented below.

Quality assurance and quality control (QA/QC) measures are incorporated in the REMP to ensure that reliable assessments can inform decision-making relating to the JUB STP marine effluent discharge.

2.2.1 Design

A radial gradient design with 21 sampling stations is proposed for the REMP. The radial gradient design is centred on the JUB STP outfall before extending over a spatial gradient away from the outfall and geographic extent of potentially discharge effects, if any. The proposed radial design is centered on the JUB STP outfall (central point herein referred to as terminus station) and extends to IDZ stations at the IDZ boundary (100 m from the most outward from the first and last diffuser ports) and Mid-Field (MF) and Far-Field (FF) stations at set distances away from the IDZ boundary (300 m and 1 km, respectively). The JUB STP outfall is proposed to be comprised of ten (10) diffuser ports each 10 m apart from one another; however, the final design is not yet determined. As such study design may be subject to change or re-evaluation.

MF and FF stations were selected based on major current directions into and out of Cowichan Bay and Sansum Narrows. Biological resource use (e.g., harvesting at shellfish beds), other activities (e.g., recreational activities, swimming, diving etc.) and First Nations and stakeholder concerns were also considered when selecting sampling stations, if the activity could potentially occur near the proposed outfall. FF stations (approximately 1 km from the IDZ boundary) are intended to represent ambient conditions, as stations are located outside the predicted influence of the JUB STP outfall. MF stations are located 300 m from the IDZ boundary to assess water quality between the NF and FF stations.

The receiving environment at the relocated marine outfall, within the extent of the sampling gradient design (within 1 km of the IDZ boundary), is generally uniform. Bottom depths are approximately 60 m, except to the north near Separation Point where a depression is recorded reaching a depth of approximately 100 m. Currents near Separation Point are also more localized. Bottom characteristics were carefully considered when selecting sampling stations for the benthic invertebrate survey to avoid confounding influences associated with changes in the physical environment, which are unrelated to effluent discharge from the JUB STP outfall and could affect results.

In addition, three (3) sampling locations for the collection of bivalve shellfish for bioaccumulation testing were selected following discussion with Cowichan Tribes. Sampling locations are based on Cowichan Tribes traditional and ecological knowledge (Appendix A2-4, Appendix 1).

The number and location of sampling stations should be re-evaluated during reassessment of the monitoring program and amended as necessary. In particular, given the predicted high dilution rate of the final effluent in the receiving environment, it is anticipated that the number of MF and FF sampling stations may be reduced when the program is re-assessed.

2.2.2 Sampling Stations

For the purpose of this report the naming convention for sampling stations was based on the numbering on a clock, with 12 o'clock located directly to the north. Stations were assigned a name based on the corresponding number closest to the position in relation to the 12 o'clock position. As discussed above, stations in the immediate area of release were named as Terminus (Term), located at the central point of all the diffuser ports, and IDZ stations, located 100 m outward from the first and last diffuser ports (i.e., IDZ-01, IDZ-03, etc.). MF and FF stations were named based on distance from the IDZ stations, namely 300 m and 1,000 m (i.e., 300-02, 300-03, 1000-01, 1000-03, etc.).

Stations for the REMP are listed in Table A1-1 (Appendix 2) and depicted in Figures A2-1 to A2-4 (Appendix 1) for each component (matrix) of the REMP and in total include:

- One (1) terminus (Term) station at the JUB STP outfall;
- Seven (7) IDZ stations at the edge of IDZ (100 m outward from the first and last diffuser port) spaced evenly in all directions;
- Six (6) MF stations, approximately 300 m from the IDZ boundary, located north, northeast, east, southeast, southwest and northwest;
- Seven (7) FF stations, approximately 1 km from the IDZ boundary, located northeast, east, southeast, south, west, northwest and southwest; and,
- Three (3) stations for collection of bivalve shellfish tissue for bioaccumulation.

Not all stations are sampled for each component of the REMP. As the outfall configuration has not been finalized, confirmation of the JUB STP outfall final configuration and re-assessment of sampling stations location will be required prior to sampling.

2.2.3 Components

The REMP includes five (5) components: effluent characterization; water quality; sediment quality; benthic invertebrate communities; and, bioaccumulation in shellfish tissue. Each component will complement one another to determine potential impacts through the different matrices. It is also recommended that sampling be done concurrently to aid in interpretation of results, in particular for sediment chemistry testing and benthic invertebrate surveys. Monitoring results will be compared to regulatory limits or guidelines to assess compliance and protection of human health and the environment.

Water Quality

Monitoring of water quality where effluent is discharged is prescribed under the *MWR* to ensure that bacteria levels meet limits at the edge of the IDZ. In addition, under the *MWR*, monitoring must ensure that effluent discharge “does not cause water quality parameters outside the initial dilution zone, to fail to meet water quality guidelines.” (BCG, 2018). Water quality guidelines are defined under the *MWR* as those “published under the authority of the Minister”, or in the absence of BC water quality guidelines or objectives, “any other water quality standard acceptable to the minister” (BCG, 2018).

Outside the IDZ, compliance with *BC Approved or Working Water Quality Guidelines for the Protection of Aquatic Life* (BCAWQGs or BCWWQGs) will ensure that aquatic organisms will not suffer deleterious effects in marine waters. In addition, marine waters will be assessed to ensure protection of human health for recreational users and through consumption of aquatic resources. Federal guidelines published by the *Canadian Council of Ministers of the Environment* (CCME) or *Federal Environmental Quality Guidelines* (FEQGs) will also be used where no provincial guidelines are available, in particular, for sediment and for contaminants of emerging concern. Spatial and temporal trends will be also be determined as part of REMP.

Sediment Quality

Sediment is a sink for many compounds released in the environment and can also be a source of the same compounds if they are re-released into the water through resuspension or desorption. Benthic organisms live in close contact with sediment and can ingest and come into contact with compounds in sediment. Sediment monitoring will assess potential long-term impacts. Spatial and temporal trends are to be determined as part of this REMP.

Biological Monitoring

Several types of biological indicators can be used for monitoring programs and were considered. Characteristics of good indicators which were sought included: relatively sedentary organisms,

presence near the area of discharge (naturally or placed *in situ* for a given period of exposure), good indicators of water quality given their feeding habit (e.g. filter feeding organisms) and/or, tendency to accumulate chemicals.

Shellfish species of specific clams (manila [*Tapes philippinarum*], varnish [*Nuttallia obscurata*], horse [*Tresus* sp.] and cockle clams [Cardiidae]) would be selected as bioindicators given their relevance as a local food resource valued by First Nations. In addition, clams are sedentary filter feeding organisms found in the general area of the relocated outfall (harvesting areas identified by Cowichan Tribes). Concentrations of potential contaminants in clam tissue will be tested to ensure that there are no impacts from the JUB STP effluent on bioaccumulation in shellfish bivalves.

Benthic invertebrate community surveys are also included in the REMP. Benthic invertebrates are generally sedentary organisms, which are exposed to compounds in sediment and/or at the sediment/water interface. Contaminant exposure to biota is typically dominated by the sediment pathway and benthic invertebrates are biological indicators that can assess potential changes over a longer time period and provide an ecosystem perspective. Depending on feeding habits, benthic invertebrates can ingest sediment and become exposed and effected by certain compounds if present in high concentrations. Benthic invertebrate community structure provides information on aquatic environmental conditions and the amount of bioavailable energy to fish and as such, a measure of fish habitat health. Benthic invertebrates are sensitive to changes in environmental conditions (e.g. exposure to chemicals and organic matter, water quality, light, substrate particle size, temperature, depth, water flow, etc.) and given their sensitivity, are widely used in assessment of environmental quality by assessing changes in community structure. Benthic invertebrate community surveys are used regionally for assessing other WWTP receiving environment (e.g., Metro Vancouver, Regional District of Nanaimo) and therefore responses can be compared. Benthic invertebrate surveys are to be done concurrently with sediment assessments to aid in interpretation of results.

STP Final Effluent Characterization

JUB conduct regular STP effluent testing required under Operational Certificate ME-01497. It is recommended that a summary of results be included in the annual REMP report. In addition, effluent testing is recommended as part of the REMP, concurrently with receiving environment water quality sampling, to aid in interpretation of receiving environment results and complement and verify regular sampling already conducted at the JUB STP. To ensure that the REMP remains cost-effective, a number of organic parameters and contaminants of emerging concern (CECs) are to be tested in STP effluent first to determine their presence and to ensure that levels are sufficiently high in effluent to warrant further receiving environment testing. Similarly, several organic parameters and CECs will only be tested in sediment and clam tissue if they were first detected in STP effluent. Given the timeframe for analysis of organic compounds and CECs, monitoring of the same parameters measured at comparatively high level in STP effluent will be tested in the receiving environment in the next seasonal sampling event.

STP final effluent will be sampled in duplicate, concurrent with receiving environment water quality sampling, once in summer (dry season) and once in winter (wet season).

2.2.4 Sampling Depths

Water quality will be monitored at three (3) depths in marine water: near surface (1 m below), near bottom (2 m above ocean floor); and, at trapping depth.

Near surface (1 m below the surface) samples will assess water quality which human and animals could encounter in the upper water column. The surface samples will also verify if the effluent will remain trapped below the surface at the sampling stations.

Water samples will be collected 2 m just above the bottom to assess water quality near-bottom where benthic organisms reside.

Water samples will be collected at the trapping depth in an effort to capture the effluent plume in the receiving environment and, therefore, highest potential concentrations of effluent parameters. As discussed in Section 1.6, the trapping depth is based on EIS Stage 2 modelling of worst-case scenarios and predicted to occur at 35 m in winter and 45 m in summer (G3, 2020).

2.2.5 Timing

Water sampling for the REMP is to be conducted annually during two (2) seasons given the potential variability in effluent quality and consequently in water quality, while the sediment sampling and benthic invertebrate community surveys are recommended once every three (3) years to assess longer-term trends in the receiving environment. The REMP was designed on a three-year cycle.

2.2.6 Seasonality

Given seasonal differences, the REMP design includes water sampling during the winter rainy season and summer low flow period to assess water quality; however, if results are comparable for the two seasons over time, the program could potentially focus only on one (1) sampling season.

Timing of water sampling for the REMP was determined based on site-specific information on climate, hydrology and oceanography (summarized in Chapter 1). There is a seasonal variation in the amount of precipitation in the Cowichan Bay area, the highest being in the winter rainy season and lowest during the summer dry period. The amount of precipitation directly influences the flow of the rivers draining into the Cowichan estuary and Cowichan Bay and, therefore, the estuarine circulation in the Bay. In 2018, increased river flow into Cowichan Bay was reflected in differences in physical parameters and bacteria levels in December compared to other times of the year when river flows were lower. Surface runoff also increases during the wet period which can potentially lead to increased concentrations of various contaminants and particulate matter from non-point sources (agricultural fields, roads and other impervious surfaces, septic fields, etc.). Finally, increased infiltration into the sanitary system increases flow to the JUB STP and discharges at the outfall. There was also a seasonal difference in the predicted trapping depth of approximately 10 m in the summer compared to the winter (35 m), trapping depth being deeper in the summer (45 m).

2.2.7 Parameters

Parameters recommended for the REMP include parameters with regulatory limits under the *MWR* (i.e. bacteria), parameters associated with wastewater effluent for which *BCAWQGs* or *BCWWQGs* are available (e.g. ammonia, some metals). Other parameters which are known or suspected to be present in the JUB STP effluent which may cause deleterious effects on human health or aquatic organisms in the receiving environment were also included. Parameters regulated under the Wastewater System Effluent Regulations (WSER) and the JUB STP Operational Certificate (ME-01497) were included as appropriate.

2.3 Pre-Discharge Receiving Environment Monitoring Program

The REMP is to be implemented prior to effluent discharge at the relocated outfall to obtain baseline data for comparison with post-discharge results. In addition, ambient monitoring conducted in Cowichan Bay and Satellite Channel provide supplemental pre-discharge data for the REMP. Results from the EIS should be compared with the REMP results when appropriate.

Pre-discharge monitoring is anticipated to occur in 2020/2021, once in summer (i.e. dry season, July or August 2020) and once in winter (i.e. wet season, November 2020, December 2020 or January 2021).

The Pre-discharge REMP sampling is to follow the description provided for the Post-discharge REMP (Section 2.4) for the receiving water monitoring and benthic invertebrate community study to ensure data are comparable for spatial and temporal trends analysis. The Pre-Discharge REMP is to include all parameters listed for the sediment monitoring and bioaccumulation in the Post-Discharge REMP to obtain

baseline data for all parameters listed (regardless of whether they were high in effluent) to be able to assess spatial and temporal trends in the future.

2.4 Post-Discharge Receiving Environment Monitoring Program

The REMP is to be implemented with the first monitoring season (summer or winter) starting approximately one month after the proposed outfall begins operation and continue for the duration of the operation of the relocated effluent outfall.

The Post-discharge monitoring program is to consist of a three (3) year cycle involving water sampling twice annually (summer dry season and winter wet season) and sampling for sediment, benthic invertebrate communities and clam tissue bioaccumulation undertaken once every three (3) years (once per cycle; Table 2.2).

Table 2-2: Sampling Regime for JUB STP Receiving Environment Monitoring Program (REMP)								
Program	Pre-discharge		Post-discharge					
Sampling	Summer 2020	Winter 2020	Year 1 Summer	Year 1 Winter	Year 2 Summer	Year 2 Winter	Year 3 Summer	Year 3 Winter
Effluent	X	X	X	X	X	X	X	X
Water	X	X	X	X	X	X	X	X
Model Verification			X					
Sediment	X				X			
Biological Communities Benthic Invertebrates	X				X			
Biological Communities Bioaccumulation	X				X			

2.4.1 Model Verification

To ensure that plume trapping depth and direction and predicted dilution using the Visual Plume model was accurate and that REMP sampling stations are appropriate to assess the effluent discharge, a tracer study is recommended in the first year of effluent discharge to verify plume dynamics.

2.4.2 Effluent Characterization

Bi-annual effluent characterization is one component of the REMP to be done in addition to regular JUB STP effluent testing required under Operational Certificate ME-01497. It is recommended to be done concurrently with receiving environment water quality sampling, to aid in interpretation of receiving environment results. The effluent characterization will include the parameters listed in Table 2-3 (below) with rationale provided in Table A2-1 (Appendix 2).

2.4.2.1 Sampling Station

Final JUB STP effluent is to be collected from a dedicated sampling outlet within the treatment plant prior to discharge.

2.4.2.2 Timing & Frequency

Effluent characterization is to be conducted bi-annually, once in the summer dry period (July or August) and once in the winter wet season (December to February), concurrently with receiving water monitoring.

2.4.2.3 Replication

Duplicate samples are to be collected.

2.4.2.4 QA/QC

Travel blanks, field blanks and other QA/QC measures are to be incorporated into the monitoring program during each sampling event.

2.4.2.5 Parameters

The rationale for effluent characterization parameters included in the REMP is presented in Table A2-1 (Appendix 2) and summarized in Table 2-3.

Table 2-3: JUB STP REMP Effluent Characterization		
Parameter	Analyte	Sampling
Freshwater (final effluent) Bacterial Parameters	Fecal Coliforms	Bi-annual once in Winter & Summer
	<i>Enterococcus</i>	
Freshwater (final effluent) Physicochemical Parameters	Alkalinity, Colour, Conductivity, pH, Hardness, Anions (Cl, F, Br, SO ₄)	
	Total Residual Chlorine (TRC)	
	Ammonia	
	Total Suspended Solids (TSS)	
	5-day Carbonaceous Biochemical Oxygen Demand (CBOD ₅)	
	Chemical Oxygen Demand (COD)	
	Total Organic Carbon (TOC) & Dissolved Organic Carbon (DOC)	
	Nutrients – Nitrogen (Total Nitrogen [TN], Total Kjeldahl nitrogen [TKN], Total Organic Nitrogen [TON], Nitrate, Nitrite)	
	Nutrients – Phosphorus (Total Phosphorus [TP], Orthophosphate [OP])	
	Total Metals - full scan (including Mercury) ¹	
	Polycyclic Aromatic Hydrocarbons (PAHs)	
	Polychlorinated Biphenyls (PCBs)	
	Polybrominated Diphenyl Ethers (PBDEs)	
	Alkylphenols & Bisphenol A	
	Pharmaceuticals and Personal Care Products (PPCP)	
	Other Contaminants of Emerging Concerns (CECs) ²	

Notes: ¹ Dissolved metals tested only if total metals levels are above water quality guidelines in the receiving environment.

² As identified and for which there are marine water quality guidelines.

2.4.3 Receiving Environment Water Quality Monitoring

The MWR stipulates that “the discharger must not discharge municipal effluent unless, at the edge of the IDZ, applicable water quality guidelines are met” (BCG, 2018) and also sets specific limits for fecal coliform and *Enterococcus* bacteria. The rationale for design elements included in the REMP were discussed above. Results are to be compared to applicable BCAWQGS and BCWWQGs (BCMOE, 2001; 2017; 2018).

2.4.3.1 Sampling Stations

Water sampling stations are listed in Table A1-1 (Appendix 2) and depicted in Figures A2-1 (Appendix 1) and include:

- One (1) terminus (Term) station at the JUB STP proposed outfall;
- Six (6) NF stations at the edge of IDZ spaced evenly in all directions (IDZ-01, IDZ-03, IDZ-05, IDZ-07, IDZ-09 and IDZ-11);
- Six (6) MF stations, 300 m from the IDZ spaced evenly in all directions (300-02, 300-03, 300-05, 300-07, 300-10 and 300-12); and,
- Seven (7) FF stations, 1 km from the IDZ and spaced for effective geographic coverage in the main current direction (1000-01, 1000-03, 1000-04, 1000-05, 1000-08, 1000-09 and 1000-10).

2.4.3.2 Sampling Depths

At all stations, sampling is to be conducted:

- near surface (1 m below);
- near bottom (2 m above ocean floor); and,
- at trapping depths (predicted to be 35 m in winter, 45 m in summer; based on EIS Stage 2 modelling [G3, 2020] results).

Sampling need to be done at the actual trapping depth as confirmed by sampling and model verification to ensure the effluent plume is captured.

2.4.3.3 Timing & Frequency

Samples collected are to provide enough data to be statistically robust and to allow for comparison against applicable long-term water quality guidelines. Applicable long-term water quality guidelines (WQG) recommend five (5) sampling events over 30 days to enable calculation of averages and an assessment of variability (BCMOE, 2018). Thirty-day averages are required for the calculation of geometric means and 90th percentile microbiological concentrations under the MWR (BCG, 2018).

It is recommended that water quality sampling be conducted bi-annually, with 5 sampling events within 30 days occurring twice in one year, once in the summer dry period (July or August) and once in the winter wet season (December to February).

2.4.3.4 Replication

Field duplicate samples to represent a minimum of 10% of samples.

2.4.3.5 QA/QC

Travel blanks, field blanks and other QA/QC measures are to be incorporated into water quality monitoring during each sampling event.

2.4.3.6 In situ Water Profiling

In situ measurements of salinity, dissolved oxygen, conductivity, temperature, turbidity and pH throughout the water column (surface to near-bottom) are to be recorded at 1 m intervals at each station during each sampling event to assess water quality with results compared to *BCAWQGs*. Stratification (thermal and for salinity) and potential presence of the plume is to be noted if detected based on physical parameters measured.

2.4.3.7 Parameters

The rationale for water parameters included in the REMP is presented in Table A2-2 (Appendix 2) and summarized in Table 2-4. Organic compounds (PAHS, PCBs, PBDEs, Alkylphenols, Bisphenol A) and CECs (Pharmaceuticals and Personal Care Products, other CECs) are to be tested in final effluent only if detected at levels sufficient high in effluent to warrant further testing (when accounting for effluent dilution).

Table 2-4: JUB STP REMP Water Monitoring Program Summary			
Parameter	Analyte	Station	Sampling Period
<i>In situ</i> profiles in seawater	Salinity, Dissolved Oxygen, Conductivity, Temperature, Turbidity, pH.	All	5 sampling events within 30 days during each season (Winter & Summer). 10 samples annually.
Seawater Bacterial Parameters	Fecal Coliforms	All	
	<i>Enterococcus</i>		
Seawater Physicochemical Parameters	Ammonia		
	Total Suspended Solids (TSS)		
	Total Organic Carbon (TOC) and Dissolved Organic Carbon (DOC)		
	Nutrients – Nitrogen (Total Nitrogen [TN], Total Kjeldahl nitrogen [TKN], Total Organic Nitrogen [TON], Nitrate, Nitrite)		
	Nutrients – Phosphorus (Total Phosphorus [TP], Orthophosphate [OP])		
	Total Metals - full scan (including Mercury)		
	Polycyclic Aromatic Hydrocarbons (PAHs) ¹		
	Polychlorinated Biphenyls (PCBs) ¹		
	Polybrominated Diphenyl Ethers (PBDEs) ¹		
	Alkylphenols & Bisphenol A ¹		
	Pharmaceuticals and Personal Care Products (PPCP) ¹		
	Other Contaminants of Emerging Concerns (CECs) ^{1,2}		

Notes: ¹ parameters only to be tested in the receiving environment if noted to be high in effluent samples.

² As identified and for which there are marine water quality guidelines.

2.4.4 Receiving Environmental Monitoring of Sediment

The rationale for the sediment quality monitoring in the receiving environment was presented in Section 2.2 and details of the program provided below. Sediment results are to be compared to applicable provincial and federal sediment quality guidelines, including the Canadian Council of Ministers of the Environment's (CCME) Sediment Quality Guidelines (CCME, 2018) and other relevant sediment quality benchmarks. CCME Interim Sediment Quality Guidelines (ISQG; CCME, 2018) are concentrations below which adverse biological effects are expected to occur rarely and CCME Probable Effects Levels (PEL) are concentrations above which adverse biological effects are likely to occur (CCME, 1995). Other published sediment quality guidelines used in sediment assessments include Threshold Effect Level (TEL; MacDonald *et al.*, 1996); and Apparent Effect Threshold (AET; Buchman, 2008).

2.4.4.1 Timing and Frequency

Sediment monitoring is to occur every three (3) years during the dry season (July or August), concurrently with water sampling, in the second year of the three-year cycle.

2.4.4.2 Stations

Proposed stations are listed in Table A1-1 (Appendix 2) and depicted on Figure A2-2 (Appendix 1) and include:

- Four (4) NF at the edge of IDZ (IDZ-03, IDZ-05, IDZ-09 and IDZ-12);
- Six (6) MF stations, 300 m from the IDZ spaced evenly in all directions (300-02, 300-03, 300-05, 300-07, 300-10 and 300-12); and,
- Seven (7) FF stations, 1 km from the IDZ and spaced for effective geographic coverage in the main current direction (1000-01, 1000-03, 1000-04, 1000-05, 1000-08, 1000-09 and 1000-10).

2.4.4.3 Replication

One chemistry composite sample is to be collected at each station; however, several stations are located at the same distance from the outfall and can be considered as replicate stations for assessments. Composite samples are to be comprised of three (3) separate grab samples. To avoid loss of volatile during mixing of composite samples, discrete samples are to be collected for acid volatile sulphide (AVS) and simultaneously extracted metals (SEM) testing.

2.4.4.4 Parameters

The rationale for sediment parameters included in the REMP is presented in Table A2-3 (Appendix 2) and summarized in Table 2-5.

2.4.4.5 QA/QC

Field duplicate samples are recommended to represent a minimum 10% of samples as well as other QA/QC measures are to be incorporated into the sediment quality monitoring program.

Table 2-5: JUB STP REMP Sediment Quality Parameters Summary			
Parameter	Analyte	Station	Sampling Period
Bacteria in Sediment	<i>Enterococcus</i>	All	Summer
	Coliform Bacteria - Fecal		
Sediment Physicochemical Parameters	Moisture	All	Summer
	pH (1:2 soil:water)		
	Particle Size Composition		
	Ammonium-N		
	Total Nitrogen		
	Total Carbon		
	Total Inorganic Carbon		
	Total Organic Carbon		
	C:N Ratio		
	C13 & N15 Stable isotopes		
	Total Metals		
	Extractable Metals		
	Acid Volatile Sulphides		
	Polycyclic Aromatic Hydrocarbons (PAHs) ¹		
	Polychlorinated Biphenyls (PCBs) ¹		
	Polybrominated Diphenyl Ethers (PBDEs) ¹		
	Alkylphenols ¹		
	Other Contaminants of Emerging Concerns (CECs) ^{1,2}		

Notes: ¹ parameters only to be tested in the receiving environment if noted to be high in effluent samples.

² As identified and for which there are marine sediment quality guidelines.

2.4.5 Biological Communities Monitoring

2.4.5.1 Benthic Invertebrate Community

Benthic invertebrate community structure is part of the REMP as a bioindicator to provide information on aquatic environmental conditions and changes associated with discharge of JUB STP effluent, if any.

2.4.5.1.1 Timing & Frequency

Benthic invertebrates are to be sampled during the summer dry season (July or August) every three (3) years, concurrently with sediment sampling in the second year of the three-year cycle. Benthic invertebrate community structure varies by season and is to be conducted at a similar time in successive cycles to allow comparison of results over time.

2.4.5.1.2 Stations

Proposed stations are listed in Table A1-1 (Appendix 2) and depicted on Figure A2-3 (Appendix 1). Stations were established along similar substrate and depth to avoid community changes associated with sediment composition, depth and water flow. Stations include:

- Four (4) NF stations at the edge of IDZ (IDZ-03, IDZ-05, IDZ-09 and IDZ-12);
- Six (6) MF stations, 300 m from the IDZ spaced evenly in all directions (300-02, 300-03, 300-05, 300-07, 300-10 and 300-12); and,
- Five (5) FF stations, 1 km from the IDZ and spaced for effective geographic coverage in the main current direction (1000-04, 1000-05, 1000-08, 1000-09 and 1000-10).

2.4.5.1.3 Replication

Five (5) replicate grab samples are to be collected at each station. Three (3) replicates are to be sent to a taxonomist for identification with power analysis completed on results and the two (2) remaining samples also to be sent for identification if required (based on power analysis results).

2.4.5.1.4 Parameters & Endpoints

Benthic invertebrates collected from a 0.1 m² area and sieved in the field using a 1.0 mm sieve are to undergo taxonomic identification to the lowest taxonomic level possible (ideally to species) using standard references and sorted into size class (adults, intermediate and juvenile). The endpoints assessed are to include benthic invertebrate abundance (density), species richness, common taxa, feeding guilds, diversity, evenness and dominance indices to describe community structure at each site. Biomass may also be assessed for each taxon. A reference collection is to be created and verified. Supporting parameters such as sediment particle size analysis and TOC are to be tested.

2.4.5.1.5 QA/QC

QA/QC measures are to include sorting efficiency, re-identification and external verification, as appropriate.

2.4.5.2 Bioaccumulation

Clam tissue chemistry analysis is a component of the REMP to assess potential bioaccumulation of compounds of interest found in JUB STP effluent.

2.4.5.2.1 Timing & Frequency

Clams are to be collected every three years in the summer dry season (July or August), concurrent with sediment quality monitoring and benthic invertebrate sampling (in the second year of the three-year cycle).

2.4.5.2.2 Stations

Proposed stations are listed in Table A1-1 (Appendix 2) and depicted on Figure A2-4 (Appendix 1). Stations include:

- One (1) station at Cherry Point (T-01);
- One (1) station near Separation Point going toward Genoa Bay (T-02); and,
- One (1) station on the south side of Salt Spring Island (T-03).

Stations are located at known shellfish harvesting areas based on input from Cowichan Tribes and in the vicinity of the proposed outfall location.

2.4.5.2.3 Replication

One composite sample comprised of sufficient individuals to facilitate analysis is to be collected from each station.

2.4.5.2.4 Parameters

The rationale for bioaccumulation parameters included in the REMP is presented in Table A2-4 (Appendix 2) and summarized in Table 2-6.

2.4.5.2.5 QA/QC

Field duplicate samples are recommended to represent a minimum 10% of samples as well as other QA/QC measures are to be incorporated into the bioaccumulation program.

Table 2-6: JUB STP REMP Bioaccumulation Parameter Summary		
Type	Analyte	Summer
Bacteria	Fecal Coliforms	✓
	<i>E. coli</i>	
Chemistry	Supportive parameters -lipids, moisture	
	Total Metals	✓
	Polycyclic Aromatic Hydrocarbons (PAHs) ¹	✓
	Polychlorinated Biphenyls (PCBs) ¹	✓
	Polybrominated Diphenyl Ethers (PBDEs) ¹	✓
	Alkylphenols ¹	✓
	Other Contaminants of Emerging Concerns (CECs) ^{1,2}	✓

Notes: ¹ parameters only to be tested in the receiving environment if noted to be high in effluent samples.

²If found in effluent and has bioaccumulation properties.

2.5 REMP REVIEW

The REMP is designed on a three-year cycle with re-evaluation after every two cycles; however, an initial review should be undertaken after completion of the pre-discharge monitoring and one cycle of the post-discharge monitoring program to assess if two (2) seasons of sampling are necessary. Sampling frequency, stations, matrices, and parameters tested, may be modified based on pre- and post discharge monitoring results.

3.0 METHODS

This chapter provides methodologies to be employed for the Receiving Environment Monitoring Program (REMP) for the Duncan/North Cowichan Joint Utility Board (JUB) Sewage Treatment Plant (STP) proposed outfall relocation. The REMP includes collection of JUB STP final effluent; field sampling of water, sediment and benthic invertebrate communities in the receiving marine environment; *in situ* water quality profiling; and, collection of shellfish tissues for bioaccumulation monitoring.

Most recent *BC Field Sampling Methodology* published and regularly updated on the BC Government website (BCG, 2019) is to be followed for field sampling or in the absence of BC Government published methods, other well-established protocols are to be followed, where appropriate. Analytical testing is to follow the *BC Environmental Laboratory Manual* with alternated well-established methods to be used in the absence of BC Government methods, as appropriate. Methods used for collecting and processing samples for benthic invertebrate community surveys are to follow well established and rigorous protocols to obtain reliable data.

Use of consistent methods to be employed for the REMP is required to ensure comparability of data and enable appropriate spatial and temporal trends assessment. Methodologies employed for the ambient monitoring are presented in the Stage 2 Environmental Impact Study (EIS) report (G3, 2020).

Quality assurance and quality control measures are to be implemented while conducting sampling and analytical tests to ensure data reliability. Field protocols are to ensure the identity and integrity of the samples are maintained, cross-contamination is avoided and that proper description of the samples are noted to enable appropriate interpretation of laboratory results. Laboratory testing is to be conducted by Canadian Association for Laboratory Accreditation (CALA) accredited analytical laboratories using appropriate methods, detection limits and done within recommended hold times. Detection limits are to be lower than the *BC Approved Water Quality Guidelines* (BCAWQGs), federal water quality guidelines, provincial and federal sediment quality guidelines and provincial and federal tissue residue guidelines, as appropriate.

4.0 REPORTING

The Receiving Environment Monitoring Program (REMP) runs on a three (3) year cycle, with sampling and analyses spread out across these years. At the end of the first and second year of the three (3) year cycle, an Annual Summary Report is to be prepared and submitted to document the program progress and to clarify any issues (i.e. exceedance of guidelines etc.). A Final Report is to be submitted at the end of the three (3) cycle and is to include comprehensive reporting of all trends over the duration of the cycle. Reports are to include (but not be limited too) the following:

- Executive summary & introduction (with rationale, objectives and any management objectives clearly defined);
- program methodology (including start-up/stations/field and laboratory analysis and QA/QC);
- a summary of adherence to data quality objectives (DQOs), standard operating procedures (SOPs) and sampling protocols;
- summary of stations (including attributes, coordinates, depths, etc);
- any details relevant to determining the quality or interpretability of the data;
- summaries of results and analyses (e.g., spatial/temporal trends, comparison to objectives/guidelines and ecological relevance);
- summary of water quality monitoring, including water column profiles and analytical results;
- summary of sediment quality and biological communities (benthic invertebrates and /bioaccumulation) results (in the year collected);
- where relevant and available, production of spatial trends analyses and any comparison with temporal trends (e.g., from previous programs);
- statistical calculations including (but not limited to) 30-day averages, maximum/minimum values and maximum concentrations (total ammonia); 90th percentile (fecal coliform and *Enterococcus*), 30-day geometric means (fecal coliform and *Enterococcus*);
- interpretation of results with respect to applicable Water Quality Guidelines (WQG);
- spatial and temporal trends in water quality where applicable;
- Summary and Conclusion of results; and,
- Recommendations.

An appendix is to include (but not be limited to):

- raw field data;
- raw taxonomic and analytical data;
- tabular summaries of each benthic invertebrate community endpoint;
- tabular summaries of major benthic invertebrate taxonomic groups;
- study area figures; and,
- summary charts, tables and any schematics.

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6.0 GLOSSARY

Glossary

Abundance	The count of all individuals (i.e., # organisms) in a sample or per unit of sampling area (same as density).
Ambient (Ecological)	Refers to current ecological conditions of the surrounding environment.
Ammonia (NH₃) / Ammonium (NH₄⁺)	Ammonia is a naturally occurring compound required by most organisms for protein synthesis and is a waste product of animal, fish and microbial metabolism. Ammonium is derived from ammonia by combination with a hydrogen ion, present in solutions of ammonia and in salts derived from ammonia.
Analyte	A substance or chemical constituent undergoing analysis.
Anion	A negatively charged ion, e.g., NO ₃ ⁻ , NO ₂ ⁻ (cf. Cation).
Anthropogenic	Human-caused.
Benthic	Relating to or occurring at the bottom of a body of water.
Benthic Invertebrates	Animals without a backbone, living on or in the bottom of a water body (ocean, sea, lake, river, etc.).
Benthos	See Benthic Fauna and Benthic Invertebrates.
Biota	The plant, animal and microbial life in a region.
BOD (Biochemical Oxygen Demand)	Determined by measuring the quantity of oxygen consumed by a water or wastewater sample under controlled conditions (20°C, neutral pH) for a defined time period. The most commonly used period is 5 days (sometimes written BOD ₅), and BOD ₅ test is common in North America and has been adopted in this report. BOD is expressed as mg/L, the same unit as is customary for dissolved oxygen, or simply as a weight.
Formalin	A preservative that has had its low pH neutralized with sodium bicarbonate or sodium borate to prevent dissolution of calcium-based samples (e.g., shellfish).
Canadian Association for Laboratory Accreditation (CALA)	Not-for-profit Canadian laboratory accreditation body that employs rigorous international standards and evaluations to ensure analytical quality assurance and quality control (QA/QC) are maintained.
Carbon-Nitrogen (C:N) Ratio	A ratio of the mass of carbon to the mass of nitrogen (e.g., 10:1, 50:1), often used to ascertain terrestrial versus marine sources of organic matter.
Chain-of-Custody (CoC)	Process of ensuring and proving documentation of proper sample identification and handling from the time of collection to the receipt of laboratory results.
Clay	Fine particles of sediment, defined as particles <4 µm in size.
Conductivity	Measuring the water's ability to conduct electricity. Conductivity increases with increasing amount and mobility of ions. A higher conductivity value indicates that there are more chemicals dissolved in the water.

Crustaceans	Animals of the large, mainly aquatic class Crustacea within the phylum Arthropoda, having a chitinous or calcareous and chitinous exoskeleton, a pair of often much modified appendages on each segment, and two pairs of antennae and that include the lobsters, shrimps, crabs, water fleas, barnacles, etc.
Density	Number of benthic invertebrate individuals in a given area (e.g., organisms per m ²).
Diversity Index	An index used to measure biological diversity, taking into account how many species and how evenly the individuals are distributed among the species.
Dissolved Oxygen (DO)	Referring to free, non-compound oxygen (O ₂) that are mixed in water and available to aquatic organisms for respiration, typically measured in milligrams/litre (mg/L), and widely used as a criterion for water quality.
Dissolved Organic Carbon (DOC)	Defined as the organic matter that is able to pass through a filter (filters generally range in size between 0.7 and 0.22 µm).
Dominant species	One of a small number of species which dominate in a community.
Ecosystem	A natural system consisting of all plants, animals and microorganisms in a given area, interacting with each other, and also with their non-living physical / chemical environments.
Effluent	A liquid waste or sewage discharged into the environment. In this report, effluent refers to final wastewater discharged from the wastewater treatment plant into natural waters and contains solid and dissolved constituents from the influent and treatment process.
Endpoint	A variable that indicates the termination of a test, and also a measurement or value characterizing results of the test (e.g., LC ₅₀). In the context of the EEM program, an endpoint also refers to a biological measurement of fish or a calculated index of benthic invertebrate community.
Environment	The sum total of all surroundings of a living organism in a particular geographical area, including natural conditions and other living things.
Estuary	A partly enclosed coastal body of brackish water with one or more rivers or streams flowing into it, and with a free connection to the open sea.
Eutrophication	Excessive richness of nutrients in a body of water, frequently due to runoff from the land, which causes a dense growth of plant life and death of animal life from lack of oxygen; or the ecosystem's response to the addition of artificial or natural nutrients.
Evenness	A measure of how evenly individuals are distributed among different species or taxa, typically measured by Pielou's Evenness Index and Simpson's Evenness Index.
Fauna	All of the animals of any particular region, habitat or time.
Field Replicate	Samples separately collected in the field at the same site during a sampling period.
Flora	All of the plants of any particular region, habitat or time.
Heavy Metals	Metallic elements that have relatively high atomic weight (e.g., mercury, cadmium, lead, etc.), and are potentially toxic or poisonous at low concentrations.
Initial Dilution Zone (IDZ)	The region near a diffuser where the effluent discharge velocity exceeds the velocity of receiving water, and therefore dominates the dilution process.
Inorganic	Relating to non-living matter or chemical compounds that do not contain carbon (cf. Organic).

Ion	An atom or molecule with a net electric charge due to the loss or gain of one or more electrons.
LC₅₀	Lethal concentration of a chemical or mixture causing 50% death of tested organisms in a given period of time.
Lethal	Causing death, or sufficient to cause death.
Matrix (plural Matrices)	Medium or substance which is examined and/or tested to enable an assessment of biological, chemical or physical conditions or properties.
Method Blank	A sample (often distilled water) that does not normally contain the analyte of interest but is processed through all steps of the analytical procedure with samples containing the analyte of interest.
mg/L	Milligrams of a substance in one litre of solution; equivalent to parts per million (ppm).
Mud	Generally referring to sediment particles <63 µm (i.e., silt and clay).
Near-Field Zone	The zone outside the initial discharge zone and with the highest effluent exposure.
Nutrient	A substance (element or compound) that provides nourishment essential for growth, development and functioning of life.
Organic	Referring to or derived from living matter; in chemistry, referring to compounds that contain carbon (cf. Inorganic).
Organic Matter	Matter composed of organic compounds that have come from the remains of organisms such as plants and animals and their waste products in the environment.
pH	A logarithmic measure of hydrogen ion (H ⁺) concentration; a scale from 0 to 14, with pH 7 representing neutral, pH below 7 acid and pH above 7 alkaline (or basic) conditions. Soft waters typically range from pH 6 to 7.5; hard waters are close to pH 8; pH can influence toxicity of chemicals in effluents.
Photosynthesis	The process by which green plants and some other organisms use sunlight to synthesize organic matter from carbon dioxide and water and generates oxygen as a byproduct.
Polychaete	A worm in the class of Polychaeta (phylum Annelida) with about 8000 species, mostly living in marine environments.
Productivity	The rate of production of new biomass by an individual, population, community, or ecosystem; includes primary productivity (biomass generated by photosynthetic and chemosynthetic autotrophs) and secondary productivity (biomass generated by heterotrophs).
Quality Assurance (QA)	A system for ensuring a desired level of quality in the development, production, or delivery of products and services.
Quality Control (QC)	A system for verifying and maintaining a desired level of quality in an existing product or service to meet the requirements of the client or customer.
Receiving Water	A body of water into which wastewater or effluent is discharged.
Richness (Species Richness or Taxa Richness)	Number of species or taxa recorded in a sampling unit.
Sand	Sediment particles <2 mm to >63 µm in size.
Silt	Sediment particles <63 µm to >4 µm in size.
Site	A station or precise location where collection of data and samples is carried out.

Sonde	A type of <i>in situ</i> water quality sensor and data recorder.
Spatial Comparison	A comparison to determine whether differences in a particular variable exist among different locations at a particular time.
Standard Operating Procedure (SOP)	A written document detailing method of analysis, operations or action whose techniques and procedures are thoroughly prescribed and that is accepted as the method for performing certain routine or repetitive tasks.
Station	A defined location within study areas where field replicate samples are collected.
Sulphide (S²⁻)	A chemical compound containing a sulphur ion (S ²⁻).
Taxon (plural Taxa)	A unit of scientific classification (i.e., taxonomy) of organisms; the major divisions are Kingdom, Phylum, Class, Order, Family, Genus and Species.
Taxonomy	A branch of biology specializing in identification, naming and classification of organisms.
Temporal Comparison	A comparison to determine whether differences in a particular variable exist among samples collected at different times in a particular area.
Thermocline	Thin but distinct layer of water in which temperature changes much more rapidly with depth than it does in either the layer above or below it.
TOC	Total organic carbon; the total amount of carbon found in organic compounds.
Total Kjeldahl Nitrogen (TKN)	The sum of all particulate and soluble organic nitrogen and ammonia.
Total Nitrogen (TN)	The sum of all forms of organic and inorganic nitrogen in water (i.e., TKN + nitrate + nitrite).
Toxic	Poisonous, dangerous, or harmful to a living organism.
Toxicity	The inherent potential or capacity of a material to negatively affect an organism under certain conditions.
Tracer	A substance that can be used to indicate the presence of effluent; the tracer concentration should be high in effluent and low in the receiving environment, detectable at each station, and variable between stations therefore showing dilution with distance from the diffuser.
Total suspended solids (TSS)	Total amount of small solid particles suspended in water; measured as the oven dry weight of solids, in mg/L, that have been collected on a standard filter paper.
Turbidity	A measure of the degree to which the water loses its transparency due to the presence of suspended particulates.

APPENDICES

Appendix 1: Figures

Appendix 2: Tables

Appendix 1

Figures

- Figure A1-1: Site Overview; Cowichan Bay, BC (2018)
- Figure A1-2: Ecologically Important Areas; Cowichan Bay, BC (2018)
- Figure A2-1: Receiving Environment Monitoring Program – Water Quality Sampling Stations
- Figure A2-2: Receiving Environment Monitoring Program – Sediment Quality Sampling Stations
- Figure A2-3: Receiving Environment Monitoring Program – Benthic Invertebrate Sampling Stations
- Figure A2-4: Receiving Environment Monitoring Program – Shellfish Bioaccumulation Sampling Sites

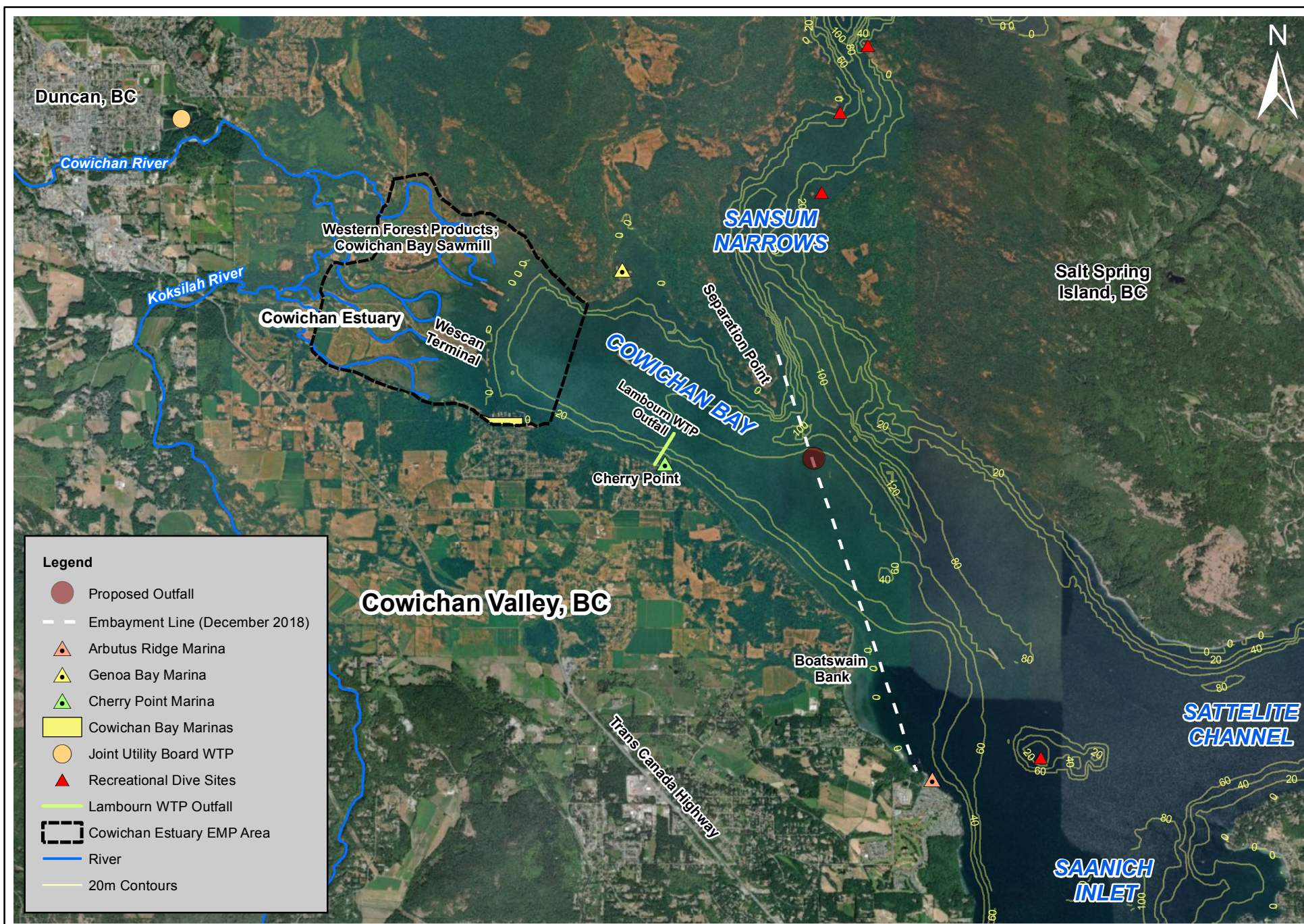


Figure A1-1: Site Overview; Cowichan Bay, BC (2018)

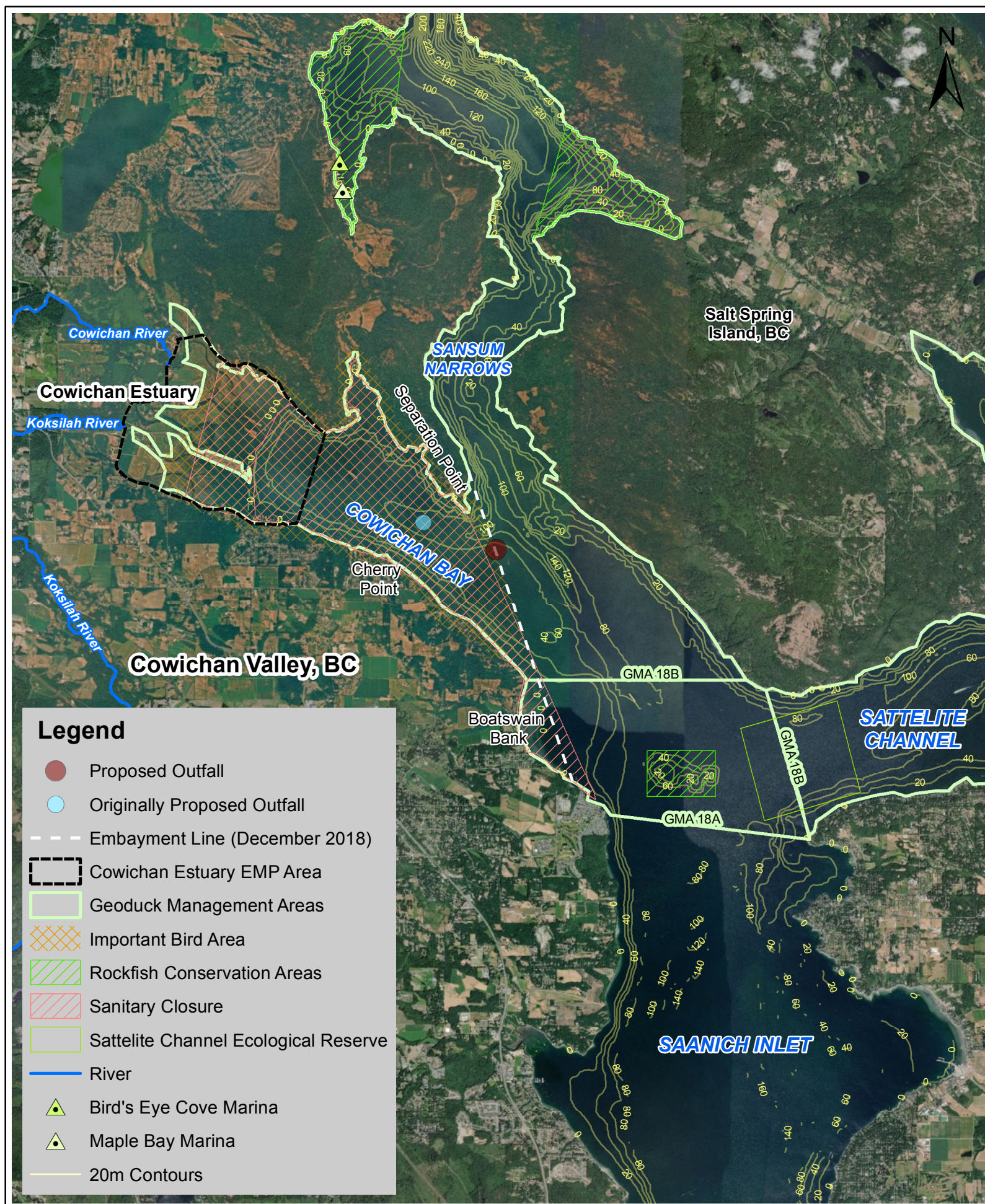
Date; Author: April 2, 2019; BM
 Coordinate System: NAD1983 UTM Zone 10N
 Scale: 1: 75,000

Notes: WTP - Wastewater Treatment Plant; EMP - Environmental Management Plan; Cowichan Bay Marinas include: Blue Nose Marina, Cowichan Bay Fisherman's Wharf, Cowichan Bay Marina Ltd, Dungeness Marina, and Pier 66 Marina;
 Contains information licensed under the Open Government Licence – Canada.

0 700 1,400 2,800 4,200
 Meters



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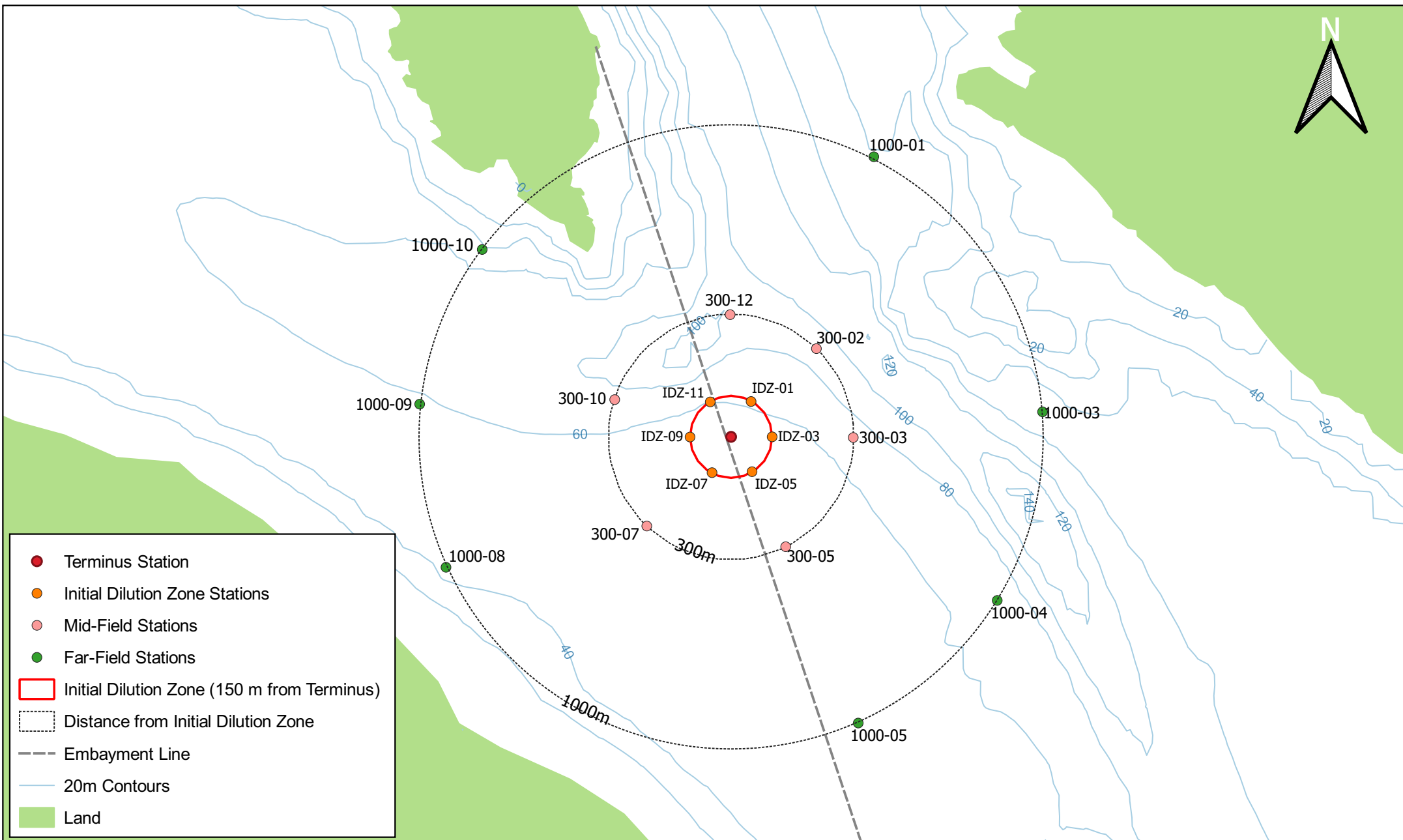


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Figure A1-2: Ecologically Important Areas; Cowichan Bay, BC (2018)

Date: Author: March 12, 2019; BM
 Coordinate System: NAD1983 UTM Zone 10N
 Scale: 1:85,000
 Note: EMP - Environmental Management Plan; GMA - Geoduck Management Area; Important Bird Area within the CVRD Electoral Area D;
 Contains information licensed under the Open Government Licence – Canada.

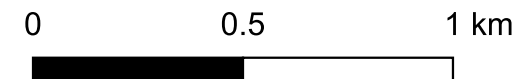
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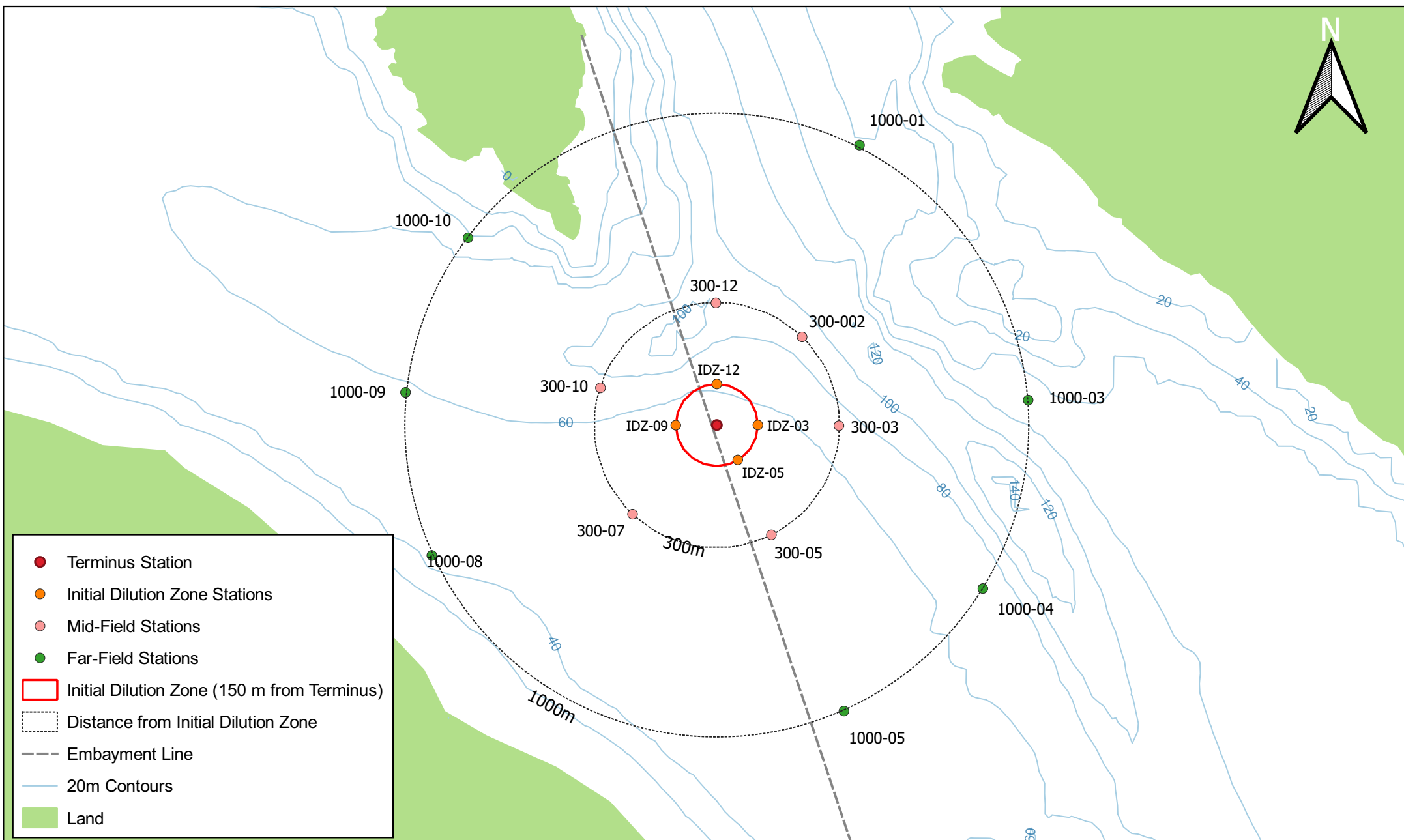


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Figure A2-1: Receiving Environment Monitoring Program - Water Quality Sampling Stations

Date; Author: February 19, 2020; SS
Coordinate System: NAD83 / UTM Zone 10N
Scale: 1 : 18,000
Note: For schematic puposes only.

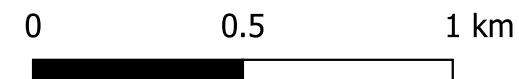


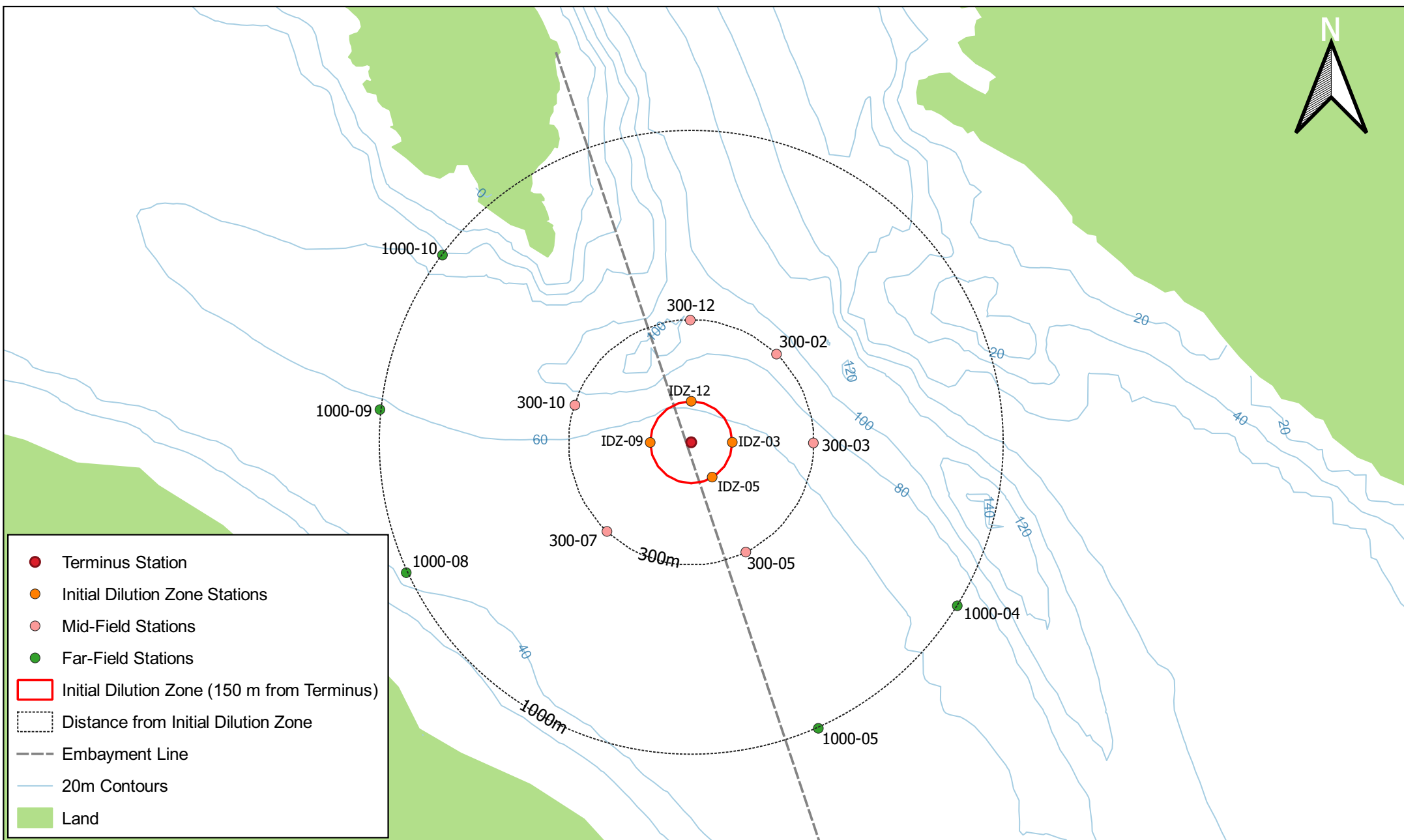


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**Figure A2-2: Receiving Environment Monitoring Program
 - Sediment Quality Sampling Stations**

Date; Author: February 19, 2020; SS
 Coordinate System: NAD83 / UTM Zone 10N
 Scale: 1 : 18,000
 Note: For schematic purposes only.





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Figure A2-3: Receiving Environment Monitoring Program

- Benthic Invertebrate Sampling Stations

Date; Author: February 19, 2020; SS

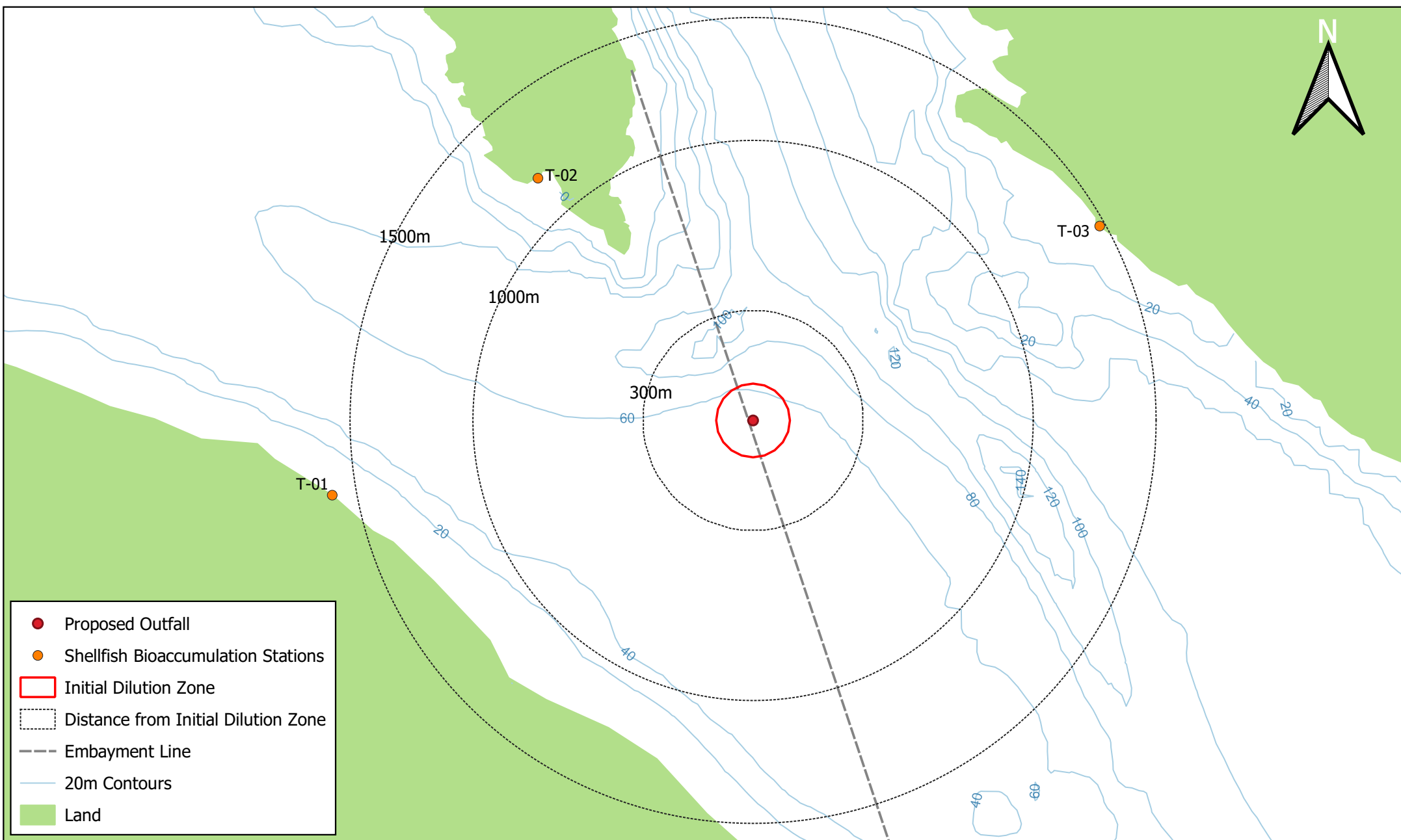
Coordinate System: NAD83 / UTM Zone 10N

Scale: 1 : 18,000

Note: For schematic purposes only.

0 0.5 1 km





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**Figure A2-4: Receiving Environment Monitoring Program
 - Shellfish Bioaccumulation Sampling Sites**

Date; Authro: February 19, 2020; SS
 Coordinate System: NAD83 / UTM Zone 10N
 Scale: 1 : 20,000
 Note: For schematic purposes only.

0 0.5 1 km



Appendix 2

Tables

Table A1-1:	JUB STP REMP Station Locations
Table A2-1:	JUB STP REMP Effluent Characterization Parameters
Table A2-2:	JUB STP REMP Water Quality Parameters
Table A2-3:	JUB STP REMP Sediment Quality Parameters Summary
Table A2-4:	JUB STP REMP Tissue Sampling Parameters Summary

Table A1-1: JUB STP REMP Station Locations

Station ID	Type	Distance from IDZ	Eastings	Northings	Water Sampling	Sediment Sampling	Benthic Invertebrate Community Survey	Shellfish Tissue
TERM	TERM	NA	458622	5398339	Y	N	N	N
IDZ-01	NF	0	458695	5398468	Y	N	N	N
IDZ-03	NF	0	458772	5398339	Y	Y	Y	N
IDZ-05	NF	0	458698	5398212	Y	Y	Y	N
IDZ-07	NF	0	458552	5398208	Y	N	N	N
IDZ-09	NF	0	458472	5398339	Y	Y	Y	N
IDZ-11	NF	0	458546	5398467	Y	N	N	N
IDZ-12	NF	0	458622	5398489	N	Y	Y	N
300-02	MF	300	458934	5398661	Y	Y	Y	N
300-03	MF	300	459068	5398337	Y	Y	Y	N
300-05	MF	300	458821	5397938	Y	Y	Y	N
300-07	MF	300	458314	5398013	Y	Y	Y	N
300-10	MF	300	458197	5398475	Y	Y	Y	N
300-12	MF	300	458618	5398786	Y	Y	Y	N
1000-01	FF	1000	459143	5399362	Y	Y	N	N
1000-03	FF	1000	459760	5398431	Y	Y	N	N
1000-04	FF	1000	459594	5397742	Y	Y	Y	N
1000-05	FF	1000	459086	5397294	Y	Y	Y	N
1000-08	FF	1000	457581	5397863	Y	Y	Y	N
1000-09	FF	1000	457484	5398459	Y	Y	Y	N
1000-10	FF	1000	457713	5399024	Y	Y	Y	N
T-01	FF	1600	456910	5398035	N	N	N	Y
T-02	FF	1200	457747	5399325	N	N	N	Y
T-03	FF	1500	460032	5399130	N	N	N	Y

Notes: TERM: Terminus; NF: Near-Field; MF: Mid-Field; FF: Far-Field; JUB STP outfall configuration needs to be confirmed prior to sampling and adjust distance of stations if necessary.

Table A2-1: JUB STP REMP Effluent Characterization Parameters

Analyte	Rationale/Notes
Bacteria - <i>Enterococcus</i> and fecal coliforms	Regulated parameter at the edge of the initial dilution zone (IDZ) under MWR. Indicator of potential human health hazard. <i>BC Approved Water Quality Guidelines</i> (BCAWQGs) are available for enterococcus and fecal coliforms.
<i>In situ</i> pH, temperature, conductivity, Dissolved Oxygen (DO), turbidity	Physical parameters to assess changes in water quality. Temperature, pH and salinity are required to determine site-specific BCAWQGs for ammonia. BCAWQGs are available for pH, temperature, dissolved oxygen and turbidity.
Alkalinity	The alkalinity of effluent is a measure of its capacity to neutralise acids.
Total Residual Chlorine (TRC)	Regulated parameter under MWR, WSER and JUB Operational Certificate. Toxic to aquatic organisms.
Ammonia	Under MWR, end of pipe limit must be calculated to ensure compliance with the BCAWQGs for ammonia in the receiving environment. Ammonia is also regulated under the WSER and JUB Operational Certificate. Ammonia is potentially toxic to fish.
Total Suspended Solids (TSS)	Regulated parameter under MWR, WSER and JUB Operational Certificate. Increased TSS (and as a result, higher turbidity) reduces light penetration through water resulting in decreased photosynthetic capacity and productivity. Suspended solids can also damage fish gills and smother fish eggs as solids settle.
5-day Carbonaceous Biochemical Oxygen Demand (CBOD ₅)	Regulated parameter under MWR, WSER and JUB Operational Certificate. A measure of oxygen requirement and indirectly measures amount of biodegradable organic matter.
Chemical Oxygen Demand (COD)	COD represents the oxygen that would be needed for aerobic microbial oxidation, assuming that all organics are biodegradable.
Total Organic Carbon (TOC) and Dissolved Organic Carbon (DOC)	Organic matter present in wastewater may change levels of TOC and DOC in the receiving environment.
Nutrients – Nitrogen (Total Nitrogen [TN], Total Kjeldahl nitrogen [TKN], Total Organic Nitrogen [TON], Nitrate, Nitrite)	Nitrogen is present in municipal wastewater under various forms. High levels of nitrogen may cause eutrophication and harmful algal blooms. Organic nitrogen is a prevalent form of nitrogen in recently contaminated water and transformed to inorganic forms. BCAWQGs are available for ammonia and nitrate.
Nutrients – Phosphorus (Total Phosphorus [TP], Orthophosphate [OP])	Phosphorus is present in municipal wastewater under various forms. High levels of phosphorus may cause eutrophication and harmful algal blooms.
Total Metals - full scan (including Mercury)	Metals are present at various concentrations in municipal wastewater. Several metals are potentially deleterious to aquatic organisms. BCAWQGs and <i>BC Working Water Quality Guidelines</i> (BCWWQGs) are available for 14 metals.
Polycyclic Aromatic Hydrocarbons (PAHs)	PAHs are present in municipal wastewater; however, PAHs are likely associated with particulates given their low solubility in water, particularly for higher molecular weight analytes. PAHs may be harmful to aquatic organisms at given concentrations. BCAWQGs are available for 6 PAH analytes.
Polychlorinated Biphenyls (PCBs)	PCBs are present in municipal wastewater; however, PCBs are likely associated with particulates given their low solubility in water. PCBs are persistent bioaccumulative organic compounds harmful to aquatic organisms at given concentrations. BCAWQGs are available for total PCBs and 4 PCB congeners.
Polybrominated Diphenyl Ethers (PBDEs)	PBDEs are used as flame retardants in many domestic products and present in municipal wastewater. PBDEs are persistent toxic compounds which can bioaccumulate. <i>Federal Environmental Quality Guidelines</i> (FEQG) are available.
Alkylphenols & Bisphenol A	Alkylphenols and bisphenol A are both found in municipal wastewater. Alkylphenols are surfactants, emulsifiers and solubilizers used in various domestic and industrial products. Alkylphenols may bioaccumulate and disrupt endocrine function, including reduced spawning potential in fish. Canadian Water Quality Guidelines published by the Canadian Council of Ministers of the Environment are available for alkylphenols. FEQGs are available for Bisphenol A.
Pharmaceuticals and Personal Care Products (PPCP)	PPCP are present in municipal wastewater at low levels and potential effects to human health & aquatic organisms are not well understood. FEQGs have been derived for a few.
Other Contaminants of Emerging Concerns (CECs)	Types of CECs can be present in wastewater. CECs is used to characterize chemicals for which the risk to human health and environment is not yet fully understood. They include substances, such as pesticides, plasticizers and metabolites, fluorinated & polychlorinated compounds and fire retardants. FEQGs for marine water are available for chlorinated alkanes, hydrazine, tetrabromobisphenol A (TBBA), hexabromocyclododecane (HBCD), perfluorooctane sulfonate (PFOS).

Table A2-2: JUB STP REMP Water Quality Parameters

Analyte	Rationale/Notes
<i>Bacteria - Enterococcus</i> and fecal coliforms	Regulated parameter at the edge of the initial dilution zone (IDZ) under <i>MWR</i> . Indicator of potential human health hazard. <i>BC Approved Water Quality Guidelines</i> (BCAWQGs) are available for <i>Enterococcus</i> and fecal coliforms.
<i>In-situ</i> pH, temperature, salinity, Dissolved Oxygen (DO), turbidity	Basic physical parameters to assess changes in water quality. Temperature, pH and salinity are required to determine site-specific <i>BCAWQGs</i> for ammonia. <i>BCAWQGs</i> are available for pH, temperature, dissolved oxygen and turbidity.
Ammonia	Must meet <i>BCAWQGs</i> at the edge of the initial dilution zone (IDZ) under <i>MWR</i> . Potentially toxic to fish.
Total Suspended Solids (TSS)	Regulated parameter in effluent under <i>MWR</i> . TSS measures particulate matter which is present in municipal wastewater. Increased TSS (as a result, higher turbidity) reduces light penetration through water resulting in decreased photosynthetic capacity and productivity. Suspended solids can also damage fish gills and smother fish eggs as solids settle.
Total Organic Carbon (TOC) and Dissolved Organic Carbon (DOC)	Organic matter present in wastewater may change levels of TOC and DOC in the receiving environment.
Nutrients – Nitrogen (Total Nitrogen [TN], Total Kjeldahl nitrogen [TKN], Total Organic Nitrogen [TON], Nitrate, Nitrite)	Nitrogen is present in municipal wastewater under various form. High levels of nitrogen may cause eutrophication of harmful algal blooms. Organic nitrogen is a prevalent form of nitrogen in recently contaminated water and transformed to inorganic forms. <i>BCAWQGs</i> are available for ammonia and nitrate.
Nutrients – Phosphorus (Total Phosphorus [TP], Orthophosphate [OP])	Phosphorus is present in municipal wastewater under various forms. High levels of phosphorus may cause eutrophication and harmful algal blooms.
Total Metals - full scan (including Mercury ¹)	Metals are present at various concentrations in municipal wastewater. Several metals are potentially deleterious to aquatic organisms. <i>BCAWQGs</i> and <i>BC Working Water Quality Guidelines</i> (BCWWQGs) are available for 14 metals.
Polycyclic Aromatic Hydrocarbons (PAHs)	PAHs are present in municipal wastewater; however, PAHs are likely associated with particulates given their low solubility in water, particularly for higher molecular weight analytes. PAHs may be harmful to aquatic organisms at given concentrations. <i>BCAWQGs</i> are available for 6 PAH analytes.
Polychlorinated Biphenyls (PCBs)	PCBs are present in municipal wastewater; however, PCBs are likely associated with particulates given their low solubility in water. PCBs are persistent bio accumulative organic compounds harmful to aquatic organisms at given concentrations. <i>BCAWQGs</i> are available for total PCBs and 4 PCB congeners.
Polybrominated Diphenyl Ethers (PBDEs)	PBDEs are used as flame retardants in many domestic products and present in municipal wastewater. PBDEs are persistent toxic compounds which can bioaccumulate. <i>Federal Environmental Quality Guidelines</i> (FEQGs) are available for PBDEs.
Alkylphenols & Bisphenol A	Alkylphenols and bisphenol A are both found in municipal wastewater. Alkylphenols are surfactants, emulsifiers and solubilizers used in various domestic and industrial products. Alkylphenols may bioaccumulate and disrupt endocrine function, including reduced spawning potential in fish. Canadian Water Quality Guidelines published by the Canadian Council of Ministers of the Environment are available for alkylphenols. Bisphenol A is a precursor to plastic and is an endocrine-disrupter. FEQGs are available for bisphenol A.
Pharmaceuticals and Personal Care Products (PPCP)	PPCP are present in municipal wastewater at low levels and potential effects to human health and aquatic organisms are not well understood. FEQGs have been derived for only a few PPCPs.
Other Contaminants of Emerging Concerns (CECs)	Many different types of CECs can be present in wastewater. CECs is used to broadly characterize chemicals for which the risk to human health and environment is not yet fully understood. They include substances such as pesticides, plasticizers and metabolites, fluorinated and polychlorinated compounds and fire retardants. FEQGs for marine water are available for chlorinated alkanes, hydrazine, tetrabromobisphenol A (TBBA), hexabromocyclododecane (HBCD), perfluorooctane sulfonate (PFOs); however, laboratory analyses may not be available commercially for each compound.

¹ Methyl mercury is not recommended to be tested given low mercury and methylmercury levels recorded in the 2018 ambient water and sediment quality samples; however, should mercury levels increase in final effluent and becomes a concern, methylmercury testing can be reconsidered. The *BCAWQG* for mercury is dependent on methylmercury (MeHg) and total mercury (Hg) ratio. In the absence of MeHg data, a conservative approach is to consider all Hg present to be in the form of MeHg.

Table A2-3: JUB STP REMP Sediment Quality Parameters Summary

Analyte	Rationale/Notes
<i>Bacteria - Enterococcus and Fecal Coliforms</i>	Regulated parameter at the edge of the initial dilution zone (IDZ) under the <i>Municipal Wastewater Regulation (MWR)</i> . Bacteria in sediment can accumulate and create eutrophication, resulting in changes in benthic community composition. An excess of organic matter and decreased oxygen can lead to increased stress on benthic invertebrate communities.
Particle Size Composition	Particle size can influence contaminants present in the sediment and benthic invertebrate community structure, as benthic invertebrate species tend to live in certain types of sediment.
Nitrogen (Total Nitrogen [TN], Total Kjeldahl Nitrogen [TKN])	Nitrogen is present in municipal wastewater under various form. Organic nitrogen is a prevalent form of nitrogen in recently contaminated water and is transformed to inorganic forms by natural biochemical processes.
Carbon -- Inorganic Carbon (IC), Total Carbon (TC), Total Organic Carbon (TOC)	Organic matter present in wastewater may change levels of TOC in sediment. TOC is often used as a non-specific indicator of sediment quality. Organic carbon is a food source for micro- and benthic organisms. Many compounds adsorb to organic matter in sediment.
Carbon to Nitrogen (C:N) Ratio	The C:N ratio indicates whether particulate matter in the sediment comes from land-based or algal-based plants, therefore, changes to the C:N ratio over time may indicate a change related to input of land-based particulate in wastewater.
Ammonium-N	Assess accumulation of ammonia from municipal wastewater. Potentially toxic to fish if released from sediment. Ammonium is also produced in sediments during the decomposition of organic matter by various heterotrophic organisms. Ammonium is a supportive parameter in benthic invertebrate community surveys.
Total Metals - full scan including mercury ¹	Metals are present at various concentrations in municipal wastewater; however, metals are also naturally present in sediment and from other anthropogenic sources in the area. Several metals are potentially deleterious to aquatic organisms.
Simultaneously Extractable Metals (SEM) and Acid Volatile Sulphides (AVS)	The ratio of the molecular concentration of simultaneously extracted metals and acid volatile sulphides determine their potential toxicity and bioavailability for organism uptake.
Polycyclic Aromatic Hydrocarbons (PAHs)	PAHs are a diverse group of organic compounds that can be potentially toxic in the environment. PAHs can accumulate in suspended matter and sediment through anthropogenic discharges such as municipal wastewater. Canadian Sediment Quality Guidelines published by the Canadian Council of Ministers of the Environment are available for 13 PAH analytes in marine sediment.
Polychlorinated Biphenyls (PCBs)	PCBs are present in municipal wastewater; however, PCBs are likely associated with particulates given their low solubility in water. PCBs are persistent bio accumulative organic compounds harmful to aquatic organisms at given concentrations. Provincial and federal (CCME) guidelines are available for total PCBs in fish/shellfish tissue.
Polybrominated Diphenyl Ethers (PBDEs)	PBDEs are used as flame retardants in many domestic products and present in municipal wastewater. PBDEs are persistent toxic compounds which can bioaccumulate. <i>Federal Environmental Quality Guidelines (FEQGs)</i> are available for PBDEs.
Alkylphenols & Bisphenol A	Alkylphenols and bisphenol A are both found in municipal wastewater. Alkylphenols are surfactants, emulsifiers and solubilizers used in various domestic and industrial products. Alkylphenols may bioaccumulate and disrupt endocrine function. Canadian Water Quality Guidelines published by the CCME are available for alkylphenols. Bisphenol A is a precursor to plastic and is an endocrine-disrupter.
C13 & N15 Stable Isotopes	Changes in C13 & N15 Stable isotopes can be an indicator of sewage in the receiving environment.

¹ Methyl mercury is not recommended to be tested given low mercury and methylmercury levels recorded in the 2018 ambient water and sediment quality samples; however, should mercury levels increase in final effluent and becomes a concern, methylmercury testing can be reconsidered.

Table A2-4: JUB STP REMP Tissue Sampling Parameters Summary

Analyte	Rationale/Notes
<i>Bacteria - Escherichia coli</i> and Fecal Coliforms	Regulated parameter at the edge of the initial dilution zone (IDZ) under the <i>Municipal Wastewater Regulation (MWR)</i> . Bacteria can accumulate in organisms. Provincial guidelines for <i>E. coli</i> and fecal coliforms are available for the human consumption of shellfish tissue.
Total Metals - full scan including mercury ¹	Metals are present at various concentrations in municipal wastewater. Several metals are potentially deleterious and can bio accumulate in aquatic organisms. Provincial guidelines for lead, selenium, mercury and methylmercury in fish/shellfish tissue are available.
Polycyclic Aromatic Hydrocarbons (PAHs)	PAHs are a diverse group of organic compounds that can be potentially toxic in the environment. PAHs can accumulate in aquatic organisms by ingestion of water and sediment through anthropogenic discharges such as municipal wastewater. Provincial guidelines are available for benzo(a)pyrene.
Polychlorinated Biphenyls (PCBs)	PCBs are present in municipal wastewater and are persistent bio accumulative organic compounds harmful to aquatic organisms at given concentrations. Provincial and federal (CCME) guidelines are available for total PCBS in tissue.
Polybrominated Diphenyl Ethers (PBDEs)	PBDEs are used as flame retardants in many domestic products and present in municipal wastewater. PBDEs are persistent toxic compounds which can bioaccumulate. <i>Federal Environmental Quality Guidelines</i> (FEQGs) are available for PBDEs.
Alkylphenols	Alkylphenols can be found in municipal wastewater and are surfactants, emulsifiers and solubilizers used in various domestic and industrial products. Alkylphenols may bioaccumulate and disrupt endocrine function.

¹ Methyl mercury is not recommended to be tested given low mercury and methylmercury levels recorded in the 2018 ambient water and sediment quality samples; however, should mercury levels increase in final effluent and becomes a concern, methylmercury testing can be reconsidered. The *BCAWQG* for mercury is dependent on methylmercury (MeHg) and total mercury (Hg) ratio. In the absence of MeHg data, a conservative approach is to consider all Hg present to be in the form of MeHg.