Environmental Monitoring Program
Lasqueti Island Landfill Facility
Lasqueti Island, BC

PRESENTED TO

qathet Regional District

AUGUST 2018
ISSUED FOR USE
FILE: 704-SWM.SWOP03810-01

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EXECUTIVE SUMMARY

Tetra Tech Canada Inc. (Tetra Tech) was retained by the qathet Regional District (qRD) to develop an Environmental Management Plan (EMP) at the Lasqueti Landfill (herein referred to as the "Site"). The qRD was requested to design a monitoring program at the Site by the British Columbia Ministry of Environment (BC MOE) in accordance with the *"Landfill Criteria for Municipal Solid Waste"* and the *"Ministry Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills"* (BC MOE 1996), carry out the monitoring program, assess and interpret the results of the monitoring program and prepare conclusions and recommendations.

The purpose of the EMP is to design and implement a monitoring and sampling program for the Site, to evaluate the potential surface water and groundwater impacts from landfill operations and interpret analytical results in accordance with applicable standards and guidelines. The EMP consists of drilling and installing three groundwater monitoring wells and the testing of surface water at two locations in the creek located south of the landfill.

Tetra Tech recommends having the monitoring wells and surface water locations monitored twice annually during the spring and the fall when conditions are optimal for sample collection. The samples will be used to determine the groundwater quality and quantity with respect to the criteria, and to ensure that the environmental control systems put in place are working effectively.

The following applicable documents regarding sampling protocols were reviewed:

- *"Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills," (*BC MOE 1996*)*
- *"British Colombia Field Sampling Manual: Part E – Water and Wastewater Sampling," (*BC MOE 2013)
- *"Landfill Manuals: Landfill Monitoring, 2nd Edition,"* (US EPA 2003)

Tetra Tech will implement a quality assurance/quality control (QA/QC) program to assess the integrity of the sampling methodology and analytical testing. The QA/QC program will adhere to the 2nd Edition of the EPA Landfill Manuals; Landfill Monitoring standards and guidelines.

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ACRONYMS & ABBREVIATIONS

Acronyms/Abbreviations	Definition
BC MOE	British Colombia Ministry of Environment
CALA	Canadian Association for Laboratory Accreditation
COC	Chain-of-Custody
EMP	Environmental Management Plan
qRD	qathet Regional District
QA/QC	Quality Assurance and Quality Control

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1.0 INTRODUCTION

1.1 General

Tetra Tech Canada Inc. (Tetra Tech) was retained by the qathet Regional District (qRD) to develop an Environmental Management Plan (EMP) for the Lasqueti Landfill (herein referred to as the "Site").

The qRD was requested to develop a monitoring program for the Site by the British Columbia Ministry of Environment (BC MOE) in accordance with the *"Landfill Criteria for Municipal Solid Waste"* and the *"Ministry Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills" (*BC MOE 1996*)*, carry out the monitoring program, assess and interpret the results of the monitoring program and prepare conclusions and recommendations[1].

The EMP presented herein has been developed in accordance with the above stated guidance documents and in accordance with the aforementioned BC MOE correspondence.

1.2 Objective

The objective of the EMP is to develop and implement an environmental monitoring program for the Site, to evaluate the potential for surface water and groundwater impacts derived from landfill operations, and interpret analytical results in accordance with applicable standards and guidelines

1.3 Background

As shown in Figure 1, the Site is located on crown land on the southeast 40 acres of North West ¼ of Section 18, Lasqueti Island. Access to the site is via Lenfesty Road (gravel road), through the west side of the Site. As shown in Appendix B, the gravel access road extends through the Site to a BC Highways and Transportation aggregate borrow pit, located approximately 300 m east of the Site. Appendix B is a Site Plan created by XCG Consulting Ltd. (XCG), which was first referred to in XCG's Landfill Site Investigation in November 2016.

The Site has a cleared area of approximately 1,800 m^2 and is approximately 80 m long (west to east) by 20 m to 25 m wide (north to south).

A limited scope investigation, comprised of 10 testpit excavations was undertaken in October 2016 by XCG as summarized below in Section 2.3. It is reported that at the time of the site investigation, two active landfill areas were observed, as shown in Appendix B, and were awaiting placement of cover soil.

It is understood that historic landfill operations employed the trench fill methodology (i.e., trenches excavated and filled to grade with waste and capped with cover soil). At the time of the 2016 investigation, it is reported that waste was being placed above local ground surface elevations in the region south of the aforementioned access road and west of the metal stockpile area (Appendix B). The average height of the waste mass was approximately 1 m to 1.5 m above-ground surface. The above-ground landfill cell was generally sloped at 25% to 30% on the north and east slopes and at grades steeper than 50% on the south and west slopes.

[1] As requested in the 2008 Compliance Review Record (BC MOE).

2.0 SETTING

The following section presents a summary of the site setting based upon the 2016 report prepared by XCG.

2.1 Topography

The Site is located in an undeveloped valley within the geographic mid island region. An ephemeral creek, emanating from groundwater seeps along the steep valley slopes, is noted to the south of the Site. Previous work conducted by XCG indicated that this creek flowed to the west toward a wetland area located approximately 2 km from the Site.

2.2 Drainage

Based upon reported Site conditions and the local topography, it was projected that the shallow groundwater gradient is to the west and generally flows the surface topography. Stormwater flow originating from the steep southern valley slope is intercepted by the landfill perimeter ditch, while stormwater flow from the east and southeast valley percolates into the groundwater flow through the waste mass.

2.3 Geology and Hydrogeology

As indicated above, a total of 10 testpits excavations were undertaken at the Site as part of the limited scope site investigation conducted in October 2016. The locations for the testpits were selected in the field based upon visual indicators of historic waste placement and estimated limit of waste based upon ground contours/relief. Testpit locations are shown in Appendix B.

Waste was encountered at all testpit locations apart from test pit locations TP5, TP9, and TP10. Waste was generally encountered at a depth of 0.3 m to 0.6 m below grade (cover soil) and extended to the base of excavation below the shallow groundwater table. Cover material found on Site at these test pit locations within the limit of waste was generally composed of native light brown sandy silt till.

Native soils encountered at test pit locations TP5 and TP9 were comprised of approximately 0.4 m to 0.6 m of red organic soil, overlying 1.0 m to 1.5 m of light brown to grey sandy silt. Bedrock was encountered at a depth of approximately 1.8 m at test pit location TP5 and at approximately 1.3 m at testpit location TP9.

Surficial soils encountered at test pit location TP10 were comprised of 1.0 m of light brown sandy silt fill. The excavation at this location was terminated at approximately 1.2 m due to the presence of groundwater in the excavation.

Based upon the results of this site investigation, it was determined that the limit of waste encompasses an area of approximately 1,400 m², which equated to approximately 80% of the cleared area of the Site. It was also noted that based upon visual indicators and the presence of waste at testpit locations TP4 and TP6, waste appeared to extend to the north beneath a significant portion of the Site access road

Groundwater within the limit of waste was encountered at an average depth of 0.9 m apart from test pit location TP6, at which groundwater was encountered at a depth of approximately 0.3 m.

2.4 Potential Receptors

The following section presents a summary of identified receptors located within 1 km of the Site. The primary waterbody receptors adjacent to the Site are Trematon Lake, Trematon Creek, and three other creeks located on

the west, north west, and north of the site, all of which are located within the 1-km radius. An ephemeral creek located immediately south of the site, which flows from east to west, is shown on Figure 3.

The nearest dwelling or building structure is located approximately 600 m west from the Site.

The nearest registered private domestic drinking water well is located approximately 2 km east-northeast of the Site is shown on Figure 2.

An ecological reserve area is situated 360 m southeast of the site. The original purpose of the reserve area was to protect vegetation and fauna characteristic of the Coastal Douglas-Fir Zone. Its current purpose is to protect a shoreline forest of one of the largest populations of seaside junipers in British Colombia, two rare plant communities and two blue-listed rare plants.

The nearest registered fishery is located approximately 1.7 km east of the Site is shown on Figure 3.

3.0 APPLICABLE STANDARDS

3.1 Regulatory Environment

The applicable criteria for regulatory compliance for groundwater and surface water quality at municipal solid waste landfills is presented in the document entitled “Landfill Criteria for Municipal Solid Waste,” (BC MOE 2016), as is summarized as follows:

4.1 Groundwater and Surface Water Quality

Current and planned future uses of groundwater and surface water shall be identified within 1 km of the landfill footprint. After considering the identified uses of groundwater and surface water, a Qualified Professional must recommend the appropriate water quality criteria, compliance locations, and provide related rationale and justification.

Water quality criteria to be considered include:

- *The BC Approved and Working Water Quality Guidelines;*
- *BC Water Quality objectives;*
- *The Contaminated Sites Regulation, Generic Numerical Water Standards for the applicable water use(s) as defined in Protocol 21 “Water Use Determination” under the Contaminated Sites Regulation;*
- *The Canadian Drinking Water Quality Guidelines; and*
- *Other water quality criteria for parameters not addressed by the preceding water quality criteria.*

The appropriate water quality criteria and compliance monitoring locations are subject to the approval of the director in writing.

As a minimum, the appropriate water quality criteria must be satisfied at and beyond the landfill site boundary, or 150 m from the landfill footprint, whichever is closer. More stringent requirements may be set by the director. Any discharges to surface water considered as potential fish habitat must also comply with the requirements of the federal Fisheries Act.

9.0 Monitoring Criteria

A detailed Environmental Monitoring Plan (EMP) for leachate, groundwater, surface water, and landfill gas must be prepared and implemented during landfill construction and landfill operation, closure and post-closure. The EMP shall:

- *Demonstrate compliance with the performance criteria;*
- *Demonstrate the monitoring results are consistent with the applicable plans and reports, listed in Section 10, including the groundwater and surface water impact assessment; and*
- *Address the need for monitoring within 1 km of the landfill footprint.*

The EMP shall be developed in accordance with the "Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills" (BC MOE 1996) for groundwater, surface water, leachate, soils and vegetation or its approved replacement. The EMP shall be included in the DOCP as per Section 10.3.

3.2 Groundwater and Surface Water Criteria

As noted above, the applicable criteria for groundwater and surface water quality are provided in the documents entitled "*The BC Approved and Working Water Quality Guidelines,"* and the proper monitoring and management of groundwater and surface water quality are provided in the *"Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills."* (BC MOE 1996).

Based upon the aforementioned identified receptors, the potential mechanisms for impact include both groundwater and surface water. Therefore, the criteria for both drinking water and aquatic life are deemed to be applicable.

4.0 PROPOSED ENVIRONMENTAL MANAGEMENT PLAN

4.1 Groundwater

4.1.1 Monitoring Locations and Frequency

It is recommended to install three groundwater monitoring wells at the Site: two down-gradient and one up-gradient (background) as indicated in Figure 3 and summarized in Table 4-1. The groundwater wells will be instrumented/screened in the shallow groundwater table.

The monitoring wells will be used to determine the groundwater quality and quantity with respect to the criteria, and to ensure that the environmental control systems put in place are working effectively. The following table presents the proposed groundwater monitoring locations.

Table 4-1: Groundwater Monitoring Locations

Monitoring Station Identification	Location	Purpose
MW1	North West of the Limit of Waste	Down-gradient
MW2	West of the Limit of Waste	Down-gradient
MW3	East of the Limit of Waste	Up-gradient (Background)

Groundwater monitoring will be undertaken at all three locations biannually (twice annually).

It is recommended that the environmental monitoring program include hydraulic measurements of groundwater elevation at all monitoring wells. This would require a topographic survey to be completed to establish vertical and horizontal control for all monitoring wells. Measurements will occur in conjunction with the groundwater sampling program.

4.1.2 Parameters

The following list of analytes proposed for monitoring is based upon the *"Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills"* (BC MOE 1996) and "*The BC Approved and Working Water Quality Guidelines"* (BC MOE 2017).

4.1.2.1 Field Measurements

Field measured water quality parameters to be recorded at the time of groundwater sampling shall include the following:

- Temperature;
- pH;
- Conductivity; and
- Dissolved oxygen (DO).

4.1.2.2 Laboratory Analysis

General Chemistry

Laboratory analysis for general chemistry parameters shall include the following:

- Ammonia;
- Chloride;
- Sulphate;
- Fluoride;
- Nitrate; and
- Nitrite.

Metals (Dissolved)

Laboratory analysis for dissolved metal parameters shall include the following:

- Aluminum;
- Antimony;
- Arsenic;
- Barium;
- Beryllium;
- Boron;
- Cadmium;
- Chromium;
- Cobalt;
- Copper;
- Iron;
- Lead;
- Manganese;
- Molybdenum;
- Nickel;
- Selenium;
- Silver;
- Thallium;
- Uranium;
- Vanadium; and
- Zinc.

4.2 Surface Water

4.2.1 Monitoring Locations and Frequency

As indicated in Section 2.4, an ephemeral creek runs through the Site, immediately south of the limit of waste. Due to the presence of an on-site surface water course, it is recommended that the EMP incorporate a surface water monitoring program which include two locations (upstream and downstream of the limit of waste) as shown in Figure 3 and summarized in Table 4-2, which are to be monitored twice annually during the spring and fall when conditions are optimal for sample collection (i.e., there is flow in the ephemeral creek).

Table 4-2: Surface Water Monitoring Locations

Monitoring Station Identification	Location	Description
SW1	Upstream of the water body (East side)	Determining the upstream (background) surface water quality.
SW2	Downstream of the water body (West side)	Determine the downstream surface water quality and to ensure there is no contamination occurring.

4.2.2 Parameters

The following list of analytes proposed for monitoring is based upon the *"Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills"* (BC MOE 1996) and "*The BC Approved and Working Water Quality Guidelines."* (2017)

4.2.2.1 Field Measurements

Field measurements shall be measured with a suitable portable multi parameter water quality measurement instrument. Field measured water quality parameters to be recorded at the time of surface water sampling shall include the following:

- Temperature;
- pH;
- Conductivity;
- Dissolved Oxygen (DO); and
- Flow Conditions.

4.2.2.2 Laboratory Analysis

General Chemistry

Laboratory analysis for general chemistry parameters shall include the following:

- Ammonia;
- Chloride;
- Sulphate;
- Fluoride;
- Nitrate; and
- Nitrite.

Metals (Total)

Laboratory analysis for dissolved metal parameters shall include the following:

- Aluminum;
- Antimony;
- Arsenic;
- Barium;
- Beryllium;
- Boron;
- Cadmium;
- Chromium;
- Cobalt;
- Copper;
- Iron;
- Lead;
- Manganese;
- Molybdenum;
- Nickel;
- Selenium;
- Silver;
- Thallium;
- Uranium;
- Vanadium; and
- Zinc.

4.3 Sampling Protocol

The following section presents an overview of sampling protocols to be implemented at the Site. The sampling protocols presented herein take into consideration the following guidance documents:

- *"Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills,"* (BC MOE 1996); *and*
- *"British Colombia Field Sampling Manual: Part E – Water and Wastewater Sampling,"* (BC MOE 2013).

4.3.1 Groundwater Monitoring

To ensure the integrity of samples collected while sampling groundwater from the monitoring wells, the following protocols should be applied:

- Record the static water level of each monitoring well.
- Purge the appropriate volume of water from the monitoring well and record the water level on completion. The purpose of purging is to remove the groundwater from the well until a representative sample of the formation groundwater is obtained. In general, purging is considered complete once sediment-free groundwater is obtained and the specific criteria (conductance, temperature, and pH) of the groundwater stabilises.
- Collect groundwater samples in the appropriate laboratory-supplied sample containers and preserve as required. Groundwater samples designated for metals analysis should be packed in a cooler, stored at a temperature of approximately 4^{o}C, and delivered to the laboratory for analysis.
- Ensure that preservatives (as required) are added to the samples after collection to ensure roper sample preservation.
- Field measurements should always be collected using a separate sub-sample that is discarded once the measurements are complete. Field measurements should never be collected using a water sample that is to be submitted for laboratory analyses.
- Samples will be packed on ice and submitted under a chain-of-custody (COC) to an accredited analytical laboratory certified for environmental analysis by the BC MOE.

4.3.2 Surface Water Monitoring

The following protocol for sampling from the stream bank shall be used to collect surface water samples:

- Secure yourself to a solid object on shore (with a safety harness and line if necessary). If possible/necessary, a second person must be nearby as the first person collects samples.
- Remove lid from a labelled bottle and place into a clean resealable bag so both hands can be used to take sample. If rinsing is required for the type of bottle, rinse three times.
- Hold the bottle well below the neck or secure it to a pole sample.
- Reach out (arm length only) and plunge the bottle under the water with the opening fading directly down and immediately orient it into the current. Completely submerge the sample container to avoid collection of any floating debris (approximately 0.15 m below the surface of the water, away from the edges of the surface waterbody).
- When the bottle is full, pull it up through the water while forcing into the current.
- Immediately recap the bottle.
- Ensure that preservatives (as required) are added to the samples after collection to ensure roper sample preservation.
- Field measurements should always be collected using a separate sub-sample that is discarded once the measurements are complete. Field measurements should never be collected using a water sample that is to be submitted for laboratory analyses.
- Once collected, the samples will then be stored in coolers with ice and transported to an appropriate Canadian Association for Laboratory Accreditation (CALA) affiliated laboratory, for laboratory analyses with COC documentation. An additional duplicate sample will be collected during each event for quality assurance/quality control (QA/QC) purposes.

4.4 Field Equipment

The following section presents a summary of the specifications for field equipment to the used to record field analytical parameters.

4.4.1 Temperature

A calibrated electronic or alcohol-filled thermometer capable of producing results within ± 0.5˚C of the true temperature.

4.4.2 pH

A calibrated electronic pH or multi-parameter meter capable of recording to the nearest 0.1 pH unit.

4.4.3 Conductivity

A calibrated electronic-specific conductance (electrical conductivity) meter or multi-parameter meter capable of recording to the nearest 1 microsiemens per centimetre (µS/cm).

4.4.4 Dissolved Oxygen

A calibrated multi-parameter capable of recording to the nearest 1 milligram per litre.

4.5 Quality Assurance/Quality Control

A QA/QC program to assess the integrity of the sampling methodology and analytical testing will be implemented as part of the environmental monitoring program for the Site.

The QA/QC protocol will include the following:

- Recording the results of field activities in the field concurrently with the activities;
- Using of clean, new sampling gloves at each sampling location;
- Placing samples into new and labelled laboratory-supplied containers, and when warranted, preserving the samples using laboratory-measured and supplied preservatives;
- Transporting temperature-sensitive samples to the analytical laboratory in chilled coolers using COC procedures either on the same day of sampling or within one day of sampling, and analyzing the samples within the appropriate holding times;
- When appropriate, forming duplicate samples using industry accepted splitting methods;
- Using CALA-affiliated laboratories that are qualified to analyze the samples using BC MOE-approved procedures;
- Submitting duplicate samples to the laboratory as “blind” samples meaning that they are not identified as duplicate samples;
- Decontaminating sampling equipment between sample locations; and
- Reviewing the results of QA/QC analyses, assessing the significance of the analytical results and identifying this information in this report.

4.6 Reporting

A qualified profession will prepare and submit an annual report for the environmental monitoring program to the Regional District each calendar year for submission to the BC MOE. The annual report will include a summary of results and the interpretive analysis of the results of all monitoring including an assessment of the need to amend the monitoring program.

5.0 CLOSURE

We trust this document meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech Canada Inc.

Aug. 16, 2018

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British Colombia Ministry of the Environment, “Landfill criteria for Municipal Solid Waste,” June 2016.

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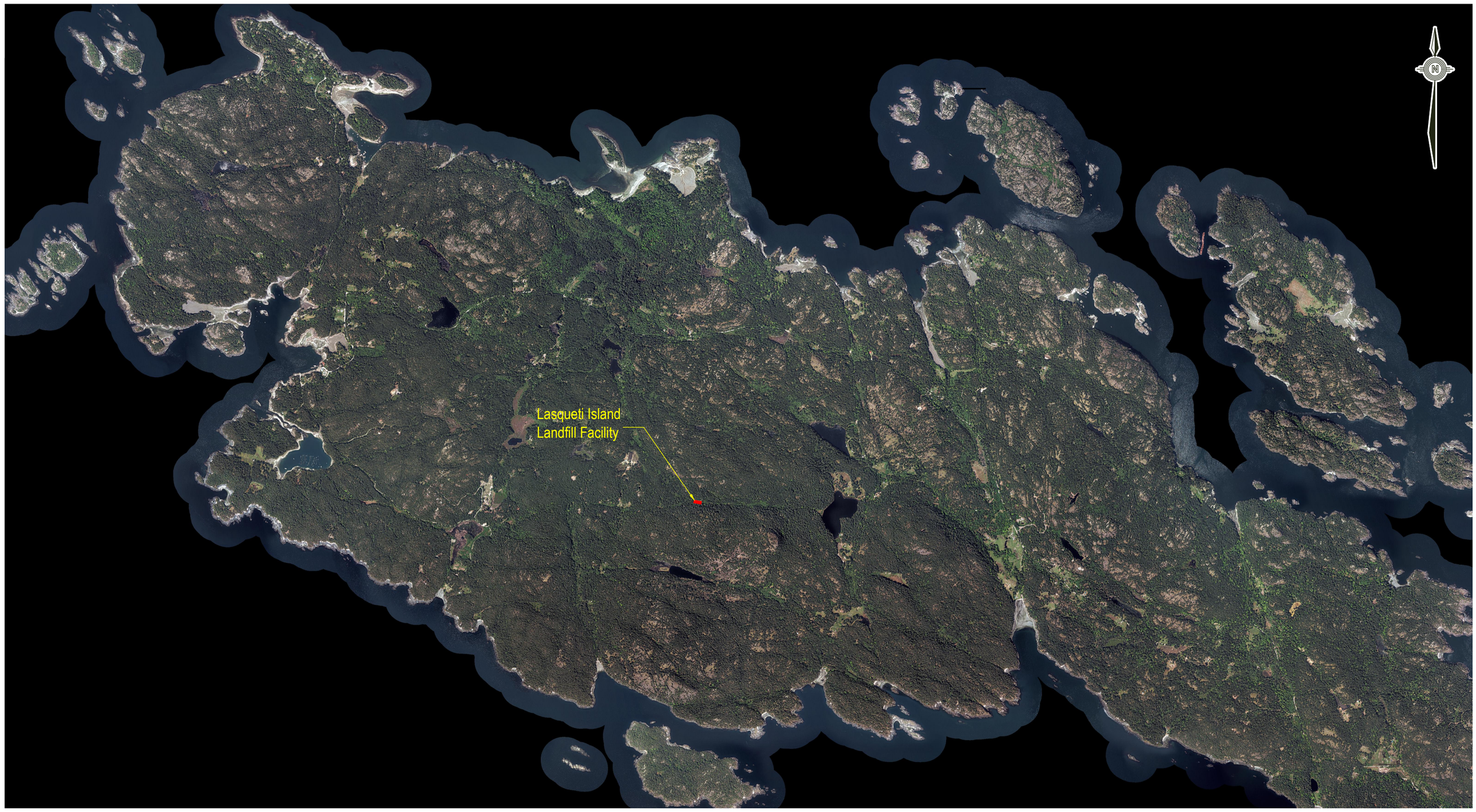
FIGURES



0 2 000 m

Scale: 1: 40 000

CLIENT

qathet Regional District

TETRA TECH

ENVIRONMENTAL MONITORING PROGRAM
LASQUETI ISLAND, BC

SITE LOCATION

PROJECT NO.	DWN	CKD	REV
SWM.SWOP03810-01	RM	ML	0

OFFICE: EDM

DATE: August 10, 2018

Figure 1

Dwellings
Dwellings
1000 m
500 m
100 m
Lasqueti Island
Landfill Facility
Trematon Lake

LEGEND:

- SITE
- DWELLINGS
- STREAM
- LAKES
- ECOLOGICAL RESERVE
- FISHERIES
- WATER WELLS

0 500 m

Scale: 1: 10 000

CLIENT

qathet REGIONAL DISTRICT

TETRA TECH

ENVIRONMENTAL MONITORING PLAN
LASQUETI ISLAND, BC

RECEIVING ENVIRONMENT

PROJECT NO.	DWN	CKD	REV
SWM.SWOP03810-01	RM	ML	0

OFFICE: EDM

DATE: August 10, 2018

Figure 2

Q:\Edmonton\Drafting\00_MASTER PROJECT BASE PLANS\Lasqueti Landfill\Production\03810-01_2 Receiving Environment.dwg [FIGURE 2] August 10, 2018 - 9:21:26 am (BY: MANDOUR, RANA)

LEGEND:

- APPROXIMATE LIMIT OF WASTE
- TREELINE
- EPHEMERAL CREEK
- MONITORING WELL LOCATION
- SURFACE WATER MONITORING LOCATION

0 200 m

Scale: 1: 4 000

CLIENT

qathet REGIONAL DISTRICT

TETRA TECH

ENVIRONMENTAL MONITORING PROGRAM
LASQUETI ISLAND, BC

MONITORING PLAN

PROJECT NO.	DWN	CKD	REV
SWM.SWOP03810-01	RM	ML	0

OFFICE: EDM

DATE: August 10, 2018

Figure 3

Q:\Edmonton\Drafting\00_MASTER PROJECT BASE PLANS\Lasqueti Landfill\Production\03810-01_3 Monitoring Plan.dwg [FIGURE 3] August 10, 2018 - 9:23:04 am (BY: MANDOUR, RANA)

APPENDIX A

TETRA TECH'S LIMITATIONS ON THE USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

GEOENVIRONMENTAL

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This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this report, at or on the development proposed as of the date of the Professional Document requires a supplementary investigation and assessment.

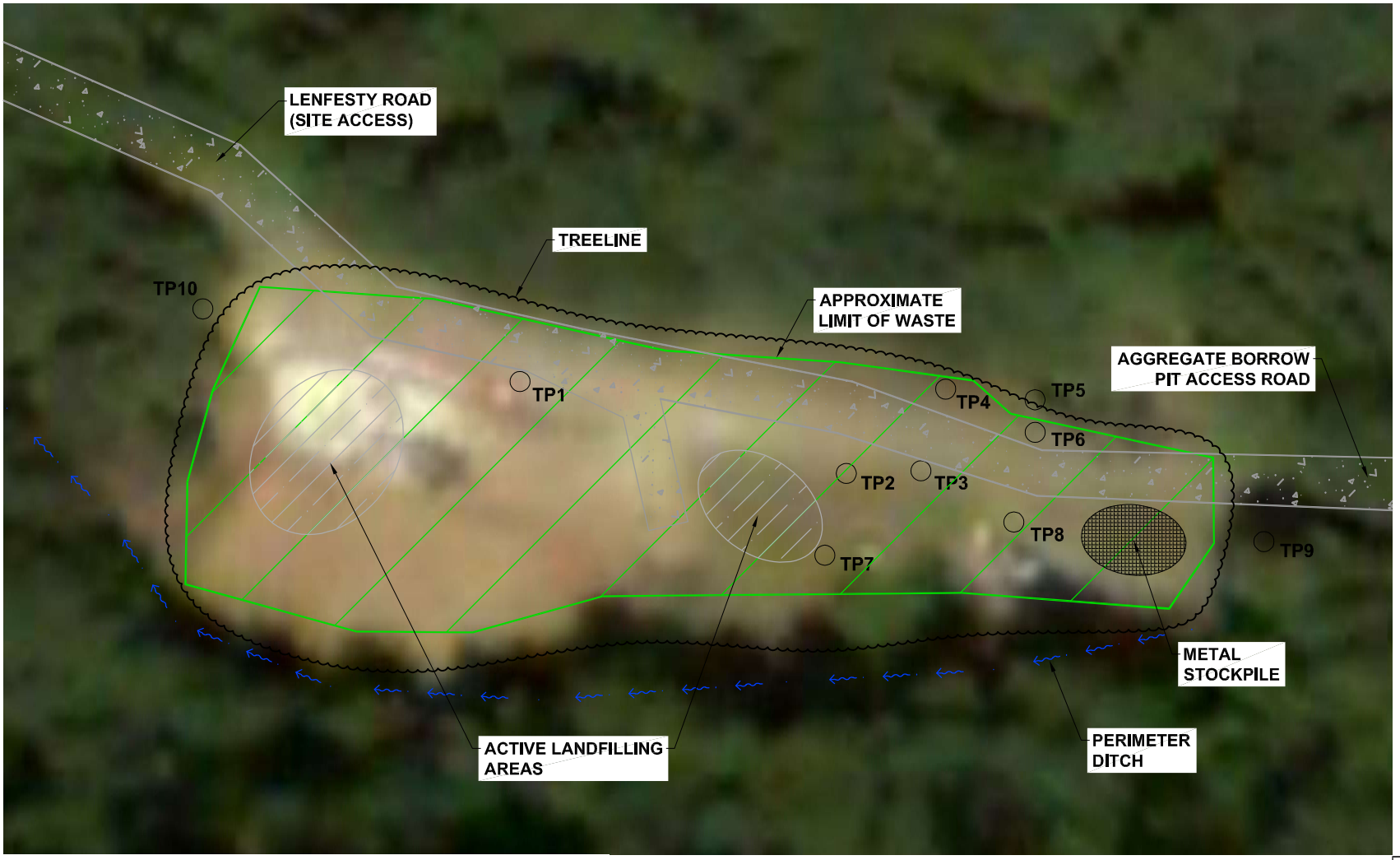
TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 NOTIFICATION OF AUTHORITIES

In certain instances, the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by TETRA TECH in its reasonably exercised discretion.

APPENDIX B

SITE PLAN (FROM XCG CONSULTING LTD.)



0 5 10 m

1 : 300

LEGEND

- LIMIT OF WASTE
- GRAVEL ROAD
- TREELINE
- SURFACE WATER
- TP1 ○ TEST PIT LOCATION

(File: R42803010201FIG2.dwg)

TEST PIT LOCATION PLAN

LANDFILL SITE INVESTIGATION

LASQUETI ISLAND LANDFILL FACILITY

LASQUETI ISLAND, BC

XCG CONSULTANTS LTD.

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