REPORT

Golden Landfill Environmental Monitoring Plan

Golden, BC

Submitted to:

Columbia Shuswap Regional District
PO Box 978
555 Harbourfront Drive NE
Salmon Arm, BC
V1E 4P1

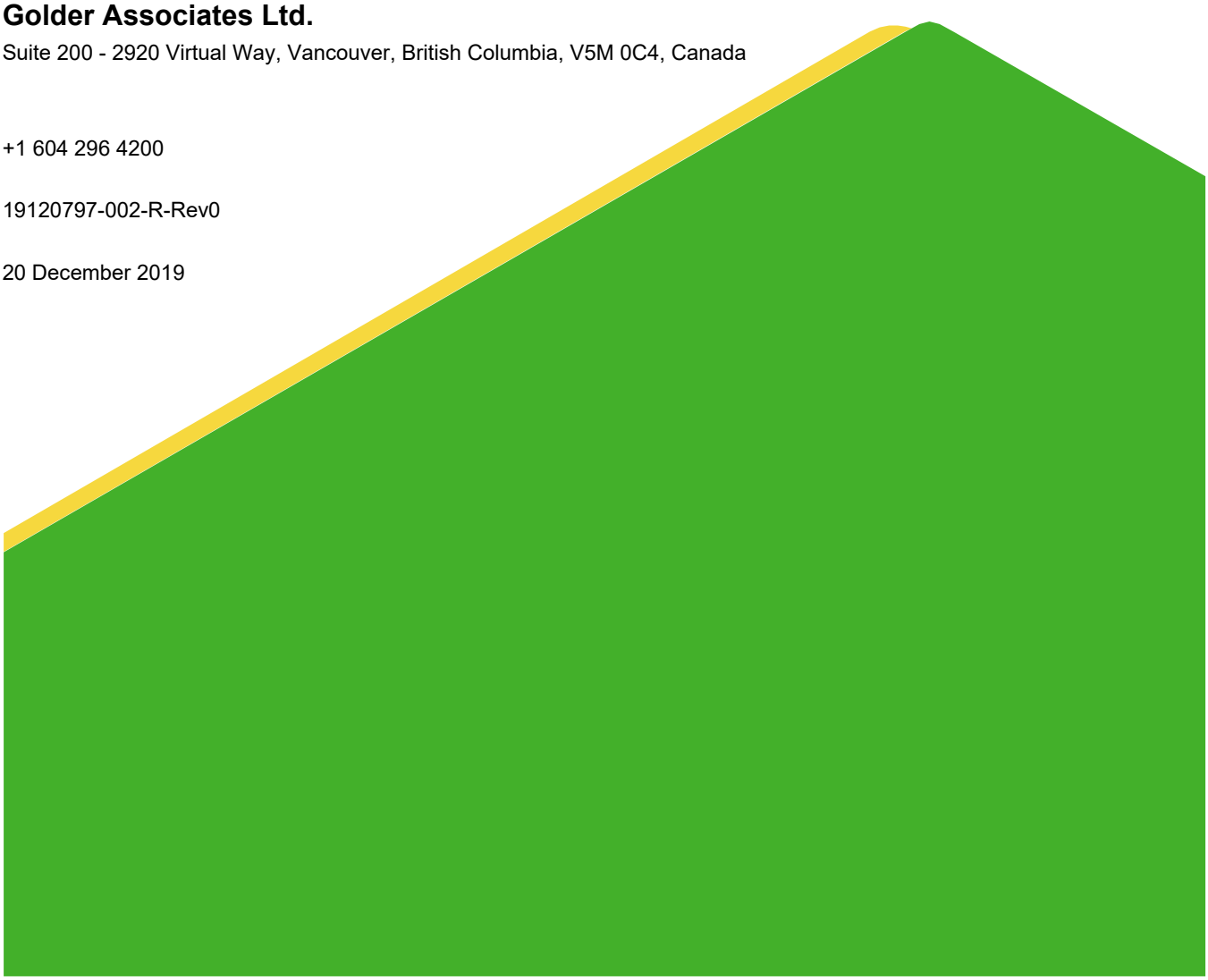
Submitted by:

Golder Associates Ltd.
Suite 200 - 2920 Virtual Way, Vancouver, British Columbia, V5M 0C4, Canada

+1 604 296 4200

19120797-002-R-Rev0

20 December 2019



Distribution List

1 electronic copy: Columbia Shuswap Regional District

1 electronic copy: Golder Associates Ltd.

Study Limitations

Golder Associates Ltd. (Golder) has prepared this document in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this document. No warranty, express or implied, is made.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, has been prepared by Golder for the sole benefit of the Client (Columbia Shuswap Regional District). It represents Golder's professional judgment based on the knowledge and information available at the time of completion. Golder is not responsible for any unauthorized use or modification of this document. All third parties relying on this document do so at their own risk.

The factual data, interpretations, suggestions, recommendations and opinions expressed in this document pertain to the specific project, Site conditions, design objective, development and purpose described to the Client, and are not applicable to any other project or location. To properly understand the factual data, interpretations, suggestions, recommendations and opinions expressed in this document, reference must be made to the entire document.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, as well as all electronic media prepared by Golder, are considered its professional work product and shall remain the copyright property of Golder. The Client may make copies of the document in such quantities as are reasonably necessary for those parties conducting business specifically related to the subject of this document or in support of or in response to regulatory inquiries and proceedings. Electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore no party can rely solely on the electronic media versions of this document.

Table of Contents

FIGURES (END OF TEXT)

1.0 INTRODUCTION

1.1 Background

On behalf of the Columbia Shuswap Regional District (CSRD), Golder Associates Ltd. (Golder) is pleased to provide this Environmental Monitoring Plan (EMP) for the Golden Landfill (Landfill or Site), located at 350 Golden Donald Upper Road in Golden, BC approximately 2 km northwest of the town centre (Figure 1). The Site is authorized under Ministry of Environment and Climate Change Strategy Operational Certificate (OC) 17006 that was last updated 29 August 2012. This Plan is based on a review of the following documents for the Site provided by CSRD:

- Operational Certificate 17006
- most recently completed Design and Operating Plan (Golder 2013) and in-progress Design, Operations and Closure Plan (DOCP) update (Golder 2019)
- annual environmental monitoring reports (Summit 2011 and 2012)
- hydrogeological characterization report (WWAL 2018)
- most recent landfill annual report (CSRD 2018)
- BC Ministry of Environment and Climate Action Strategy (BC ENV) Environmental Impact Assessment Review (BC ENV 2018a)

1.2 Objective

This EMP has been prepared to fulfill the requirements of OC 17006 Section 4 whereby a monitoring program must be developed by Qualified Professional and submitted to the satisfaction of the Director, *Environmental Management Act.* To meet these requirements, the EMP has been designed to assess compliance of the Landfill performance with respect to groundwater quality at the landfill boundary, residential well water quality and surface water quality, and to characterize the Landfill leachate.

1.3 Regulatory Context

1.3.1 General

A description of the requirements for design and operations of the Site landfill are detailed in the DOCP (Golder 2019). The following regulatory and guidance documents were consulted in the development of this EMP:

- Operational Certificate 17006 amended August 29, 2012
- BC *Environmental Management Act* (EMA [SBC 2003]), including the *Landfill Gas Management Regulation* BC Reg 391/2008 O.C. 903/2008, brought into force on 1 January 2009.
- *Landfill Criteria for Municipal Solid Waste* (Landfill Criteria; BC ENV 2016)
- *Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills* (BC ENV 2019)
- *British Columbia Field Sampling Manual* (BC ENV 2103a)
- *British Columbia Environmental Laboratory Manual* (BC ENV 2013b)

The Landfill Criteria guidance document (BC ENV 2016) specifies that current and planned future uses of groundwater and surface water shall be identified within 1 km of the landfill footprint and after considering these uses, a Qualified Professional must recommend the appropriate water quality criteria, compliance locations, and provide related rationale and justification. As a minimum, the criteria must be satisfied at and beyond the landfill site boundary, or 150 m from the landfill footprint, whichever is closer. The water quality criteria and compliance monitoring locations are subject to approval of the Director, who may set more stringent requirements.

1.3.2 Water Quality Standards and Guidelines

The following provincial water quality standards and guidelines apply within BC:

- BC Contaminated Sites Regulation (CSR; BC Reg. 375/96 O.C. 1480/96, including amendments up to B.C. Reg. 116/2018, 24 January 2019. EMA [SBC 2003]) Schedule 3.2 Generic Numerical Water Standards.
  - One or more of Aquatic Life (AW), Irrigation (IW), Livestock (LW), or Drinking Water (DW) standards may be applicable at a site, depending on the water use determination.
  - Aquatic Life standards are typically 10 times greater than the respective BC WQGs based on the assumption that 10-fold dilutions will occur before discharge.
- BC Water Quality Guidelines (BC WQGs) for the protection of aquatic life, which apply to receiving surface waters and comprise working and approved guidelines (BC ENV 2017a; BC ENV 2018b).
  - Approved Water Quality Guidelines, which are considered safe concentrations of substances for particular water uses and have been developed to provide policy direction for decision makers within the ENV, including for the purpose of assessing allowable limits in waste discharge authorizations.
  - Working Water Quality Guidelines, which have been adopted for substances that do not have formally approved water quality guidelines. They provide benchmarks for parameters that have not been fully assessed by BC ENV; however, as they may be based on historical information or different derivation protocols from different agencies, they should be used with caution.

In addition, the Guidelines for Canadian Drinking Water Quality established by Health Canada apply to groundwater derived from water supply wells.

1.3.3 Selection of Applicable Water Quality Standards and Guidelines

The qualified professional responsible for implementing the environmental monitoring plan and interpreting the results should select appropriate guidelines for comparison of environmental monitoring program sample results that consider the current and future land use, background conditions, and provincial regulatory guidance. In addition to the regulations and standards listed above, the following guidance documents are considered applicable with respect to groundwater monitoring:

- *Technical Guidance on Contaminated Sites 3: Environmental Quality Standards* (BC ENV 2017b)
- *Technical Guidance on Contaminated Sites 15: Concentration Limits for the Protection of Aquatic Receiving Environments* (BC ENV 2017c)
- *Protocol 21 for Contaminated Sites Water Use Determination* (BC ENV 2017d)

Based on the regulations, standards and guidance documents above, the following water quality standards are considered applicable to the assessment of groundwater conditions:

- for the Site monitoring wells, CSR drinking water (DW) standards to protect drinking water in the area are applicable because groundwater is extracted for drinking water use in the area and based on *Protocol 21* (BC ENV 2017d)
- for the monitored off-Site water supply wells, CSR drinking water (DW) standards and Canadian Drinking Water Guidelines are applicable

CSR aquatic life (AW) standards are not considered applicable since the only mapped surface water bodies within 500 m of the Site are ephemeral streams. CSR standards for irrigation and livestock are not considered applicable because groundwater in the vicinity of the Landfill is not known to be used for irrigation or livestock watering.

In addition to water quality standards, the groundwater sampling results should be evaluated in the context of background groundwater chemistry.

Descriptions of the sampling locations and frequencies are presented in Section 2.0 and descriptions of regulatory limits, triggers and remedial actions are presented in Section 4.0 of this report.

1.3.4 Landfill Gas

The Landfill Criteria (BC ENV 2016) requires that:

- Soil gas concentrations at the landfill Site boundary must not exceed the lower explosive limit of methane (5 percent by volume) at any time and combustible gas concentrations measured in on-site buildings must not exceed 20 percent of the lower explosive limit of methane (1 percent by volume) at any time.
- Landfill gas must be managed in accordance with all migration and health and safety requirements, for example, WorkSafe BC.
- Landfill gas management should meet the requirements of the Landfill Gas Management Regulation. In addition to the reporting requirements of this regulation, landfills determined to be generating more than 1,000 tonnes of methane per year are required to prepare a LFG management plan and implement a LFG management system. Methane generation at the Golden Landfill is currently less than 1,000 tonnes per year and is estimated to remain below this threshold for the remaining lifespan of the facility.

It is noted that OC 17006 states that the Landfill must not cause combustible gas concentrations to exceed the lower explosive limit in soils at the property boundary or 25 percent of the lower explosive limit in on-site structures. However, it is recommended that the 20 percent LEL guideline presented in the Landfill Criteria be adopted for on-site structures since it provides a safer trigger limit.

1.4 Site Setting

Detailed descriptions of the Landfill site setting are provided in the Design and Operating Plan (Golder 2013) and hydrogeological characterization report (WWAL 2019a). A summary of the site setting and identified environmental receptors is provided below.

1.4.1 Topography, Drainage and Land Use

The Landfill property occupies a plan area of approximately 16 hectares. The Landfill generally slopes down to the southwest from elevation 955 m (above sea level) at its northeast corner, to elevations of about 925 to 930 m along the northwest southeast diagonal of the Site (Golder 2013). The topography is flatter from the northwest-southeast diagonal to the southwest corner of the Landfill. The slopes at the southwest corner of the Site are about 120 m higher than the Kicking Horse River. Currently, other than roads along its east, north and west perimeter, the Landfill is surrounded by natural terrain vegetated with trees. Based on the 2011 Town of Golden Zoning (bylaw 1294), planned future land use for land to south and west of the Landfill boundaries is residential; parks and trails; and, community education and culture.

As documented in the DOCP (Golder 2019), surface water will be directed around the Landfill footprint, including intermittent flows which enter from a ravine at the northeast corner. The ravine is normally dry but flows in extremely wet weather or periods of high runoff. Ponds will be established on-site outside of the landfill footprint to detain surface water and allow it to infiltrate into the subsurface. Any overflow from these ponds will enter the drainage system adjacent to Golden Donald Upper Road which flows to the south and then west for about 2.5 km and discharges to the Kicking Horse River. Another unnamed surface watercourse exists approximately 180 m south of the Site. This watercourse flows to the southwest for about 1.1 km and discharges to a catch-basin near Station Avenue.

Hospital Creek collects drainage from the sub-watershed area northwest of the Landfill. It is located approximately 800 m from the Landfill and flows in a southwesterly direction until discharging to the Kicking Horse River.

1.4.2 Geology

The Landfill is underlain with ablation till to the east and ice-contact materials to the west, both of which primarily comprise silt, sand and gravel (Golder 2013). Surficial deposits vary across the Site, with the surficial sediments on the east side of the Site being siltier and comprising, dense, gravelly sand and silty till-like material (Golder 2013). These deposits are estimated to have low hydraulic conductivity. Clean, bedded sand and gravel alluvial deposits are present on the south side of the Landfill and have been characterized as moderately permeable (Golder 2013).

Unconsolidated material is thicker in the southwest area of the Site and thinner toward the north and bedrock outcrops at the eastern edge of the Site (WWAL 2019a). Geological Survey of Canada mapping classifies bedrock beneath the Site as McKay Group limestone, limestone conglomerate, shale and associated meta-sedimentary rocks.

1.4.3 Hydrogeology

Conceptual Model of Regional Hydrogeology

Golder developed a regional conceptual hydrogeological model for the Town of Golden (including the area of the Landfill) as part of groundwater protection planning work (Golder 2006). Based on this model, regional groundwater flows occur in the surficial deposits (i.e., sand and gravel), and in the bedrock strata below. The upland areas are typically groundwater recharge areas, and the Columbia River valley represents a regional discharge area. Groundwater infiltrating the bedrock in the upland areas migrates downward, and then laterally into the surficial deposits that occur in the river valley, via fractures in the bedrock. Groundwater flow in the main sand and gravel aquifer that occupies the river valley is relatively slow and generally from southeast to northwest, along the Columbia River valley; however, lateral inflow also occurs (Golder 2006).

The ENV Water Resources Atlas (Province of BC 2019) has mapped one unconfined sand and gravel aquifer (No. 456) in Golden at the confluence of the Kicking Horse River and the Columbia River. Previous work by Golder indicates that there are three generally laterally continuous, sand and gravel deposits that make up the regional aquifer system (Golder 2006). The deeper water-producing strata are interlayered with finer-grained strata that act as aquitards. Most of the groundwater supply wells in the area that are completed in unconsolidated material are installed beneath confining layers and are protected from potential impacts to groundwater quality from surface activities. Based on previous publicly available groundwater protection work completed for the Town of Golden, the Landfill lies to the north, outside of the extent of Aquifer No. 456 and outside of the time-of-travel capture zones and buffer zones for municipal wells No. 4 and No. 6 (Golder 2006).

Hydrogeological Characterization of Site

A detailed description of the Site hydrogeology is provided in the recently completed hydrogeological characterization report by others (WWAL 2019a). Below is a summary of the information from the report that is relevant to the development of this environmental monitoring plan.

The ENV Water Resources Atlas (Province of BC 2019) does not report an aquifer beneath the Landfill. Based on well records for drilling completed at the Site, the unconsolidated deposits are thicker in the southwest area of the Landfill (115 m at MW18-11) and thinner toward the north, with bedrock outcropping at the eastern edge of the Site. Drilling records indicate that the unconsolidated materials in the area of the Landfill are largely unsaturated; however, there are areas where saturated conditions within the overburden sediments were encountered e.g., MW09-06 (WWAL 2019a). The saturation level of shallow unconfined sediments in the area of the Landfill will be strongly controlled by groundwater recharge from precipitation and surface water loss to ground. WWAL inferred that the majority of recharge to groundwater from precipitation infiltrating the Landfill will migrate downward to the bedrock surface.

Groundwater flow in bedrock aquifers can be complex and less predictable than flow in unconsolidated materials since fracture orientation and density are important factors. With the available information it is difficult to assess the groundwater flow paths and travel times for transport of leachate constituents from the Landfill. Based on data from four monitoring wells installed in the bedrock, groundwater flow at the site is from northeast to southwest (WWAL 2019a). The steeply dipping bedrock surface at the southern boundary makes it difficult to estimate the groundwater flow direction and gradient immediately downgradient of the Landfill, and it is uncertain how and where potential leachate-affected groundwater migrates through the bedrock aquifer and discharges to Aquifer No. 456 (WWAL 2019a).

1.5 Potential Environmental Receptors

Based on the Site setting and land use, the following potential environmental receptors were considered in the development of the Environmental Monitoring Plan:

- Groundwater used for drinking water downgradient of Site
- Aquatic receiving environments downstream of the Site
  - Kicking Horse River
  - Hospital Creek
- Soil quality on adjacent lands where daylighting of leachate seepage from the Site may occur
- Air quality within on-Site structures and crawl spaces

Based on the surface water regime described in Section 2.2, the aquatic receiving environment is not considered to be subject to a Landfill influence and therefore surface water monitoring has not been included in the Environmental Monitoring Plan. Based on the soil sampling conducted by others that is described in Section 1.6, Bullet 7, the soil quality on adjacent lands is not characterized by constituents associated with a Landfill influence and therefore the Environmental Monitoring Plan does not include monitoring of soil chemistry. The Monitoring Plan includes provisions for groundwater monitoring to assess the potential influence of the Landfill on downgradient groundwater resources (Section 2.1) and for Landfill gas monitoring (Section 2.3).

1.6 Potential Impacts

The hydrogeological characterization and analysis of environmental monitoring data for the Landfill have been completed by others. Based on the hydrogeological characterization (WWAL 2019a) and most recent environmental monitoring annual report (WWAL 2019b) contained within the 2018 Annual Operations and Monitoring Report (CSRD 2019):

- Western Water Associates Ltd. estimated the potential mass loading of chloride from the Landfill to Aquifer 456 of on the order of 394 mg/day which was estimated to represent less than 1% of the annual chloride contained in the aquifer. As a result, they infer that the Landfill is not contributing to measurable water quality degradation within Aquifer No. 456 (WWAL 2019a).
- Exceedances of drinking water guidelines/standards for arsenic, lithium, strontium, fluoride, iron, manganese, and cobalt observed at the historically-monitored wells, the two new monitoring wells installed at the Landfill in 2018, and the five additional domestic wells sampled in 2018 are interpreted by WWAL to be naturally-occurring within the bedrock (WWAL 2019a).
- Domestic wells DWM-1b and DWM-4, which are located upgradient of the Landfill, are not interpreted to be impacted by the Landfill (WWAL 2019a).
- There is the potential that groundwater beneath a portion of the neighboring property exceeds the groundwater quality standards based on chloride and nitrate exceeding applicable drinking water guidelines/standards at MW18-10, which is located at the south boundary of the Site and installed in bedrock to a depth of 36.4 m below grade (WWAL 2019a),

- Groundwater quality at MW09-6S, located near the western boundary and installed in overburden to a depth of 34.5 m below grade, shows evidence of groundwater quality impact from Landfill leachate. Concentrations of chloride and nitrate appear to have decreased since 2009 (WWAL 2019b).
- Based on one sample collected since it was drilled, groundwater quality at MW18-11, which was installed in bedrock to a depth of 146.3 m below grade, does not appear to be impacted by Landfill leachate (WWAL 2019b).
- Based on soil sampling conducted at the neighboring property to the south of the Site in 2018, no impact on soils related to metals and chloride from off-site surface water runoff were detected (WWAL 2019b).
- During spring freshet and high precipitation periods, surface water may flow onto, through and off the Landfill site, and there is evidence that this flow has at times been impacted by the Landfill (BC ENV 2018a).

In Golder's opinion, the assessment of potential impacts from the Landfill must be carried out in the context of local hydrogeological conditions, which are highly complex. Only isolated portions of the unconsolidated material in the vicinity of the Landfill are saturated. The occurrence of groundwater in the underlying bedrock, through which most local groundwater flow occurs, is variable, ranging from approximately 30 m below ground surface beneath the Landfill to 150 m below ground surface downgradient and southwest of the Landfill. This variability complicates the interpretation of the groundwater flow pattern downgradient of the Landfill. The lithologies of the underlying sedimentary bedrock material vary from limestone to argillite to slate. These differing lithologies influence the groundwater geochemistry in the monitoring wells and can result in naturally occurring exceedances of some metals and possibly dissolved anions. The occurrence of elevated chloride in groundwater that is not hydraulically downgradient of the Landfill suggests that the elevated chloride concentrations in groundwater at some locations is not related to the Landfill but rather to alternative sources, such as road salt. Finally, the decline in concentrations of chloride and nitrate in downgradient monitoring wells MW09-06S and MW09-06D raises the possibility that the elevated concentrations of these constituents at those locations could have been the result of water introduced during the drilling process, rather than the Landfill.

2.0 ENVIRONMENTAL MONITORING PROGRAM

The following sections describe the environmental monitoring program currently recommended for the Landfill. Monitoring locations are shown in Figure 2. The monitoring program should be updated when new information becomes available, and at a minimum every five-years as required by OC 17006.

2.1 Groundwater

Groundwater monitoring has been carried out at the Landfill by Sperling Hansen Associates prior to 2008, by Summit Environmental Consultants (now Associated Engineering) from 2008-2013, and Western Water Associates Ltd. since 2014. From 2010-2018 the groundwater monitoring program was carried out three times per year. The following subsections describe the groundwater monitoring program implemented in 2018 and any recommended modifications.

2.1.1 Groundwater Well Network

The monitoring wells in which groundwater levels and groundwater samples are collected are located either along or outside the Landfill perimeter. Their locations are shown in Figure 2. A summary of the Site monitoring wells and other historically monitored wells, and their respective installation details is provided in Table 1.

Table 1: Details of Groundwater Monitoring Wells at the Golden Landfill and other Wells Historically Monitored

Well ID	Screened Unit	Lithology	Location Relative to Landfill	Approximate Ground Surface Elevation (masl)	Total Depth (mbtoc)
MW95-2 (TH2) – Decommissioned	Overburden		Downgradient	915	22.5
MW09-06S (MW-6S)	Overburden	Gravel	Within Landfill footprint	920	34.5
MW09-06D (MW-6D)	Bedrock	Limestone	Within Landfill footprint	920	65.9
MW09-07 (TH-7) Status Unknown	Overburden	Gravel, sand	Downgradient	Unknown	31.7
MW10-08 (TH-8)	Bedrock	Slate and “quartz bedrock”	Upgradient	921	26.2
MW18-10	Bedrock	“Mapped as argillite, shale, limestone”	Within Landfill footprint	920	36.4
MW18-11	Bedrock	“Mapped as argillite, shale, limestone”	Downgradient	915	146.3
Town Well #4	Unknown (assumed to be overburden)		Side-gradient	790	Unknown
Town Well #6	Unknown (assumed to be overburden)	Sand and gravel	Side-gradient	Unknown	Unknown
DMW-1b	Bedrock		Up-gradient	975	60
DMW-4	Unknown (assumed to be bedrock based on depth)		Up-gradient	Unknown	120

Notes:
Data is from WWAL 2019b.
masl=metres above sea level, mbtoc = metres below top of casing, mbgs = meters below ground surface

2.1.2 Groundwater Sampling and Groundwater Level Monitoring

Groundwater monitoring was carried out twice per year before 2010, and three times per year after 2010. Sampling in 2018 was carried out in June, September and December, with groundwater samples collected from four monitoring wells (MW09-6S, MW10-08, MW10-10 and MW18-11); two domestic wells (DMW-1b and DMW-4) considered to represent background conditions; and, two municipal supply wells (Town Well #4 and Town Well #6). Groundwater monitoring wells MW95-2 (TH2) and MW09-07 (TH7) have been historically dry, and samples were not obtained from either well in 2018. MW95-2 was decommissioned by a qualified well driller in June 2018. Water quality monitoring of MW09-6D was stopped in 2011 because it was considered redundant to MW09-6S (WWAL 2019b).

The hydrogeological review presents a figure showing the inferred groundwater flow direction in the bedrock (WWAL 2019a); however, the 2018 annual monitoring report (WWAL 2019b) does not present groundwater level measurements.

The 2018 annual report (WWAL 2019b) contains the following recommendations regarding the groundwater monitoring program at the Site:

- Continue to monitor the newly added monitoring wells (MW18-10 and MW18-11) and, if the landowner agrees, add private water Well ID 22653 (screened in gravel and sand) to the groundwater monitoring program.
- Conduct two more years of water level and aquifer geochemical data collection to assess variation in groundwater flow direction in the bedrock and the presence of trends in concentrations of chloride and nitrate. If further exploration of the bedrock aquifer to assess for contamination is deemed appropriate, a downgradient, off-site monitoring well should be drilled, potentially at Pine Road and Golden Donald Upper Road, approximately 250 m southwest of MW18-10.

In addition to the recommendations made in the hydrogeological review (WWAL 2019a) and 2018 monitoring (WWAL 2019b) reports, Golder recommends that:

- Monitoring of bedrock monitoring well MW09-6D should be recommenced. The groundwater geochemistry at MW09-6D differs from the overburden well at that location (MW09-6S) and monitoring both wells will help to discern the potential for Landfill-impacted groundwater to migrate through both the bedrock and overburden sediments at that location.
- The groundwater monitoring frequency be increased to quarterly to assess seasonal variations in water levels and chemistry. In 2018 sampling was conducted in June, September, and December. The first quarter sampling event should be timed to target peak groundwater levels (i.e. inferred to be March).
- A water level monitoring program should be implemented at the Landfill monitoring wells to assess seasonal variations in groundwater levels and flow direction. A high-accuracy geodetic elevation survey should be completed for the monitoring wells and should include the ground surface and water level monitoring datum for each well. A round of manual groundwater level measurements should be recorded for each water quality sampling event. After a year of water level measurements is collected, the frequency of water level measurements should be re-evaluated by the qualified professional responsible for analysis of the hydrogeological monitoring data. The water level data collected during the monitoring program should be tabulated and plotted appropriately to assess for seasonal changes in groundwater flow direction and

gradient. Installation of automatic recording pressure transducers in select monitoring wells at the Landfill would be helpful for this purpose.

- Should results of the groundwater level monitoring indicate that the groundwater monitoring program is not capturing the full range of annual seasonal fluctuations in groundwater level, consideration should be given to increasing the water level monitoring and quality sampling frequency. The sampling events should be timed to capture seasonal high and low groundwater levels.
- Response testing should be carried out at monitoring wells where the hydraulic conductivity has not already been estimated.

A summary of the proposed groundwater monitoring program is presented in Table 2.

Table 2: Proposed Golden Landfill Environmental Monitoring Groundwater Program

Well ID	Location	Water Level Monitoring	Field Parameters and Water Quality Sampling
MW09-6S (MW-6S)	Within Landfill footprint	Yes, assess for seasonal variations	quarterly
MW09-6D (MW-6D)	Within Landfill footprint	Yes, assess for seasonal variations	quarterly
MW09-07 (TH-7)	Downgradient	If accessible, monitor to confirm well is dry	None
MW10-08 (TH-8)	Upgradient	Yes, assess for seasonal variations	quarterly
MW18-10	Within Landfill footprint	Yes, assess for seasonal variations	quarterly
MW18-11	Downgradient	Yes, assess for seasonal variations	quarterly
Town Well #4	Side-gradient	Not required as part of landfill monitoring	annually
Town Well #6	Side-gradient	Not required as part of landfill monitoring	annually
DMW-1b	Upgradient	If possible	quarterly
DMW-4	Upgradient	If possible	quarterly
Private Well 22653	Downgradient	Not required as part of landfill monitoring	quarterly

Well records for upgradient wells DMW-1b and DMW-4 are not available; however, based on their depths, both wells are inferred to be completed in bedrock. A review of bedrock mapping for the area indicates that bedrock upgradient, beneath and downgradient of the Site is characterized by mudstone, siltstone, shale and fine clastic rocks of the McKay Group. As a result, DMW-1b and DMW-4 are considered appropriate for monitoring of upgradient groundwater bedrock chemistry.

2.1.3 Field Measurements

At each sampling event a record should be made of the monitoring well condition, and a water level measurement should be recorded, along with the date and time of the measurement. Depending on the sampling method used, field parameter measurements should be recorded either following purging of the standing water, or stabilization (for low-flow, minimal drawdown sampling).

The following field parameters should be recorded:

- temperature
- pH
- electrical conductivity
- oxidation-reduction potential
- dissolved oxygen

In addition, the sample turbidity, colour and any other notable observations (odour, sheen) should be recorded. Efforts should be made to collect groundwater samples with a turbidity of less than 50 NTU.

2.1.4 Chemical Analyses

After the collection of groundwater samples, selected samples should be submitted to a certified analytical laboratory for chemical analyses. Each groundwater sample collected should be analyzed for the following suite of geochemical parameters, which are typical indicators of landfill leachate:

- electrical conductivity and pH
- total suspended solids and turbidity
- hardness and total alkalinity
- anions (chloride, fluoride, bromide, and sulphate)
- nutrients (ammonia, nitrate, and nitrite)
- dissolved metals

In addition, analyses should be conducted for total dissolved solids (TDS), biological oxygen demand (BOD) and chemical oxygen demand (COD).

Analysis for petroleum hydrocarbons and volatile organic compounds is recommended for each monitoring well location once per year, to evaluate potential impacts from contaminated soils that have been handled at the Landfill.

To provide additional insight into the groundwater chemistry of the site, sampling for isotopes is recommended on an annual basis over a two-year period (monitoring years 2020 and 2021). The analysis may include sampling and analysis for tritium (a leachate indicator parameter), oxygen and deuterium (an indicator of groundwater origin) and chlorine isotopes (as an indicator of chloride sources).

2.2 Surface Water Monitoring

The Landfill is located in an area with a relatively dry climate, with hot summers and moderate winters. The climate normals from 1981 to 2010 for the Golden A Climate Station (ID 1173210) from Environment Canada indicate that the average temperature at the Site is 5.1ºC. The coldest month is January, with an average daily minimum temperature of -11.5ºC. The warmest month is July, with an average daily maximum temperature of 24.5ºC.

The general area where the Landfill is located receives an average annual precipitation of 467 mm. Most of this precipitation occurs as rainfall (325 mm), with the remainder as snowfall. Monthly precipitations vary from 24.1 to 51.1 mm.

Given the climate conditions at the Landfill, surface water is observed at or near the Landfill only during the spring melt, although ephemeral surface water might be present in the summer during and after short-duration, high-intensity rainfall events. Since surface water is not present at the Landfill consistently, no regular surface water monitoring is currently conducted at the Landfill.

The OC 17006 requires that the quality of surface water at the Site be monitored. No regular surface water monitoring is currently recommended because surface water is not present at the Landfill consistently; and, the closest water body to the Landfill is Hospital Creek, located approximately 800 m to the northwest. Similarly, the Kicking Horse River is located over 1 km to the southwest. Furthermore, upgrades to the Landfill surface water drainage are planned that would divert water around the footprint. Thus, a surface water monitoring program is not recommended at this time.

The 2019 DOCP update (Golder 2019) is recommending that future Landfill development phases be constructed with an engineered leachate containment and collection system. Leachate sampling should be included in the EMP once the leachate collection system is in place so that leachate quality can be characterized.

2.3 Landfill Gas Monitoring

As described in the DOCP (Golder 2019), the predicted annual rate of potential methane generation is expected to remain below the 1,000 tonne per year trigger in the *Landfill Gas Management Regulation* for preparing an LFG management facility design plan and the subsequent installation of such a system at the Landfill. Therefore, a detailed LFG monitoring plan is not required for the Landfill at this time.

Landfill gas has been monitored by CSRD since 2013 using two nested gas sampling probes, installed along Landfill property boundaries (CSRD 2019). Gas probe 6 (GP-6S/GP-6D) is located on the west side of the property and gas probe 7 (GP-7S/GP-7D) is located at the southwest corner of the property. The gas sampling probes are nested with monitoring wells MW09-06 and MW09-07 (Figure 2). Each probe has 3 m of screened pipe and the nested probes are isolated by a 1 m length bentonite plug. The shallow probes are screened from approximately 1-4 m below grade and the deep probes are screened approximately 5-8 m below grade within loose unsaturated sediments. The installation of additional soil gas probes is recommended on the eastern Landfill property boundary since there are off-site structures to the east of the Landfill.

The Landfill has a weigh scale and a reuse centre. The weigh scale is occupied by the Site attendant during most of the operating hours, and the reuse centre is frequented occasionally by staff or Landfill users. Typically, Landfill buildings and offices are, and will be, all built above ground to reduce the potential for LFG migration into

the structures. The scale house is equipped with a continuous gas monitoring detection unit so no additional gas monitoring is considered necessary at this time. The CSRD should carry out periodic LFG monitoring within the reuse centre and any other future enclosed structures (if any) to confirm that air in the structures and their crawlspaces complies with the *Occupational Health and Safety Regulation* BC Reg. 296/97 of the *Workers Compensation Act* (RSBC 1996).

The proposed landfill gas monitoring locations, frequency and constituents are provided in Table 3. The following QA/QC protocols should be implemented as part of the LFG monitoring program:

- The combustible gas meter used to sample ambient air within the scale house and reuse centre should be bump tested weekly and calibrated annually
- Field staff who monitor the soil gas probes should ensure that the portable landfill gas analyzer has been calibrated within the 30 days prior to the monitoring event

These QA/QC activities should be documented and included with the monitoring records.

Table 3: Landfill Gas Sampling Locations

Location	Instruments	Constituents	Monitoring Frequency
GP-6S/GP-6D	Portable landfill gas analyzer such as a Landtec GEM series or equivalent	Methane CO_2 H_2S O_2 %LEL[1]	Twice a year
GP-7S/GP-7D	Portable landfill gas analyzer such as a Landtec GEM series or equivalent		Twice a year
Soil Gas Probes on Eastern Property Boundary	Portable landfill gas analyzer such as a Landtec GEM series or equivalent		Twice a year
Reuse Centre[2]	Portable combustible gas meter to sample ambient air	%LEL	Daily or as required by OHS legislation[3]

Notes:
[1] Percent lower explosive limit
[2] Monitoring requirements can be avoided if building ventilation is enhanced as described in Section 2.3.1
[3] Air sampling to detect landfill gas in enclosed work areas should be conducted according to applicable occupational health and safety legislation. If the frequency of sampling is not specified in the legislation, then a health and safety professional should be consulted to develop a risk-based monitoring plan. In the interim, daily monitoring would provide a regular frequency that should make scheduling easier to implement along with other site operation and maintenance activities.

2.3.1 Landfill Gas Monitoring in the Reuse Centre

The Landfill reuse centre has a sliding door that is open during Landfill operating hours and some ventilation provided by gaps below the side walls. However, there is the risk that if the building door remains closed for an extended period of time, landfill gas concentrations could accumulate within the structure.

If the CSRD would rather avoid the recommended monitoring requirements associated with this structure, it is recommended that building ventilation be improved. The recommended improvements include either removing the existing door or adding four 150 mm x 300 mm vents or openings on opposite walls and positioning them so that they are 0.6 to 1.5 m off the ground. These vents should remain unobstructed by materials inside the shed.

3.0 METHODS

3.1 Field Program

3.1.1 Protocols

As indicated in OC 17006, sampling for the environmental monitoring program must be carried out in accordance with the procedures described in the most recent edition of the British Columbia Field Sampling Manual (BC ENV 2013a), or suitable alternative procedures as authorized by the Director.

3.1.2 Health and Safety

The contractor responsible for implementing the environmental monitoring program should prepare a site-specific health and safety plan to identify hazards and appropriate controls to mitigate the risks. The contractor should implement the health and safety plan and conduct daily checks during field work to verify that the controls being implemented are appropriate.

3.2 Laboratory Analyses

As indicated in OC 17006, laboratory analyses for the environmental monitoring program must be carried out by a certified analytical laboratory in accordance with the procedures described in the most recent edition of the British Columbia Environmental Laboratory Manual (BC ENV 2013b), or suitable alternative procedures as authorized by the Director.

3.3 Quality Assurance/ Quality Control

The environmental monitoring program should implement quality assurance/quality control (QA/QC) measures that meet the requirements of OC 17006, the British Columbia Field Sampling Manual (BC ENV 2013a), and the British Columbia Environmental Laboratory Manual (BC ENV 2013b). The QA/QC measures should include:

- Chain-of-Custody procedures for the collection environmental quality samples and transportation to the analytical laboratory
- Decontamination of re-useable equipment
- Calibration of field equipment
- Collection of samples in laboratory-supplied containers, preservation of samples with chemicals supplied by the laboratory (if required), and storage of samples under refrigerated conditions until delivery to the analytical laboratory
- Field blank samples to assess the potential for contamination of samples
- Field replicate samples to assess the reproducibility of the sampling
- Checks and reviews during data tabulation, analysis and reporting

The OC 17006 has a requirement for CSRD to produce, on request, “Field and Laboratory Quality Protocols and Quality Assurance Criteria” acceptable to the Director. Specific requirements of these protocols and criteria are described in OC 17006, and include: procedures to assess precision, accuracy and blank quality; procedures for sampling and handling; corrective measures; and acceptance criteria for accuracy, precision, and method blanks.

3.4 Data and Interpretation

3.4.1 Data Management and Analysis

Documentation and samples collected for the environmental monitoring program should use consistent naming conventions. It is recommended that the environmental monitoring data be saved in a secure database-type system where results can be easily queried for reporting purposes. If required, analytical laboratory results for samples with EMS IDs should be uploaded to the Province of BC Environmental Monitoring System (EMS) database.

To meet the requirements of OC 17006, the data should be tabulated in accordance with the Guidelines for Environmental at Municipal Solid Waste Landfills (BC ENV 2019) and should be analyzed using appropriate statistical and graphical analyses to evaluate the potential impacts of the discharges on the receiving environment.

4.0 REGULATORY LIMITS, TRIGGERS AND REMEDIAL ACTIONS

4.1 Groundwater

The groundwater data from the monitoring wells should be compared with the CSR drinking water standards. Groundwater data from the off-Site drinking water wells should be compared to the same standards, along with the Canadian Drinking Water Guidelines established by Health Canada. Potential exceedances of these standards should be interpreted in the context of background groundwater quality conditions.

Should exceedances of the standards and/or guidelines occur at concentrations considered above the background groundwater quality, analysis of the results by a qualified professional should be undertaken to determine whether the exceedances are attributable to the Landfill (as opposed to alternative sources, such as road salt). This assessment should consist of refining the conceptual model for the Site through additional geochemical sampling and analysis (for example, isotopic analysis and review of major ion ratios) of existing monitoring wells, and if possible, leachate characterization.

If, based on this analysis, groundwater exceedances are inferred to be attributable to the Landfill, the recommended action, which is consistent with the 2018 Hydrogeological Assessment Report (WWAL, 2019a), is to collect two years of additional water-level and aquifer geochemical data to support the interpretation. Based on discussions with the CSRD, it is recommended that this data be reviewed and the Environmental Monitoring Plan be updated to reflect the findings by the end of the 2021 monitoring year. If, based on that review, the additional data suggests a Landfill source, a field investigation (including installation of one or more additional monitoring wells) should be implemented to further investigate the extent of the Landfill influence, the inferred groundwater flow pathways, and the potential impact on downgradient receptors. This may include the installation of an off-site downgradient bedrock monitoring well near Pine Drive and Golden Donald Upper Road as recommended by WWAL (2019a), and/or an on-site overburden monitoring well near the southwest corner of the Landfill. The

investigation should include an updated survey of nearby drinking water wells in accordance with WWAL (2019a). Should the field investigation identify a potential threat to downgradient receptors as a result of the Landfill, mitigative measures should be identified and implemented. Potential mitigative measures may include a Human Health and Environmental Risk Assessment to assess potential impacts, and/or the implementation of Landfill engineering controls.

4.2 Landfill Gas

Should elevated LFG concentrations be observed in enclosed spaces at the Landfill, the contingency response plans presented in the DOCP (Golder 2019) should be implemented immediately. If LFG concentrations exceed the regulatory criteria in the gas probes at the property boundary, then a qualified professional should be retained to assess the nature of the exceedance and recommend appropriate actions. Such follow-up actions could include verification monitoring, passive gas controls or active gas controls.

4.3 Reporting

The environmental monitoring program data should be compiled and reviewed annually by a qualified professional for submission of an annual report that meets the requirements of OC 17006. The current reporting requirements are to submit an Annual Report to the Director on or before 30 April each year for the previous calendar year and to submit a Five-Year Report to the Director on or before 30 April on the five-year anniversary of the last submission. Both these reports must include an outline of the current Environmental Monitoring Program and a compendium of all environmental monitoring data in accordance with requirements specified in the most recent version of Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills and Landfill Criteria for Municipal Solid Waste. The reports must document any potential effect of the discharge on the quality of the receiving environment using appropriate statistical and graphical analysis. Trend analyses, as well as an evaluation of the potential impacts of discharges on the receiving environment must be included.

5.0 DOCUMENT TRACKING

The following table provides information on the revision status of this environmental monitoring plan.

Table 4: Document Revision Tracking Table

Version	Date Issued	Author	Reference No.	CSRD Approver	Distribution
1.0	December 20, 2019	Golder	19120797-002-R-Rev0	Ben Van Nostrand, P.Ag.	Golder CSRD

6.0 CLOSURE

This Environmental Monitoring Plan was prepared by Golder Associates Ltd. with inputs from the Columbia Shuswap Regional District. Any required updates to this Plan should be identified in each year's annual Landfill report submitted to ENV as a requirement of OC 17006.

Golder Associates Ltd.

Pattie Amison

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA M. S. BUDZIK Dec 20, 2019

Pattie Amison, MSc, EP, PGeo
Senior Hydrogeologist

Michael Budzik, MEng, PEng
Senior Solid Waste Engineer

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA J. P. SACRE Dec 20/19 GEOSCIENTIST

Jillian Sacré, MSc, PGeo
Principal, Senior Hydrogeologist

PVA/MB/JS/asd

https://golderassociates.sharepoint.com/sites/107360/project files/6 deliverables/issued to client_for wp/issued to client_for wp/19120797-002-r-rev0/19120797-002-r-rev0-enviro monitoring plan 20dec_19.docx

7.0 REFERENCES

BC ENV. 2013a. British Columbia Field Sampling Manual for Continuous Monitoring and the Collection of Air, Air-Emission, Water, Wastewater, Soil, Sediment, and Biological Samples, 2013 Edition (Permittee).

BC ENV. 2013b. British Columbia Environmental Laboratory Manual (2013 Permittee Edition).

BC ENV. 2016. Landfill Criteria for Municipal Solid Waste.

BC ENV. 2017a. British Columbia Working Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture, Updated June 2017.

BC ENV. 2017b, Technical Guidance on Contaminated Sites 3. Environmental Quality Standards. Version 2. 1 November 2017.

BC ENV. 2017c, Technical Guidance on Contaminated Sites 15. Concentration Limits for the Protection of Aquatic Receiving Environments. Version 2. 1 November 2017.

BC ENV. 2017d. Protocol 21 for Contaminated Sites, Water Use Determination. Version 2.0. 31 October 2017.

BC ENV. 2018a. Environmental Impact Assessment Review, Columbia Shuswap Regional District, Golden Refuse Disposal Site OC 17006.

BC ENV. 2018b. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture, Summary Report. March 2018.

BC ENV. 2019. Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills, undated document downloaded from ENV website on 11 June 2019: https://www2.gov.bc.ca/gov/content/environment/waste-management/garbage/landfills

CSRD (Columbia Shuswap Regional District). 2019. Solid Waste Management Annual Operations and Monitoring Report, Golden Refuse and Disposal Facility (MR - 17006), 2018.

Golder (Golder Associates Ltd.). 2006. Conceptual Model, Preliminary Numerical Model and Contaminant Inventory. Town of Golden, BC. Aquifer Protection Plan.

Golder (Golder Associates Ltd.). 2013. Golden Landfill Design and Operating Plan, Golden, BC. Prepared for Columbia Shuswap Regional District. Golder Document No. 1314470187-001-R-Rev0-6000.

Golder (Golder Associates Ltd.). 2019. Draft Report in progress: Golden Landfill Design, Operations and Closure Plan. Prepared for Columbia Shuswap Regional District.

Kala (Kala Groundwater Consulting Ltd.). 1995. Hydrogeological Assessment, Columbia Shuswap Regional District Sanitary Landfill – Golden, BC. Report prepared for Reid Crowther & Partners Ltd. Kelowna, BC. Reference No. KG095.-057.

Province of BC. 2019. BC Water Resource Atlas. http://maps.gov.bc.ca/ess/hm/wrbc/

RSC (Revised Statues of Canada). 1985. *Fisheries Act*, c. F-14, s.1.

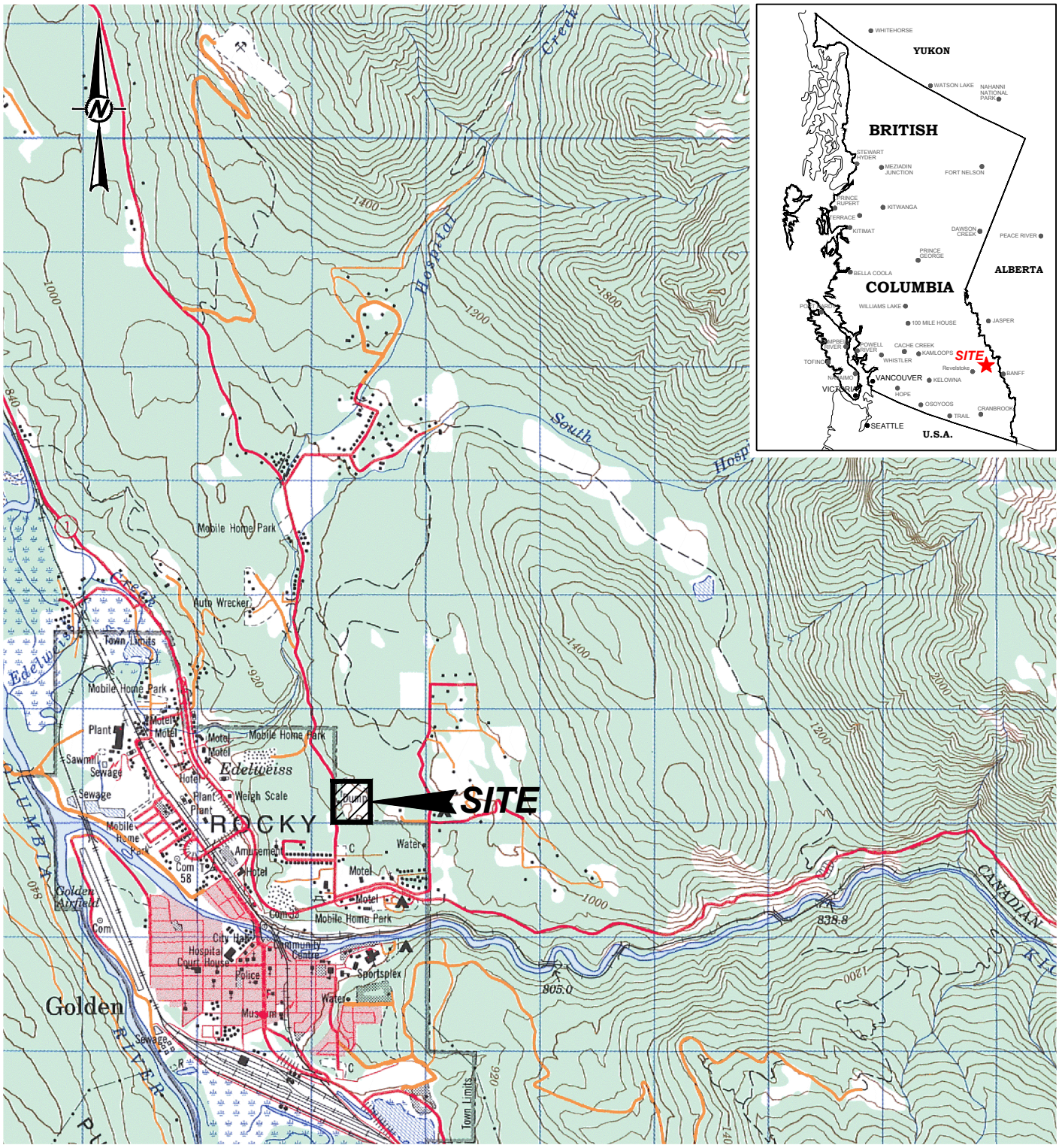
RSBC (Revised Statues of British Columbia). 1996. ch. 492. *Workers Compensation Act.* Current to 29 May 2019.

SBC (Statues of British Columbia). 2003. ch. 53. *Environmental Management Act.* Current to 15 May 2019.

Summit (Summit Environmental Consultants Inc.). 2012. 2011 Annual Environmental Monitoring Report, Golden Refuse Disposal Site, Golden, BC. Prepared for Columbia Shuswap Regional District. Summit Project No. 2009-8130.040.

WWAL (Western Water Associates Ltd.). 2019a. 2018 Hydrogeological Characterization Report, Golden Refuse and Disposal Facility (MR - 17006), Golden, BC. Prepared for Columbia Shuswap Regional District. WWAL Project No. 14-024-21.

WWAL (Western Water Associates Ltd.). 2019b. 2018 Environmental Monitoring Report Golden Refuse and Disposal Facility (MR - 17006), Golden, BC. Prepared for Columbia Shuswap Regional District. WWAL Project No. 14-024-16.



REFERENCE

BASE MAP FROM ETOPO, 1:50,000 NTS MAP 82N07, EDITION 4, UTM ZONE 11.

0 1,000 2,000 3,000

APPROXIMATE SCALE METRES

CLIENT

COLUMBIA SHUSWAP REGIONAL DISTRICT

CONSULTANT

GOLDER

YYYY-MM-DD	2019-12-18
DESIGNED	MB
PREPARED	GB
REVIEWED	MB
APPROVED	JS

PROJECT

GOLDEN LANDFILL
ENVIRONMENTAL MONITORING PLAN
GOLDEN, B.C.

TITLE

KEY PLAN

PROJECT NO.	PHASE/TASK	REV.	FIGURE
19120797	1000/300	0	1

Last Edited By: gbettoschi Date: 2019-12-19 Time:8:36:18 AM | Printed By: GBettoschi Date: 2019-12-20 Time:9:24:05 AM
Path: \\golder.gds\gal\burnaby\CAD-GIS\Client\Columbia_Shuswap_Regional_District\Golden_Landfill\99_PROJECTS\19120797\1000\300\02_PRODUCTION\DWG\ | File Name: 19120797-1000-300-02.dwg

LEGEND

- DOMESTIC MONITORING WELL BY OTHERS
- MONITORING WELL BY OTHERS
- PRODUCTION WELL BY OTHERS
- MONITORING WELL AND LANDFILL GAS MONITORING LOCATION BY OTHERS

REFERENCE

SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY

CLIENT
COLUMBIA SHUSWAP REGIONAL DISTRICT

CONSULTANT
GOLDER

YYYY-MM-DD	2019-12-18
DESIGNED	MB
PREPARED	GB
REVIEWED	MB
APPROVED	JS

PROJECT
GOLDEN LANDFILL
ENVIRONMENTAL MONITORING PLAN
GOLDEN, B.C.

TITLE
MONITORING LOCATION PLAN

PROJECT NO.	PHASE/TASK	REV.	FIGURE
19120797	1000/300	0	2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
0 25 mm

golder.com