2021 Design, Operations and Closure Plan

Northwin Landfill
Upland Pit Property
Campbell River, British Columbia

Upland Excavating Ltd.

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Symbols and Abbreviations

%	Percent
AMSL	Above Mean Sea Level
AW	Fresh Water Aquatic Life
BC	British Columbia
BOD	Biological Oxygen Demand
C&D waste	Construction and Demolition Waste
Ca	Calcium
CH_4	Methane
CHI	Computational Hydraulics International
City	City of Campbell River
CLS	Contaminating Life Span
cm/sec	centimetre per second
CO_2	Carbon Dioxide
COC	Contaminant of Concern
COD	Chemical Oxygen Demand
CSR	Contaminated Sites Regulation
DOCP	Design, Operations, and Closure Plan
DW	Drinking Water
EMA	Environmental Management Act

EMP	Environmental Monitoring Program
Fe	Iron
FOS	Factor of Safety
GCL	Geosynthetic Clay Liner
H2S	Hydrogen Sulfide
Ha	Hectare
HDPE	High Density Polyethylene
HEC-HMS	Hydrologic Engineering Centre-Hydrologic Modelling System
HELP	Hydrologic Evaluation of Landfill Performance
HHCR	Hydrogeology and Hydrology Characterization Report, GHD 2021
HWR	Hazardous Waste Regulation
ID	Identification Number
IDF	Intensity-Duration-Frequency
km	kilometre
Landfill	New Landfill or Northwin Landfill
Landfill Criteria	Second Edition Landfill Criteria for Municipal Solid Waste, dated June 2016
LCP	Leachate Collection Pipe
LFG	Landfill Gas
LTF	Leachate Treatment Facility
m	Metre
m^2	Square Metre
m^3	Cubic Metre
mm	Millimetre
mm^2	Square millimetre
mm/yr	Millimetre per year
MDL	Method Detection Limit
Mg	Magnesium
ENV	British Columbia Ministry of Environment
MOLO	Manager of Landfill Operations
MSW	Municipal Solid Waste
N_2	Nitrogen
NBCC	National Building Code of Canada
O_2	Oxygen
OC	Operational Certificate
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls

Pit	Upland Sand and Gravel Pit
Ppm	Parts Per Million
Property	7295 Gold River Highway
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance and Quality Control
scfm	standard cubic feet per minute
Site	7295 Gold River Highway
SRD	Strathcona Regional District
SWANA	Solid Waste Association of North America
SWMP	Surface Water Management Plan
TAC	Transportation Association of Canada
TDG	Transportation of Dangerous Goods
TDS	Total Dissolved Solids
TEH	Total Extractable Hydrocarbons
US	United States
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Hydrocarbons
WBM	Water Balance Method
WQG	Water Quality Guidelines
Zn	Zinc

1. Introduction

GHD was retained by Upland Excavating Ltd. (Upland) to prepare the 2021 Design, Operations and Closure Plan (DOCP) for the New Landfill, also known as Northwin Landfill (Landfill) located on the Upland Pit Property (Site).

The Site operates as a sand, gravel and rock quarry and a waste management facility. Aggregate and rock extraction activities have been on-going since 1976 within the Upland Pit, which contains large reserves of sand, gravel and basalt. An existing landfill containing a lined cell and an unlined cell (referred to as the Original Landfill) is located in the southeastern corner and has been in operation since 1992. The plan for the development of a new modernized landfill at the Site and discontinuation of the Original Landfill is described within this DOCP.

The Site is owned by Upland Excavating Ltd., which is part of Upland Group, one of the largest and most diversified construction companies on Vancouver Island, British Columbia (BC). The development of the Landfill has been undertaken by Upland Excavating Ltd. Northwin Environmental, an affiliated company, is responsible for Landfill operations. Mining operations of the Pit are carried out by Upland Contracting Ltd.

The New Landfill is authorized to accept demolition waste, construction waste, landfill clearing waste, soil meeting applicable British Columbia Contaminated Sites Regulation (CSR) industrial land use Standards, and sludge from Landfill leachate or water management works, at a maximum rate of 45,000 tonnes per year.

This DOCP was prepared to satisfy the requirements of the Operational Certificate 107689 (OC) issued August 1, 2019 and following the guidelines of the ENV BC Landfill Criteria for Municipal Solid Waste, Second Edition, dated June 2016 (Landfill Criteria).

Upland submitted an application for an OC amendment in June 2021 to request authorization to discharge contaminated soil that is nonhazardous waste to the New Landfill. This DOCP outlines operational procedure that meet the current authorized waste discharge under Section 1.3 of the OC and provides alternative procedures that will be following subsequent to the issuance of an OC amendment. In addition, the DOCP presents the New Landfill design that meets the considerations outlined in ENV's Interim Considerations for Landfill accepting Contaminated Soils Factsheet (Interim Considerations) (March 2021)[1].

1.1 Definitions

Northwin Landfill is referred to as *New Landfill* in the OC, and *Original Landfill* refers to the existing landfill on the Upland Pit Property.

For the purpose of this report, the term *Landfill* refers to the Northwin Landfill footprint including liner systems, leak detection system, leachate collection and treatment system and related appurtenances. *Original Landfill* is used to describe the existing landfill consisting of an unlined cell

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[1] https://www2.gov.bc.ca/assets/gov/environment/waste-management/garbage/gui-tec-04_landfilling_contaminated_soil_factsheet.pdf

and a lined cell. The Original Landfill is operated under the Operations and Closure Plan developed specifically for that site (GHD, Oct 2019).

The term *Site* refers to the Upland Pit Property that supports Landfill operations. The Upland Pit Property also supports operations of a sand, gravel and rock quarry authorized under the Mine Act.

1.2 Purpose and Scope

The purpose of this document is to outline the design, operations, and closure planning for the Landfill, and to fulfill the requirements specified in the OC (Appendix A) and the Landfill Criteria.

The scope of the DOCP is as follows:

- Present the conceptual design of the Landfill including base liner system, leak detection system, secondary base liner system, leachate collection and treatment systems, surface water management systems and final cover.
- Present groundwater flow model and water quality impact assessment.
- Present the Surface Water Management Plan and Leachate Management Plan, including the Leachate Management Works Commissioning Plan.
- Present the operational procedures for waste acceptance and landfilling, including the Soil Acceptance Plan and Original Landfill waste relocation plan.
- Present the Environmental Monitoring Plan.
- Present the Trigger Level Assessment Program and Contingency Plan.
- Present the closure and post-closure requirements for the Landfill.
- Present the Financial Security Plan.
- Demonstrate that the Landfill design, operations, and closure will meet the requirements of the Landfill Criteria and the Interim Considerations.

1.3 Site Location

The Site is located on the eastern portion of central Vancouver Island, approximately 7 km southwest of Campbell River, BC, city centre. The Site has an area of approximately 48 hectares (ha) and is located at civic address 7295 and 7311 Gold River Highway, Campbell River, BC. The Site’s southern property coincides with the boundary between the Campbell River (City) and the Strathcona Regional District (SRD). The Gold River Highway and McIvor Lake are located to the north and west of the Site. The legal description is LOT A PLAN VIP30709 DISTRICT LOT 85, SAYWARD DISTRICT, PLAN 30709 EXCEPT PART IN PLAN EPP15087 W ½ of DL 85 (PID: 001-223-321). A Site location map is presented in Figure 1.1. The Landfill and Original Landfill are located in the southern portion of the Site.

1.4 Site Zoning and Adjacent Land Use

The Site is zoned as I-3, as defined by the City of Campbell River Zoning Bylaw No. 3250 dated 2006; last amended June 9, 2015.

The land uses in proximity to the Site include residential, industrial and resource extraction activities (logging and gravel extraction). The area surrounding the Site is not serviced by a municipal sanitary sewer system or water distribution system. Highway 28, also referred to as the Gold River Highway, is located to the north of the Site.

Current adjacent land use is presented in Figure 1.2. To the north and west, on the opposite side of the Gold River Highway, lakefront residential properties line the McIvor Lake shore. To the immediate west surrounding Rico Lake are Upland-owned industrial properties, including the K&D Contracting storage yard on the industrial property north of Rico Lake. There is also a residential property west of the Site just north of Rico Lake. To the northeast of the Site on the opposite side of Argonaut Road, there are a number of industrial properties/activities including a gravel extraction pit, concrete redi-mix manufacturer, wood recycling and processing facility and the Campbell River Waste Management Centre. To the east of the Site on the same side of Argonaut Road is an area of industrial land uses including gravel extraction activities; further east is a large undeveloped rural area that extends generally uninterrupted to the Quinsam River. The property located at the northeast corner of the Site on the same side of Gold River Highway and Argonaut Road is crown land occupied by a telecommunication tower. The Site is bound to the south by forested Upland Resource land located within the administrative boundaries of Strathcona Regional District.

1.5 Regulatory Setting

The Landfill will be operated in accordance with the OC. The following Provincial legislation and guidance documents are applicable to the design, operations, and monitoring of the Landfill at this Site:

- Environmental Management Act
- BC Landfill Criteria for Municipal Solid Waste (BC ENV, 2016) (Landfill Criteria)
- Comox Strathcona Waste Management – 2012 Solid Waste Management Plan, December 2012
- Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills, January 1996 (Environmental Monitoring Guidelines)
- A Compendium of Working Water Quality Guidelines for British Columbia
- Contaminated Sites Regulation
- Hazardous Waste Regulation
- BC Mines Act
- Health, Safety and Reclamation Code for Mines in British Columbia (Revised April 2021)
- Interim Considerations for Landfill accepting Contaminated Soils Factsheet (March 2021)

1.5.1 Previous Waste Discharge Permit (Superseded)

Acceptance and discharge of certain waste materials at the Site were previously authorized under Waste Discharge Permit No. PR-10807, issued under the Environmental Management Act. The Permit was first issued on June 1, 1992. Under the Permit, the Site accepted clean wood wastes that were burned in the permitted Burn Area located along the southern boundary of the Site. The Permit also allowed for the discharge of wastes consisting of construction, demolition, and land clearing waste. Land clearing waste included stumps, trees, selected building demolition debris and residue of combustion from the open burning of wood waste. Permit No. PR-10807 has been superseded by the OC issued in August 2019.

1.5.2 Operational Certificate

Operational Certificate No. 107689 was issued to Upland for the Site on August 1, 2019. The OC allows for a New Landfill to be developed in the southern portion of the Site. The OC authorizes the acceptance and discharge of 45,000 tonnes of waste materials per year into the New Landfill at the Site. The characteristics of the authorized waste materials include construction, demolition, and land clearing wastes and soil that meets the industrial land use standards per the Contaminated Site Regulations (CSR).

The OC also authorizes continued discharge of waste to the Original Landfill until waste discharge commences within the New Landfill, at which point waste located in the Original Landfill is required to be removed and relocated to the New Landfill or other approved facility.

In June 2021 Upland submitted an application to amend the OC to request authorization to discharge soils greater than CSR Industrial Land Use Standards (IL+ soils). IL+ soils are defined as soils with parameter concentrations that exceed CSR Industrial Land Use Standards but are less than criteria for hazardous waste per the Hazardous Waste Regulation (HWR). The amendment application is currently under review by ENV.

1.5.3 Mine Act Permit

Quarry activities for excavation of pit run, blasting, crushing, screening and washing are conducted at the Site under the Mines Act Permit G-8-114 issued December 27, 1989, last amended in March 16, 2021.

2. Site Physical Characteristics

The Site physical characteristics are detailed in GHD's 2021 report entitled Hydrogeology and Hydrology Characterization Report Revision 1 (HHCR). A summary of the Site's physical characteristics is provided below. The monitoring well network referenced in this Section is described in Environmental Monitoring Plan in Section 14.

2.1 Site Topography and Drainage

2.1.1 Surface Water Features On-Site

Natural surface water features are not present on Site. There are two surface water points of diversion located within a one km radius of the Site: Rico Lake and McIvor Lake (iMapBC accessed on May 28, 2020).

2.1.2 Topography

The Site is located on a terrace that is partially surrounded by mountainous terrain to the south and southwest. The natural surface topography on-Site has been altered due to aggregate extraction activities. The aggregate extraction area (the Pit) is located in the centre of the terrace and has been excavated down to a base elevation of approximately 168 mAMSL. The on-Site areas surrounding the Pit are relatively level at an approximate elevation of 190 to 192 mAMSL.

To the southeast and east of the Site, the terrace slopes towards the adjoining property, which operates as a gravel extraction pit, and also gradually toward the Quinsam River located approximately 3.8 km from the nearest Site boundary. The Quinsam River channel is at an elevation approximately 100 m below the base of the Site's excavation.

To the west and south of the Site, surface topography steeply slopes in areas to reflect the following prominent topographic features:

- Rico Lake – Rico Lake is held within a topographic depression. The surrounding land dips toward the lake from 192 mAMSL to a base elevation between 168 mAMSL (CREC, August 2016) and 172 mAMSL (GHD, September 2018).
- Small Mountain – A small mountain is located southwest of the Site. The surface topography in this area rises approximately 100 m above the Site to 292 mAMSL. The mountain ridge gradually slopes to the east along the south Site boundary, towards the adjoining property.

2.1.3 Drainage and Watercourses

Two tertiary watersheds are located on-Site: the Campbell River Watershed and the Quinsam River Watershed, both of which are within the Campbell River Watershed Group. The local watershed divide is located within the southwestern portion of the Site.

The Campbell River Watershed is a sub-watershed of the Campbell River Watershed Group and covers an area of 182,000 ha. The Campbell River Watershed is intersected by three manmade dams, which form Upper Campbell Lake, Campbell Lake, John Hart Lake, and McIvor Lake. McIvor Lake is contiguous with Campbell Lake. Rico Lake drains into McIvor Lake. McIvor and Campbell Lakes drain into John Hart Lake north of the Ladore Falls Dam. John Hart Lake drains into Campbell River.

The Quinsam River Watershed is a sub-watershed of the Campbell River Watershed Group and covers an area of 20,900 ha. The Quinsam River Watershed is bound to the north and west by a mountainous divide that isolates it from the Campbell River Watershed (Blackmun, Lukyn, McLean and Ewart, 1985). The confluence of Campbell and Quinsam Rivers is located approximately 6 km northeast of the Site. The principal surface water feature of the Quinsam River Watershed is the Quinsam River, which is located approximately 3.8 km to the southeast of the eastern Site boundary.

Several ephemeral creeks located approximately 1.0 km to the southeast of the Site provides local drainage. Based on the local topographic data in this area, these creeks either loose water to the underlying aquifer or discharge into the Quinsam River. Lost Lake (also known as Hidden Lake) is located 1.8 km to the northeast of the southeast corner of the Site. Lost Lake drains through Cold Creek, which feeds the Quinsam Hatchery before discharging into the Quinsam River.

The watershed divide between the Campbell River and Quinsam River Watersheds passes just north of the Site (north of the Gold River Highway) and turns southward near the western Site boundary to traverse the southwestern portion of the Site. The watershed divide was determined based on information sourced from iMapBC (2019) and Site-specific data. West of the divide is the Campbell River Watershed. East of the divide is the Quinsam River Watershed.

Further details on the surface water flow model, as well as downgradient site drainage are outlined in the HHCR (GHD, 2021).

2.2 Geology

2.2.1 Regional Geology

Vancouver Island is part of the Wrangellia Terrane, which includes most of Vancouver Island, the Queen Charlotte Islands and parts of central Alaska. The Wrangellia Terrane is composed mostly of widespread, late Triassic aged flood basalts, including the Karmutsen Formation. The Karmutsen Formation consists mostly of submarine flood basalts up to 6 km in thickness. Vancouver Island is extensively faulted with thrust faults associated with the subduction of the Juan de Fuca Plate under the North American Plate (BC MOE and Guthrie, 2005) (Greene, Scoates and Weis, 2005).

At several time periods during the Pleistocene Epoch, Vancouver Island was glaciated with ice up to 2 km thick. During the recession of the last glaciation approximately 14,000 years ago, glacial and glacio-fluvial sediments were deposited, and in some cases reworked and redeposited, to make up many of the present surficial deposits of Vancouver Island. These deposits consist of till that was deposited directly by glacial activity[2] and of glacial outwash composed primarily of poorly sorted, coarse-grained sand and gravel sediments deposited by glacial melt water (Greene, Scoates, and Weis, 2005; McCammon, 1977).

2.2.2 Site Geology

The Site-specific geology has been characterized based on the results of the subsurface investigations including test pitting, drilling and geophysical programs, examination of the Pit sidewalls and bedrock outcrops, and documents reviewed by GHD. Documents reviewed included regional maps, previous reports, and well completion logs from private wells. Field investigations are detailed in the HHCR (GHD, 2021).

Based on the results of the investigations, five major stratigraphic units were identified as follows:

1. Cut/Fill unit
2. Sand and silt unit

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[2] This till consists of larger clasts supported in a matrix of fine-grained sediment

3. Sand and gravel unit
4. Sand unit
5. Karmutsen basalt bedrock

2.2.3 Surficial Geology

The surficial geology on-Site is comprised of four units including: cut/fill (gravel extraction or fill), a sand and silt unit, a sand and gravel unit, and a sand unit.

Cut/Full Unit

The Surficial cut/fill units include historical gravel extraction and fill material from on-Site sources.

- Gravel Extraction – The Pit has been in operation since 1969 and extensively modified the natural contours of the Site. In its natural condition, the Site terrace gradually sloped southeast and east toward the adjacent property. Prior to 2013, it is estimated that approximately 25 million cubic metres of granular material was removed from the Pit. The rate of extraction of granular material since 2014 has been approximately 190,000 tonnes per year.
- Fill Material – On the northwest (adjacent to the K&D property) and the southwest corners of the Site, granular fill consisting primarily of sand and gravel was encountered in several of the investigative locations up to a maximum thickness of 4.7 m.

Sand and Silt Unit

A discontinuous, interbedded sand and silt unit consisting of layers of sand with silt, silty sand, or silt with clay was encountered underlying a sand and gravel fill unit in the northwest (next to K&D Property) and southwest corners of the Site underlying the fill unit. The maximum thickness of the interbedded layers to the northwest is approximately 2.9 m (at MW15B-18). To the southwest, this unit is approximately 2.1 m in thickness (at MW5A-15).

Sand and Gravel Unit

A native interbedded sand and gravel unit makes up the majority of the overburden material throughout the Site. The unit consists of coarse grained materials, primarily sand and gravel of varying degrees, with occasional seams of sand and silty sand. This unit varies in thickness from less than 0.5 m to greater than 55 m due to the presence of the underlying bedrock. Along the western portion of the Site, the sand and gravel unit is either not present or thin due to the presence of bedrock outcrops and shallow bedrock. Within the remaining portion of the Site, where bedrock was encountered at much lower elevations, the thickness of the sand and gravel unit is substantial.

Sand Unit

Within the sand and gravel unit, a zone of finer grained sand was encountered at MW2A-16, MW4A/B-15 in the central portion of the Site, at MW10-17 in the southeast portion of the Site, and at MW11-19 at the northeast corner of the Site. This sand unit ranges in thickness from approximately 12 m (at MW4A/B-15) to 25 m (at MW10-17) and varies in composition from sand with gravel to silty sand/sandy silt. The sand unit is a minor component of the larger sand and gravel unit.

2.2.4 Bedrock Geology

Bedrock was encountered on and off-Site at numerous locations during Site investigations.

The bedrock at the Site can be described as fine grained, porphyritic, basalt of the Karmutsen Formation, which varies in colour from blueish black to dark grey and green to dark grey and pink to dark brown (Golder, 2014).

Fracturing is apparent within the upper bedrock unit including evidence of weathering (i.e., iron staining) and secondary mineralization. Fractures vary in size, density and orientation (vertical, horizontal, and oblique). The most significant fracturing was noted in the boring advanced within the Pit (MW4A-15). According to laboratory tests, calcite is present in fractures and amygdules (Golder, 2014). Underlying the upper fractured bedrock is competent bedrock.

The bedrock surface at the Site can be characterized with the following:

- A small mountain is present to the southwest of the Site. The foot of the mountain extends to the southwest corner of the Site boundary where bedrock outcrops are encountered at elevations of approximately 216 mAMSL.
- Bedrock can be described as competent or fractured. Competent bedrock was encountered at MW5A-15 which has a high rock quality designation (RQD), low hydraulic conductivity (1.4×10^{-5} cm/sec), and few fractures. Fractured bedrock was encountered at MW15A-18 which has a low RQD, higher hydraulic conductivity (8.3×10^{-3} cm/sec) and shows signs of weathering. At this location, no primary porosity or obvious weathering on fractured surfaces was apparent within the upper 1.2 m of bedrock. Weathered and sub-vertical and horizontal fractures were observed below the upper 1.2 m of bedrock from 9.5 to 15.2 m BGS. Precipitate of fractured surface was observed.
- The bedrock surface dips sharply across the Site towards the northeast and east. Underlying the Pit, bedrock was encountered between 183.0 mAMSL (outcrop in the southwest corner) to 145.25 mAMSL in the central portion of the Pit. Bedrock was not encountered in the investigation locations east of BH1-16. MW2A-16 was completed at an elevation of 127.68 mAMSL and did not intersect the bedrock surface. Thus, bedrock is at an elevation below 127.68 mAMSL.
- A bedrock highpoint was encountered northwest of the Pit, on the K&D Contracting property. This localized highpoint is present at elevations 183.5 to 182.1 mAMSL.
- South of the highpoint on the K&D Contracting property and northwest of the foot of the mountain, bedrock dips steeply towards Rico Lake.
- Several outcrops of competent bedrock were identified between the Small Mountain and the bedrock highpoint on the K&D Contracting property. This line of bedrock outcrops is interpreted to be a bedrock high within the western portion of the Site. Bedrock topography is the primary controlling feature on groundwater flow and overland surface water flow within the western portion of the Site. Bedrock in this area is interpreted to form a flow divide, which is part of the watershed divide between the Campbell River and Quinsam River Watersheds. Groundwater and overland flow east of the bedrock high is interpreted to flow towards the Site and into the Pit area, while groundwater and overland flow to the west is directed towards Rico or McIvor Lake.
- Borehole and geophysical data identified the presence of a sand and gravel scour channel that extends northeast from Rico Lake through the vicinity of MW15A/B-18.

2.3 Hydrogeology

2.3.1 Site Hydrogeology

The following three hydrostratigraphic units have been identified for the Site:

1. Sand and gravel aquifer
2. Shallow aquifer
3. Bedrock aquifer

The hydrogeologic properties and division of these aquifers are discussed in the following sections.

2.3.1.1 Sand and Gravel Aquifer

The sand and gravel aquifer occurs across the Site in the sand and gravel unit where the sand and silt unit is not present (northwest and southwest). As no bedrock was encountered during drilling along the northern Site boundary (MW8-17 and MW9-17) the sand and gravel aquifer is inferred to extend off Site to the north to intersect McIvor Lake.

The sand and gravel aquifer identified on-Site is a major aquifer in the region and is identified in iMapBC (May 29, 2020) as Aquifer 975. This aquifer is interpreted to be the principal groundwater flow zone at the Site. In the context of the future Landfill, this aquifer is the receptor of infiltrated treated effluent and infiltrated stormwater runoff. As such, this aquifer is of particular importance to this hydrogeologic characterization.

Groundwater elevations within the sand and gravel aquifer, (measured on March 11, May 7, and September 30, 2019), ranged from 144.8 mAMSL (MW11-19) to 184.8 mAMSL (MW7-17). Groundwater within the sand and gravel aquifer flows from northwest to southeast (i.e., from McIvor Lake to the southeast corner of the Site).

The McIvor Lake surface water elevation is partially controlled by BC Hydro's Ladore Dam located on the northern shore of McIvor Lake approximately 1.7 km northwest of Site. BC Hydro attempts to maintain a preferred water elevation at Ladore Dam between 176 and 178 mAMSL and has established a minimum operational water elevation of 174 mAMSL (BC Hydro, 2016). Based on BC Hydro records, water elevations at Ladore Dam have fluctuated between 174.5 and 177.9 mAMSL since 2008.

An average hydraulic gradient of 0.03 m/m is calculated for the sand and gravel aquifer across the Site (gradient calculated between McIvor Lake and MW10-17).

Based on single well response testing and pumping tests, the conservative estimate of hydraulic conductivity for the sand and gravel aquifer is approximately 2 x 10^{-2} cm/s.

Across the Site, the vadose zone ranged in thickness from 2.5 m at MW4B-15 to 49.2 m (MW11-19). Underlying the landfill footprint and downgradient of the landfill, the thickness of the vadose zone ranged from 13.1 m (MW3-14) and 49.2 m (MW11-19), respectively.

Further discussion on the properties of the sand and gravel aquifer, as well as seasonal variability can be found in the HHCR (GHD, 2021).

2.3.1.2 Shallow Aquifer

A relatively thin, discontinuous shallow aquifer is present in an area within the northern portion of the Site and throughout the K&D Property, between Rico Lake and the Pit, and in the southeastern corner of the Site (outside of the Pit). Groundwater flow in this area is largely controlled by bedrock surface topography.

Groundwater flow within the shallow aquifer in the northern portion of the Site varies west and east of the groundwater divide. West of the divide, groundwater flows to north toward McIvor Lake and south to Rico Lake. East of the divide, groundwater flows east towards the Pit and recharges the underlying sand and gravel.

Between Rico Lake and the Pit, groundwater within the shallow aquifer flows horizontally toward the Pit, and the scour channel and well nest MW15A/B-18 before recharging the sand and gravel aquifer.

Groundwater at the southeastern corner of the Site, in the vicinity of MW5A/B-15 is present within a thin overburden layer overlying competent bedrock. Groundwater at this location is approximately 23 m above the base of the Pit. Based on the presence of a mountain to the south, groundwater will likely flow downwards (potentially daylighting as seepage or through overburden materials as unsaturated flow) towards the Pit area where it will ultimately join the principal flow zone within the sand and gravel aquifer, flowing to the southeast. Flow from the vicinity of MW5A/B-15, is expected to be limited. This is evidenced by the relatively thin saturated thickness compared to the remaining sand and gravel aquifer monitoring wells.

2.3.1.3 Bedrock Aquifer

Groundwater movement through the upper bedrock is variable across the Site based on the presence of fractures. Shallow fractured bedrock was encountered underlying the sand and gravel aquifer at MW3-14, MW4A-15, BH1-16, BH2-16 and MW15A-18. Competent bedrock was encountered at MW5A-15. Due to the significant thickness of the sand and gravel aquifer in the eastern portion of the Site the bedrock was not encountered in the eastern portion of the Site.

Groundwater within the shallow fractured bedrock is monitored at MW15A-18 and MW4A-15. Monitoring well MW15A-18 is located on the K&D property. MW4A-15 is located in the central portion of the Site[3]. The bedrock aquifer in competent bedrock is monitored at MW5A-15, which is located southwest of the Pit.

Groundwater elevations at bedrock monitoring well MW15A-18 were 0.3 to 0.9 m higher than MW15B-18, which is screened within the shallow aquifer. This well nest is also screened in fractured bedrock and the shallow aquifer. The differences in elevation indicate the presence of an upward vertical hydraulic gradient between the fractured bedrock and the overlying shallow aquifer. As such, the bedrock recharges the shallow aquifer.

Groundwater elevations at bedrock monitoring well MW4A-15 were on average 0.2 m higher than at MW4B-15 which is screened within the sand and gravel aquifer, with the exception of the 2.2 m difference recorded during the April 6, 2017 monitoring event which appears to be anomalous.

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[3] MW3-14 is located in the west side of the aggregate pit and is partially screened in the bedrock aquifer and partially screened in the sand and gravel aquifer. The predominant flow system in this area is in the sand and gravel aquifer. Groundwater elevations measured in MW3-14 are more representative of overburden groundwater conditions in the sand and gravel aquifer.

The difference in elevation indicates the presence of an upward vertical hydraulic gradient between the shallow fractured bedrock and the overlying sand and gravel aquifer. As such, the bedrock recharges the sand and gravel aquifer in this area.

It is expected that the flow in the shallow fractured bedrock will follow regional flow (i.e., southeast towards the Quinsam River). This groundwater flow movement within bedrock is expected since the upper fractured bedrock is in direct hydraulic contact with the overlying sand and gravel aquifer and the similar hydraulic conductivity measured in the sand and gravel aquifer and the shallow fractured bedrock unit will limit groundwater flow-line inflections (i.e., direction changes).

The upward gradient noted above indicates that a component of groundwater from the shallow fractured bedrock aquifer will flow upwards and join the principal groundwater flow in the sand and gravel aquifer towards the south-southeast.

2.4 Climate

The climate of the east coast of Mid Vancouver Island, where the Site is located, is marked by wet and mild winters, and warmer drier summers.

Climatic data for the Site are based on Environment Canada's Climate Normals measured between 1980 and 2010 at the Campbell River Airport (Climate ID: 1021261). The average total monthly precipitation data and average daily temperature records are presented in Table 2.1, following the text. The average annual precipitation is reported to be 1,489 millimetres (mm) with over 75 percent of the precipitation occurring between October and March. November and December experience the most precipitation with an average of 232 and 226 mm, respectively. On average 84 mm of snowfall is recorded per year.

The Pacific Climate Impacts Consortium Plan2Adapt tool[4] was used to estimate the potential climate impacts that may be observed in the Campbell River area during the life of the Landfill as a result of climate change. The tool was used to model current climate change predictions in terms of precipitation rates. The model results for the Strathcona Region are summarized in the table below.

Table 2.1 Plan2Adapt Estimated Change in Precipitation (2050s)

		Projected Change from 1961-1990 Baseline to 2050s (2040-2069) Study Period for Comox Valley	
	Season	Ensemble Median	Range (10th to 90th Percentile)
Precipitation (%)	Annual	+2.7%	-1.4% to +6.7%
	Summer	-15%	-41% to +3.6%
	Winter	+5.2%	+0.004% to +10%

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[4] https://services.pacificclimate.org/plan2adapt/app/ Accessed June 26, 2021.

3. Landfill Design

3.1 Design and Siting Criteria

The Landfill design is based on the design requirements outlined in the Landfill Criteria and the OC. The following design criteria were considered in developing this DOCP:

3.1.1 Design Criteria from the Landfill Criteria

Siting Criteria

- Minimum 50 metre (m) buffer zone between limit of refuse and the property boundary.
- Minimum 30 m of natural or landscaped screening (berms and/or vegetative screens) adjacent to the property boundary.
- Minimum 500 m buffer zone between the limit of refuse and an existing or planned sensitive land use. Sensitive land uses include, but are not limited to: schools, residences, hotels, restaurants, cemeteries, food processing facilities, churches and municipal parks.
  - One residence is approximately 450 m upgradient from the Landfill footprint. As the waste will not contain significant quantities of organic material, the potential for nuisance impacts from odour or birds will not occur, as further discussed in Section 6.8.
- Minimum 100 m buffer zone between the limit of refuse and a heritage or archaeological site.
- Minimum 8 km buffer zone between the limit of refuse and an airport.
  - The nearest airport is located approximately 6.5 km from the Site; however, it is not anticipated that this will cause a problem as birds will not be attracted to the non-putrescible waste to be deposited at the Site.
- Minimum 300 m buffer zone between the limit of refuse and a water supply well or water supply intake.
- Minimum 500 m buffer zone between the limit of refuse and a municipal or other high-capacity water supply well.
- Minimum 100 m buffer zone between the limit of refuse and a geologically unstable area.
- Minimum 100 m buffer zone between the limit of refuse and an environmentally sensitive area.
- Minimum 100 m buffer zone between the limit of refuse and surface water.
- Minimum 100 m buffer zone between the limit of refuse and the sea level maximum high tide or seasonal high watermark of an inland lake shoreline.

Landfill Design

- Landfill base shall be a minimum 1.5 m above groundwater.
- Landfill base shall be graded to provide a minimum 2 percent grade for the primary drainage path (leachate collection piping) and minimum 0.5 percent for the secondary drainage path (drainage blanket).

- 300 mm thick stone drainage blanket with perforated collector pipes with protective geotextile layers. Stone drainage blanket shall be constructed of 50 mm diameter clear stone with minimal fines. The maximum drainage path in the drainage blanket to a leachate collection pipe shall be 50 m.
- The final cover barrier layer (permeability less than 1 x 10^{-7} cm/s) shall have a minimum compacted thickness of 0.6 m measured perpendicular to the slope with a minimum 0.15 m topsoil layer capable of establishment and sustained growth of the vegetative cover.
- Minimum top slope of 10H:1V (10 percent).
- Maximum side slope of 3H:1V (33 percent).

3.1.2 Design Criteria from the OC

- The secondary base liner and the primary base liner must each include an upper high-density polyethylene double sided textured geomembrane of minimum 1.5 mm thickness underlain by a lower geosynthetic clay liner of hydraulic conductivity less than or equal to 1 x 10^{-7} cm/s. However, geosynthetic clay liners are not required on the south slope of the base more than 1 m above the primary base liner.
- The leachate treatment pond must include from bottom to top; a secondary base liner, leak detection drainage layer and leak collection pipe(s), and a primary base liner. The secondary base liner and the primary base liner must each include an upper high-density polyethylene double sided textured geomembrane of minimum 1.5 mm thickness and a lower geosynthetic clay liner of hydraulic conductivity less than or equal to 1 x 10^{-7} cm/s.
- The leachate treatment pond(s) and treated leachate infiltration pond must maintain a minimum freeboard of 0.6 m at all times.
- Stormwater infiltration area (i.e., pond) must maintain a minimum freeboard of 0.6 m and all other authorized works (i.e., ditches) must maintain a freeboard of 0.3 m.

3.1.3 Design Criteria from the Interim Considerations

- Double composite liner systems should be considered for large landfills and/or any size of landfill that is nearby (less than 1 km) to a drinking water source. (Interim Consideration #5)
- A double composite liner at the leachate collection point with the ability to detect and contain a leak in the secondary leachate collection system should be considered. (Interim Consideration #6)
- Retention ponds and surface water ditches should be designed to retain water from and withstand a 200-year storm event. (Interim Consideration #7)

3.2 Site Layout

The Site activities include active aggregate extraction in the central Pit area and Landfill operations in the southern portion of the Site. The Site layout includes an access road network to facilitate both operations. The Site layout and operations is shown on Drawing C-02.

Site access to Gold River Highway is located in the northwest corner of the Site. A Site office, weigh scale, and operations shop is located near the entrance. An access road descends from the entrance area into the adjacent Pit, which is currently excavated to a depth of approximately 20 m below the surrounding topography. The base of Pit is not intended to be further excavated beyond the current bottom elevation for the purposes of gravel extraction. An aggregate wash plant is located near the centre of the Pit. The Original Landfill Area is located in the southeast corner of the Site and is accessed by an on-site access road around the perimeter of the central Pit area.

The Landfill footprint is shown on Drawing C-02 and located 50 m north of the southern property boundary to provide a buffer zone in accordance with the Landfill Criteria. The Original Landfill will be decommissioned as part of executing the plan of removal all waste from the Original Landfill, required under Section 2.9 (a) of the OC.

The Landfill leachate treatment facility (LTF) will be located northeast of the landfill footprint, adjacent to the current Original Landfill footprint. The LTF includes a leachate treatment pond and a treated effluent holding pond or equally sized tank. Treated effluent that meets the applicable quality criteria will be discharged into the infiltration pond located north of the Landfill footprint and infiltrated into the aquifer beneath the Site. In the future, the leachate treatment pond and effluent holding pond/tank may be re-located to facilitate aggregate extraction activities.

Surface water infiltration areas will be located north of the Landfill at the base of the Pit, away from the landfilling and aggregate extraction operations.

3.3 Landfill Base Contours

To maximize airspace and to conform with Landfill Criteria design criteria of maintaining the base of the Landfill a minimum of 1.5 m above the groundwater table, the Landfill base will have a grade of 2.75 percent west to east, which will act as the primary drainage pathway, and a two percent grade along the secondary drainage path from south to north. The southern portion of the Landfill will be constructed on the slope of the Pit. The slope will be excavated to slope of two horizontal to one vertical (2H:1V).

The base contours will be constructed on the in-situ sand, gravel, and bedrock material. The geotechnical characteristics of the in-situ soils are discussed in Section 7.

The base contours extend to a maximum depth of approximately 3.5 m below the existing Pit floor elevation, with the exception of the leak detection and leachate collection sumps which extend deeper than the surrounding base contours, as discussed in Sections 3.5 and 3.6. The maximum depth is located at the north-east corner of the Landfill footprint. The base contours extend to the existing Pit floor elevation toward the south-west of the Landfill footprint. The excavation required for construction of the Landfill cells is shown in Drawing C-03.

3.4 Base Liner Systems

The *primary* base liner refers to the composite liner system comprised of an HDPE geomembrane liner and geosynthetic clay liner which underlies the leachate collection system, and the *secondary* base liner refers to the composite liner system comprised from of an HDPE geomembrane liner and geosynthetic clay liner which underlies the leak detection system. Detail 2 on Drawing C-13 shows the base liner layers from bottom to top as: Geosynthetic clay liner, HDPE geomembrane, geocomposite drainage layer (for leak detection), Geosynthetic clay liner, HDPE geomembrane, non-woven geotextile, stone drainage blanket (for leachate collection) and woven geotextile.

For both the primary and secondary liner systems:

High Density Polyethylene (HDPE) geomembrane

The HDPE geomembrane liner will meet or exceed the following specifications:

- Minimum thickness of 1.5 mm (60 mil)
- Minimum service life of 100 years
- High quality seams

A leak detection survey will be completed on the HDPE geomembrane after installation to ensure a quality installation.

A review of HPDE liner performance is included in Appendix B.

Geosynthetic clay liner

Per the Landfill Criteria, the geosynthetic clay liner will have equivalent performance to the following compacted clay liner specifications:

- Soil will contain minimum 25 percent clay and minimum 60 percent silt and clay by weight
- Minimum compacted thickness of 0.75 m
- Maximum compacted hydraulic conductivity of 1 x 10^{-7} cm/sec
- Minimum organic carbon content of 0.1 percent

A QA/QC program conducted by a qualified professional will be implemented during the construction of the base liner systems to minimize the occurrence of installation defects. The QA/QC program will include non-destructive testing of each seam.

3.5 Leak Detection System

The leak detection system will comprise a geocomposite drainage layer (comprised of a geonet laminated with geotextiles on both surfaces) underlain by the secondary base liner, as described in Section 3.4 above. A sand cushion layer will separate the secondary base liner from the excavated base.

The leak detection system includes the following components:

- Geosynthetic drainage layer.
- Minimum 2.75 percent slope along primary flow path.
- Minimum 2 percent slope along the secondary flow path.
- A leak detection sump at elevation 161.1 m AMSL with a diameter 300 mm riser pipe bedded in a sand drainage layer for monitoring of potential leakage through the Landfill primary base liner.
- Six monitoring ports used for monitoring potential leakage through the Landfill primary base liner.

The leak detection system will lie directly beneath the primary Landfill base liner.

3.6 Leachate Collection System

The leachate collection system for the Landfill includes the following components:

- 300 mm thick, 50 mm diameter, clear, round stone drainage blanket, with minimal fines
- Perforated leachate collection pipes (LCP) with minimum diameter of 200 mm
- Maximum 15 m lateral spacing between leachate collection pipes (LCP) running south to north
- Maximum 50 m drainage path for leachate to travel before it is intercepted by the LCPs
- 2.75 percent slope along primary flow path of the LCPs
- 2 percent slope along the secondary flow path to the LCPs
- Clean-outs at each end of the LCPs
- Maximum leachate head of 0.3 m at any point on the Landfill base liner
- Leachate collection header pipe at the east end of the Landfill running towards the leachate collection sump at a minimum slope of 2 percent
- Leachate sump at elevation 161.1 m AMSL with two leachate sump riser pipes with minimum diameters of 600 mm

3.7 Perimeter Containment Berms

A perimeter containment berm will be constructed on all sides of the Landfill. The purpose of the perimeter containment berm is to:

1. Ensure containment of the leachate within the Landfill. The perimeter containment berm will be lined consistent with the base liner to ensure leachate from within the waste is contained and directed to the leachate collection system. The berm will ensure that precipitation that comes in contact with the side slope of waste and/or daily cover, will not enter the clean surface water perimeter ditching. The berm will separate the runoff within the Landfill and the clean surface water outside of the Landfill. The berm will direct all runoff from within the Landfill to the leachate collection system during fill operations.
2. Provide an embankment to facilitate construction of perimeter ditching, the Site perimeter maintenance road, and the intermediate/final cover tie-in. After placement of intermediate or final cover, surface water run-off will be directed to the perimeter ditch outside of the containment berm.
3. Prevent surface water run-on to the Landfill from the adjacent aggregate pit side slopes and the upper portion of the Site above the Pit. The southern perimeter containment berm will extend on top of the Landfill and will direct surface water run-off from south of the Pit to the east. This surface water berm will extend beyond the limit of waste in the east and west direction, as shown in Drawing C-06.
4. Provide support for the toe of slope of the waste mass.

Details of the berms are presented on Drawings C-16 and C-17 as part of the perimeter tie-in details.

3.7.1 Interim Containment Berms and Rain Flaps

Interim containment berms will be constructed along the inner perimeter of landfill cells where waste will be placed against the berm during filling of an adjacent landfill cell. The interim perimeter berms will ensure containment of waste and leachate within the active cell footprint. Rain flaps will reduce the infiltration area by temporarily covering the inactive portion of a constructed cell with HDPE geomembrane. Surface water diversion swales will also be constructed to promote clean surface water diversion.

3.8 Final Contours

The final contours (top of waste) are presented in Drawing C-06. The final contours were designed in accordance with the Landfill Criteria and provide a maximum side slope of 3H:1V (33 percent) and minimum top slope of 10H:1V (10 percent). The top final cover will have a crest elevation of 192.3 m AMSL, and a peak elevation of 195.3 m AMSL.

The final cover ties into the top of the perimeter berm to minimize the potential for leachate seepage from the perimeter of the Landfill. By constructing the perimeter berm and final cover in this manner, the perimeter ditching and maintenance road may be constructed independently of the final cover and therefore effectively manage storm water run-off at the Site during waste placement activities.

3.9 Surface Water Management Works

The surface water management works will be designed and constructed to meet the following criteria:

- Prevent surface water run-on onto the active Landfill footprint
- Minimize the potential for erosion of cover soils
- Control surface water flow from the clean soil covers from the Landfill
- Design storm water ditching for the conveyance of 1:200-year, 24-hour storm event
- Include allowances for additional precipitation due to climate change, snow-melt, and multi-day precipitation events

The surface water management works are described in Section 8.

3.10 Landfill Gas Management Works

The Landfill gas (LFG) management works will be designed to meet the following criteria:

- Soil gas concentrations at the Landfill boundary will not exceed the lower explosive limit of methane.
- Combustible gas concentrations in on-site buildings will not exceed 20 percent of the lower explosive limit of methane at any time.
- To meet the requirements of LFG Management Regulations and WorkSafeBC requirements.
- All federal, provincial and local ambient air quality objectives for LFG emissions.

Generally, the LFG management works will include a passive LFG venting system within the Landfill footprint and Landfill site perimeter soil gas monitoring probes. The layout of the LFG venting system will be presented at the time of final cover design. The LFG generation assessment and forecasted management works are described in Section 10.

3.11 Final Cover

Final Cover will be applied to the Landfill upon reaching final contours to achieve the following objectives:

- Prevent exposure of waste to humans and wildlife
- Control infiltration of precipitation
- Minimize the uncontrolled release of methane to the atmosphere
- Limit erosion and release of sediment to the surrounding area
- Control the release of odours
- Minimize oxygen infiltration and fire risks
- Provide compatibility with the planned Site end use

The final cover design consists of, from bottom to top:

- 150 mm sand grading layer
- Geosynthetic Clay Liner (GCL)
- 600 mm sand protective layer
- 150 mm vegetated topsoil layer

Topsoil with a minimum thickness of 150 mm and vegetation will be placed on the final cover to promote runoff, evapo-transpiration, and reduce erosion of the cover soil. Topsoil will be comprised of suitable soil to support growth of local vegetation. The vegetation selected will consist of non-invasive plant species with root depths that will not compromise the integrity of the final cover barrier system.

The final cover characteristics are discussed in Section 6.5.3.

3.12 Site Security and Fencing

The Site is fenced along Gold River Highway to prevent unauthorized access to the Site outside of the Landfill operating hours. The security fencing along the Highway includes 2 m high chain link fencing. The Site entrance is secured with a gate and vandal proof locking mechanism.

3.13 Access Roads

The existing Site layout includes a network of safe all-weather access roads to various parts of the Site. The same access roads will be maintained throughout the Landfill operations to provide access to the on-site facilities and to allow for inspection and maintenance. Additional access roads are planned for the future to facilitate access to Landfill and Pit operation areas as shown on Drawing C-02.

3.14 Vector and Wildlife Management and Nuisance Controls

Vector, wildlife, and nuisance management strategies will be employed at the Landfill as discussed in Section 6.9.

4. Life Span Analysis

4.1 Landfill Layout Criteria

Based on the maximum allowable annual discharge volume of 45,000 tonnes per year, and a maximum design capacity of 532,365 m^3 or 692,076 tonnes the Landfill has an approximate lifespan of 13.3 years as shown on Table 4.1. The area of the limit of waste is approximately 180 m by 200 m (Landfill footprint).

4.2 Total Site Volume and Airspace Consumption

The Landfill has a total airspace volume of approximately 532,365 m^3 for waste and cover material. The Landfill is expected to have a lifespan of 13.3 years based on an annual airspace consumption of approximately 106,337 m^3 in the first year (based on 74,746 m^3 from the Original Landfill and up to a maximum of 34,615 m^3 new waste to fill Cell 1 East) and 34,615 m^3 annually each subsequent year. The assumed apparent density, as discussed in Section 4.4, is 1.3 tonnes per m^3, which results in 138,238 tonnes of waste disposed in the first year and 45,000 tonnes annually subsequently. As discussed in Section 1.5.2, waste from the Original Landfill Area is planned to be relocated into the Landfill. The waste relocated from the Original Landfill to the Landfill does not contribute to the allowable 45,000 tonnes per year (see Section 2.9 (b) of the OC). For the purpose of airspace consumption calculations, it is assumed that waste relocation will occur in the first year of operations. The actual timing of waste relocation will depend on factors such on the timing of the issuance of an amended OC by ENV. The first year's airspace consumption is estimated based on the volume of waste in the Original Landfill and the capacity of the Cell 1 East of the Landfill.

4.3 Apparent Density

The apparent waste density, which is used to calculate airspace consumption, is not a true density but a performance measure that represents the mass of waste discharged into each cubic metre of landfill air space. The apparent waste density is a more accurate measure of the efficiency of landfilling since cover soil is excluded from the ratio. The apparent waste density is based on the comparison of the waste tonnage landfilled and the airspace consumed. Soil used as daily and intermediate cover is excluded from consideration since an increase in cover soil usage can increase the true density and provide a skewed representation of landfilling efficiency. In contrast, an increase in cover soil usage will reduce the apparent density.

The forecasted apparent density at the Site is interpolated by comparing typical apparent densities of the two sources of waste streams to be accepted at the Site. Generally, the apparent density observed at waste soil landfills are in the range of 1.5 to 1.8 tonnes per m^3. The apparent density observed at construction and demolition landfills is generally in the range of 0.6 to 1.0 tonne per m^3. As it is anticipated that approximately half of the waste disposed of in the Landfill will originate from each waste stream, an average apparent density of 1.3 tonnes of waste per m^3 of airspace is forecasted for the Site.

5. Development and Progressive Closure Plan

The Landfill development plan has been designed to minimize the area of the active cell, maintain access for operations, and allow for progressive closure of the Landfill. The general north to south filling allows for the continued gravel extraction in the southern Landfill footprint while landfilling commences in the north and allows for integration with Upland Pit Mine Plan (GHD, 2020). The base liner and leak detection system will be constructed in three stages. Similarly, the final closure will be placed in a minimum of three applications.

The conceptual Landfill development plan is presented in Drawings C-08 through to C-12. The conceptual Landfill development plan includes a three-phase approach. Phase 1 contains two stages of filling and Phases 2 and 3 contain three stages of filling.

The Sections below describe the development plan. A summary of the Landfill stages and corresponding airspace is presented in Table 5.1. Table 5.2 provides a material requirement summary for each phase.

5.1 Phase 1

Phase 1 contains two stages, 1 East and 1 West as presented on Drawings C-08 and C-09. The total estimated airspace is 207,784 m^3. The major construction activities during this phase are as follows:

- Construction of the perimeter berms to north and east and required excavation
- Construction of the north eastern most lined cell
- Construction of temporary divider berm to the west and south of the first cell
- Construction of the leak detection system including geocomposite liner, sump and leak detection monitoring ports
- Construction of leachate collection system including collection pipes, leachate header pipes and sump
- Construction of associated leachate management systems, including leachate pump station, leachate treatment pond, effluent holding pond (or equivalent tanks), and treated leachate infiltration pond
- Filling in Stage 1 East
- Construction of the second cell and corresponding leak detection and leachate collection systems to the west including required excavation, perimeter berm and temporary containment berm construction
- Filling in Stage 1 West and application of intermediate cover over eastern, northern and southern portions of Stage 1 East
- Intermediate cover over a portion of Stage 1 East
- Construction of the third lined cell and corresponding leak detection and leachate collection system to the south including excavation and grading of southern slope
- Deployment of final cover over the northeast corner slopes of Stage 1 East (where the slopes have reached final conditions)

5.2 Phase 2

Phase 2 contains three Stages – 2A, 2B, 2C as presented on Drawings C-09 and C-10. The total estimated airspace is 178,820 m^3. The major construction activities during this phase are as follows:

- Filling in Stage 2A
- Removal of intermediate cover as required and filling in Stage 2B
- Application of intermediate cover over southern portion of Stage 2A
- Filling in Stage 2C
- Extension of liner up the southern slope in preparation for Phase 3

5.3 Phase 3

Phase 3 contains three stages, 3A, 3B, 3C as presented on Drawings C-11 and C-12. The total estimated airspace is 145,761 m^3. The major construction activities during this phase are as follows:

- Filling in Stage 3A
- Final cover over side slopes extended
- Filling in Stage 3B
- Filling in Stage 3C
- Complete final cover application over entire Landfill

6. Site Operations

6.1 Authorized Waste

The waste authorized by the OC to be accepted at the Site and discharged into the Landfill is:

- Demolition waste
- Construction waste
- Land clearing waste
- Soil that meets industrial land use standards (<IL), as defined by the CSR
- Sludge from New Leachate Management Works or New Stormwater Works
- Waste asbestos containing materials (ACM) managed according to Section 40 of the HWR
- Other wastes as authorized in writing by the director

The waste not authorized to be accepted at the Site and discharged into the Landfill is:

- Hazardous waste according to HWR, except waste asbestos
- Controlled wastes as defined by the Landfill Criteria
- Attractants (such as domestic waste)
- Waste or recyclables prohibited in writing by the director

6.1.1 Anticipated Change to Authorized Waste

As described in Section 1, Upland has applied for an OC amendment to request authorization for the acceptance of contaminated soils that are not hazardous waste. Subsequent to receiving an OC amendment, the following waste will be accepted for discharge to the Landfill:

- Demolition waste
- Construction waste
- Land clearing waste
- Soil that is not hazardous waste
- Sludge from New Leachate Management Works or New Stormwater Works
- Waste asbestos containing materials (ACM) managed according to Section 40 of the HWR
- Other wastes as authorized in writing by the director

The waste not authorized to be accepted at the Site and discharged into the Landfill is:

- Controlled wastes as defined by the Landfill Criteria
- Attractants (such as domestic waste)
- Waste or recyclables prohibited in writing by the director

6.2 Material Recovery

Materials recovered from the incoming waste streams for re-use/recycling include:

- Yard waste
- Clean wood
- Concrete
- Asphalt
- Gypsum drywall

6.3 Waste Acceptance Policy

This section describes the policies for waste acceptance and adherence to the list of authorized wastes listed in Section 6.1.

6.3.1 Soil Acceptance Plan

The Soil Acceptance Plan provides the procedure that will be carried out before soil is accepted for discharge at the Landfill including screening, receipt of a signed soil acceptance agreement, and review of documents, if necessary. Documents supporting the Soil Acceptance Plan are provided in Appendix C.

The OC states that soil discharge must be “soil in which the concentrations of all substances that are less than the lowest applicable industrial land use standard specified for those substances in (i) the generic numerical soil standards and (ii) the matrix numerical soil standards or (iii) a director’s interim standard for soil, referred to in Section 41(1)(a) of the Contaminated Sites Regulation, B.C. Reg. 375/96." Subsequent to obtaining a revised OC, Upland will update soil acceptance procedures to allow for acceptance of IL+ soil (soil that is not hazardous waste) per the revised authorization.

Per the OC Section 2.7 (b)(iii), a Qualified Professional is to certify that characterization of fill and soil from sites that may be contaminated is carried out in accordance with ministry procedures and applicable CSR Guidance, Protocols and Procedures prior to acceptance for discharge in the lined cell.

Prior to the acceptance of soil for disposal, Northwin will require a completed Soil Acceptance Agreement (Agreement) and the completion of a soil screening process at the Site by Northwin staff. The Agreement as presented in Appendix C may be amended from time to time.

The Agreement must be executed before any soil can be received and accepted at the Site. With an executed Agreement, the soil screening process, which is a two phased approach, will be completed on soil arriving at the Site for disposal. First, Northwin staff will visually inspect the soil for presence of waste materials or any non-compliance with the soil acceptance plan. Suspect loads will be rejected. Next, Northwin staff will complete an additional visual inspection of the soil following receipt at the Landfill active face to confirm that the accepted soil does not contain waste material and is compliant with the soil acceptance plan. Suspect loads will be isolated and tested or removed off-site by Northwin staff at the cost of the generating company. All rejected or non-compliant loads will be recorded and included in the annual report. The soil screening process is outlined in Appendix C.

6.3.2 Construction and Demolition Waste

Prior to the acceptance of construction and demolition (C&D) waste, the C&D waste will be subject to a waste screening process. Material from deconstructed buildings should be accompanied with a record of Hazard Assessment, as per WorkSafeBC's requirement to confirm the presence of asbestos or other hazardous materials. Additional testing to confirm the C&D waste is non-hazardous may be required as per the requirements of the HWR and ENV Technical Guidance. The submitted data will be compared by Northwin to the Site acceptance criteria to ensure compliance with the OC. Construction debris from new construction will not require a hazard assessment.

6.3.3 Plan to Remove all Waste from Original Landfill

The plan to remove all waste from the Original Landfill is outlined below, as per the requirements of Section 2.9 of the OC:

> *The DOCP submitted pursuant to section 2.5 of this operational certificate must include a plan to remove all waste from the Original Landfill, categorize such waste, discharge all such waste to the New Landfill or to other identified and authorized waste management facility(ies), carry out sampling to confirm all such waste has been removed, and decommission the Original Landfill and the Original Leachate Management Works.*

6.3.3.1 Original Landfill Background

The Original Landfill is located near the southeast corner of the Site and includes an approximately 0.7 hectare (ha) un-lined cell and a 0.72 ha (85 m x 85 m) lined cell, material sorting area, leachate treatment system and related appurtenances.

The unlined waste discharge area has received waste from the early 1990s until the lined cell was constructed in 2015. The OC does not authorize any further discharge to the un-lined portion of the Original Landfill.

The lined cell is equipped with two 20 mil Coated Woven Polyethylene (CWPE) liners and a leak detection layer between the liners. The leak detection layer consists of a 0.3 m granular material and a 100 millimetre (mm) polyvinyl chloride (PVC) riser pipe that extends from within the granular layer at the toe of the slope of the north and east perimeter berms to the top of the berms.

The lined cell's leachate collection system includes leachate sumps, a leachate extraction chamber located within the west side of the cell and a series of tanks for leachate treatment and temporary storage.

As outlined in Section 1.5, the Original Landfill was previously permitted under Permit PR-10807 issued in June 1992, which was superseded by the OC issued in 2019.

6.3.3.2 Original Landfill Waste

Unlined Area

The unlined portion of the Original Landfill contains an estimated volume of 35,000 m^3 of waste in place at a thickness of approximately 5 m, as reported in the Location and Volume of Existing Waste letter addressed to ENV, dated May 12, 2017. The waste in the unlined portion of the landfill consists of:

- Land clearing waste – 25,000 m^3
- Combustion residue – 10,000 m^3

No further waste has been discharged to the unlined area of the Original Landfill.

Lined Cell

The following non-hazardous wastes are accepted for discharge to the Original Landfill lined cell, under the OC:

- Demolition waste
- Construction waste
- Land clearing waste
- Sludge from the Original Landfill leachate management works
- Soil meeting applicable CSR industrial land use standards
- Other waste as authorized in writing by the Director

Previously, under Permit PR-10807, the Original Landfill was authorized to accept:

- Stumps and trees
- Land clearing waste
- Select building demolition debris
- Residue of combustion for open burning of wood waste

As of December 31, 2020, the lined cell of the Original Landfill contains approximately 17,703 m^3 of waste in place (2020 Annual Report GHD, 2021). The waste types and approximate volume of waste placed in 2020 include:

- Construction and demolition waste – 653 m^3
- Soil meeting applicable CSR industrial land use standards – 7,159 m^3

Wastes placed in the lined cell between 2015 and August 2019, pursuant to then-Permit PR-10807, include:

- Contaminated soil below the HCR – 2,910 m^3
- Demolition debris – 114 m^3
- Treated wood waste/demolition debris – 1,275 m^3
- Wood waste – 147 m^3

The discharge of contaminated soil below HCR criteria was authorized under Section 42 of the CSR.

6.3.3.3 Plan for Removal of Waste and Discharge to New Landfill

Per Section 1.4.1 of the OC, authorization to discharge waste to the Original Lined Cell ceases on the earlier of the date the Original Lined Cell is filled to capacity or the date of commencement of waste discharge to the Landfill. After this time, the Original Landfill and Original Landfill leachate management works will be decommissioned.

Waste from the Original Landfill, including the unlined and lined portions, will be exhumed and segregated by category for relocation to the Landfill, as authorized by Section 2.9(b) of the OC. Waste will be segregated into soil, fine debris and coarse debris. The segregation of the materials will allow for placement of the waste into the Landfill cell under proper procedures. To protect the integrity of the base liner, coarse debris is not suitable for landfilling in the first lift. The first lift of waste shall consist primarily of soil.

Materials will be excavated from the Original Landfill area until a clean base is encountered through visual inspection. The CWPE liners at the base of the lined cell will also be removed and disposed of as waste to the Landfill. The leachate management works will be decommissioned. Components of the leachate management works may be salvaged for re-use.

A confirmatory soil sampling program will be carried out to ensure clean closure of the entire Original Landfill area footprint and adjacent buffer zone (50 m), and the soils in-place meet the applicable industrial land use standard.

The relocation of waste from the Original landfill to the Landfill will occur once Upland has received an amended OC to authorize the discharge of contaminated soil (IL+).

6.4 Landfilling of Wastes

All waste will be placed within the Landfill footprint in accordance with the recommended fill methods described in the Landfill Criteria for a landfill receiving 20,000 to 50,000 tonnes of waste per year. The recommendations include the following:

- The active face will be kept to a minimum, while maintaining sufficient area for safe unloading of waste and traffic operations. The Landfill Criteria recommended maximum area of 243 square metres will be maintained when possible.
- The lift height will be kept to the Landfill Criteria recommended maximum of 2.5 m.
- The waste will be compacted to achieve an efficient compaction density.

6.4.1 Landfilling of Waste Asbestos Containing Materials

ACM, as defined by the HWR, will be transported in compliance with the Transportation of Dangerous Good (TDG) Act and Regulations. The disposal of ACM will be completed in accordance with Part 6, Section 40 of the HWR.

6.5 Cover Placement

Covering of placed waste is generally required to control landfill nuisances such as vectors, wildlife, fire, wind-blown litter, odour, infiltration, landfill gas, scavenging, etc.

6.5.1 Daily Cover

As waste will be received intermittently by appointment and will consist primarily of C&D material and soil, application of cover on a daily basis may not be required. As such, daily cover shall be applied over placed waste as a means of landfill nuisance control on an as-needed basis, as determined by landfill staff.

Daily cover, when used, will consist of either 150 mm of soil that meets industrial land use standards, as defined by the CSR or approved alternative cover. Polyethylene tarps may be used as temporary and re-useable daily cover. Soil used for daily cover may be removed from the active face immediately prior to landfilling in the same area. Soil used for daily cover will have minimal fines to minimize the potential for perched leachate within the waste and to minimize dust migration from the Landfill.

Surface water contact with the daily cover will be treated as leachate and will be contained and conveyed to the leachate management system discussed in Section 9.

6.5.2 Intermediate Cover

Intermediate Cover will be placed on areas of the Landfill that are not scheduled to receive the placement of additional waste for 30 days or more. Intermediate cover will consist of 300 mm of soil that meets industrial soil quality standards, as defined by the CSR or approved alternative cover. The thickness may include daily cover if daily cover is present in the area. Soil used for intermediate cover may be removed from the active face immediately prior to landfilling in the same area.

The surface water runoff from the intermediate cover will be treated as clean surface water and will be conveyed through the surface water management system, as discussed in Section 8.

6.5.3 Final Cover

Final Cover will be placed within 365 days on any part of the Landfill footprint within that has reached final contours and is large enough to warrant final cover application. The final cover barrier layer will consist of the following layers from top to bottom:

- 150 millimetres of topsoil with suitable vegetation
- 600 millimetres of sand as a protective cover
- GCL
- 150 millimetres sand cushion layer over the waste

The final cover system is shown in Drawing C-06. A water balance model, as discussed in Section 9.6.1, was used to determine the resulting infiltration through the final cover system. The results forecast this final cover system to exceed the performance of the minimum final cover specified in the Landfill Criteria (600 millimetres of low permeable soil).

The surface water runoff from the final cover will be treated as clean surface water and will be conveyed through the surface water management system, as discussed in Section 8.

The soil used for final cover will meet the applicable CSR industrial land use standards.

6.6 Hours of Operation

The hours of operations of the overall site are Monday to Friday 7:30 a.m. to 4:00 p.m. The Landfill hours will generally be restricted to the overall site hours. Special arrangements may be made to receive waste outside of these hours from time to time. The Landfill will not be open for receiving waste unless otherwise scheduled in advance, and waste characterization procedures have been completed to ensure the waste is suitable for disposal at the Site. When required, the Landfill will be open on Saturday and Sunday to receive incoming waste from approved sources.

6.7 Neighbour Relations Plan

Upland and Northwin recognize the need to maintain positive relations with landowners adjacent to and nearby the Site. Ongoing efforts to mitigate the impacts of nuisance factors such as dust, litter and odour will be carried out in accordance with the protocols discussed in the following sections.

All operational complaints received by Landfill personnel will be recorded and directed to the Site Manager. The Landfill personnel will undertake corrective action(s) as soon as possible after identification of need. A complaint response procedure, including an email address and phone number, will be provided at the Site entrance for the submission of nuisance complaints from the public. The complaint, nature of complaint, time received, and corrective action taken for resolution will be documented. The records must be kept in accordance with the record keeping procedures described in Sections 6.16 and 14.9, and included in the next annual operations report, as discussed in Section 14.10.

6.8 Nuisance Controls

The Landfill will comply with all local government nuisance bylaws.

6.8.1 Dust Control

Dust generation occurs at landfill sites due to the handling of soils, dry waste such as demolition waste, plaster, and concrete, as well as the movement of vehicles along gravel and dirt access roads. Dust mitigation measures will be employed at the Site on an as-needed basis and may include the following:

- Use of granular daily cover material with minimal fines content (i.e., silts and clays)
- Reduction of vehicular speeds on Site
- Application of water to control dust
- Seeding programs
- Proper placement of stockpiles and covers to minimize dispersion
- Vegetative buffer zones around the Site to provide shelter to the landfill
- The topographical changes and Pit walls to provide shelter to the landfill

Soil stockpiles not used for more than one year are to be seeded.

6.8.2 Noise Control

Potential noise impacts from the Site may result from the operation of the landfill equipment. The operation of this equipment will comply with the noise emission standards as outlined in the Society of Automotive Engineers (S.A.E.) J88 – Latest Edition "Sound Measurement – Earth moving Machinery". Noise mitigation will also be provided by the following Site features:

- Vegetative buffer zones
- Distance of Landfill operations from Site boundary and neighbouring properties
- The topographical changes and Pit walls

6.8.3 Litter Control

Preventative litter control measures are steps taken to minimize wind-blown litter from the active area of the Landfill and from incoming waste loads. Litter must not migrate beyond the Landfill property boundary. The following measures will be used at the Site to control and minimize wind-blown litter:

- All vehicle loads must be tarped to prevent litter from blowing out of the vehicle. Northwin reserves the right to not accept loads that are not tarped.
- The active face will be selected based on the direction and intensity of the wind to provide maximum shelter for the active area. The aerial extend of the working face will be kept to a minimum on windy days.
- Litter will be collected within the Site and along the Site boundaries when necessary.

- Appropriate use of cover soil.
- Installation of litter fences and use of operational berms within the Landfill, as necessary.
- The topographical changes and Pit walls.

6.8.4 Odour Control

The waste streams that will be discharged at the Landfill are generally not a source of odour due to low-organic content. The Landfill operations will, however, be carried out in a manner that prevents generation of nuisance odours. The following measures will be used at the Site to control and minimize nuisance odours:

- Appropriate cover will be applied as outlined in Section 6.5.
- Leachate management systems will include adequate odour controls such as aeration to prevent unpleasant odours.
- Implementation of odour control measures will be planned for when odorous waste is anticipated.

6.8.5 Sight Lines

The sight lines from the Gold River Highway to the active face of Landfill will be minimized. To minimize the sight lines, the following measures will be in place:

- Vegetated perimeter buffer zone
- Landfill footprint location within the base of the Pit
- Final contours will be below the adjacent tree lines
- Berms constructed within the Landfill to minimize sightlines to exposed waste, when necessary
- Application of daily and intermediate cover
- Application of final cover on the northern edge of the Landfill including vegetative cover as soon as reasonably possible

6.9 Vector and Wildlife Management

The Landfill is not expected to attract vectors or wildlife due to the lack of organic matter in the waste and soil to be disposed of in the Landfill. Furthermore, the Landfill will comply with the daily, intermediate, and final cover requirements stated in Section 6.5. If vector and wildlife become problematic at the Site, these measures will be revised to ensure the protection of the wildlife and the environment.

The leachate aerated equalization pond is not expected to attract wildlife or waterfowl, due to the aerators that will operate intermittently and will deter access to the pond at that time. Should waterfowl become an issue in the aeration pond during the passive filling or decanting portions of the treatment cycle, bird abatement strategies will be employed, such as the use of a falconer.

6.10 Landfill Fire Management

The Landfill will be operated in a manner that reduces the risk of landfill fires. The following measures will be in place:

- Appropriate placement, thickness, and compaction of inert daily and intermediate cover and compaction as outlined in Section 6.5 to minimize oxygen intrusion.
- Fire breaks will be maintained surrounding the Landfill footprint with a minimum width of 15 m. The Fire breaks will be free of trees, brush, tall grass, and other combustible materials.
- The Landfill has year-round and immediate access to a water supply from the wash plant ponds.
- Fire safety measures in place in accordance with the fire safety plan discussed in Section 15.

6.11 Scavenging

Scavenging is defined in the Landfill Criteria as the informal and unauthorized recovery and removal of waste. Scavenging of waste from the active face and within the Site is prohibited due to health and safety concerns. Recovery of items from the incoming waste that has potential re-use value will occur as discussed in Section 6.2.

6.12 Site Health and Safety Plan

A Site Health and Safety Plan (HASP) will be prepared and kept on Site at all times. The Site operations will meet the requirements of WorkSafeBC.

6.13 Site Security and Signage

Access to the Site will continue to be via the existing Site entrance off Gold River Highway, which enters the Site from the north, as shown on Drawing C-01. The Site entrance gate is locked outside of normal operating hours to prohibit vehicle entrance and uncontrolled disposal when the Site is closed. A chain link fence is present along the northern property boundaries along Gold River Highway and Argonaut Road.

Signage will be erected and maintained at the Site entrance and will include the following information:

- Name of Owner/Site Operator
- Owner/Site Operator Contact Information
- Hours of Operation
- Emergency Contact Information
- Waste and recyclable material accepted, prohibited, and restricted

The existing signage will be maintained for continued operation of the Site. The signage will be reviewed from time to time by Landfill staff for adequacy and additional signage implemented as required.

6.14 Weigh Scale

A weigh scale is currently located at the Site entrance. The weigh scale will be maintained in proper working order and meet the requirements of the federal Weights and Measures Act.

6.15 Traffic Volumes

Traffic volumes will be dependent on the amount of waste destined for the Landfill during any given period. The waste may be received at specific times of the year and be distributed unequally throughout the year. In general, future traffic flow volume is expected to increase marginally from the existing traffic volumes to the Site.

6.16 Records

All relevant records will be maintained by the Site owner for the entire operating life of the Landfill and for the duration of the contaminating lifespan, as estimated in Section 12. Relevant records will be maintained on-site for a minimum of 7 years, and all records will be submitted to the Director within 14 days of a request from the ENV. Records will include the following:

- The Operational Certificate
- All plans and reports prepared in support of the development for the Site
- Inspection records conducted by regulatory agencies
- Public complaints including source of complaint, nature of complaint, time received and actions taken
- Waste tonnages and volumes disposed of in the Landfill for each category of waste received
- Waste sources, characterization, and approvals

6.17 Operational Personnel

The Landfill will employ a Site Manager/Operator who oversees all daily Landfill operations.

The Site Manager or Operator will be present at all times that the facility is open for business and will inspect every load of incoming waste to ensure it matches the waste characterization, and complies with the requirements of the OC.

The Site Manager, Operator, or other designated staff members are responsible for accepting and recording waste loads, as discussed above, and also for collecting tipping fees, stockpiling, placement of waste, and placement of daily cover, as required. An equipment operator is responsible for the operation of the front-end loader, bulldozer, hydraulic excavator, and compactor.

Additional staff will be used at the Site as the workload demands to meet environmental control requirements including dust, litter, and odour control measures.

6.18 Operator Training

At least one supervisor will successfully complete the Solid Waste Association of North America's (SWANA) Manager of Landfill Operations (MOLO) course. At least one of the operations staffs working regularly at the Landfill active face will successfully complete SWANA BC's Qualified Landfill Operator's course. These certifications will be kept current as per by SWANA's requirements.

Under the Environmental Management Act, Municipal Wastewater Regulations, Part 4, Division 1, Section 47, the aeration pond must be operated by a person certified by, and in accordance with, the Environmental Operators Certification Program.

6.19 Equipment Requirements

Adequate equipment will be maintained at the Site to ensure that operational requirements will be met. The equipment to be used on-site will include:

- Front-end loader
- Dozer
- Waste Compactor
- Excavator

6.20 Winter and Wet Weather Operation

Winter operations require advanced planning for Site preparation, snow removal, and the stockpiling and storage of cover material. Winter operations for the Landfill will be coordinated with the active aggregate extraction activities.

Many operational problems can occur as a direct result of failure to prepare an adequate disposal area in advance of winter weather. An area sufficient to hold more than the expected volume of waste will be prepared in advance of the onset of winter.

During the winter months the active disposal area will be located in such a manner so as to be free draining, sheltered from the prevailing winds and if possible, located with a southern exposure. Up to twice the estimated required area for disposal through the winter months, will be prepared to minimize problems due to heavy snow and equipment failure. During winter conditions, flatter grades may be required at the daily working face to facilitate equipment travel.

Snow plowing and a snow storage area will be considered in advance of winter conditions. A snow storage area will be created adjacent to the active disposal area to permit storage of snow removed from the tipping face, such that it does not interfere with daily Landfill operations. The snow storage area will be located such that during snow melt events, the runoff will be treated as storm water and not flow into the active disposal area. Snow which has contacted waste will be managed as leachate. In the event of extreme weather conditions, or at the discretion of the operator, the Site may temporarily close and stop receiving waste material.

Snow maintenance and wet weather operation will be conducted in such a manner as to minimize infiltration.

During wet weather operations surface water will be directed away from the active disposal area by means of temporary soil berms constructed upgradient of the active area, as required. Under extremely wet weather conditions the waste disposal operations may be moved to drier working areas to facilitate vehicle travel at the working face.

On-site equipment used for continued Landfill operations during rainfall events, will be provided with closed cabs.

Site roadways will be maintained in a passable condition during wet weather conditions. Should washouts of the Site roadways occur due to rainfall events, the roadways will be reconstructed in a timely fashion.

7. Seismic Assessment

7.1 Geotechnical Overview

Site geology consists of a native interbedded sand and gravel unit consistent with glacio-fluvial and outwash depositional sources and an underlying competent bedrock unit. The surface of the bedrock unit is highly variable across the Site.

The native interbedded sand and gravel unit is present throughout the majority of the Site varying in thickness from not present to greater than 55 m bgs. Along the western portion of the Site, bedrock outcrops and shallow bedrock are present. In this area, the sand and gravel unit is not present or thin as a result. Within the remaining portion of the Site, where bedrock is present at lower elevations, the thickness of the sand and gravel unit is substantial.

The sandy overburden is generally in dense to very dense conditions, with SPT ‘N’ values in the ranges of 30 blows per 0.3 m of penetration.

Bedrock can be described as competent, fine grained, porphyritic, igneous rock of the Karmutsen Formation, which varies in colour from blueish black to dark grey and green to dark grey and pink to dark brown (Golder, 2014). Fracturing is apparent within the upper bedrock unit including evidence of weathering (i.e., iron staining) and secondary mineralization. Fractures vary in size, density and orientation (vertical, horizontal, and oblique). The most significant fracturing was noted in the boring advanced within the Pit (MW4A-15). According to laboratory tests calcite is present in fractures and amygdules (Golder, 2014).

The bedrock surface orientation differs across the Site:

- West of the Pit, bedrock dips steeply toward Rico Lake and a sand and gravel filled scour channel, which extends northeast of Rico Lake. Bedrock elevations in this area range between 215 mAMSL at the small mountain to the south and 170 mAMSL at the base of the scour channel toward the north. The top of bedrock to the southeast and east of Rico Lake occur at elevations above the Rico Lake water level.
- Northwest of the Pit, at K&D Contracting, bedrock is orientated around a bedrock outcrop. This localized highpoint is present at elevations 183.5 to 182.1 mAMSL.
- Underlying the Pit, bedrock generally dips steeply from west to east from 183.0 mAMSL (outcrop) to at least 145 mAMSL.

7.2 Landfill Settlement

The Landfill area was analyzed for three types of potential settlement (total or differential). The results will be considered during detailed design to ensure the design provides allowance for forecasted settlement.

7.2.1 Short-term Settlement

Short-term settlement, or elastic settlement, may occur almost immediately after changes in loading occurs. Immediate settlements in the order of 100 mm to 200 mm are expected during the vertical expansion of the Landfill.

7.2.2 Long-term Settlements

Long Term settlements, or primary consolidation settlements, occurs due to the expulsion of pore water from the waste material. Depending of the loading, saturation degree, and the drainage path within the Landfill, this settlement may take years to complete and can be differential in nature. Due to the compaction of the waste and the duration of the construction, these settlements are expected to be tolerable.

7.2.3 Creep Settlement

Creep settlement, or secondary consolidation, occurs under nearly constant effective stresses and is associated with plastic adjustment of the material. Theoretically, this type of settlement will never end, but will slow down with time. Due to the compaction of the material and the staged construction approach, these settlements are expected to be tolerable.

7.3 Seismic Evaluation

A seismic evaluation was carried out based on hazard values recommended by the National Building Code of Canada (NBCC 2010), as discussed in GHD's 2016 Geotechnical Investigation Report, considering the low consequence of failure at the Site, seismic hazard values with 2 percent and 5 percent probability in 50 years (return period of 2475 and 1000 years, respectively) were used in the seismic evaluation. The evaluation concluded that the historical data does not show the potential for liquefaction within the waste material, and the liquefaction potential in the existing native soils is very low to low during extreme seismic events with return periods of 2475 years or less.

7.4 Slope Stability

Slope stability analysis was carried out, as discussed in GHD's 2016 Geotechnical Investigation Report. Limit equilibrium method was utilized to evaluate the stability of the slopes across the Landfill under different material, water level, and loading conditions.

Considering the low consequences of failure of the Landfill, as further discussed in the GHD's 2016 Geotechnical Investigation Report, a target Factor of Safety (FOS) of 1.2 to 1.3 is considered adequate for short term (during construction) stability of the slopes under static loading. For long term (post construction) conditions, a target FOS of 1.5 is considered adequate. For seismic events with a return period of 2,475 years, FOS of 1.1 is considered adequate. The slope stability study concluded that the target FOS are obtained along the studies cross sections and that the FOS will increase with time due to the nature of the material.

8. Surface Water Management Plan (SWMP)

8.1 SWMP Objectives

Completion of the Landfill closure design will result in changes in landform and surface water runoff patterns within the lower Pit area of the Site. The SWMP will ensure the following objectives are met:

- The runoff from the Landfill is conveyed in a manner that does not cause erosion or possible damage to the Landfill.
- The runoff from the watershed around the Landfill is conveyed and directed away from the Landfill to minimize surface water contact with waste and minimize leachate generation.
- The potential for on-site erosion and sediment loading in the base of the Pit minimized (there are no downstream water courses that will be impacted by sediment loading).

This SWMP has been developed for the Landfill only and does not consider the overall Property storm water management system.

8.2 SWMP Design Criteria

8.2.1 SWMP Design Criteria – Landfill Criteria

Section 5.6 of the Landfill Criteria requires hydrologic modeling to assess the performance of the surface water management works under minor and major storm events, and is to be completed for 5-, 10-, and 100-year design storm events. Per the Interim Considerations, hydrologic modeling for the 1:200-year design storm event was also completed.

Based upon these objectives, the SWMP design criteria is as follows:

- The storm water channels shall be designed to convey the discharge of a 1:200-year, 24-hour storm event.
- Maintain a positive grade to prevent sedimentation and maintain hydraulic design capacity. Ditches shall be designed to accommodate localized settlement (no grade reversals).
- Armor (rip rap, erosion control matting, or vegetative cover) ditches to prevent erosion of bottom and side slopes, as necessary.
- Make allowances for additional water that may result from snowmelt.
- Consideration for the effects of multi-day precipitation events.

8.2.2 Additional SWMP Design Criteria Considered

The following design criteria were used as guidance documents for the design of the SWMP:

1. In accordance with the BC Supplement to TAC (Transportation Association of Canada) Geometric Design Guide 2007 Edition (Tab 10-1000 Hydraulics Chapter) (BCMOT, 2007) the channels shall have the following characteristics:
    - The maximum allowable depth of flow is 0.6 m.
    - The recommended minimum freeboard is 0.3 m for small drainage channels.
    - Typical channel side slopes range between 1.5:1 (H: V) to 4:1.

2. In accordance with the Best Management Practices Guide for Stormwater, prepared for Greater Vancouver Sewerage and Drainage District (Gibb, Kelly & Schueler, 1999), the sediment forebay should meet the following criteria:
    - Sediment forebay should provide 10% volume of permanent pool storage for wet pond.
    - Sediment forebay should provide 10% volume of total design storage volume for dry pond.
3. In accordance with the Storm Water Management Planning and Design Manual (ENV Ontario, 2003), the infiltration areas should meet the following criteria:
    - Minimum length to width ratio is 3:1.
    - Maximum ponding depth is 0.6 m.
    - Minimum 1 m depth for sediment forebay.
    - Minimum 2:1 length to width ratio for sediment forebay.
4. In additional criteria include:
    - The storm water management system will be designed using the 24-hour, 25-year and 200-year synthetic design storm with a Type 1A distribution.
    - To account for frozen or saturated ground conditions and the Landfill cap liner design, the sub-catchment parameters for depression storage and infiltration will be adjusted to be lower than would be typically considered for this type of soil and vegetative cover.
    - Allowances for additional precipitation and greater storm events to consider climate change.
    - Allowances for additional precipitation over multi-day precipitation events.

8.3 SWMP Overview

The SWMP includes the following elements:

- Perimeter berms to ensure the run-off from the landfill sides slopes (i.e. with daily cover or exposed waste) will remain within the landfill and separate from the surface water system.
- Mid-slope swales incorporated into the final cover approximately halfway up the side slopes to shorten the drainage path and help prevent erosion.
- Drop-down channels where the southern edge of the Landfill final contours intercepts the excavated slope of the Pit.
- Energy dissipation pools at the base of the drop-down channels along the southern edge of the Landfill.
- Ditches on the east and west sides of the Landfill to convey surface water to the north of the Landfill into the infiltration areas located in the base of the Pit.
- A surface water diversion berm south of the Landfill on the upper portion of the Site to convey water from the upper portion of the Site around the Landfill to the base of the Pit or to other areas of the Site. The purpose of this diversion is to ensure the upper portion of the Site is not part of the Landfill surface water catchment.

- Energy dissipaters and infiltration area sediment forebays located at the ditch outlets north of the Landfill will also act as sediment traps to minimize larger sediment migration into the infiltration areas.
- Infiltration area in the base of the Pit sized to accept surface water flow that matches the pre-Landfill surface water flow.

8.4 Hydrologic Assessment

8.4.1 Model Overview

A hydrologic assessment of the Site watershed was completed to provide estimates of the peak discharge that is expected within the proposed channels. The hydrologic assessment was completed by developing a hydrologic model of the Site to estimate the runoff volume and discharge rate for post-development condition. Storm water modeling for the Site was conducted using the software program PCSWMM 2015 developed by Computational Hydraulics International (CHI). PCSWMM uses the USEPA SWMM5 engine (currently version 5.1.010) and is a spatial decision support system for the USEPA SWMM5 program. The USEPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model that can be used for either single event or long-term (continuous) simulation of runoff quantity and quality.

PCSWMM allows modelling of runoff and conceptual design of drainage works such as piping network, open channel (rivers, creeks and ditches), weirs, dams, orifices, and storage/detention units. The computer model uses hydrologic and hydraulic methods to calculate and route hydrographs. The model requires input of a hyetograph, topographical features (catchment area, width, slope and hydraulic roughness), soil parameters, ground cover conditions (land use and vegetation cover) and drainage paths (rivers, pipes and storage units).

8.4.2 Design Storms

There are three Environment Canada weather stations in relatively close vicinity of the Site which generate Intensity-Duration-Frequency (IDF) reports that are used to develop the synthetic design storms. The locations of these three weather stations, Strathcona Dam (ID 1027775), Campbell River Airport weather station (Station No. 1021261), and Campbell River STP (ID 1021265) are presented on Figure 8.1.

The Campbell River Airport station IDF report was selected based on the proximity to the project site, length of record and physiographic characteristics. The elevation for Campbell River Airport is 108 m, which is lower than the minimum elevation of the site (approximately 167 m). The Campbell River Airport IDF report is provided in Appendix D.

The design of the storm water management system is based upon the return-period rainfall depths derived from the Campbell River Airport Intensity-Duration-Frequency (IDF) reports developed by Environment Canada. The total rainfall depths were increased by 10% to compensate for the change in elevation between the Campbell River Airport and Site elevation. Synthetic design storms were developed to assess the performance of the proposed storm water management features which are based upon the IDF total rainfall depths.

To account for the potential increase in rainfall depths as a result of climate change, as discussed in Section 2.4, GHD also increased the synthetic design storm rainfall depths by 5.2%, which represents a total increase of 15.2% over the IDF reported values.

Synthetic design storms were created for the 5-year, 10-year, 100-year, and 200-year, 24-hour storm event using the Soil Conservation Service's Type 1A distribution which is appropriate for this geographic area. Rainfall parameters representing design storms are listed in Table 8.1.

Multi-day precipitation events were also considered. The probability of a multi-day precipitation event with the same intensity as the 100-year, 24-hour storm event for all days within the multi-day event is low. It is more likely that a multi-day precipitation event would result in a lower intensity than the design storm used (100-year, 24-hour storm). For this reason, the 100-year storm event was used as the design storm parameter for the design of the surface water channels and sediment forebays. The infiltration areas were sized to accommodate the 200-year, 24-hour storm with allowance for additional water from snowmelt and multi-day precipitation events, as discussed in Section 8.4.4.

8.4.3 Hydrologic Model

The SWMP was developed for the full Landfill closure condition. The Landfill cover will be fully vegetated and consist of 150 mm of topsoil over 600 mm sand over a GCL, as described in Section 6.5.3. The design of the SWMP features has assumed that there will be little to no storage capacity within the Landfill cover system and the majority of rainfall will result in runoff from the Landfill cover. This assumption would account for frozen ground conditions or antecedent wet moisture conditions, such as during a multi-day precipitation event. Therefore, the sub-catchment parameters for depression storage and infiltration will be adjusted to be lower than would be typically considered for this type of soil and vegetative cover which would have a greater infiltration capacity.

The Landfill cover system is divided into a series of catchments. The catchment boundary delineation is presented on Figure 8.2. Corresponding catchment model input parameters are summarized in Table 8.2. A surface water diversion berm will be required to route surface runoff away from the Landfill area that is not considered within the overall catchment boundary.

Runoff generated from each catchment is routed to a series of channels which will convey it away from the Landfill cover. A flow schematic, describing the SWM conveyance features (i.e., channels, ponds) and flow direction is presented in Figure 8.3.

8.4.4 Infiltration Area Configuration

The infiltration capacity of the overburden soils on the floor of the Pit is relatively high (Section 4.9, HHCR). The existing surface of the base of the Pit may be used as the infiltration areas. The designated infiltration area will contain an overflow route that will convey excess surface water to other portions of the Pit for infiltration, in the event of a large multi-day precipitation event temporarily overwhelming the infiltration areas.

It is proposed that the infiltration area for stormwater runoff from the Landfill should be divided into two portions. A west infiltration area will be used to store and infiltrate the surface runoff from west part of the Landfill and an east infiltration area will be used to store and infiltrate the surface runoff from east part of the Landfill. The bottom elevation of both areas will be approximately 167.3 m which is approximately 10 m higher than the groundwater table. The infiltration areas may be delineated by berms and existing ground features and may be shaped to allow for the continued use of the Site during storm events.

The required bottom surface area for each of the infiltration area is estimated at 2,930 m^2, while the top surface area of both infiltration areas will be 3,969 m^2 excluding sediment forebay area. The total available storage volume from each of the pond is approximately 1,232 m^3 from bottom of the pond to the maximum ponding depth at 0.4 m, and approximately 3,313 m^3 from bottom of pond to top of pond for the entire depth (1.0m). These volumes are based on an assumed length to width ratio of 3:1, and a horizontal to vertical slope of 3:1 at the pond perimeter. A stage-area table for pond configuration is included in Appendix D.

8.4.5 Infiltration Rate

The area to the adjacent north of the Landfill is proposed as an infiltration area. Stratigraphic and single well response tests were completed for this area and are presented in the HHCR.

The borehole log for this area indicates:

1. Groundwater elevation is greater than 1.5 m below the ground surface.
2. Gravel and sand are the predominant soil types.

According to the Best Management Practices Guide Prepared for Greater Vancouver Sewerage and Drainage District, an infiltration rate of 60 mm/hr was conservatively assumed to represent the infiltration rate.

8.4.6 Infiltration Discharge Estimation

Using the stage area table provided in Appendix D, the infiltration area at an elevation of 167.3 m was interpolated as 2,682 m^2. Infiltration discharge was calculated as the product of infiltration rate and the infiltration area bottom area. This infiltration discharge was applied in the PCSWMM model as outflow from the infiltration areas.

8.4.7 Sediment Forebay

A sediment forebay will be installed at the inlet of the stormwater infiltration areas to preferentially settle large particulates in the sediment load within an area that can be conveniently accessed for maintenance. The sediment forebays for the infiltration areas were sized according to the design guidelines given in Section 8.2.2. Detailed calculations for the length and width for the sediment forebays are provided in Appendix D.

An energy dissipation structure at the outlet of the steep channels is required to prevent erosion of the base of the Pit. A basin approximately 1 m deep that is 5 m wide and 10 m in length will be constructed to transition the discharge from super-critical to sub-critical flow. The basin will be lined with the concrete block lining similar to the channel lining.

8.4.8 Modelling Results

All hydrologic models were analyzed using synthetic design storms with return periods of 5-year, 10-year,100-year, and 200-year design storms.

Table 8.3 provides a summary of the estimated peak discharge rates from each catchment. Table 8.4 provides a summary of the estimated runoff volume from each catchment. The model results indicate during the 200-year design storm that in excess of 90% of the rainfall results in runoff. Hydrologic model outputs files are provided in Appendix D.

The model also calculates the peak discharge within the channels. The channels were designed to convey the peak discharge from the 200-year design storm event with at least 0.3 m of freeboard. A summary of the channel characteristics and performance is provided in Table 8.5. Table 8.5 also provides recommendations for the addition of erosion protection (i.e. turf reinforcement matting or ditch lining) for ditches with excessive grades resulting in a higher shear stress. Ditch lining is recommended for any ditch that would have an estimated shear stress in excess of 50 Pascal's (U.S. Soil Conservation Service Channel Design Handbook for Retardance Class C Vegetation) during the 100-Year event.

Table 8.6 provides a summary of the ponding depths and storage volumes for the infiltration areas. The infiltration areas will provide sufficient volume to store the 200-year design storm event and have a sufficient surface area to drain in less than the maximum limit for all storms (48-hours). As discussed in Section 8.4.4, overflow infiltration areas will be designated as a contingency.

9. Leachate Management Plan

9.1 Leachate Management Objectives

The objective of the leachate management plan is to achieve water quality compliance at the Site by minimizing leachate generation, collecting, and treating all leachate, discharge all treated leachate through on-Site infiltration and provide on-Site attenuation for further polishing.

The leachate generation will be minimized by:

- Maintaining a small active face
- Applying appropriate intermediate and final cover at the earliest opportunity
- Promoting clean surface water diversion away from the Landfill
- Pursuing progressive closure of the Landfill

9.2 Typical Construction and Demolition (C&D), Land Clearing, and Contaminated Soil Leachate General Overview

Principle factors affecting the composition of leachate include (McBean et al., 1995):

- Waste composition
- Age of refuse
- Landfill operations
- Climatic conditions
- Hydrogeological conditions
- Conditions within the landfill (e.g., chemical and biological activities, temperature, pH, and redox conditions)

The mass of refuse stored in a landfill represents a finite source of pollutants. Typical construction and demolition (C&D), land clearing, and contaminated soil waste leachate is a mixture of organic and inorganic compounds produced from refuse materials by a combination of physical, chemical and biochemical processes. Physical processes, related to leachate generation, involve the flushing and dissolution of pollutants as water percolates through the refuse material. Chemical processes, including ion exchange, sorption/desorption, and change in pH, contribute to leachate production by enhancing the mobilization of various pollutants (leachate constituents). Biological processes contribute to leachate production via the degradation of organic constituents into simpler and more mobile compounds.

The mass of pollutants available for leaching is largely a function of the physio-chemical nature of the waste, the extent of waste stabilization, and the volume of infiltration into the landfill (Lu et al., 1984). As a result, the leachate composition may be significantly impacted by not only the above-stated factors, but also key elements of the landfill design and operations.

Leachate produced from typical Demolition, Land Clearing and Construction (DLC) waste landfills is generally considered to be less threatening to human health and the environment compared to leachate from other types of disposal facilities, such as municipal solid waste (MSW) landfills (Townsend, 2000) that contain large quantities of putrescible waste. Unlike MSW, DLC waste consists largely of inorganic components and organic matter with a low degree of biodegradability. Preliminary investigation results of DLC lysimetric testing show concentrations of Chemical Oxygen Demand (COD) in the range of 44 to 1,700 mg/L (Townsend, 2000) which is significantly lower than the typical COD concentration range of 3,000 to 45,000 mg/L in MSW (SWANA, 1991).

Typically, the most potentially prominent contaminants in the leachate from C&D landfills are sulphate, arsenic, iron, manganese, and Total Dissolved Solids (TDS).

A major source of sulphate can be attributed to the presence of gypsum drywall in typical C&D landfills. Gypsum drywall has widely been used as interior walls in construction due to its high fire resistance. When gypsum drywall is landfilled and comes in contact with infiltrating water, calcium and sulphate are released into solution.

In the 1970's to 1980's, wood was preserved with chromated copper arsenate (CCA-treated wood) and used in the construction of decks, patios, gazebos, and other wooden structures. CCA-treated wood in typical C&D waste landfills contributes to arsenic, chromium, and copper levels in typical C&D waste leachate. It is anticipated the technological advancements of wood treatment will eventually lead to a phase-out of CCA-treated wood products. CCA-disposal rates at typical C&D waste landfills will peak and then eventually level-off (Jambeck, 2004).

Manganese is found in alloys, paints, and naturally in plant tissue. In a study of demolition waste leachate, high concentrations of manganese (17 mg/L) were found from wood-based laboratory landfill experiments. Therefore, wood waste is likely a source of manganese present in C&D waste leachate.

High TDS concentrations in C&D leachate are mostly likely attributed to calcium, sulphate and alkalinity ions from the dissolution of gypsum drywall and the leaching of calcium carbonate and calcium hydroxide from concrete.

Non-hazardous contaminated soil may contain a large variety of contaminants depending on the source of the waste material. Common soil contaminants include metals, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs) and petroleum hydrocarbons (PHCs). Some metal-contaminated soils may increase metals concentrations in the leachate but this is dependent on the form of the metal in the soil, the metal solubility and the conditions in the landfill.

Contaminated soil could increase the concentrations of PAHs, VOCs, and PHCs in leachate but these compounds are readily biodegradable within the leachate. Contaminated soil must be considered non-hazardous for acceptance at the Site, as defined by the HWR. The leachability of the pollutants in non-hazardous contaminated soil will be low compared to hazardous waste and free-product concentrations.

ACM does not affect the quality of the leachate in terms of impacts from the asbestos material, as asbestos does not have the leachability characteristic that distinguished hazardous chemicals, identified in the HWR. ACM is only hazardous when the potential for asbestos fibres to become airborne prior to and during landfilling, once landfilled ACM is an inert material.

9.3 Typical C&D Leachate Generation Lifecycle

The composition of typical C&D leachate will vary over time as conditions within the waste material change. Biological activity is a major influence affecting leachate chemistry. An awareness of the microbial activity degrading the refuse throughout landfill development is central to understanding the resultant leachate chemistry. Biological degradation generally involves aerobic and anaerobic phases, which can occur simultaneously and have varying impacts on leachate chemistry.

When refuse is landfilled in an active cell, the initial biodegradation phase occurs under aerobic conditions resulting in the partial degradation of organic components in the refuse material. The aerobic decomposition typically results in high carbon dioxide (CO_2) concentrations, a lowering of pH and an increase in temperature, COD, biochemical oxygen demand (BOD) and specific conductance levels in leachate.

As the availability of oxygen is limited, the organic material will undergo anaerobic decomposition. In the beginning of this anaerobic phase, generally elevated levels of organic acids, ammonia, hydrogen and carbon dioxide are produced. The production of organic acids and carbon dioxide can lower the pH in the leachate, enhancing the dissolution of inorganic constituents including iron (Fe), magnesium (Mg), zinc (Zn) and calcium (Ca). This phase is also characterized by elevated levels of BOD, COD, and specific conductance. As the degradation of organics into simpler and more mobile compounds continues, lower BOD levels will be reached and the pH will stabilize. Inorganic elements such as sulphate, chloride, iron, sodium and potassium, however, can continue to leach and dissolve for a prolonged period of time.

In anaerobic conditions, the three most important bacteria capable of degrading organics include Iron(III)-reducing (Fe(III)-reducing bacteria), sulphate-reducing and methanogenic bacteria. The Fe(III)-reducing bacteria oxidate organic matter with the reduction of Fe(III), sulphate-reducing bacteria oxidize organic matter by reducing sulphate and producing hydrogen sulphide, while methanogenic bacteria convert organic matter to carbon dioxide and methane. Typically, these bacteria are not active simultaneously, thus no hydrogen sulphide or methane production will occur until the Fe(III) reduction is complete and no methane production until sulphate is depleted (Lovley, 1987). In other words, Fe(III)-reducing bacteria can out-compete both sulphate-reducing and methanogenic bacteria for fermentable substrates until Fe(III) becomes depleted, then sulphate-reducing bacteria can out-compete methanogenic bacteria for organics until sulphate is depleted. Generally, over time, more methane generation will occur as this is the last phase of anaerobic decomposition.

Over time, generated leachate typically decreases in "strength" or chemical concentration as a result of "washout" (i.e., tendency of contaminants to be transported away from the Site by infiltrating water) (Reinhart, 1995). This does not present a problem to the surrounding environment so long as careful monitoring of both the leachate quantity and quality are carried out, and leachate is collected and treated in an appropriate manner.

9.4 Leachate Indicator Parameters

A number of leachate parameters can be used as indicators of leachate derived impacts. As chemicals are transported in landfill leachate, their concentrations can be reduced or attenuated by a variety of processes including dilution, dispersion, sorption, ion exchange and biological degradation. An indicator parameter of landfill derived impacts should be a chemical which is subject to minimal attenuation so that it can signal the early movement of a leachate plume.

Chloride is one of the preferred indicator parameters as it is usually present in landfill leachate at elevated concentrations and is attenuated only by dilution and dispersion. Chloride, which is commonly found in MSW leachate at elevated concentrations, is also found in C&D landfill leachate but at lower levels. Typical MSW landfill leachate contains chloride concentrations in the range of 100 to 3,000 mg/L (SWANA, 1991) whereas C&D landfill leachate chloride concentrations are reported to typically range from 5 to 62 mg/L (Townsend, 2000). The use of chloride as an indicator parameter must be evaluated further based on the observed leachate quality for the Site.

The major contaminants of concern with respect to C&D, land clearing and contaminated soil landfills are metals and hydrocarbons. Hydrocarbons do not make good indicator parameters as there are many processes that degrade these parameters within the landfill. Metals can make good indicator parameters depending on the type, quantity, solubility, and other variables; however, in many cases metals are not sufficiently mobile due to their ability to adsorb to soil particles.

Site specific leachate indicator parameters will be finalized during the commissioning phase of the leachate collection and treatment system during the first year of the landfill operation. These leachate indicator parameters will be selected based on the actual leachate chemistry observed. The leachate indicator parameters will be reviewed annually as part of the annual operations and monitoring report discussed in Section 14.10.

At this time, the forecasted leachate indicator parameters include the following, consistent with the HHCR.

- Hardness
- Total Dissolved Solids (TDS) (lab)
- Conductivity (lab)
- Chloride
- Alkalinity (total)
- Hydrogen Sulphide
- Sulphate
- Ammonia
- Boron
- Iron
- Manganese

9.5 Site Specific Leachate Quality Forecast

This section presents the conceptual leachate quality forecast. The leachate treatment design is based on a pilot scale treatment study undertaken on Original Landfill leachate.

For the purpose of this DOCP, a forecasted leachate profile has been developed using leachate quality data from similar landfills in BC, including the Original Landfill located at the Site, and compared with similar landfills in other parts of Canada for verification purposes. The forecasted leachate profile contained in this report serves as a baseline for the leachate quality but will be revised based on Site specific conditions and incoming waste types to continue to assess the level of treatment required. Leachate quality will be reviewed as part of the annual operations and monitoring report discussed in Section 14.10.

Table 9.1 provides a range of leachate concentrations from four similar landfills and the historic Site landfill that are used to forecast the leachate quality profile for the Site. As shown in Table 9.1, parameters that are expected to exceed the CSR Schedule 3.2 Column 6 DW Standards within the untreated leachate include iron, manganese, and PAHs. Parameters forecasted to potentially exceed the CSR Schedule 3.2 Column 6 DW Standards within the untreated leachate include:

- Chloride
- Sulphide
- Arsenic
- Boron
- Iron
- Manganese
- Sodium
- PAHs

9.6 Leachate Quantity

The principal factors governing the quantity of leachate generated at a landfill include:

- Moisture addition
- Thickness of refuse layer
- Compaction and permeability of refuse mass
- Slope, thickness, and permeability of intermediate and final cover

Moisture addition to a landfill can arise from several possible sources (McBean et al., 1995):

- Water present in waste mass when landfilled
- Percolation of water (precipitation) through the landfill surface
- Horizontal flow through sides (not applicable to Northwin due to lined slope and berms)
- Upgradient flow from the bottom (not applicable to Northwin due to lined base)

Water entering the landfill is retained within the waste by surface tension and capillary pressure until the waste reaches field capacity, which is defined as the point at which the force of gravity on the leachate overcomes the forces retaining the leachate (El-Fadel et. al., 2002). In general, waste is placed at a water content below field capacity, hence percolation and inflow are considered to be the principal sources of water infiltration for leachate generation. The specific moisture content of the waste at field capacity varies with the waste composition, density, and porosity. The heterogeneous nature of the waste and channeling of leachate through paths of low hydraulic resistance causes leachate generation prior to the waste mass reaching field capacity, however, it can be expected that leachate flow rates will increase once field capacity has been reached.

Horizontal flow into the Landfill through the sides will not occur at this Site. The north, west, and east sides of the Landfill are not connected to adjacent land mass and, therefore, horizontal flow into the Landfill could only be possible through the buried portion of the landfill. The buried portion of the landfill on the southern side of the Landfill will not be subjected to horizontal flow into the Landfill due to the base liner system extended up the southern side slope and over the perimeter berm. A vadose zone exists between the groundwater and the base liner system. The high hydraulic conductivity of the underlying soils will provide a preferential pathway for groundwater flow through the soils and not through the liner system.

9.6.1 Estimating Leachate Quantities

The Hydrologic Evaluation of Landfill Performance (HELP) Model was used to estimate leachate generation under daily cover, intermediate cover and final cover scenarios. The HELP Model is a quasi-two-dimensional hydrologic model for conducting water balance analysis of landfills, cover systems, and other solid waste containment facilities. It is a long-accepted standard model for landfill cover performance developed by the US Army Corp of Engineers.

Leachate generated from a landfill area with daily cover applied was estimated based on the infiltration rate through daily cover as well as the surface runoff rate. Surface water coming into contact with waste or daily cover will be intercepted by the perimeter containment berms and managed as leachate. HELP Model outputs are presented in Appendix E.

9.6.2 Conceptual Leachate Generation Model

The generation of leachate is dependent on a number of factors including the precipitation rates, landfill cover systems, landfill development, and the duration of each stage of landfill development.

Precipitation data for the Campbell River Airport (Station 1021262) from 1981 to 2010 is summarized in Table 2.1, following the text. The precipitation data is provided by month and used to calculate average daily precipitation rates. It is noted that November, December, and January account for 45% of the annual precipitation. As discussed in Section 8, climate change models forecast an increase of up to 5.2 percent during winter months. To conservatively estimate leachate generation, an increase of 5.2 percent was applied on the total estimated generation rate.

The cover systems are discussed in Section 6.5. A summary of the HELP results, or monthly, annual, and peak leachate generation for each cover system is provided in Table 9.2.

The Landfill development is described in Section 5. During each of the eight stages, the estimated area that will be covered with daily, intermediate and final cover varies. Furthermore, when a new cell is initially constructed, the leachate generation rate will be higher due to the lack of waste with the capacity to retain moisture. The estimated area of each type of cover during each stage is presented in Table 9.3.

During construction of Stage 1 East and Stage 1 West, elevated leachate generation rates would be expected during the period immediately after the new cell is opened. Precipitation in this area will not have a waste mound to retain any moisture. To mitigate this situation, a temporary rain flap will be constructed in the base liner, including a berm constructed in the granular drainage blanket and a

HDPE geomembrane flap welded to the base liner and ballasted to prevent damage from wind. This will divide precipitation falling in the new cell to collect leachate in the active side and clean surface water on the other side. The clean surface water will be manually pumped from the non-active side.

The development plan includes a Landfill footprint of 34,148 square metres. The Landfill will have varying combinations of daily, intermediate, and final cover throughout the life of the Landfill that will affect the leachate generation, as presented in Table 9.4. Annual leachate volumes were calculated by multiplying the corresponding leachate generation rate of each cover system, presented in Table 9.2, by the respective areas during each stage of development, presented in Table 9.3. The approximate annual collected leachate volumes will range from 8,805 m^3 (24 m^3/day) in first half of Stage 1 East, to 24,303 m^3 (67 m^3/day) in Stage 2A to 573 m^3 (2 m^3/day) post-closure, as shown in Table 9.4.

Once a waste mound has been developed, the waste in the landfill will provide a significant amount of detention capacity that will prevent instantaneous surcharges in leachate volumes in the Landfill leachate collection system as a result of a large precipitation event.

9.7 Leachate Collection

The Landfill leachate will be collected by a series of perforated collection pipes installed at the bottom of each cell, as shown in Drawing C-04. The collection pipes will discharge to a sump to be constructed at the low point of the Landfill the north-east corner of the footprint. The leachate will be pumped from the sump via a submersible pump housed in one of the two sump riser pipes. The leachate will be conveyed to the aeration pond for treatment, after which it will be decanted to the effluent holding pond and once the water quality is confirmed, to the infiltration pond. The location of the treatment ponds is shown on Drawings C-03 and C-04.

9.8 Leachate Treatment

9.8.1 Treatment Objectives

The leachate treatment system will be designed to treat the leachate to meet the applicable CSR water quality standards (Schedule 3.2 Column 6 DW) prior to discharge to the Infiltration Pond. The CSR standards are published by the BC ENV and are designed to be protective of human health and the environment. The DW standards protect the potential for future drinking water use of the overburden, sand and gravel aquifer downgradient of the Site.

As noted in Section 13.1.1 the average groundwater flow in the shallow aquifer beneath the Pit is approximately 640 m^3/day, one order of magnitude above the average annual daily leachate generation rate. As such the available on-Site attenuation capacity within the overburden, sand and gravel aquifer provides for contingent reduction of treated leachate concentrations further protecting the off-Site receiving environment.

9.8.2 Treatment Capacity

As discussed in Section 9.6, the leachate volume was estimated using the HELP model and the development Stages of the Landfill. For the purposes of designing a leachate treatment system, it is assumed that all leachate generated will be collected and treated as any losses that occur from Landfill base liner leakage are negligible.

Based on the leachate generation rates during the individual stages of the Landfill development plan, the maximum annual average leachate generation will occur in Stage 2A. During Stage 2A, the annual leachate generation rate is estimated to be 24,303 cubic metres (67 m^3/day).

The leachate treatment system has been designed to manage the maximum annual average leachate generated with 100% redundancy. The treatment pond capacity was also verified to ensure sufficient capacity is available to treat the maximum monthly average of leachate generated through the winter months (highest precipitation months) during Stage 2A as shown on Table 9.4. An equalization system at the front-end of the treatment system will serve to buffer peak flows to the treatment system.

As an additional measure of redundancy, the Landfill storage capacity was evaluated. Because the Landfill is lined, leachate can be temporarily stored within the Landfill. It is noted that the design criteria for the leachate collection system and landfill liner indicates that the leachate head should not exceed 0.3 m. Based on an average head of 0.3 m over the base area of the Landfill and an assumed leachate collection system porosity of 0.3, the maximum capacity of the leachate collection system to temporarily store leachate is 2,572 cubic metres.

If the leachate volumes are found to differ during detailed design, commissioning, or at any point in the landfill lifespan, modifications to the treatment system capacity may be required.

9.8.3 Conceptual Treatment Process

The treatment system will operate in a batch treatment setup, generating a batch of effluent for infiltration. To target operation of a weekly batch at the peak daily rate, a batch size is considered to be approximately 466 m^3, based on seven times the average daily leachate generation in Stage 2A. The batch sizes will vary with seasonality and landfill development stages, requiring operational adjustments to the treatment system. Based on the pond sizing described in Section 9.8.3.1, the maximum batch size is 932 m^3. The conceptual leachate treatment process is shown in Figure 8.1 below.

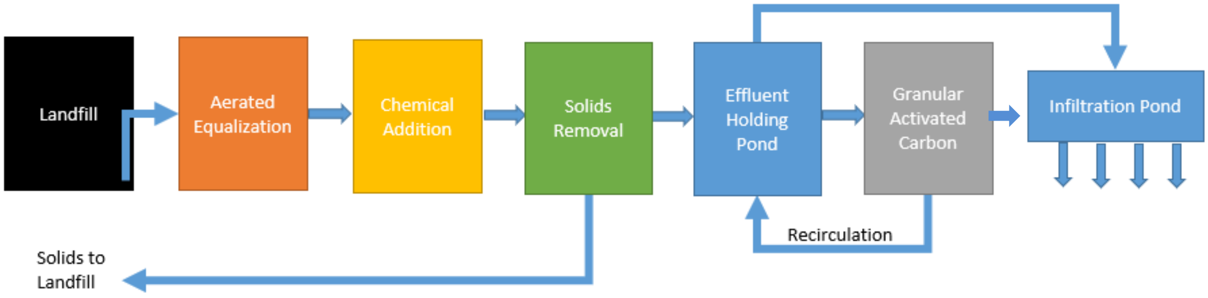

Figure 9.1 Leachate Treatment Process Schematic

9.8.3.1 Process Components

Lined Cells

The entire footprint of the Landfill will be lined and equipped with the leachate collection system as it is developed. The lined Landfill allows for containment of leachate prior to treatment. As discussed above, several processes occur within the Landfill to reduce concentrations of contaminants and these processes vary over time with the development of the Landfill. The details of the liner system are shown in Drawing C-13.

Leachate Collection

The leachate collection system will include the installation of leachate collection pipes and drain rock layer (Drawing C-04), as described in Section 3.7. The details of the leachate collection system are shown on Drawing C-13. Leachate will be conveyed via the leachate collection system to the north of the cell, where a leachate sump will be installed. The sump details are provided on Drawings C-14 and C-16. A pump will be installed in one of the sump risers and the second sump riser provides redundancy to allow for maintenance and cleaning and the use of a secondary pump, if required.

Aerated Equalization

Equalization will be used to attenuate peak generation rates in conjunction with the storage available within the landfill. The addition of aeration to the equalization system accomplished the first step in the treatment process.

Aeration oxidizes dissolved metals such as iron and manganese to less soluble forms and produces flocs that will be removed through filtration. Concentrations of other metals present in the leachate that are not readily oxidized in an aeration lagoon will also be reduced when the suspended (not dissolved) components of these metals are filtered.

Though not anticipated as a contaminant of concern, should hydrocarbons and volatile organic compounds be present, they will be readily volatized in an aeration lagoon. Some PAHs are also reduced through aeration.

Aerated equalization will be accomplished through a lined lagoon. For the purpose of conceptual sizing, a lagoon has been assumed.

The conceptual design features of the aerated equalization lagoon include:

- 2.5H:1V side walls double lined with two layers of 60-mil HDPE liner overlying a GCL with a Geosynthetic drainage layer between the two liner layers.
- Leak collection sump with 300 mm HDPE riser pipe to facilitate the removal of liquid collected within the drainage layer.
- A submerged coarse bubble aeration system.
- Positive displacement blowers, sized to provide the required air demand.
- Submerged decant pump.
- Approximate bottom dimensions of the aeration pond will be 15 m by 15 m. The approximate top dimensions of the aeration pond will be 30 m by 30 m.
- Approximate depth of 3 m with a 0.6 m freeboard.
- Provides storage capacity of over 7 days at the target average daily generation rate with 100 percent redundancy to account for peak storm events. This facilitates operation of a weekly batch treatment.
- Resulting available volume is approximately 1,087 m^3, accounting for precipitation over the pond area (based on above bullet plus 10 percent).
- Aeration is anticipated to require a retention time of 1-3 days.

- The aerated equalization system is anticipated to be filled with automated pump shutoffs based on liquid level in the Landfill and in the pond. To fill the aeration basin over the course of 2 days. Therefore, pumping capacity to fill the aerated equalization system should be 0.77 litres per second (L/s) (12 gallons per minute [gpm]) for an average size batch, and 1.7 L/s (27 gpm) for a maximum size batch.

Solids Removal

Effluent from the aerated equalization system will contain elevated concentrations of suspended solids following oxidation of metals and the presence of other inorganics. The next step is solids removal. This can be accomplished through settling in a clarifier or filtration.

Clarification or filtration will require a capacity of 5.4 L/s (86 gpm) for an average size batch and 11.9 L/s (188 gpm) for a maximum size batch to complete solids removal within one day.

Chemical Addition

Aeration and solids removal will remove the majority of dissolved iron and manganese. Additional dissolved metals removal may be required to achieve the discharge criteria. The dissolved metals will be removed, if required by chemical precipitation, by adding a volume of chemical that will cause an increase or decrease of pH of the leachate to facilitate the formation of an insoluble salt. Chemical addition will take place in a complete mixed reactor or with inline mixing.

Following chemical addition, the formulation of additional suspended solids will require solids removal using a solids removal system as described above.

Effluent Holding Pond or Tank(s)

Effluent from the chemical addition and solids removal step will be collected in a holding pond (or tank(s) of the same capacity). The effluent holding pond or tank(s) will have sufficient capacity to store effluent prior to batch discharge to the Infiltration Pond. The conceptual design features of the effluent holding pond include:

- 2.5H:1V side walls lined with one layer of 60-mil HDPE liner
- Approximate bottom dimensions of the aeration pond will be 15 m by 15 m. The approximate top dimensions of the aeration pond will be 30 m by 30 m.
- Approximate depth of 3 m with a 0.6 m freeboard.
- Provides storage capacity of over 7 days at the target average daily generation rate with 100 percent redundancy to account for peak storm events.
- Approximately 1,087 m^3 available volume.

Tank(s) may be selected in lieu of constructing an effluent holding pond.

Effluent in the effluent holding pond (or tank) will be sampled to determine if the discharge criteria have been achieved. If the discharge criteria are achieved, effluent will be conveyed directly to the infiltration pond.

If discharge criteria have not been achieved, the effluent will be recirculated through a granular activated carbon (GAC) filter as described below and resampled to confirm the discharge criteria are achieved prior to infiltration.

Granular Activated Carbon

An optional GAC filter will be used to polish effluent stored in the effluent holding pond should an initial sample indicate that the effluent does not achieve the discharge criteria. A GAC filter has been selected to ensure the effluent PAH criteria can be consistently achieved.

Treated Leachate Infiltration Pond

The infiltration pond will be used to infiltrate treated leachate and any intercepted storm water into the groundwater system. The design and construction of the infiltration pond is supported by the results of the hydrogeologic characterization of the Site, as provided in the HHCR.

The location of the infiltration pond has been selected to allow for natural attenuation to occur while allowing for continued Site operations. The Site is underlain by a vadose zone of varying thickness, and will be used to attenuate, via sorption, diffusion, dilution, dispersion, and biodegradation, the treated leachate to further reduce the concentrations of the leachate constituents prior to reaching the sand and gravel aquifer and the downgradient property line.

The forecasted treated leachate quality is presented in Table 9.1. The results of pilot studies conducted on Original Landfill leachate will be used to inform leachate treatment design to ensure an adequate level of treatment is attained. The leachate treatment process may be modified throughout the life of the Landfill to ensure the performance and compliance criteria are met.

9.8.4 Operating Sequence

The treatment system will operate in batches. First, the aerated equalization pond will be filled and the aeration system will be on during the filling process. Following aeration, the leachate will be pumped through a solids removal process, dosed with chemical in a complete mixed reactor or inline mixing system, and pumped through a solids removal process into the effluent holding pond. During the LTF commissioning period, once the batch is fully pumped through the chemical addition and solids removal process, the effluent batch will be sampled with a 3-day turnaround on the laboratory analysis. Following receipt of sample results, the batch will be pumped to the infiltration pond or recirculated through the GAC, if PAHs do not meet discharge criteria. During operations the batches will be tested periodically to confirm discharge criteria are being met.

At the Stage 2A average daily leachate generation rate, a batch will be approximately 466 m^3 and the aerated equalization system and effluent holding pond will have 100 percent redundancy to manage a batch if an effluent sample result fails and it needs to be recirculated through the treatment system. As operations are optimized and batches are consistently treated, the system will be capable of operating a maximum batch size in a 7-day period as illustrated in Table 9.1, below.

Table 9.1 Leachate Treatment – Example Operating Sequence

Operating Sequence	Fri.	Sat.	Sun.	Mon.	Tue.	Wed.	Thur.
Fill	X	X					
Aerate	X	X	X				
Solids Removal, Chem. Dose/Mix, Solids Removal				X	X		
Sample					X		
Sample Turnaround	X					X	X
Recirculate/Infiltrate		X	X				

9.8.5 Leachate Treatment Facility Commissioning and Sampling Program

The Leachate Treatment Facility Commissioning Plan is presented in Appendix F.

During the commissioning of the leachate treatment system and during the operation in Stage 1 East, the leachate treatment system will not be at maximum capacity. The untreated leachate and treated effluent will be sampled regularly during the commissioning to develop a relationship between the parameters of concern within the leachate and the batch treatment sampling program. Because the treatment system will not be operating at full capacity the batches may be held while the commissioning program is underway to ensure only leachate meeting the treatment objectives is infiltrated. The finalized leachate treatment sampling program will outline the parameters sampled in every batch to indicate the effectiveness of the treatment process and the confirmatory sampling required at the quarterly environmental monitoring events. Additional confirmatory sampling may be conducted.

Subsequent to commissioning, samples will be collected at a minimum on a quarterly basis to analyze for the parameter list below. The collection of the samples sent to for laboratory analysis may be collected more frequently to verify the batch sampling program, and to assist in the operation and maintenance of the leachate treatment facility.

- COD
- Alkalinity
- Metals
- pH
- PAHs
- Sulphate

10. Landfill Gas (LFG) Management Plan

10.1 LFG Production

LFG is primarily generated as a result of biological decomposition of organic waste material. The processes involved in biological decomposition of solid waste are highly variable. In the early stages of decomposition (typically less than 2 years after initial placement), microbial activity is oxygen consuming (aerobic). This results in relatively high in-situ temperatures, production of gases composed primarily of carbon dioxide (CO2) with other trace compounds, and production of acidic leachate.

As the oxygen in the solid waste mass is consumed, activity of anaerobic microbes increases and eventually results in production of LFG that is predominantly methane (CH_4) and CO_2, and in some cases hydrogen sulphide gas (H_2S). In this phase of the decomposition, the in-situ temperatures are typically in the range of 30 to 40°C and the leachate has a more basic pH. This methanogenic phase of decomposition will reach an equilibrium level, which will continue for some length of time. The equilibrium condition and the duration of methanogenic decomposition are the primary determinants of the LFG production over time. Within a few years, this anaerobic stage typically becomes and remains dominant until all organic matter in the Landfill has been fully decomposed. The typical LFG production stages are illustrated in Figure 10.1.

These processes are dependent upon the following primary parameters:

- Age of solid waste
- Quantity of solid waste
- Solid waste composition
- Moisture content
- Density and filling practices
- Climate (i.e., precipitation and temperatures)
- Landfill chemistry

This list is not considered comprehensive but serves to illustrate the complexity of the processes involved in the production of LFG. The solid waste age, quantity, and composition, along with site moisture content are considered the primary influences on the rate and duration of LFG production.

The composition and quantity of the solid waste placed in a landfill will determine the amount of material available for decomposition. Materials with a higher organic content are more readily decomposable than those wastes with a low or no organic content. For example, food and agricultural wastes contribute more readily to LFG production than construction rubble. In general, waste that is derived from residential sources contains a higher decomposable fraction than those derived from other sources.

LFG may contain varying amounts of nitrogen (N_2) and oxygen (O_2) due to intrusion of outside ambient air into the landfill. The typical composition of the gas may be in the following range depending on the operation of the LFG collection system:

- Methane – 35 to 60 % by volume
- Carbon dioxide – 35 to 60 % by volume
- Oxygen – 0 to 5 % by volume
- Nitrogen – 0 to 15 % by volume

For modelling and design purposes, the composition of LFG produced and collected is assumed to be 50% CH_4 and 50% CO_2, each by volume.

The optimal range of moisture content in refuse for methane production is reported to be 40 to 70% by weight (Reinhart & Townsend, 1998). Actual LFG production is sensitive to moisture; however, the degree of moisture distribution and saturation within the landfill are difficult to determine. Furthermore, there are various technical difficulties in ensuring adequate leachate distribution and collection within a landfill.

Due to the complexity of the processes involved in LFG production, the methods available to predict variations in production over the life of a site provide only estimates to permit the design of control systems. Flexibility to address changes in the LFG production should always be a primary design consideration in any LFG management program.

The use of predictive models provides the best method of defining a particular site's LFG generation potential. The following subsections present the results of estimated LFG production at the Site with mathematical models.

10.2 Regulatory Criteria

The BCENV Landfill Gas Management Regulation requires the following:

- Landfills receiving over 10,000 tonnes of waste per year, or landfills that have over 100,000 tonnes of waste in place, complete a LFG generation assessment every five years.
- The assessment of the forecasted LFG generation rate in the year of the assessment and for the next 5 years be prepared by a qualified professional and submitted to the ENV.
- If the landfill is currently generating over 1,000 tonnes of methane per year, according to the LFG generation assessment, then a LFG Management Facilities Design Plan must be submitted to the ENV within one year.
- Once the LFG design plan is accepted, an active landfill gas collection system is required to be installed within four years of the LFG design plan acceptance.

The production of hydrogen sulphide gas is related to health and safety concerns, as well as nuisance impacts, and is regulated under WorksafeBC, as discussed in Section 10.5.

10.3 LFG Generation Model

There are numerous models available for estimating rates of production of LFG. Accepted industry standard models are generally first order kinetic models that rely on a number of basic assumptions. These models are used to predict the variation of LFG generation rates with time for a typical unit mass of solid waste. This generation rate curve is then applied to records (or projections) of solid waste filling at a site to produce an estimate of the landfill's LFG production rate over time.

The Scholl Canyon model, a first-order kinetic function, is the accepted industry standard model to evaluate LFG production and emission rates for the purpose of assessing potential LFG impacts. The Scholl Canyon model is used to estimate LFG production over time as a function of the LFG generation constant (k), the methane generation potential (L), historic filling records, and future projections for waste filling rates. Typical values of k range from 0.006 per year for dry sites to 0.07 per year for wet sites. Depending upon the regional precipitation and waste composition, production of LFG may continue for more than 50 years after closure and can result in total yields ranging from approximately 10 to 350 cubic metres of methane per tonne of waste.

The formula for the Scholl Canyon model can be expressed as follows:

$$Q_T = \sum_{t=1}^{n} 2\, L_0 k M_t e^{-kt}$$

Where:

Q_T = total LFG emissions (50 % CH_4 and 50 % CO_2 by volume)
K = LFG generation constant (year^{-1})
L_o = methane generation potential (m^3 CH_4/tonne of waste)
M = mass of waste (tonnes) placed in year t
T = time in years

10.4 LFG Generation Assessment

10.4.1 Landfill Gas Generation Assessment Requirements

As required by Section 4(5) of the Regulation, this Section relates to the tonnage thresholds that determine the regulatory requirement to prepare a landfill gas (LFG) generation assessment. A landfill is termed a regulated landfill site under the Regulation if it has 100,000 tonnes or more of MSW in place or receives 10,000 or more tonnes of MSW in any calendar year after 2008.

Based on the estimated annual tonnages, the Landfill will be considered a ‘regulated landfill site’ as per Section 4(5) of the Regulation and a landfill gas (LFG) generation assessment report will need to be submitted to the ENV following the first year of landfill operations as required in Section 4(5) of the Regulation.

10.4.2 Waste Characterization

This section summarizes characteristics at the Site, anticipated waste tonnage, and waste characterization, as required by Sections 4(2)(a), 4(2)(b), 4(2)(c), 4(3)(a), and 4(3)(d) of the Regulation and described in Section 5.1 of the Guidelines.

For this assessment, waste landfilled was segregated into the following three categories by mass:

- Relatively inert (waste includes waste materials with low or no degradable organic carbon, such as metal, glass, plastic, soil, contaminated soils, and water treatment plant screened fines).
- Moderately decomposable (includes materials with a degradable organic carbon fraction that will decompose at a moderate or slower rate such as paper, wood, wooden furniture, rubber, textiles, and construction and demolition material).
- Decomposable (includes materials with a high degradable organic carbon fraction that will decompose relatively quickly such as food waste, yard waste, and slaughterhouse waste).

As per Section 4(3)(d) of the Regulation and described in Section 5.1 of the Guidelines, waste characterization information is required as part of the generation assessment. This information should include the historical, where possible, and projected annual waste mass categorized into mass of relatively inert, moderately decomposable, and decomposable wastes, and historical and projected waste mass.

The site-specific waste characterization is presented in Table 10.1. As shown, the waste that will be received at the Site is categorized into 75 percent relatively inert, 25 percent moderately decomposable, and zero percent decomposable.

10.4.2.1 Climate

The moisture content within a landfill is one of the most important parameters affecting the gas generation rate. Moisture provides an aqueous environment necessary for anaerobic processes responsible for LFG production, and serves as a medium for transporting nutrients and bacteria that play a major role in the decomposition process. The precipitation data, as discussed in Section 2.4 was used to determine appropriate values for model input parameters. The potential effects of climate change on the annual precipitation rate were evaluated. It was found that the model inputs do not change for annual increase of up to 25 percent, which exceeds the forecasted precipitation rate change due to climate change, as discussed in Section 2.4 and 8.4.2.

10.4.2.2 Model Input Parameters Used and Justification

The following section presents the information required by Section 4(3)(d) of the Regulation and described in Sections 5.2 (Methane Generation Rate Selection Matrix) and 5.3 (Water Addition Factor) of the Guidelines.

The methane generation potential, L_o, represents the total potential yield of methane from a mass of waste (m^3 of methane per tonne of waste). The L_o value is dependent on the composition of waste, and in particular the fraction of organic matter present. The methane generation rate, k, represents the first-order biodegradation rate at which methane is generated following waste placement. This constant is influenced by moisture content, the availability of nutrients, pH, and temperature.

Moisture content is influenced primarily by the infiltration of precipitation through the Landfill cover and the nature and composition of the waste. For this assessment, a water addition factor of 1.0 was selected. The water addition factor may increase or decrease the LFG generation rate by 10 percent. The potential Landfill leachate storage in the Landfill during the winter months will not significantly increase the moisture within the Landfill, as the leachate will be stored primarily within the leachate collection system, and not within the waste.

10.4.2.3 Landfill Gas Generation Model Results

The Regulation Sections 4(2)(d), 4(2)(e), and 4(3)(a)] requires that a LFG generation assessment include the following:

- The annual tonnage of waste received for disposal at the Site in the calendar year immediately preceding the year in which the assessment is conducted.
- An estimate of the quantity of methane generated at the Landfill in the calendar year immediately preceding the calendar year in which the assessment is conducted.
- Projections for methane anticipated to be generated annually at the Site in the calendar year of the assessment and in each of the four calendar years following the calendar year of the assessment.

For this assessment, the maximum annual waste tonnages throughout the life of the Landfill were used (45,000 tonnes per year, except if landfilling waste from the Original Landfill). When an actual LFG assessment is produced for submission to the ENV, the recorded waste tonnages will need to be used for the assessment.

This assessment projects the methane generated annually at the Landfill for each calendar year that the Landfill is anticipated to be operational.

Table 10.2 presents a summary of the above information. As noted on the table, the peak methane generation occurs in the year after closure. The maximum annual methane generation is estimated to be approximately 560 tonnes per year in the year following closure. The methane generation rate will steadily decline in post-closure years.

Table 10.3 presents the input values for the Scholl Canyon Model and LFG generation results. Figure 10.2 shows a graphical representation of the annual LFG generation estimate commencing in 2021 (assumed Landfill start date) to 2063 (end of the 30 post-closure monitoring period).

10.4.2.4 Future Considerations

The estimated 2035 (Landfill closure year) methane generation for the Site is approximately 649 tonnes. As the regulatory threshold is 1,000 tonnes of methane per year, the Landfill is not expected to surpass the threshold during the Landfill lifespan. If the methane generation rate surpasses the threshold due to higher annual tonnages, more decomposable waste, the Landfill continuing for a longer timeframe than originally plan, or due to a regulatory revision, an LFG Management Facility Design Plan will be submitted to the ENV director. Within 4 years of submitting the LFG Management Facility Design Plan, a LFG Management system designed to target a landfill gas collection efficiency of 75 percent must be commissioned and operational. The LFG regulation may change between now and the closure of the Site.

The LFG Management Facility Design Plan must be prepared by a qualified professional in accordance with the Landfill Gas Management Regulation.

10.5 LFG and Safety

As indicated in Section 10.1, LFG is produced primarily due to biological decomposition, generating CO_2 and CH_4. Predominantly due to pressure gradients, LFG migrates through either the landfill cover or adjacent soil and enters the atmosphere, contributing greenhouse gas (GHG) emissions, creating health and toxicity issues, and creating nuisance odours. These impacts are largely dependent upon the pathway by which humans and the environment are exposed.

Sub-surface migration of LFG is influenced by pressure differentials within the waste mass, LFG migration from areas of high pressure to areas of low pressure, diffusion of LFG through from areas of high concentrations to low concentrations, and the permeability of the waste, liner, and cover systems.

Sub-surface migration of LFG poses two primary concerns related to the accumulation of gases within or below structures near the Landfill. First, accumulation of LFG in a subsurface structure (i.e., basement, buried manhole, etc.) may expose those required to enter the structure to an oxygen deficient environment. Second, accumulation of LFG introduces the risk of an explosion if a source of ignition is present. The risk of explosion occurs when the concentration of methane in air exceeds its Lower Explosive Limit (LEL). Due to the fact that the LEL of methane is approximately 5% by volume in air, only a small proportion of LFG (containing approximately 50% methane by volume) is necessary to create explosive conditions.

Visual observation of the sub-surface migration of LFG is possible through identification of areas impacted by vegetative stress. Vegetative stress occurs due to the displacement of oxygen in the soil and the resultant oxygen deprivation of the plant roots. Deterioration of vegetation on or near landfills may be both an aesthetic and a practical issue. In areas where vegetative cover is diminished, erosion of the cover may occur. This may result in a "cascade" effect resulting in increased LFG emissions.

H_2S, if present, presents immediate danger to the health and safety of workers. WorkSafeBC regulations and guidelines must be followed. At a minimum, the following procedures are recommended, if the potential for H_2S becomes an issue.

- No persons shall traverse or operate equipment within the limit of waste or in the vicinity of the leachate management infrastructure without wearing a 4-gas meter.
- All leachate collection system cleanout and sump riser pipes blind flanges should be completely sealed, bolted, locked, and identified with appropriate signage.
- Appropriate measures should be taken to prevent persons untrained in H2S safety and without the appropriate personal protective equipment from entering the site. Appropriate signage should be installed around the limit of waste.
- Appropriate chain link fencing and signage should be installed around leachate sumps, leachate manhole, and toe drains.
- All workers and contractors working in designated Site “Hot Zones” (fenced areas) should be required to have completed the H2S Alive course.
- All workers and contractors working on-site should be required to have reviewed and acknowledged the Site health and safety plan which discusses the H2S safety plan and restricts smoking anywhere onsite.

10.6 LFG as a Greenhouse Gas

As discussed in Section 10.1, LFG consists of varying levels of CH_4, CO_2, oxygen, and nitrogen. For modelling and design purposes, the composition of LFG produced is often assumed to be 50% CH_4 and 50% CO_2, each by volume. These two gases are two of the recognized greenhouse gases that contribute to climate change. CH_4 has a global warming potential approximately 25 times that of CO_2.

10.7 LFG Control

The Landfill will use a geosynthetic liner system, which will limit subsurface migration of LFG into the subsurface surrounding the landfill. As such, migration of LFG will likely primarily occur through the final cover, resulting in potential degradation of the final cover and vegetative stress. As such, the LFG Management Plan for the Landfill will involve the installation of a passive gas venting system as part of the final cover design.

The use of passive bio-filters will be evaluated as part of the detailed design of the final cover and passive gas venting system. Methane from the Landfill would be directed to a biofilter(s) via the passive venting system. Biofilters are typically a mix of sand and wood chips that facilitate the growth of aerobic bacteria that oxidizes methane to carbon dioxide, reducing the greenhouse gas emissions from the landfill. Passive biofilters will be considered at the detailed design stage of the final cover system, when it is possible to assess the actual methane generation rates based on the characteristics of the waste landfilled.

The guidance document entitled “Technologies and Best Management Practices for Reducing GHG Emissions from Landfills Guidelines” provides guidance for the selection of technologies and best management practices for reducing GHG emissions from landfills.

10.8 LFG Monitoring and Assessment

The highly permeable overburden unit at the Site may allow the LFG to migrate away from the Landfill if there is a breach in the Landfill base liner system. It is therefore recommended that the potential for off-Site LFG migration be monitored at the periphery of the Site, and into the existing on-site buildings currently occupied by the operational personnel. The soil gas concentrations at the Site boundary must not exceed the lower explosive limit of methane (five percent by volume). The soil gas concentrations in on-Site buildings must not exceed 20 percent of the lower-explosive limit of methane (one percent by volume) at any time.

In accordance with the above-noted recommendation, two soil-vapour monitoring locations will be installed at site as part of the construction of the cells.

1. Near the Wash Plant
2. At the southern property boundary to monitor migration of LFG off site

The monitoring requirements are further discussed in Section 14.

11. Closure Plan

The following sections outline site-specific closure activities and post-development care requirements in accordance with the Landfill Criteria.

11.1 Total Site Capacity

The total and remaining Site capacity is estimated to be 532,365 m^3.

11.2 Landfill Site Life

The estimated Landfill Site life is approximately 13.3 years and landfilling in the Landfill is assumed to start in 2022.

11.3 Final Closure Design

The final contours for the Landfill area are based on the construction of a 0.90-metre-thick final cover (0.15 metres of sand overlain by a GCL, 0.6 metres of protective sand layer, 0.15 m of topsoil) constructed over top of the final waste grades presented on Drawing C-06. In accordance with the Landfill Criteria, the final cover slopes will be a maximum of 3H:1V (33 percent) on all side slopes and a minimum of 10H:1V (10 percent) on the top slopes of the Site.

Details concerning final cover design and construction, including final cover soils, topsoil, and cover vegetation are discussed in Section 3.12. When a section of the Landfill reaches final contour elevations, final cover will be installed by an experienced contractor and inspected by a qualified professional engineer to ensure that construction has been completed in accordance with detailed design.

11.4 Progressive Closure Strategy

In keeping with a progressive closure strategy at the Site, areas of the Landfill that reach final waste contours in accordance with the Landfill Development plan presented on Drawings C-08 through to C-12 will be closed once sufficient area to warrant construction of final cover is available.

The Site life will be updated in the annual operations and monitoring report based on the final waste contours and the average annual fill rates.

11.5 End Use

The End Use Plan for the Landfill has been developed as part of the Reclamation Plan for the Upland Pit. It is anticipated that the Site will remain industrial land use and continue the aggregate extraction activities.

A detailed End Use Plan will be developed for the Site within one to two years prior to closure. The end use plan will comply with the requirements of the CSR and a new declaration under Part 8 of the CSR may be submitted to the ENV Director. The End Use Plan will be submitted to the City and the Regional Waste Manager for review and approval prior to implementation.

11.6 Post-Closure Requirements

11.6.1 Site Monitoring

The long-term environmental monitoring program for the Site will include hydraulic monitoring and chemical analysis of surface water and groundwater at the Site in accordance with the Environmental Monitoring Plan (EMP) discussed in Section 14. The EMP will be maintained during and after Site closure and will be evaluated on an annual basis. In accordance with the Landfill Criteria, the long-term monitoring program will be maintained for a minimum post-closure period of 30 years. Any proposed amendments to the long-term monitoring program will be submitted to the Director for review and approval prior to implementation.

11.6.2 Vector, Vermin and Animal Control

After closure, the Site will continue to be monitored for the presence of vectors, vermin, and wildlife and should problems become evident, the appropriate steps will be taken to address the issue.

11.6.3 Surface Water Control

The strategy outlined in the SWMP (Section 8) will be implemented into the post closure surface water control measures. The mid-slope swales, surface water diversion berm, ditches, sediment forebays, and infiltration areas will be completed and maintained around the landfill. Channels with steep slopes will require reinforcement to prevent erosion, as discussed in the SWMP. The ditches and ditch outlets will require reassessment upon closure to ensure that they are functioning satisfactorily. Vegetation will be maintained on the Landfill surface and in the channels to ensure channels flow freely and are not overloaded at peak rainfall events. Monitoring of the Landfill surface conditions will be required, and if damage due to erosion, settlement, or other factors are found, maintenance will be performed.

11.6.4 Post-Closure Infiltration Areas

The post-closure conditions of the Landfill will require the designation of infiltration areas within the base of the Pit to manage the surface water in large rainfall events. The conceptual design of the infiltration areas is discussed in Section 8.4.

11.6.5 Post Closure Maintenance and Monitoring Requirements

The EMP should be maintained for a minimum period of 30 years post-closure. This will be to assess the need to implement a contingency measure to further reduce the environmental risk. If monitoring results are as expected, the frequency of the monitoring events may be decreased to annually. The parameters should be analyzed annually until they completely stabilize at which time a monitoring program every 5 years is appropriate. It is important to continue monitoring for any change in Site conditions.

11.6.6 Site Facilities

The Landfill facilities for storm water and leachate management will remain intact and operational post-closure of the Landfill. A closure plan shall be submitted to the Director for approval at least 6 months prior to the closure of the Landfill.

12. Contaminating Lifespan Assessment

The purpose of this assessment is to evaluate the contaminating lifespan (CLS) of the Landfill. The CLS is the time period after the final closure of the Landfill until which the Landfill leachate no longer poses a risk to the environment because the concentrations of leachate contaminants have decreased sufficiently that the leachate constituent concentrations meet the applicable CSR standards for regulatory compliance.

During the CLS, the Landfill will require treatment, monitoring, and maintenance of the leachate management system to manage the post-closure Landfill conditions. These measures can be terminated at the end of the CLS.

The CLS of the Site was estimated based on the available data, and relevant models acquired through a literature review. In this case, GHD has utilized a first order decay function to estimate the CLS of the Site. The contaminants modeled to estimate the CLS include chloride and sulphate. These contaminants were selected as conservative parameters, as they decay only through dissolution and are not subject to biological degradation. GHD also investigated chromium, copper, and cadmium, however, forecasted leachate concentrations are below applicable environmental protection guidelines. GHD used the Rowe (1995, 2004) CLS model to confirm/evaluate the first order decay results for chloride.

The potential effects of climate change on the annual precipitation rate were evaluated. It was found that forecasted precipitation rate change of 6% was due to climate change, as discussed in Section 2.4. However, for the CLS it is more conservative to not include the potential increase in precipitation due to climate change as this will have a negligible effect on the infiltration into the Landfill through the final cover system but will increase the rate of decay resulting in a shorter contaminating lifespan.

The CLS assessment should be updated regularly and include amendments to the list of parameters, where required, based on the actual parameters within the Landfill leachate. The CLS assessment updates should form part of the updates to the Design, Operation, and Closure Plan, as required by the Landfill Criteria.

12.1 First Order Decay Model

Contaminant transport was simulated utilizing the 1DTRANSEN model. The leachate source concentration in the one-dimensional transport model is governed by the time function.

$$C_0 = \begin{cases} (t/t_1)C_B + C_A & 0 < t < t_1 \\ C_B & t_1 \le t < t_2 \\ C_B e^{-\mu t} & t \ge t_2 \end{cases}$$

For the purpose of this assessment the time period where t is greater than or equal to t_2, was used representing Landfill closure. When the simulation time is greater than t_2, the source concentration is assumed to decay exponentially at a rate of μ, the first order decay constant. The initial concentration, C_B, was estimated for each contaminant of concern (COC), based on data from existing C&D landfills that accept a similar waste stream as the Landfill.

12.1.1 Constituents of Concern

Based on the nature of waste normally found in C&D, land clearing, and contaminated soil landfills, the quality of leachate is generally much weaker in comparison to leachate from municipal landfills and also tends to have a lower organic content. The landfill leachate strength at any given time depends primarily on waste composition. Concentrations of the leachate constituents of concern were estimated based on data from existing similar landfills. The data was compiled from several similar landfills and utilized the maximum concentrations forecasted for the Landfill.

The forecasted constituents of concern concentrations in leachate are provided in Table 9.1.

12.1.2 Results

The CLS as estimated by the First Order Decay method in years for the constituents of concern identified for the Site, are as shown in the table below. The supporting calculations are provided in Appendix G.

Parameter	Years to Meet CSR DW Criteria
Chloride	28.0
Sulphate	9.0

12.2 Rowe Model

12.2.1 Model Based On Rowe (1995, 2004)

Rowe (1991) examined the issue of leachate strength decrease for conservative contaminant species (e.g., chloride) where the decrease in strength is essentially due to dilution (i.e., no biological breakdown or precipitation) as water infiltrated through the waste with time. Assuming that the decrease is due to dilution, the variation in concentration at any time t is given by:

$$C_{(t)} = C_0^{-q_0 t/H_r}$$

Where:

$$H_r = \frac{M_a}{A_0 * C_0}$$

Source: Rowe, 1994

$$M_a = H_w * \rho_{dw} * P$$

Where:

M_a = mass of contaminant per unit area (kg)

H_r = reference height of leachate (m)

A_o = area (m^2)

H_w = maximum waste thickness (m)

ρ_{dw} = dry density of waste (kg/m^3)

p = proportion of the total mass of waste that is contributed by chloride

C_o = peak or average chloride concentration (mg/L)

q_o = average rate of infiltration (m/yr)

$C_{(t)}$ = target concentration [i.e., ODWS] (kg/m^3)

T = time required (yr)

This model was used to validate the results of the First Order Decay Model. Note that this model was utilized for two scenarios, as follows:

- Scenario 1: maximum chloride concentration, average proportion of chloride in waste
- Scenario 2: maximum chloride concentration, maximum proportion of chloride in waste

Scenario 2 represents the worst case conditions.

12.2.2 Site Parameters

Concentrations of Leachate Constituents of Concern

As described in Section 12.1.1.

Dry Density of Waste

The estimated dry density of waste, based on expected waste stream, is 1,300 kg/m^3.

Volume of Waste

The total volume of waste is 532,365 m^3 within an area of 36,000 m^2.

Chloride Percentage in Waste

The mass of contaminant can be characterized in terms of the mass of waste and proportion of that mass which is the chemical of interest. Rowe (1995) reports that the data on the mass of contaminants in waste are relatively sparse and published data of chloride representative of municipal waste are in the range of 0.07 percent and 0.21 percent of the in-situ mass of refuse. Laner et al. (2011) reported a range of 0.003 to 0.09 percent of chloride in the dry mass of waste. Fellner et al. (2009) reported that chloride in the dry mass of waste is 0.05 percent.

As noted above, based on the nature of waste normally found in C&D, land clearing, and contaminated soil landfills, the chloride concentration in waste is generally less than in municipal solid waste landfills. An investigation at another landfill included advancement of three boreholes into waste to characterize the chloride contribution. Chloride was found to be 0.064 percent, 0.042 percent, and 0.014 percent of the total waste in the three boreholes (Genivar, 2012a). The average measured chloride in the waste is 0.04 percent. This parameter is of paramount importance since it determines the mass of chloride present in the landfill, which has to be carried out by the infiltration water.

Target Concentration

The target concentration is defined by the CSR standards required to achieve compliance in the groundwater. The Drinking Water standard is 250 mg/L. For the purpose of the CLS assessment, a resulting concentration above this threshold would be defined as an "unacceptable impact" at the Site boundary.

12.2.3 Results

The CLS for chloride was evaluated using the Rowe Model to confirm the result of the First Order Decay Method for estimated CLS. The estimated CLS, in years, for each scenario modelled is presented in the table below. The supporting calculations are provided in Appendix G.

Scenario	Years to Meet CSR DW Criteria
Maximum chloride concentration, average proportion of chloride in waste	26
Maximum chloride concentration, maximum proportion of chloride in waste	27

12.3 Summary

The CLS of the Landfill was estimated using the First Order Decay Method to determine the time period required after the closure of the Landfill for the concentration of select leachate constituents to reach the compliance criteria. The governing leachate constituent was determined to be chloride as it had the longest CLS of the modelled parameters. The First Order Decay Method determined that the time period for chloride to decrease to meet the CSR DW standards was 28 years. The Rowe Model was used to verify the CLS of chloride from the Landfill. The result of the Rowe Model was a CLS of 26 to 27 years, which confirms the results of the First Order Decay Method. Based on these results, the CLS of the Landfill is estimated to be 28 years. For the purpose of calculating Financial Security, the CLS will be set to 30 years, the minimum post-closure period according to Section 8.3 of the Landfill Criteria.

13. Groundwater and Surface Water Impact Assessment

In order to estimate potential impacts to groundwater quality at the downgradient Site boundary, a generalized water balance and mass balance approach has been used. The following sections provide discussion of the calculations and assumptions used to assess future groundwater quality compliance at the Site as well as the predicted groundwater quality under ‘worst-case’ conditions.

13.1 Water Balance

A generalized water balance has been developed for the Site to quantify and characterize the basic hydrogeologic functioning in the vicinity of the Landfill. The water balance considers the primary inputs, and movement of water within and across the Site using both empirically derived data and theoretical calculations where data is unavailable (e.g., leachate leakage from the Landfill). These inputs are then used in combination with forecasted contaminant mass inputs to derive the predicted future groundwater concentrations at the downgradient Site boundary.

The inputs to the water balance are as follows:

- Groundwater flow into the Landfill area, below the liner, from upgradient sources
- Precipitation over the Landfill area that results in:
  - Leachate generation, which, in turn, results in:
    - Leakage into the underlying aquifer
    - Leachate that is collected for treatment

- Runoff infiltrating into overburden soils
- Infiltration of the treated leachate effluent
- Infiltration of precipitation falling downgradient of the Landfill footprint and effluent infiltration pond

As discussed in Section 2.4, precipitation in the winter months is anticipated to increase by 5.2 percent due to climate change. However, for the impact assessment it is more conservative to not include this potential increase in precipitation as this will have a negligible effect on the rate of leakage through the liner system but will increase the rate of dilution downstream of the Landfill due to increased infiltration.

13.1.1 Groundwater Flow beneath the Landfill

Groundwater flow beneath the Landfill footprint was estimated using aquifer properties as measured using the on-Site monitoring well network. The locations of the monitoring well network is discussed in Section 14.

Seasonal changes in precipitation are anticipated to be reflected in changing groundwater elevations. It is expected that, in general, groundwater elevations will rise and fall uniformly across the Site with the seasons so that, while the saturated thickness may change, the average hydraulic gradient across the Site should remain generally consistent.

The groundwater flow direction and gradient were calculated using groundwater monitoring data previously collected during the months of January, March, April, September, October, and November between 2015 and 2017. Hydraulic gradients for these periods range from 0.026 to 0.031 m/m with an average of 0.028 m/m. Groundwater elevations at MW3-14 have varied from 155.30 to 157.25 mAMSL over the same time period which corresponds to a range of saturated thickness of 4.45 to 6.42 m in the sand and gravel aquifer (November 27, 2017 and January 25, 2016).

Groundwater flow beneath the Landfill is directed to the southeast. To determine the cross-sectional area through which groundwater flow occurs beneath the Landfill perpendicular to the direction of groundwater flow, the northeast to southwest diagonal of the Landfill footprint, approximately 250 m in length, is multiplied by the saturated thickness of the sand and gravel aquifer beneath the Landfill.

The hydraulic conductivity value for the shallow aquifer is conservatively estimated at 2×10^{-2} cm/sec based on single well response testing carried out in 2015 and confirmed by pumping tests carried out in 2018.

Using Darcy’s flow equation, an estimate of groundwater flux (or groundwater flow through the cross-section area perpendicular to groundwater flow beneath the Landfill) can be made using the hydraulic conductivity (estimated from single well response testing), maximum and minimum hydraulic gradient, and saturated thicknesses measured at the Site.

$$\text{Groundwater flux } (Q) = K \times i \times b \times W$$

Where

K = Hydraulic conductivity

i = Horizontal hydraulic gradient

b = Saturated thickness of the shallow aquifer

W = Diagonal width across Landfill perpendicular to groundwater flow

The range in hydraulic gradients and saturated thicknesses with the rounded hydraulic conductivity results in a flux estimate ranging from approximately 500 to 865 m^3/day with an average value of approximately 640 m^3/day.

13.2 Potential Leachate Leakage

A series of HELP models were developed to evaluate the potential leakage rate through the primary base liner generated under daily, intermediate and final cover for the following scenarios:

- Scenario 1 – Base case with good quality primary liner installation
- Scenario 2 – Partial degradation of the primary HDPE geomembrane equivalent to a poor installation quality (2 pinholes and 12 installation defects per hectare)
- Scenario 3 – Total degradation of the primary HDPE geomembrane (no geomembrane)
- Scenario 4 – Total degradation of the primary HDPE geomembrane (no geomembrane) with an underlying secondary liner system

Table 12.1 in-text below summarizes modeled leakage rates. The HELP model outputs for liner leakage scenarios are provided in Appendix H.

Table 13.1 Modelled Leakage Rates

Scenario	Landfill Leakage Rate (mm)		
	Daily Cover	Intermediate	Final Cover
1 - Base Case with Good Quality Installation	0.0058	0.0053	0.0001
2 - Base Case with Poor Quality Installation	0.0367	0.0341	0.0005
3 - Complete failure of Geomembrane	8.2910	7.7746	0.9662
4 - Complete failure of Geomembrane with underlying Secondary Liner System	0.0018	0.0016	0.0002

As can be seen from the modeling results the deployment of intermediate cover reduces the leakage rates while deployment final cover reduces the leakage rate to nearly zero in all cases except for Scenario 3. The inclusion of the secondary liner system with no primary geomembrane shows a further decrease in the overall leakage rate. The leakage rate modeling illustrates the inclusion of a secondary liner system is effective in eliminating leakage to the underlying aquifer in the event of a complete failure of the primary liner system.

Table 12.2 below provides the daily leakage rates for the Landfill for each of the scenarios during the period of highest leachate generation (Stage 2A of Landfill development). Although highly unlikely, the complete failure of geomembrane (Scenario 3) was modeled as a worst-case scenario by removing the geomembrane and modeling the performance of the primary liner system with only the GCL. Holding all other model inputs constant, it is determined that the maximum leachate leakage rate through the primary liner system would increase to approximately 480 L/day from the base case of 0.32 L/day. Scenario 3 was used to determine the appropriate trigger levels for the Trigger Level Assessment Program (TLAP) described in Section 16.

Under a primary geomembrane failure scenario leachate would enter the Landfill's leak detection system drainage layer. The leakage rate through the secondary liner system below the leak detection system drainage layer is modeled by Scenario 4 to be 0.037 m^3/year or 0.10 L/day. This leakage rate is carried forward in the groundwater quality compliance assessment.

Table 13.2 Leachate leakage through Landfill – Stage 2A

Scenario	Landfill Leakage Rate (m^3/yr)			
	Daily Cover	Intermediate Cover	Final Cover	**Total**
	A = 8,135 m^2	A = 12,639 m^2	A = 9,650 m^2	**A = 30,424 m^2**
1 - Base Case with Good Quality Installation	0.047	0.067	0.001	0.115 (0.315 L/day)
2 - Base Case with Poor Quality Installation	0.568	0.196	0	0.734 (2.012 L/day)
3 - Complete failure of Geomembrane	0.299	0.431	0.005	175.034 (479.547 L/day)
4 - Complete failure of Geomembrane with Secondary Liner System	0.027	0.009	0	0.037 (0.101 L/day)

13.2.1 Infiltration from Treated Effluent

It can be assumed that all leachate generated and collected is ultimately treated and infiltrated into the shallow aquifer. Based on the anticipated maximum leachate generation rate occurring during Stage 2A, the maximum annual average daily leachate collection and treatment rate is 67 m^3/day.

13.2.2 Downgradient Precipitation

Precipitation that falls downgradient of the Landfill footprint and infiltration pond will provide an additional source of un-impacted water entering the saturated shallow, sand and gravel, overburden aquifer. The downgradient area between the Landfill footprint and the southern Site boundary is approximately 78,400 m^2.

Using the precipitation data from the Campbell River Airport Station (summarized in Table 2.1) precipitation near the Site falls annually at an average rate of 1,489 mm annually. Periods of lower or higher precipitation result in changing volumes of infiltration downgradient of the Site, and changes in volumes of runoff and lateral drainage from the Landfill surface. Low precipitation will result in a lower volume of non-impacted water available to dilute potential Landfill-derived impacts downgradient of the Landfill. Periods of high precipitation will have the opposite effect. November is typically the wettest month with approximately 232 mm of precipitation over the course of the month (on average - 7.5 mm/day), and conversely, July is the driest month with approximately 39 mm of precipitation throughout the month (average - 1.3 mm/day).

A HELP model simulating the downgradient portion of the Site was created to estimate the percentage of precipitation that will infiltrate into the subsurface. The outputs of the HELP model are presented in Appendix I.

The results of the HELP model show that of the 1,489 mm of precipitation annually, approximately 24 mm will run-off, 370 mm will be removed from the water balance through evapotranspiration, 24 mm will be stored in in the soil, and the remaining 1,068 mm, or 71.9%, will infiltrate directly into the shallow overburden. Thus, an average of 229 m^3/day will infiltration into the subsurface.

To demonstrate the influence of seasonality on downgradient groundwater quality, the groundwater compliance model also includes scenarios based on precipitation values from the dry (July) and wet (November) periods. This results in infiltration of runoff from the Landfill surface and lateral drainage ranging from 1.0 to 6.6 m^3/day for the dry and wet seasons, respectively, and downgradient infiltration rates of 69 and 432 m^3/day for the dry and wet seasons, respectively. Based on the leachate generation HELP model discussed in Section 9, the annual average daily runoff from the Landfill during Stage 2A is approximately 4.9 m^3/day.

13.3 Contaminant Mass Balance

To predict future groundwater contaminant concentrations, a generalized mass balance approach has been used to estimate the contaminant inputs across the Site. Combining the water balance components calculated above with pre-landfilling groundwater quality, forecasted leachate characteristics, and treated leachate effluent characteristics, the total mass of key landfill contaminants can be estimated.

The water quality for each component of the contaminant mass balance equation was determined as follows:

- Pre-landfilling groundwater quality was determined using the average concentrations from groundwater samples collected from each of the sand and gravel overburden monitoring wells during September and October 2015.
- Leachate quality was determined using the forecasted leachate profile discussed in Section 9.
- As treated effluent must meet CSR DW standards prior to discharge into the infiltration pond, the treated effluent concentrations were conservatively assumed to be equal to the upper limit of the CSR DW standards or the maximum concentration found in the leachate (if below CSR DW standard).

The Interstate Technology and Regulatory Council provides guidance for using mass discharge to evaluate contaminant mass balance (ITRC, 2010), and the contaminant mass balance approach presented below follows this guidance.

Multiplying the average concentrations by the existing groundwater flux provides a mass of each parameter. For example:

$$M_d^{UP} = \bar{C} \times Q \times \frac{1{,}000\ L}{m^3}$$

Where:

M_d^{UP} = Chloride mass discharge from upgradient locations (mg/day)

$\bar{C}$ = Average 2015 measured contaminant concentration (mg/L)

Similarly, the mass discharges resulting from surface water runoff from the Landfill footprint (i.e., M_d^{R-O}) precipitation infiltration downgradient of the Landfill footprint (i.e., M_d^{DG-I}) are calculated as follows:

$$M_d^{R-O} = \bar{C} \times Q_{R-O} \times \frac{1{,}000\ \text{L}}{\text{m}^3}$$

and

$$M_d^{DG-I} = \bar{C} \times Q_{DG-I} \times \frac{1{,}000\ \text{L}}{\text{m}^3}$$

Where:

M_d^{R-O} = Chloride mass discharge from Landfill run-off (mg/day)

M_d^{DG-I} = Chloride mass discharge from downgradient precipitation infiltration (mg/day)

Q_{R-O} = Total run-off vertical flow rate from Landfill footprint (m^3/day)

Q_{DG-I} = Infiltration vertical flow rate over downgradient locations (m^3/day)

13.4 Groundwater Compliance Assessment

Adding the mass discharge from each of the groundwater flow inputs (existing groundwater, surface water runoff, leachate, treated leachate effluent, and downgradient precipitation) and dividing by the total volume (i.e., the sum of each input in the water balance) provides an estimate of the final concentration of each parameter. For example:

$$C_{PRED} = \frac{M_d^{UP} + M_d^{R-O} + M_d^{DG-I} + M_d^{LL} + M_d^{EFF}}{Q + Q_{R-O} + Q_{DG-I} + Q_{LL} + Q_{EFF}} \times \frac{1\ \text{m}^3}{1{,}000\ \text{L}}$$

Where:

C_{PRED} = Predicted contaminant concentration in groundwater at the downgradient property boundary (mg/L)

M_d^{LL} = Contaminant mass discharge from leachate[5] (mg/day)

M_d^{EFF} = Contaminant mass discharge from treated leachate effluent[6] (mg/day)

Q_{LL} = Landfill leachate vertical flow rate (m^3/day)

Q_{EFF} = Landfill leachate treated effluent vertical flow rate (m^3/day)

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[5] The mass discharge from landfill leachate was estimated based on the forecasted leachate concentrations and the leachate vertical flux rate.

[6] The mass discharge from treated leachate effluent was estimated based on the forecasted leachate effluent quality and the effluent vertical flux rate.

The four scenarios have been developed to provide a range in the forecasted groundwater quality to account for variability in the inputs to the model as well as uncertainty in the model. The four scenarios are described below:

1. Primary HDPE Liner Failure – represents the failure of the primary HDPE geomembrane liner, while the secondary liner system remains intact (see Scenario 4 in Table 12.3). The input parameters minimize dilution while maximizing mass loading from the Landfill and treated effluent infiltration to provide a scenario of the largest anticipated contaminant mass loading to the sand and gravel aquifer and represents maximum groundwater quality degradation while including the leak detection system.
2. Base Case – represents the downgradient groundwater quality based on operating the Landfill under average conditions with a primary liner system only (Scenario 1 in Table 12.3). The input parameters include average upgradient groundwater flux and average downgradient infiltration.
3. Dry Season – represents the dry season or periods when precipitation is lower than average. The input parameters include minimum upgradient groundwater flux and low downgradient infiltration.
4. Wet Season - represents the wet season or periods when precipitation is higher than average. The input parameters include maximum upgradient groundwater flux and high downgradient infiltration.

The input parameters for each scenario are summarized in Table 12.3 below.

Table 13.3 Groundwater Compliance Assessment Modelling Scenarios

Scenario	Contaminant Loading from Leachate	Flux into Landfill Footprint Area	Landfill Leakage	Treated Leachate Infiltration	Infiltration of Runoff from Landfill Cap	Infiltration Downgradient of Landfill
		m^3/day				
1 – Primary HDPE Liner Failure	Maximum	500	0.00010	67	1.0	73
2 – Base Case	Average	640	0.00032	67	4.8	225
3 – Dry Season	Average	500	0.00032	67	1.0	73
4 – Wet Season	Average	860	0.00032	67	6.6	430

Table 13.1 A through D (following the text) provides the forecasted contaminant concentrations at the downgradient Site boundary for each of the scenarios described above.

The predicted groundwater quality at the downgradient Site boundary demonstrates some minor variability in response to changes in model inputs related to seasonal conditions or liner system design and performance. Notwithstanding the variability, the predicted groundwater quality at the downgradient Site boundary meets all applicable CSR DW standards under all scenarios modeled.

13.5 Confirmatory Comparison

The groundwater compliance assessment was also used to confirm that groundwater containing parameters with concentrations above the CSR Schedule 3.1 Fresh Water Aquatic Life (AW) will not migrate beyond 500 m from the property boundary.

As shown in Table 13.1 the predicted concentrations of each of the parameters is below the CSR Schedule AW standard for all scenarios modelled.

14. Environmental Monitoring Program

The EMP for the Site has been developed to monitor the performance of the Landfill design within its environmental setting. The EMP will ensure performance and compliance criteria are met throughout the lifespan of the Landfill through to post-closure. The EMP has been developed in accordance with the following documents:

- Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills
- Landfill Criteria

The EMP includes leachate, groundwater, surface water, soil gas, geotechnical, and refuse/soil volume monitoring. The EMP includes a quality assurance/quality control (QA/QC) plan to ensure representative data is collected. The EMP must be reviewed annually and may be modified in the future if warranted based on findings during routine inspections, monitoring events and any other information related to the effect of discharge on the receiving environment.

14.1 Compliance Criteria

The compliance criteria for the water quality comparison for the on-site groundwater was determined in the HHCR. The compliance criteria are the CSR Schedule 3.1 DW standards. These standards will form the basis of the EMP.

14.2 Leachate Monitoring

The objective of the leachate monitoring program is to provide the following data:

- Leachate Quality to confirm leachate indicator parameters, leachate treatment requirements and efficiencies, and assess the potential impacts to the receiving environment.
- Leachate quantity – to assess the suitability of leachate treatment system components.
- Leachate level in the Landfill – to ensure a maximum depth of 0.3 m on the base liner within the Landfill to ensure geotechnical stability and minimize pore pressure over the base liner system.

Leachate monitoring will be conducted at the leachate sump located at the north end of the Landfill, and from the leachate treatment pond. Leachate samples will be collected and analyzed quarterly. The leachate will be analyzed for field parameters, general chemistry, nutrients, LEPH/HEPH, and

CSR metals. Once annually, the samples collected may be analyzed for a comprehensive set of parameters to determine if additional parameters should be included in the EMP.

The samples collected from the leachate treatment pond will be used to assess the leachate treatment system performance and determine if changes to the treatment process are required.

The leachate monitoring as part of the EMP is in addition to the requirements of the LMP, discussed in Section 9, to assess the treatment effectiveness prior to discharge of treated leachate to the infiltration pond.

14.3 Groundwater

The objective of the groundwater monitoring program is to detect at the earliest opportunity the potential for impacts to groundwater associated with landfilling activities. The groundwater monitoring will provide information regarding the extent and magnitude of potential impacts, identify the need to mitigate potential environmental risk, and ensure regulatory compliance.

The groundwater monitoring program also includes the assessment of upgradient groundwater quality for comparison to the down-gradient and cross-gradient groundwater quality.

Groundwater samples will be collected and analyzed quarterly. The groundwater samples will be analyzed for field parameters, general chemistry, nutrients, LEPH/HEPH, and CSR metals. The monitoring locations are shown on Figure 14.1. The existing monitoring wells that will be included in the EMP are shown in yellow. The well completion details are presented in Table 14.1. The proposed monitoring wells to be installed at the Site that will be included in the EMP are shown in magenta. The groundwater monitoring program will include the following monitoring wells:

- Up-gradient – MW6-17, MW9-17, MW1-14, MW4A-15, MW4B-15
- Cross-gradient – MW2-14, MW2A-16
- Immediate Downgradient – MW13-17 (proposed)
- Downgradient Compliance wells: MW-10-17, MW11-17 (proposed), MW12-17 (proposed)

The existing upgradient monitoring wells, MW7-17 and MW8-17, were installed to characterize the groundwater regime in the vicinity of the Site and are not included in the EMP. MW3-14 may be included as supplemental information in the EMP early in the Landfill lifespan, however, the monitoring well will be decommissioned to allow for the construction of the Landfill cells during Phase 2 of the Landfill development. The existing monitoring wells MW5A-15 and MW5B-15 are not included in the EMP as they are hydraulically upgradient and disconnected from the overburden, sand and gravel aquifer.

Hydraulic monitoring of groundwater levels will be conducted at each groundwater monitoring event and the data included in the Annual Operation and Monitoring Report discussed in Section 14.10. Pre-landfilling water levels were measured during the baseline monitoring events in September 2015, October 2015, January 2016, February 2016, and April 2017. The hydraulic monitoring results are presented in Table 14.2.

14.4 Surface Water

The objective of the surface water monitoring program is to continue to obtain supplementary information from nearby lakes to characterize background water quality. The two lakes, McIvor Lake and Rico Lake, will be included in the EMP for this purpose. Surface water samples from the Lakes will be collected annually.

There are no permanent surface water features on the Site or downgradient of the Site to include as part of the surface water compliance monitoring.

The location of the lakes and the monitoring locations are shown on Figure 14.1.

The water level in the lakes will be recorded as part of the EMP and the data included in the Annual Operations and Monitoring Report discussed in Section 14.10. The Rico lake level will be recorded using the existing Rico Lake gauge, as shown on Figure 14.1. The McIvor Lake level will be obtained from the BC Hydro reservoir level records.

Additional surface water sampling may be conducted within the surface water ditches on the east and west side of the Landfill when water is present.

14.5 Quality Assurance/Quality Control

In order to ensure adequate quality control for water quality samples, the following quality assurance/quality control (QA/QC) measures will be used as a minimum:

- Activities performed by qualified and trained personnel
- Field QA/QC including field duplicate and field blank analysis
- Use of charge balance calculations
- Analytical testing by an accredited laboratory

14.6 LFG Monitoring

LFG monitoring will be undertaken to protect the health and safety of the Northwin/Upland staff, users of the Site and the public. The LFG monitoring will be conducted annually using subsurface soil vapour probes, consistent with the BC Landfill Gas Management Facilities Design Guidelines, Section 6 of the Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills, and Sections 4.2 and 9.3 of the Landfill Criteria. The soil gas concentration limits are discussed in Section 10.8.

The proposed locations of the soil vapour probes are shown on Figure 14.1 and will include one location near the Site office, and one location at the northern property boundary along Gold River Highway.

14.7 Geotechnical

The geotechnical condition of the landfill will be monitored as part of the EMP. Monitoring staff will record the condition of the Landfill including observations of evidence of the following conditions:

- Distress (i.e., berms, cover, vegetation, ditches, etc.)
- Slope stability

- Settlement
- Potential for leachate breakout/pore pressure building up
- Erosion on side slopes, ditches, or sediment forebays (once constructed during progressive final closure)

All notable observations will be reported to Landfill Staff and included in the Annual Operations and Monitoring Report discussed in Section 14.10. If appropriate, a qualified professional will be engaged to complete a supplemental Site inspection.

14.8 Refuse/Soil Volume Monitoring

A topographic survey of the active Landfill area will be conducted on a regular basis (i.e., every 1 to 2 years) during Landfill operations. The survey data will be used to calculate the volume of airspace consumed, an estimate of the apparent waste density obtained, and the remaining airspace available. From this data, predictions of remaining Site life will be updated and included in the Annual Operations and Monitoring Report discussed in Section 14.10.

14.9 Inspection and Record Keeping

Regular Landfill inspections will be conducted by Landfill personnel and include inspections of the following:

- Nuisance factors associated with the Landfill
- Regular housekeeping procedures such as dust, litter, and odour
- Locations of distress (i.e., berms, cover, vegetation, ditches, etc.)

The Landfill staff will maintain a checklist of housekeeping items that need to be implemented on a regular basis. Records of observations made during the Landfill inspections and all regular housekeeping activities carried out will also be maintained.

14.10 Annual Operations and Monitoring Report

An annual operations and monitoring report will be submitted to the Director by March 31 of each year. The annual report will include the following information as per Section 3.2 of the OC:

- An executive summary
- Tonnage and disposition of each type of waste received at the facility for the year including tonnage received, stored on-Site, and discharged to the Landfill
- Remaining selected waste Landfill life and capacity
- Recommendations to improve operational efficiencies, if applicable
- Leachate management monitoring results including leachate quantities and qualities
- Landfill gas monitoring results
- Review of the preceding year of operation, plans for the next year and a summary of any new information or changes to the facilities and plans, programs, assessments, surveys and reports

- In the event of any non-compliance with the conditions of the operational certificate, an action plan and schedule to achieve compliance
- Updated groundwater contours and discussion of seasonal fluctuations
- Comparison of the monitoring data with the performance criteria in Section 4 of the Updated Landfill and the Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills, interpretation of the monitoring data, identification and interpretation of irregularities and trends, recommendations, and any proposed changes to the monitoring program

The annual reports will be made available to the City of Campbell River staff and the Regional Districts Waste Management Board.

15. Fire Safety and Emergency Response Plan

15.1 Overview

The introduction of ambient air (i.e., oxygen) into a landfill can potentially lead to landfill fires. The prevention and control of landfill fires is an important operational consideration. While the occurrence of landfill fires is still relatively infrequent, it is critical to understand landfill fires, their prevention, and control.

Effective fire management can be achieved by understanding the causes of landfill fires as part of a preventative strategy and by understanding the means of addressing a landfill fire if one occurs.

15.2 Background

A landfill fire will only occur if the following conditions are present:

- A fuel is provided (e.g., waste and/or the methane component of LFG is a combustible fuel source)
- Oxygen is present (oxygen can be present in the voids of uncompacted waste)
- An ignition source is provided

Fires can occur for a variety of different reasons or combinations of conditions including:

- Introduction of an ignition source to the landfill
- Deposition of hot loads in the landfill
- Chemical reactions occurring within the landfill

Landfill fires can be surficial, subterranean, or both, depending on the transmission and migration pathways within the waste matrix. Surficial fires typically occur along the working surface of the landfill and are easily observable.

Subterranean fires occur under the cover of the landfill and may not be visually observable by site personnel. Subterranean fires typically start out small and in a localized area, spreading beneath the landfill cover as conditions permit. Landfill operations can also affect the spread of landfill fires, with landfill fires following preferential flow paths along waste lift lines or in areas of low waste densities (i.e., upper levels of waste, new and uncompacted waste), where the mixture of oxygen and methane is optimal as a fuel.

Signs that a subterranean fire may be occurring or has occurred include:

- High oxygen and carbon monoxide (1,000 ppm) concentrations
- High LFG temperatures (> 60 degrees Celsius indicates aerobic conditions; > 75 degrees Celsius indicates that combustion is likely occurring at some location within the waste)
- Accelerated landfill settlement in localized areas
- Impacted infrastructure (e.g., melted piping)
- Smoke, odour, or residue

A landfill fire can be confirmed through monitoring for incomplete combustion compounds (e.g., carbon monoxide) using field-monitoring equipment or for more accurate results, laboratory analysis. Field samples collected from installed LFG probes for laboratory analysis should be collected in tedlar bags or in evacuated canisters.

15.3 Implications of Landfill Fires

Implications of a landfill fire include:

- Risks to health and safety which include release of toxic gases, site hazards, sink holes on the landfill surface, and equipment interaction
- Impacts to the surrounding environment including surface water impacts, leachate generation, and air emissions
- Damage to site infrastructure including landfill liner damage and leachate collection system impacts
- Potential damage to equipment

Landfill fires pose a health and safety risk to humans due to the unsafe conditions that the fires create. The burning waste can emit toxic gases. Sink-holes and waste settlement may occur as a result of waste combustion, posing additional hazards to site personnel and equipment.

Landfill fires also pose a great risk to environmental conditions of the landfill and the surrounding area. As previously stated, fires can generate toxic air emissions; uncontrolled combustion of halogenated compounds often results in emission of dioxins and furans.

15.4 Fire Prevention

There are several obvious means of preventing fires at landfills, including rules and plans that prevent smoking, welding, or equipment repair on or near the Landfill. If work is absolutely necessary within the Landfill, permit requirements should be developed for performing hot work in areas of potential LFG generation.

Recognition of changing Site conditions will provide site personnel with the necessary information and time to take preventative measures. Conditions that may be observed prior to a subterranean fire include problems at the surface of the Landfill that may be indicative of high oxygen infiltration potential (e.g., poor final cover quality, final cover erosion, vegetative stress). Particular note should be made of any protrusions through the interim and/or final cover system such as vertical extraction wells, gas vents, monitoring points, etc., as these are potentially weak points in a final cover system.

The above conditions should be closely monitored, and a fire control strategy implemented, if it is determined that a landfill fire is occurring. The following Landfill operations can be instrumental in preventing and controlling landfill fires:

- Placement of intermediate cover material
- Adequate stockpile of soil material for intermediate cover and fire control
- Availability and maintenance of appropriate equipment for fire control

It is recommended that all intermediate cover material be removed subsequent to additional waste placement to aid in maintaining the interconnectivity of waste lifts for the improved LFG collection efficiencies. Leaving intermediate cover material in place as a permanent fire control measure (i.e., fire breaks) is an incorrect approach and is not recommended.

15.5 Fire Control and Extinguishment

The methods used to control and terminate a landfill fire are dependent on several site-specific factors including:

- The location of the landfill fire (i.e., active disposal areas, passive LFG venting areas)
- Waste composition (i.e., C&D)

A single solution for managing landfill fires does not exist. Therefore, a multifaceted approach to preventing and controlling landfill fires is necessary. The following approaches need to be considered individually or in combination to most effectively determine if there is a fire and to control and extinguish a landfill fire:

- Supplemental soil cover material to cut off the supply of oxygen to a fire, returning the waste to anaerobic conditions.
- Availability of water to hydrate low permeability soil cover material.
- Fire suppressant foams to assist in sealing the surface where there may be air infiltration to the waste mass.
- Fire breaks and containment berms can be possible augments for very specific applications and locations but should not be considered as primary control mechanisms.
- Injection systems such as steam, carbon dioxide, or nitrogen are possible if they are necessary to cut off air supply to the fire.
- Operational considerations including the use of cover material, stockpiling of soil material on Site, availability of information on historic waste placement, as-recorded drawings, and equipment availability.
- Confirmatory/field investigations including thermographic imaging, intrusive investigations (i.e., boreholes), and thermistors.

An operator needs to be aware of the type of landfill fire (i.e., waste or LFG). If it is a waste fire within the waste mass and not simply at the surface, it may not be possible to physically cut off the source of fuel and/or air. The operator must also be aware of the many different approaches associated with extinguishing landfill fires.

The primary mechanism for extinguishing a landfill fire is its fuel source (i.e., methane). By allowing methane concentrations to increase within the waste matrix, conditions will reach a point whereby the oxygen-methane fuel mixture will be too methane rich for combustion and the fire will no longer be self-sustaining. In short, the subterranean fire will be extinguished through an abundance of methane and a deficiency of oxygen (i.e., creating an environment that cannot support continued combustion). Creating this environment can be enhanced through the use of a low permeability cover material. The low permeability cover material will provide a layer that will minimize the venting of LFG and the intrusion of atmospheric air (i.e., oxygen). The use of low permeability cover material in combination with the application of water will be effective in helping to seal the surface and remove the air infiltration pathway that allows oxygen to feed and support the fire (i.e., to decrease the hydraulic conductivity of low permeability material).

While this type of response may be counter intuitive to typical fire management programs, more common approaches such as excavation of the landfill cover in the vicinity of a suspected fire to expose the source should never be undertaken; it merely serves to introduce additional air, and thus oxygen, into the waste, thereby potentially propagating/feeding the fire. Excavation of suspected fires also puts equipment and equipment operators at risk. The operation of heavy equipment in the vicinity of a landfill fire should be undertaken with care, and only to develop access to the area in question or to spread soil cover material.

15.6 Fire Safety and Emergency Contingency Plan

A Fire Safety and Emergency Contingency Plan has been developed for the Site operating in accordance with the BC Occupational Health and Safety Regulation 296/97 Part 4, S.4.13 - 4.18 (Emergency Preparedness and Response) and Part 5, s.5.97 - 5.102 (Emergency Procedures), as well as Section 2.8 of the BC Fire Code. The Fire Safety and Emergency Contingency Plan has been submitted to the appropriate fire authority(ies), the responding fire department(s), the Director, and the City.

A copy of the draft Fire Safety and Emergency Contingency Plan is provided in Appendix J. This plan will be reviewed and updated at least once annually.

16. Contingency Plan

The Contingency Plan presents site-specific, practical, and implementable contingency measures to address possible failure and/or non-compliance scenarios of the landfill operating systems. The Contingency Plan was developed based on planning that included review of the Landfill base liner performance, modeling of liner leakage rates, development of a trigger level assessment program (TLAP) and identification of practical and implementable contingency measures. This Plan satisfies Section 10.3 of the Landfill Criteria.

A site-specific tiered TLAP has been developed to assess primary liner system leakage rates and groundwater quality at the Site. The TLAP outlines a procedure to investigate and confirm a possible failure or non-compliance condition and to identify appropriate contingency or remedial actions. The two TLAP triggers are:

1. Primary liner leakage rate detected in the leak detection system(s) above the trigger level threshold.
2. Leachate constituent concentration in downgradient water exceeding trigger level concentrations.

The TLAP and the trigger thresholds are discussed in detail within Appendix K of the DOCP.

16.1 Conditions Indicating Possibility of Failure or Non-Compliance

The following are descriptions of possible conditions associated with failure of the landfill operating systems or non-compliance with the landfill performance criteria. If present, these conditions provide indication of a potential issue and would warrant contingency or remedial measures to be put in place.

Primary Liner Non-Performance

- Increasing volume of leachate detected in the leak detection system of either the landfill or the leachate aeration pond.

Groundwater Quality Alterations

- Increasing concentrations of leachate indicator parameters in groundwater adjacent to and/or downgradient of the Landfill or leachate treatment pond.

Surface Water Quality Alterations

- Elevated concentrations of leachate indicator parameters in surface water discharging to the infiltration pond.

Leachate Treatment Facility (LTF) Non-Performance

- Worsening trend observed in leachate effluent quality
- Treated leachate effluent does not meet CSR DW standards
- Volume of leachate exceeds forecasted treatment capacity

Nuisance Impacts

- Nuisance odours are detected in the vicinity of the landfill
- Receipt of nuisance complaint

16.2 Contingency Measures

The table below provides a description of practical and implementable contingency measures to address the potential failure or non-compliance conditions listed in Section 16.1. The contingency measures developed for the Site include the following operational controls:

Table 16.1 Contingency Measures/Actions

Condition	Contingency Measure/ Action
Primary liner non-performance (landfill or aeration pond)	Replace or repair the primary liner system in the leachate treatment pond. If possible, waste may be locally excavated to complete repairs to the primary landfill liner. It is noted, however; that the integrity of each liner system will be tested at the time of construction prior to acceptance and placement of waste.
	Operate the leachate collection system under drained condition to eliminate leachate head on the primary liner system to minimize leakage. Leachate levels in the sump will be kept at a level below the crest of the sump.
	Deploy intermediate or final geomembrane cover over completed/inactive phases of the Landfill in advance of planned schedule to reduce/eliminate generation of leachate.
Groundwater quality alterations	Address infiltration of surface water with elevated leachate constituents by implementing contingency measures associated with surface water quality alterations. (See surface water quality alterations row in this table.)
	Reduce concentration of leachate constituents in infiltration pond influent by increasing level of treatment in LTF.
	Address leachate leakage from landfill or aeration pond by implementing contingency measures associated with primary liner non-performance. Increase deployment of final cover and/or use of low permeable tarps for daily cover.
Surface water quality alterations	Improve surface water containment measures and/or landfill containment berms.
	Remediate any identified leachate seeps.

Condition	Contingency Measure/ Action
LTF Non-performance	Re-circulate aeration pond effluent into the landfill for re-treatment in the LTF.
	Review leachate treatment process modelling and refine leachate treatment process.
	Pre-treat leachate on-site and haul to off-site wastewater treatment facility for further treatment.
Nuisance Impacts	Increase use of daily and intermediate cover.
	Develop and implement an odour monitoring program.
	Install passive landfill gas (LFG) venting and filtration system.

16.3 Contingency Measure Implementation

In the event that one or more conditions are present that warrant contingency or remedial measures/actions, this Plan will serve as a guide to respond appropriately and in a timely manner. Implementing contingency measures involves the following sequence of actions:

- Selection of appropriate measure based on the conditions present on site
- Design of measure
- Submission of design and implementation schedule for regulatory concurrence, if applicable
- Notification to regulators of proposed actions
- Implementation
- Confirmatory monitoring and reporting

17. Financial Security Plan

Financial security is required for all private landfills in accordance with *Section 8.0 - Financial Security* of the Landfill Criteria. The amount of the financial security provided in each year must be adequate to fund the closure of the landfill in that year and fund post-closure operations, monitoring, and maintenance for the estimated contaminated lifespan.

The Financial Security Plan is provided in Appendix L.

18. Closure

All of Which is Respectfully Submitted,

GHD

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