2021 Design, Operations and Closure Plan

Northwin Landfill
Upland Pit Property
Campbell River, British Columbia

Upland Excavating Ltd.

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088877 | Report No 14 | July 8, 2021

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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

[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

[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.

[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%

[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 1×10^{-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.

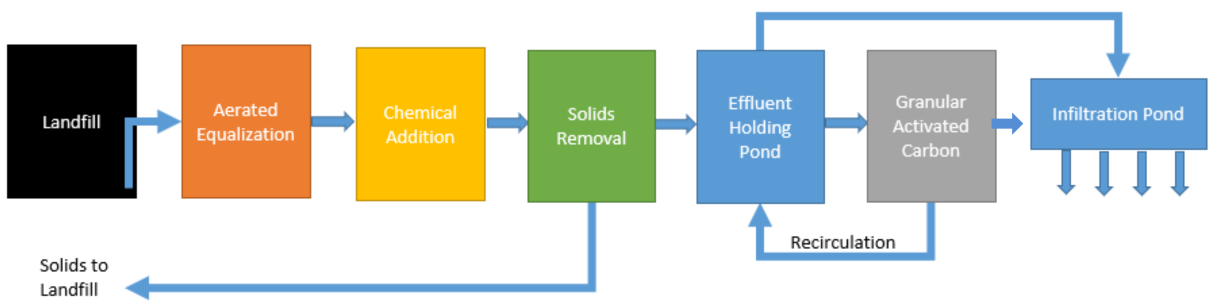

Figure 9.1 Leachate Treatment Process Schematic

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:

QT = total LFG emissions (50 % CH_4 and 50 % CO_2 by volume)

K = LFG generation constant ($year^{-1}$)

Lo = 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:

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

and

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

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)

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

Roxy Hasior, P.Eng.

Deacon Liddy, P.Eng., MBA

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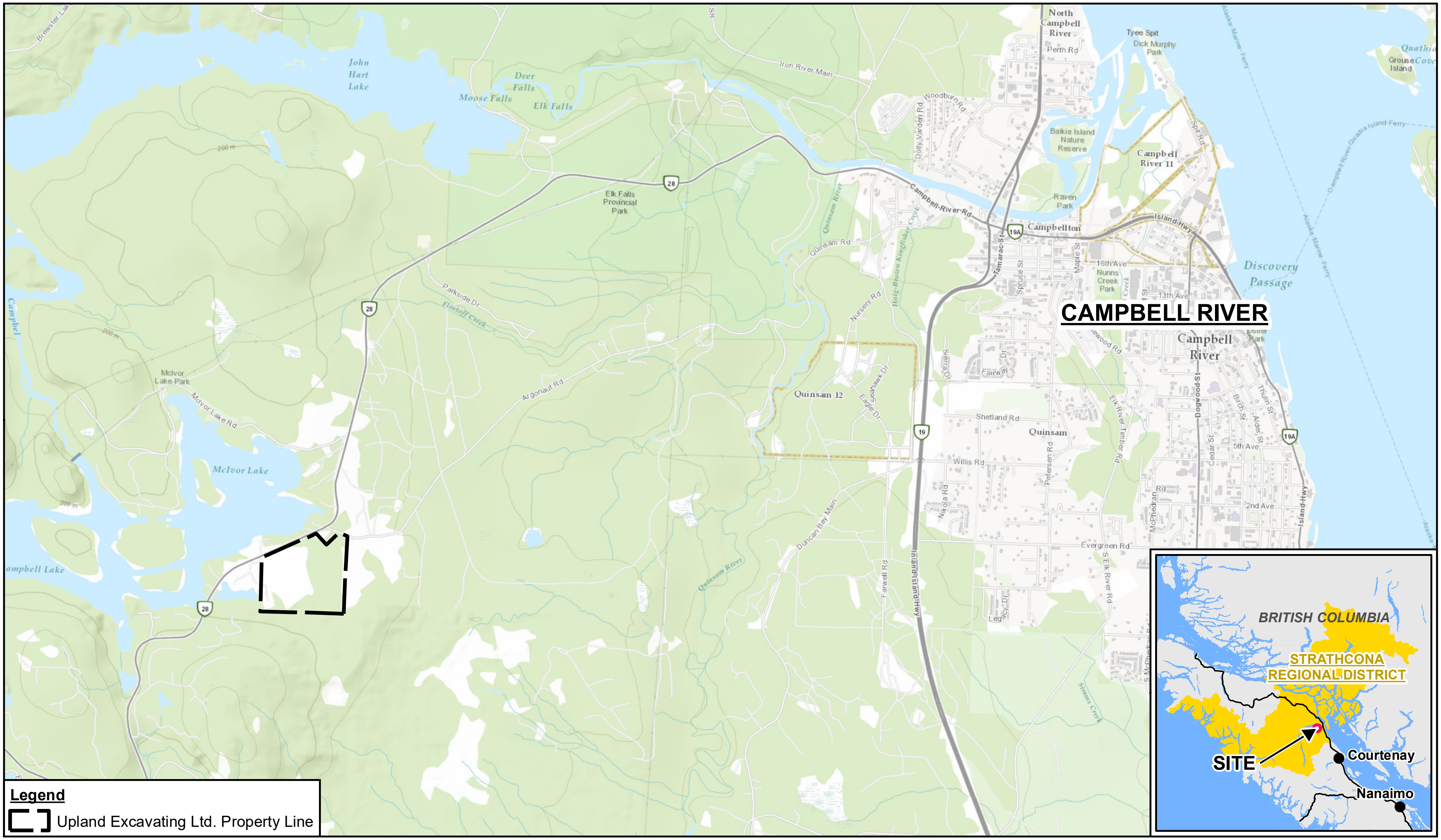
Figures



Source: ESRI Topographic Basemapping, Accessed 2020

0 500 1,000 1,500
Meters

Coordinate System:
NAD 1983 UTM Zone 10N

N

GHD

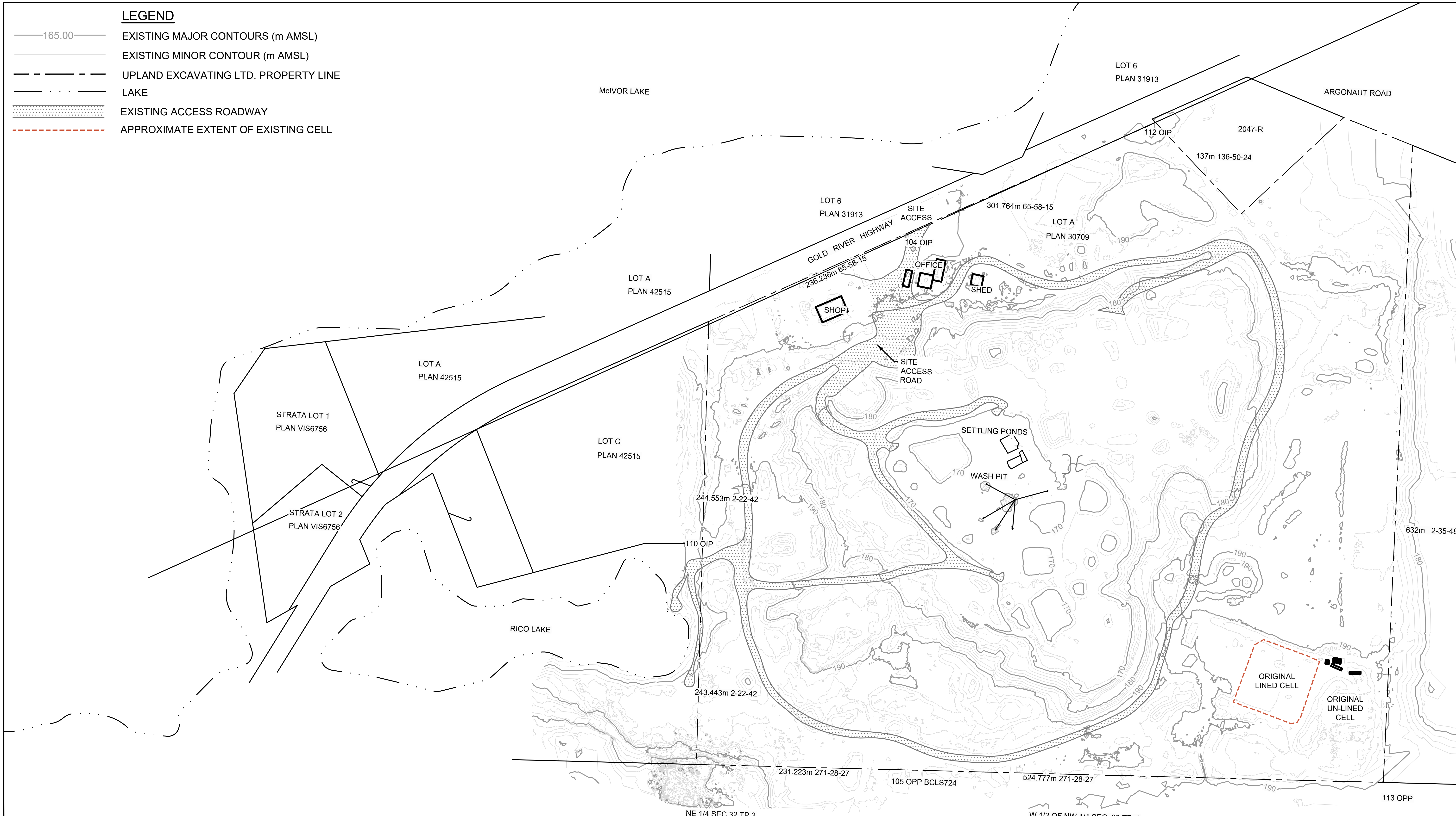
UPLAND EXCAVATING LTD.
2021 DESIGN, OPERATIONS AND CLOSURE PLAN
NORTHWIN LANDFILL, CAMPBELL RIVER, B.C.

SITE LOCATION MAP

088877
Jun 24, 2020

FIGURE 1.1

GIS File: Q:\GIS\PROJECTS\88000s\88877\Layouts\014\088877(014)GIS-OT001.mxd



SOURCE: TOPOGRAPHICAL SURVEY CONDUCTED BY McELHANNEY ASSOCIATES LAND SURVEYING LTD., NOVEMBER 21, 2016.

0 40 80 120m
SCALE = 1:4000

N

GHD

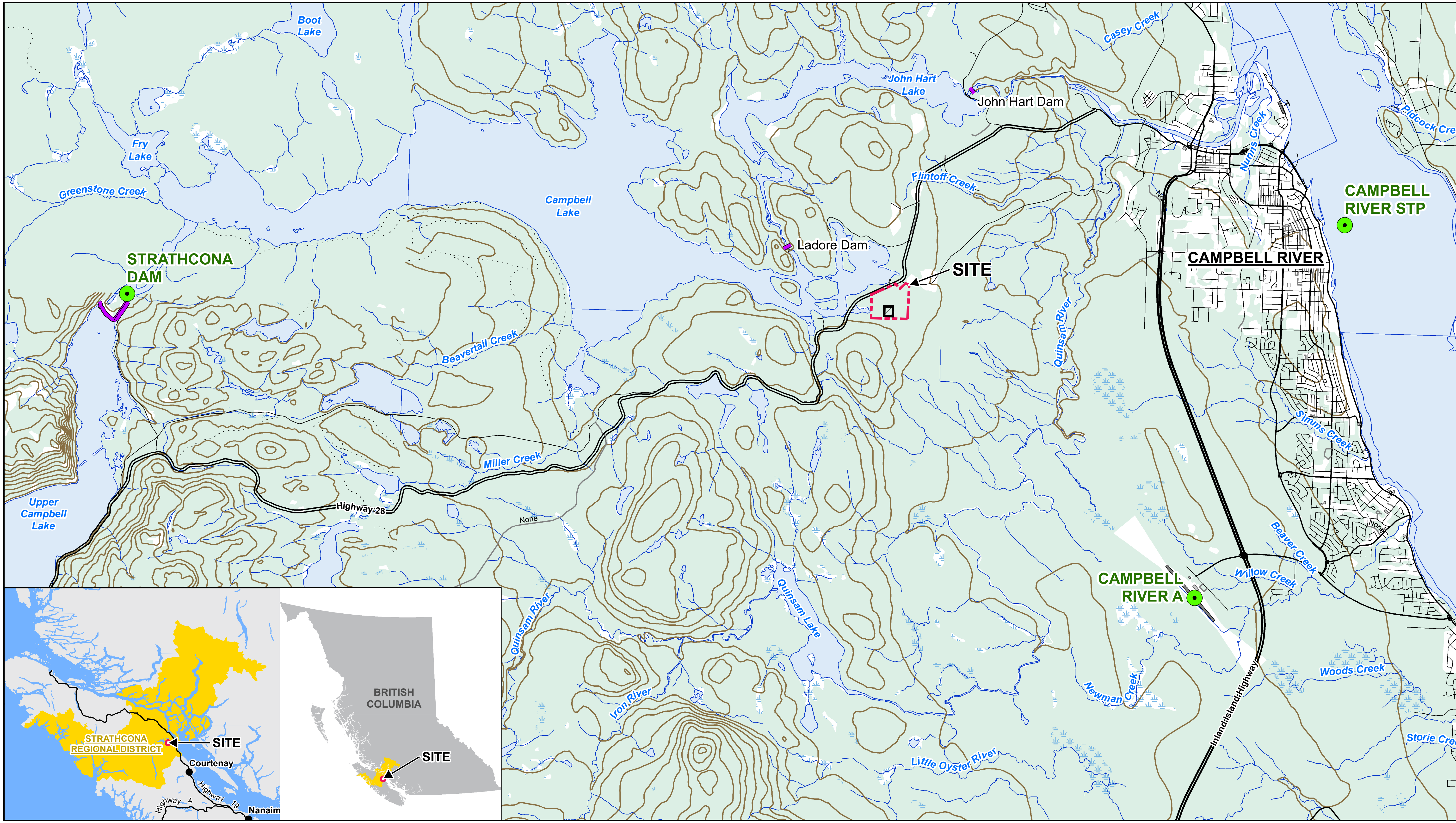
UPLAND EXCAVATING LTD.
2021 DESIGN, OPERATIONS AND CLOSURE PLAN
NEW LANDFILL (NORTHWIN LANDFILL), CAMPBELL RIVER, B.C.

088877-11
Jul 7, 2021

EXISTING SITE PLAN

FIGURE 1.2

CAD File: 88877-11(014)GN-WA001.dwg



Source: CanVec Edition 1.1 © Department of Natural Resources Canada, all rights reserved. National Road Network 2.0 GeoBase. ESRI Base Data, 2008.

0 750 1,500 2,250
Meters

Coordinate System:
NAD 1983 UTM Zone 10N

N

Legend

- IDF Station
- Manmade Hydrographic Entity (Dam)
- Discharge Area
- Upland Excavating Ltd. Property Line

GHD

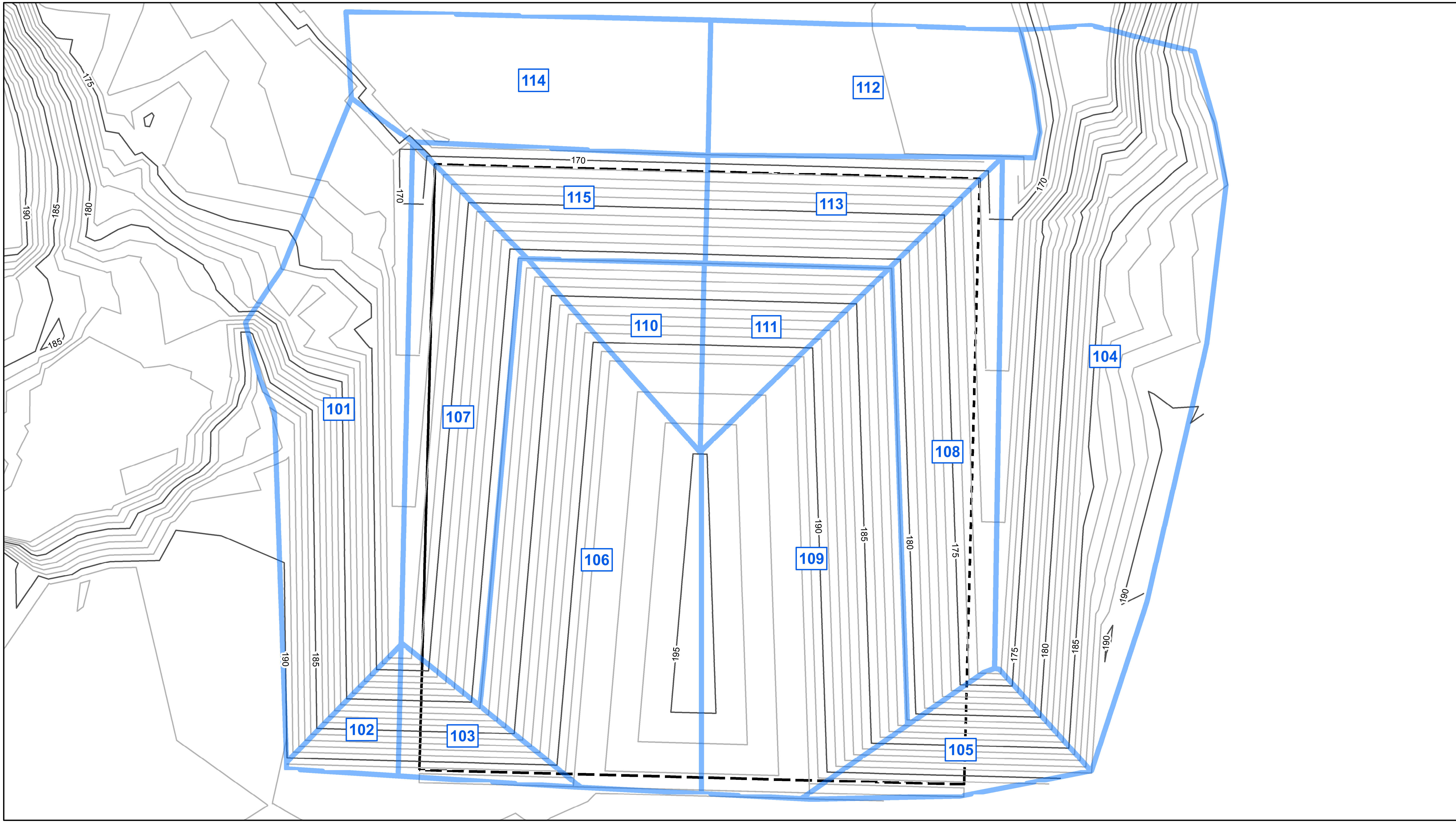
UPLAND EXCAVATING LTD.
2021 DESIGN, OPERATIONS, AND CLOSURE PLAN
NORTHWIN LANDFILL, CAMPBELL RIVER, B.C.

SITE LOCATION & IDF STATION LOCATIONS

088877-03
Jun 28, 2021

FIGURE 8.1

GIS File: Q:\GIS\PROJECTS\88000s\88877\Layouts\010\88877-03(010)GIS-OT005.mxd



Source: CanVec Edition 1.1 © Department of Natural Resources Canada, all rights reserved. National Road Network 2.0 GeoBase. ESRI Base Data, 2008.

0 12 24 36
Meters

Coordinate System:
NAD 1983 UTM Zone 10N

Legend

- Limit of Waste
- Major Contour (5 m)
- Minor Contour (1 m)
- Subcatchment Boundary
- 100 Subcatchment Number

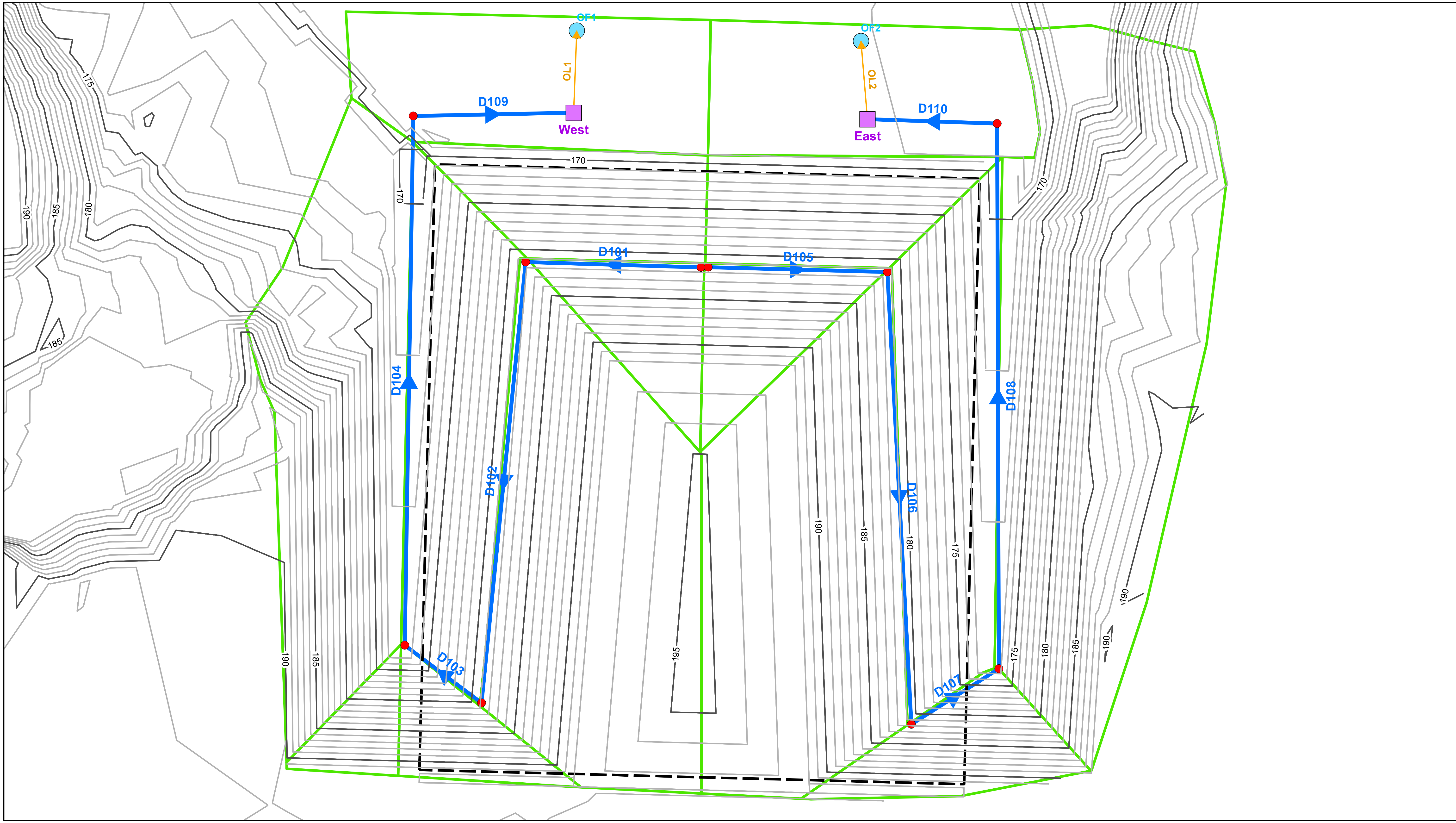
UPLAND EXCAVATING LTD.
2021 DESIGN, OPERATIONS, AND CLOSURE PLAN
NORTHWIN LANDFILL, CAMPBELL RIVER, B.C.

SURFACE WATER CATCHMENT BOUNDARIES

088877-03
June 28, 2021

FIGURE 8.2

GIS File: Q:\GIS\PROJECTS\88000s\88877\Layouts\010\88877-03(010)GIS-OT002.mxd



0 12 24 36
Meters

Coordinate System:
NAD 1983 UTM Zone 10N

N

Legend

- Limit of Waste
- Major Contour (5 m)
- Minor Contour (1 m)
- Conduits
- Outlets
- Sediment Forebay
- Junctions
- Infiltration Area

GHD

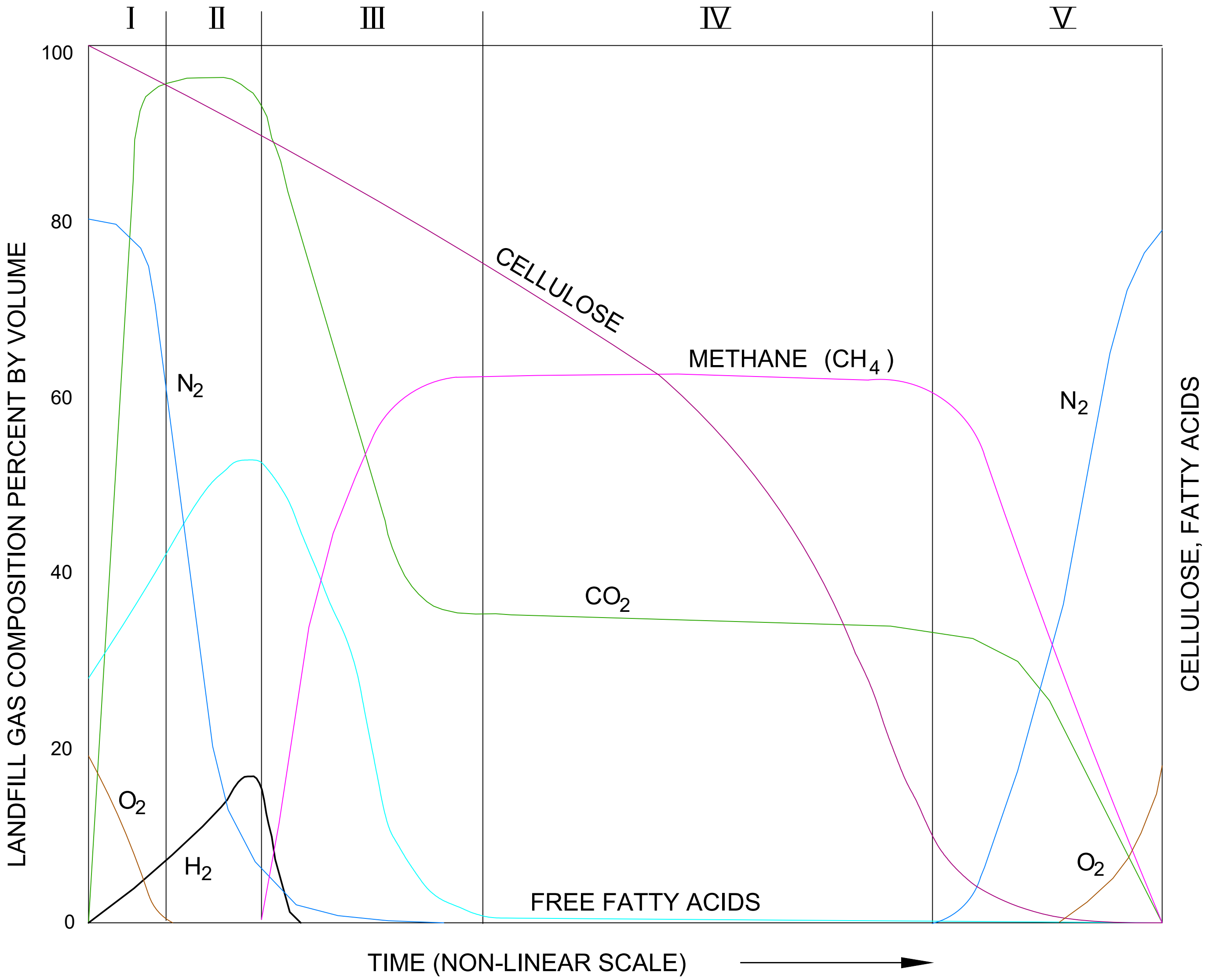
UPLAND EXCAVATING LTD.
2021 DESIGN, OPERATIONS, AND CLOSURE PLAN
NORTHWIN LANDFILL, CAMPBELL RIVER, B.C.

SURFACE WATER FLOW SCHEMATIC

088877-03
June 28, 2021

FIGURE 8.3

GIS File: Q:\GIS\PROJECTS\88000s\88877\Layouts\010\88877-03(010)GIS-OT003.mxd



PHASES	CONDITION	TIME FRAME - TYPICAL
I	AEROBIC	HOURS TO 1 WEEK
II	ANOXIC	1 TO 6 MONTHS
III	ANAEROBIC, METHANOGENIC, UNSTEADY	3 MONTHS TO 3 YEARS
IV	ANAEROBIC, METHANOGENIC, STEADY	8 TO 40 YEARS
V	ANAEROBIC, METHANOGENIC, DECLINING	1 TO 40+ YEARS
TOTAL		10 TO 80+ YEARS

SOURCE:

FARQUHAR AND ROVERS, 1973,
AS MODIFIED BY REES, 1980,
AND AUGENSTEIN & PACEY, 1991.

UPLAND EXCAVATING LTD.
2021 DESIGN, OPERATIONS AND CLOSURE PLAN
NORTHWIN LANDFILL, CAMPBELL RIVER, B.C.

88877
Jun 10, 2020

TYPICAL LANDFILL GAS PRODUCTION STAGES

FIG. 10.1

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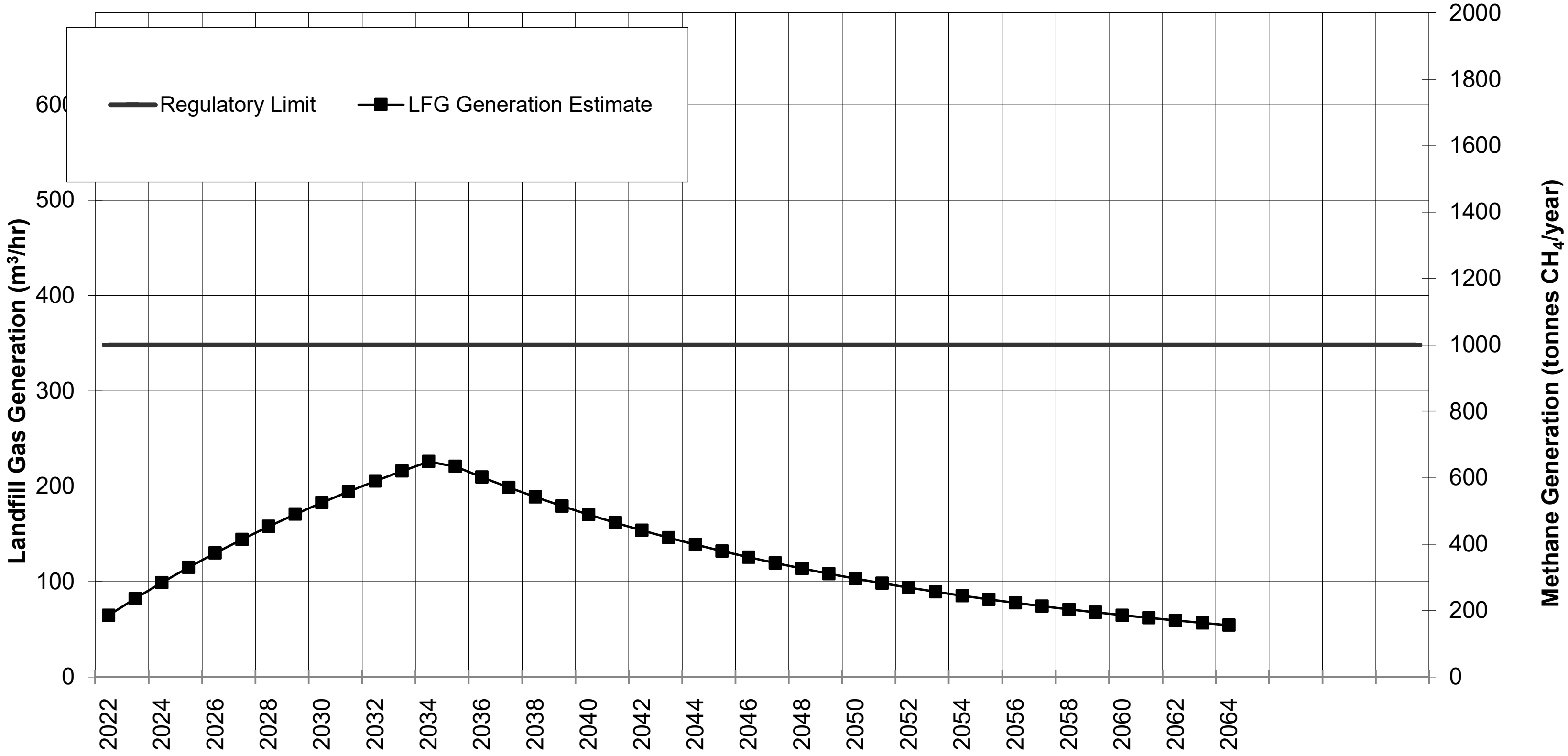


k values ($year^{-1}$)	0.02, 0.06, 0.11	<u>Waste Composition</u>	
L_o (weighted) (m^3 CH4/tonne)	20, 120, 160	Relatively Inert (%)	75.0%
Precipitation (mm/year)	1,489	Moderately Decomposable (%)	25.0%
Volumetric LFG Composition (percent methane)	50%	Decomposable (%)	0.0%

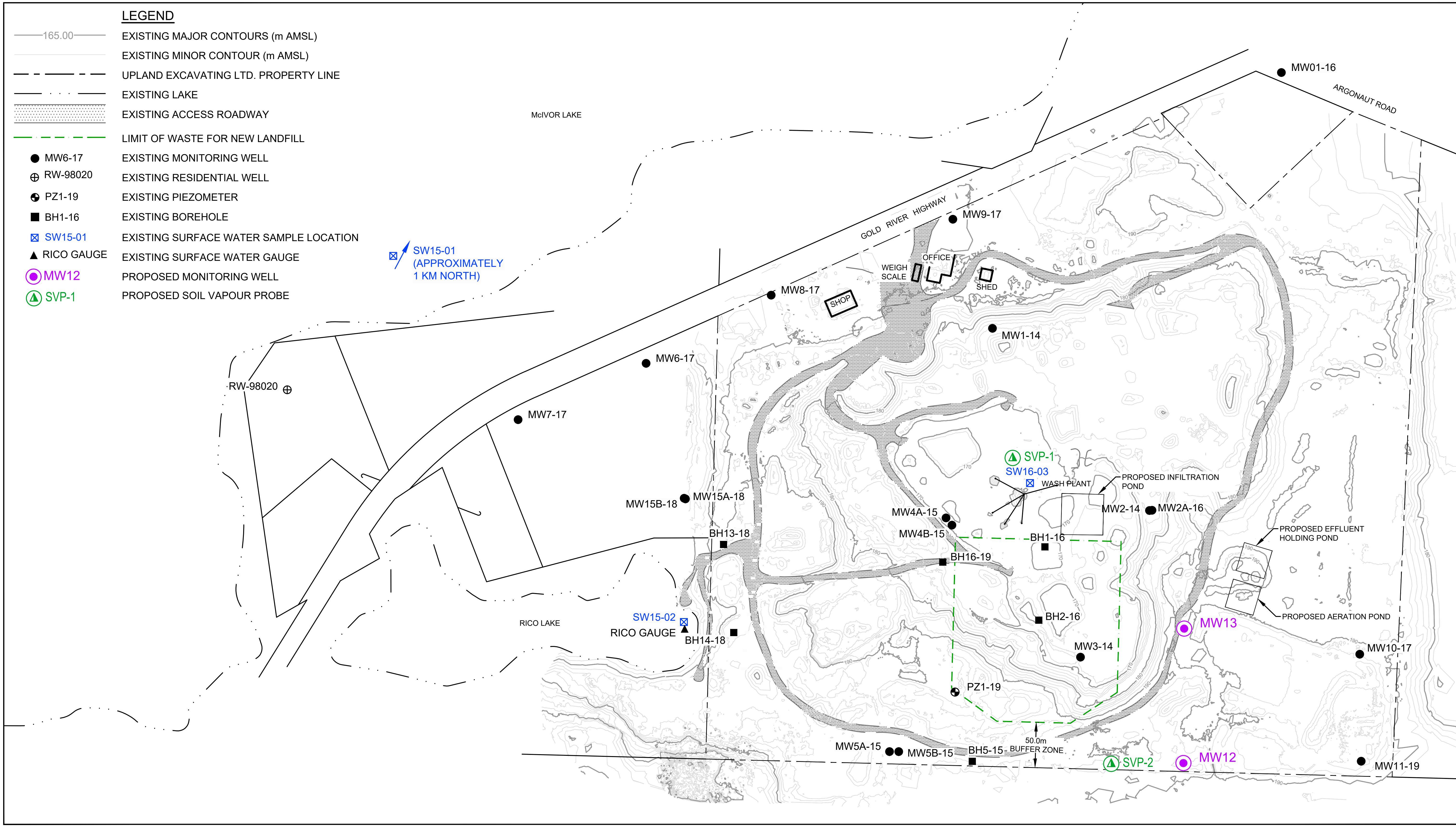
FIGURE 10.2

LANDFILL GAS GENERATION ESTIMATE

2021 DESIGN, OPERATIONS, AND CLOSURE PLAN

NORTHWIN LANDFILL

Upland Excavations Ltd.
Campbell River, British Columbia



SOURCE: TOPOGRAPHICAL SURVEY CONDUCTED BY McELHANNEY ASSOCIATES LAND SURVEYING LTD., NOVEMBER 21, 2016.

UPLAND EXCAVATING LTD.
2021 DESIGN, OPERATIONS AND CLOSURE PLAN
NORTHWIN LANDFILL, CAMPBELL RIVER, B.C.

ENVIRONMENTAL MONITORING PROGRAM
PROPOSED INVESTIGATION LOCATIONS

88877

July 3, 2020

FIGURE 14.1

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Tables

Table 2.1

Climate Data
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

Month	Daily Average Temperature (Celcius)	Daily Maximum Temperature (Celcius)	Daily Minimum Temperature (Celcius)	Rainfall (mm)	Snowfall (cm) [1]	Precipation (mm) [1]
January	2.4	5.5	-0.8	195	23	218
February	3.2	7.2	-0.7	136	14	150
March	5.2	9.7	0.7	128	12	140
April	8	13.2	2.8	92	1	92
May	11.6	17	6.2	68	0	68
June	14.7	20.1	9.3	63	0	63
July	17.3	23	11.5	39	0	39
August	17.2	23.3	11.1	45	0	45
September	13.7	19.8	7.6	55	0	55
October	8.6	13.1	4.0	161	1	162
November	4.4	7.7	1.0	222	11	232
December	2.1	4.9	-0.8	204	23	226
Annual	**9.0**	**13.7**	**4.3**	**1408**	**84**	**1489**
Plan2Adapt Climate Change Factor	**+ 1.5**					**+ 5.2%**
Annual (Adjusted for Climate Change)	**10.5**					**1567**

Notes:
Source: Environment Canada: Climate Normals - Campbell River Airport (Station No. - 1021261), 1981 - 2010 Station Data
[1] 1 cm of snowfall corresponds to 1 mm of precipation

Table 4.1

Average Annual Tonnes of Waste to be Disposed in Landfill
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

	Year	Stage	Forecasted Annual Waste Discharged (tonnes)	Waste in Place Cummulative (tonnes)
1	2022	Stage 1 East	138,238	138,238
2	2023	Stage 1 West	45,000	183,238
3	2024	Stage 1 West	45,000	228,238
4	2025	Stage 1 West/ Stage 2 A	45,000	273,238
5	2026	Stage 2 A	45,000	318,238
6	2027	Stage 2 A	45,000	363,238
7	2028	Stage 2 A	45,000	408,238
8	2029	Stage 2 A/ Stage 2 B	45,000	453,238
9	2030	Stage 2 B/ Stage 2 C	45,000	498,238
10	2031	Stage 3 A	45,000	543,238
11	2032	Stage 3 A	45,000	588,238
12	2033	Stage 3 A / Stage 3 B	45,000	633,238
13	2034	Stage 3 B / Stage 3C	45,000	678,238
14	2035	Stage 3 C	13,836	692,075

Table 5.1

Landfill Stages
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

Landfill Phase	Landfill Capacity m^3	tonnes	No. of Years	Years Active	
Phase 1 East	106,337	138,238	1.0	2022	2023
Phase 1 West	101,447	131,881	2.9	2023	2025
Phase 2A	106,823	138,870	3.1	2025	2029
Phase 2B	44,912	58,386	1.3	2029	2030
Phase 2C	27,085	35,211	0.8	2030	2031
Phase 3A	67,949	88,334	2.0	2031	2033
Phase 3B	44,266	57,546	1.3	2033	2034
Phase 3C	33,546	43,610	1.0	2034	2035
Total	**532,365**	**692,075**	**13.3**	**2022**	**2035**

Notes:

Apparent Density of Waste
1.3 t/m^3

Allowable Discharge Year 1 = original landfill tonnes + allowable tonnes
138,238 tonnes

Allowable Discharge Year 2 onward
45,000 t/yr

Table 5.2

Material Requirement
2020 Design, Operations and Closure Plan
New Landfill (Northwin Landfill)
Upland Excavating Ltd.
Campbell River, British Columbia

		Cell Construction						Operations	Final Cover		
		Area					Volume	Volume	Area	Volume	
Phase	Stage	Base Liner Geomembrane + GCL Area (m²)	Secondary Liner Geomembrane + GCL Area (m²)	Non-Woven Geotextile (m²)	Woven Geotextile (m²)	Geocomposite drainage layer (m²)	Drain Rock (m³)	Intermediate Cover Volume (m³)	Final Cover GCL Area (m²)	Final Cover Sand (m³)	Final Cover Topsoil (m³)
1	East	13,763	13,763	13,763	13,763	13,763	4,129	0	0	0	0
1	West	8,527	8,527	8,527	8,527	8,527	2,558	2,744	0	0	0
2	2A	9,117	9,117	9,117	9,117	9,117	2,735	3,792	9,650	5,790	1,448
2	2B	0	0	0	0	0	0	2,975	0	0	0
2	2C	0	0	0	0	0	0	3,843	0	0	0
3	3A	3,225	3,225	3,225	3,225	3,225	968	263	8,165	4,899	1,225
3	3B	0	0	0	0	0	0	2,390	0	0	0
3	3C	0	0	0	0	0	0	0	16,330	9,798	2,450
	Total	**34,632**	**34,632**	**34,632**	**34,632**	**34,632**	**10,390**	**16,006**	**34,145**	**20,487**	**5,122**

[1]Intermediate Cover 300 mm thickness

Table 8.1

Design Storm Parameters
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

Return Period	Type	Depth	Snowmelt Correction Factor	Climate Change Correction Factor	Rainfall Depth with Snowmelt and Climate Change Correction	Peak Intensity	Duration
		(mm)	(%)	(%)	(mm)	(mm/hr)	(hour)
5-year	SCS Type 1A	70.0	10	5.2	80.6	12.65	24
10-year	SCS Type 1A	77.7	10	5.2	89.5	14.05	24
100-year	SCS Type 1A	101.9	10	5.2	117.4	18.43	24
200-year	SCS Type 1A	110.1	10	5.2	126.8	19.91	24

Note:

1. 5-year, 10-year and 100-year design storm depths obtained from Environment Canada intensity-duration-frequency data for the Campbell River A (1021261) IDF Station. 200-year storm depth extrapolated

Table 8.2

Post Development Conditions Catchment Parameters
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

Subcatchment ID	Area (ha)	Flow length (m)	Slope (%)	Imperviousness (%)	Manning' n Impervious (-)	Manning' n Pervious (-)	Depression Storage Impervious (mm)	Depression Storage Pervious (mm)	Infiltration Maximum (mm/hr)	Infiltration Minimum (mm/hr)
101	0.79	40	45	0	0.01	0.05	1.27	2.5	7	0.2
102	0.08	40	45	0	0.01	0.05	1.27	2.5	7	0.2
103	0.13	40	45	0	0.01	0.05	1.27	2.5	7	0.2
104	1.35	55	35	0	0.01	0.05	1.27	2.5	7	0.2
105	0.20	30	20	0	0.01	0.05	1.27	2.5	7	0.2
106	0.95	65	22	0	0.01	0.24	1.27	5.1	5	0.1
107	0.51	35	30	0	0.01	0.24	1.27	5.1	5	0.1
108	0.53	35	30	0	0.01	0.24	1.27	5.1	5	0.1
109	0.92	65	22	0	0.01	0.24	1.27	5.1	5	0.1
110	0.18	45	22	0	0.01	0.24	1.27	5.1	5	0.1
111	0.19	45	22	0	0.01	0.24	1.27	5.1	5	0.1
115	0.28	35	30	0	0.01	0.24	1.27	5.1	5	0.1
112	0.46	25	15	100	0.01	0.24	1.27	5.1	5	0.1
114	0.50	25	15	100	0.01	0.24	1.27	5.1	5	0.1
113	0.29	35	30	0	0.01	0.24	1.27	5.1	5	0.1
Total	7.38									

Table 8.3

Post Development Conditions Peakflow Summary
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

Subcatchment ID	*Peak Discharge Rate*			
	5-year (m^3/s)	10-year (m^3/s)	100-year (m^3/s)	200-year (m^3/s)
101	0.03	0.03	0.04	0.04
102	0.00	0.00	0.00	0.00
103	0.00	0.01	0.01	0.01
104	0.05	0.05	0.07	0.07
105	0.01	0.01	0.01	0.01
106	0.03	0.04	0.05	0.05
107	0.02	0.02	0.03	0.03
108	0.02	0.02	0.03	0.03
109	0.03	0.04	0.05	0.05
110	0.01	0.01	0.01	0.01
111	0.01	0.01	0.01	0.01
115	0.01	0.01	0.01	0.02
112	0.02	0.02	0.02	0.03
114	0.02	0.02	0.03	0.03
113	0.01	0.01	0.01	0.02

Table 8.4

Post Development Conditions Runoff Volume Summary
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

Subcatchment ID	*Runoff Volume*			
	5-year (m^3)	**10-year (m^3)**	**100-year (m^3)**	**200-year (m^3)**
101	570	640	860	940
102	60	70	90	100
103	100	110	150	160
104	980	1100	1480	1610
105	150	170	220	240
106	680	770	1030	1120
107	370	410	560	600
108	380	420	570	620
109	660	740	1000	1080
110	130	150	200	210
111	140	150	210	220
115	200	230	310	330
112	370	410	540	580
114	400	440	580	630
113	210	230	310	340

Table 8.5

Channel Performance Summary
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

Channel Section	Length (m)	Slope (m/m)	Cross-Section (-)	Depth (m)	Bottom Width (m)	Left Side Slope (H:V)	Right Side Slope (H:V)	Manning's 'n' Value	200-Year Storm Max. Flowrate (m^3/s)	Max. Velocity (m/s)	Max. Depth (m)	Minimum Freeboard (m)	Max. Shear Stress (Pa)	Recommended Channel Lining
D101	58	0.003	TRIANGULAR	0.6	3.6	NA	NA	0.03	0.02	0.02	0.29	0.31	10	Vegetation, Unreinforced
D102	146	0.002	TRIANGULAR	0.6	3.6	NA	NA	0.03	0.07	0.10	0.22	0.38	4	Vegetation, Unreinforced
D103	32	0.261	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.08	0.01	0.12	0.39	294	FLEXMAT
D104	175	0.017	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.16	0.08	0.15	0.35	25	Vegetation, Unreinforced
D105	59	0.003	TRIANGULAR	0.6	3.6	NA	NA	0.03	0.00	0.00	0.25	0.35	8	Vegetation, Unreinforced
D106	150	0.002	TRIANGULAR	0.6	3.6	NA	NA	0.03	0.05	0.07	0.20	0.40	4	Vegetation, Unreinforced
D107	34	0.241	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.06	0.01	0.12	0.39	271	FLEXMAT
D108	180	0.017	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.16	0.09	0.16	0.35	25	Vegetation, Unreinforced

Table 8.6

Post-Development Conditions Infiltration Pond Performance Summary
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

West Infiltration Pond

Design Storm	Peak Inflow (m^3/s)	Infiltration Discharge (m^3/s)	Maximum Depth (m)	Maximum Elevation (AMSL m)	Maximum Storage (m^3)	Minimum Freeboard (m)	Duration Time (Hour)	Peak Time	Baseline Time	
5-Year	0.13	0.049	0.13	150.13	375	0.87	6	9:35 AM	3:30 PM	5:55
10-Year	0.14	0.049	0.16	150.16	481	0.84	8	9:55 AM	5:35 PM	7:40
100-Year	0.18	0.049	0.30	150.30	902	0.70	14	11:30 AM	1:10 AM	13:40
200-Year	0.20	0.049	0.35	150.35	1082	0.65	15	11:55 AM	3:10 AM	15:15

East Infiltration Pond

Design Storm	Peak Inflow (m^3/s)	Infiltration Discharge (m^3/s)	Maximum Depth (m)	Maximum Elevation (AMSL m)	Maximum Storage (m^3)	Minimum Freeboard (m)	Duration Time (Hour)			
5-Year	0.13	0.049	0.14	150.14	404	0.86	7	9:40 AM	4:05 PM	6:25
10-Year	0.14	0.049	0.17	150.17	520	0.83	9	10:00 AM	6:15 PM	8:15
100-Year	0.19	0.049	0.32	150.32	975	0.68	14	11:40 AM	1:30 AM	13:50
200-Year	0.21	0.049	0.38	150.38	1164	0.62	16	12:00 PM	3:50 AM	15:50

Table 9.1

Forecasted Leachate Quality Profile
2020 Design, Operations and Closure Plan
New Landfill (Northwin Landfill)
Upland Excavating Ltd.
Campbell River, British Columbia

Parameters	Units	Historical Results from Similar Landfills for Comparison							Original Upland Landfill 2019	Forecasted Upland Landfill Leachate Concentrations		Discharge Criteria	Treatment Efficiency		Forecasted Upland Landfill Treated Leachate Concentrations	
		HWMF Lowest Concentration Observed in Leachate 2012-2015 [1]	HWMF Average Concentration Observed in Leachate 2012-2015 [2]	Confiential BC Contaminated Soil Landfill - Average Concentrations Observed in Leachate 2012[6]	Confidential BC Contaminated Soil Landfill - Average Concentration Observed in Leachate 2013 [7]	Highest observed - C&D Levis Landfill, Quebec 2003 [3]	Highest observed - Mayer Waste Disposal Site 1994-2001 [4]	Highest observed - Inter-Recycling Systems Landfill 1988-2001 [5]		Minimum	Maximum	CSR Schedule 3.2 DW	Minimum Percent Reduction From Leachate Treatment	Maximum Percent Reduction From Leachate Treatment	Minimum	Maximum
GENERAL CHEMISTRY																
Alkalinity (total)	mg/L	327	1152	-	-	--	1550	3050	-	50	2500	-	50%	90%	25	250
Ammonia-N	mg/L	1.07	20.1	24.1	25.7	--	27	--	0.57	1	30	-	10%	90%	0.9	3
BOD	mg/L	8.3	13.5	9	10	17	69	648	41	10	50	-	10%	65%	9	17.5
Chloride (Cl) (dissolved)	mg/L	75	1642	710	667	243	98.9	702	16	50	700	250	-	64%	50	250
COD	mg/L	52	431	300	390	132	517	--	144	50	500	-	25%	70%	37.5	150
Conductivity	us/cm	1800	7974	4100	3920	--	2730	6900	618	200	5000	-	-	-	200	5000
Hardness	mg/L	581	1855	980	1050	--	1341	3100	323	750	2500	-	-	-	750	2500
pH	pH units	6.84	7.35	7.02	6.88	6.2-7.3	6.2-7.1	6.1-8.4	7.77	6	8	-	-	-	6	8
Phenols	mg/L	0.005	0.044	-	-	0.026	0.0075	0.172	-	0.005	0.1	1	25%	90%	0.00375	0.01
Sulphate (S04)	mg/L	36	529	40	40	742	521	356	74	50	500	500	-	-	50	500
Sulphide	mg/L	0.023	1.979	-	-	-	-	-	0.03	0.01	1	0.05	25%	95%	0.0075	0.05
Total Suspended Solids (TSS)	mg/L	13.7	27.2	100	237	-	-	-	55.2	10	150	-	50%	50%	5	75
Total Dissolved Solids (TDS)	mg/L	1180	5742	-	-	-	-	-	504	500	1000	-	50%	50%	250	500
Total Kjeldahl Nitrogen (TKN)	mg/L	2.89	26.3	36.1	43.1	-	-	-	-	3	50	-	25%	65%	2.25	17.5
Phosphorus	mg/L	0.08	0.31	0.2[8]	-	-	-	-	-	0.1	0.5	-	-	-	0.1	0.5
HYDROCARBONS																
HEPH	mg/L	0.49	1.10	-	-	-	-	-		0.5	2	-	-	-	0.5	2
LEPH	mg/L	0.36	1.08	-	-	-	-	-		0.5	2	-	25%	75%	0.375	0.5
METALS																
Aluminum (Dissolved)	mg/L	0.022	0.063	0.100	0.070				0.0174	0.01	0.1	9.5	-	-	0.01	0.1
Arsenic	mg/L	0.001	0.009	0.008	0.042	-	0.001	0.019 [10]	0.003	0.001	0.04	0.01	-	75%	0.001	0.01
Arsenic (Dissolved)	mg/L	0.006	0.010	0.003	0.003				0.00182	0.001	0.04	0.01	-	75%	0.001	0.01
Barium	mg/L	0.060	0.284	1.000	3.760	-	-	0.97	0.0218	0.05	0.7	1	-	-	0.05	0.7
Barium (Dissolved)	mg/L	0.059	0.289	0.550	0.724				0.0161	0.05	0.7	1	-	-	0.05	0.7
Boron	mg/L	1.74	7.81	10.4	10.9	-	-	-	0.063	0.1	10	5	-	50%	0.1	5
Boron (Dissolved)	mg/L	1.71	7.78	11.4	11.4				0.057	0.1	10	5	-	50%	0.1	5
Cadmium	mg/L	0.0001	0.0001	0.0003	0.0003	<0.001	0.0006	0.005	0.000095	0.0001	0.0003	0.005	-	-	0.0001	0.0003
Cadmium (Dissolved)	mg/L	0.0001	0.0001	0.0005	0.0005				0.000015	0.0001	0.0003	0.005	-	-	0.0001	0.0003
Calcium	mg/L	179	548	262	288	-	376	720	121	200	700	-	-	-	200	700
Calcium (Dissolved)	mg/L	179	550	243	226				113	200	700		-	-	200	700
Chromium	mg/L	0.002	0.011	0.006	0.020	0.11	0.054	0.241	0.003	0.005	0.05	0.05	-	-	0.005	0.05
Chromium (Dissolved)	mg/L	0.001	0.009	0.007	0.007				0.0012	0.005	0.05	0.05	-	-	0.005	0.05
Cobalt	mg/L	0.001	0.002	0.003	0.005	-	0.02	0.018	0.00324	0.001	0.02	0.02	-	-	0.001	0.02
Cobalt (Dissolved)	mg/L	0.001	0.002	0.003	0.004				0.00235	0.001	0.02	0.02	-	-	0.001	0.02
Copper	mg/L	0.002	0.043	0.007	0.023	0.32	0.06	0.067	0.017	0.005	0.05	1.5	-	-	0.005	0.05
Copper (Dissolved)	mg/L	0.007	0.031	0.007	0.007				0.001	0.005	0.05	1.5	-	-	0.005	0.05
Iron	mg/L	0.418	5.46	47.6	267	69	65	180	10.3	10	70	6.5	35%	91%	6.5	6.5
Iron (Dissolved)	mg/L	0.032	3.31	0.130	2.39				6.97	0.1	7	6.5	-	7%	0.1	6.5
Lead	mg/L	0.0015	0.0024	0.001	0.038	<0.05	0.062	0.053	0.00046	0.001	0.01	0.01	-	-	0.001	0.01
Lead (Dissolved)	mg/L	--	--	0.001	0.001				<0.001	0.001	0.01	0.01	-	-	0.001	0.01
Magnesium	mg/L	30	115	77.8	77.7	-	111	365	20.1	30	300	-	-	-	30	300
Magnesium (Dissolved)	mg/L	30	118	75.7	71.2				19.5	30	300	-	-	-	30	300
Manganese	mg/L	0.300	1.93	1.47	0.846	-	6.01	2.62	3.68	2	5	1.5	25%	89%	1.5	0.55
Manganese (Dissolved)	mg/L	0.297	1.81	1.31	0.360				3.86	2	5	1.5	25%	89%	1.5	0.55
Mercury	mg/L	--	--	0.00003	0.00001	<0.0002	<0.00005	<0.00005	0.0000026	0.00001	0.00003	0.001	-	-	0.00001	0.00003
Mercury (Dissolved)	mg/L	--	--	0.00001	0.00001				<0.000002	0.00001	0.00001	0.001	-	-	0.00001	0.00001
Molybdenum	mg/L	0.0017	0.0018	0.001	0.001	-	<0.05	0.006	<0.0001	0.001	0.002	0.25	-	-	0.001	0.002
Molybdenum (Dissolved)	mg/L	0.0012	0.0016	0.001	0.001				<0.001	0.001	0.002	0.25	-	-	0.001	0.002
Nickel	mg/L	0.0075	0.0120	0.020	0.017	0.13	0.02	0.086	0.0026	0.0075	0.02	0.08	-	-	0.0075	0.02
Nickel (Dissolved)	mg/L	0.0052	0.0114	0.010	0.016				0.0012	0.0075	0.02	0.08	-	-	0.0075	0.02
Selenium	mg/L	ND	ND	0.005	0.004	-	0.021	0.046	0.00022	0.0001	0.005	0.01	-	-	0.0001	0.005
Selenium (Dissolved)	mg/L	-	-	0.004	0.004				0.00022	0.0001	0.005	0.01	-	-	0.0001	0.005
Silver	mg/L	0.0001	0.0001	0.0002	0.0002	-	0.0002	<0.0001	<0.00002	0.0001	0.0002	0.02	-	-	0.0001	0.0002
Silver (Dissolved)	mg/L	--	--	0.0002	0.0002				<0.00002	0.0001	0.0002	0.02	-	-	0.0001	0.0002
Sodium	mg/L	107	1153	541	516	-	256	889	25.1	50	550	200	-	64%	50	200
Sodium (Dissolved)	mg/L	92.3	1173	577	518				27.2	50	550	200	-	64%	50	200
Zinc	mg/L	0.027	0.238	0.050	0.110	0.72	2.12	2.57	0.0622	0.05	2	3	-	-	0.05	2

Table 9.1

Forecasted Leachate Quality Profile
2020 Design, Operations and Closure Plan
New Landfill (Northwin Landfill)
Upland Excavating Ltd.
Campbell River, British Columbia

Parameters	**Units**	Historical Results from Similar Landfills for Comparison							Original Upland Landfill 2019	Forecasted Upland Landfill Leachate Concentrations		Discharge Criteria	Treatment Efficiency		Forecasted Upland Landfill Treated Leachate Concentrations	
		HWMF Lowest Concentration Observed in Leachate 2012-2015 (1)	HWMF Average Concentration Observed in Leachate 2012-2015 (2)	Confiential BC Contaminated Soil Landfill - Average Concentrations Observed in Leachate 2012(6)	Confidential BC Contaminated Soil Landfill - Average Concentration Observed in Leachate 2013 (7)	Highest observed - C&D Levis Landfill, Quebec 2003 (3)	Highest observed - Mayer Waste Disposal Site 1994-2001 (4)	Highest observed - Inter-Recycling Systems Landfill 1988-2001 (5)		Minimum	Maximum	CSR Schedule 3.2 DW	Minimum Percent Reduction From Leachate Treatment	Maximum Percent Reduction From Leachate Treatment	Minimum	Maximum
Zinc (Dissolved)	mg/L	0.006	0.137	0.020	0.030				0.01	0.025	1	3	-	-	0.025	1
PAHs																
1-Methylnaphthalene	ug/L	-	-	-	-	-	-	-	74	50	150	5.5	89%	96%	5.5	5.5
2-Methylnaphthalene	ug/L	-	-	-	-	-	-	-	100	50	150	15	70%	90%	15	15
Acenaphthene	ug/L	-	-	-	-	-	-	-	70	50	150	250	50%	90%	25	15
Anthracene	ug/L	-	-	-	-	-	-	-	6.1	1	10	1000	50%	90%	0.5	1
Benzo(a)anthracene	ug/L	-	-	-	-	-	-	-	2.1	0.1	5	0.07	30%	99%	0.07	0.07
Benzo(a)pyrene	ug/L	-	-	-	-	-	-	-	1.2	0.1	5	0.01	90%	100%	0.01	0.01
Benzo(b)fluoranthene/Benzo(j)fluo	ug/L	-	-	-	-	-	-	-	1.6	0.1	5	0.07	30%	99%	0.07	0.07
Benzo(b)pyridine (Quinoline)	ug/L	-	-	-	-	-	-	-	1.2	0.1	5	0.05	50%	99%	0.05	0.05
Chrysene	ug/L	-	-	-	-	-	-	-	2.7	0.1	5	7	50%	90%	0.05	0.5
Dibenz(a,h)anthracene	ug/L	-	-	-	-	-	-	-	0.11	0.01	1	0.01	50%	99%	0.005	0.01
Fluoranthene	ug/L	-	-	-	-	-	-	-	11	1	50	150	50%	90%	0.5	5
Fluorene	ug/L	-	-	-	-	-	-	-	28	1	50	150	50%	90%	0.5	5
Naphthalene	ug/L	-	-	-	-	-	-	-	900	100	1500	80	20%	95%	80	80
Pyrene	ug/L	-	-	-	-	-	-	-	8.8	1	50	100	50%	90%	0.5	5

Notes:
(1) Chemical analyses results - HWMF surface water - Highest concentration -1995 (Appendix B).
(2) Chemical analyses results - HWMF ash leachate - Highest concentration -1995 (Appendix B).
(3) Highest concentration reported for the C&D Landfill in Levis, Quebec in 2005 (Appendix C).
(4) Highest concentration reported for the Mayer Industrial Landfill Site between 1994 and 2001 (Appendix C).
(5) Highest concentration reported for the Inter-Recycling Systems Landfill Site between 1988 and 2001 (Appendix C).
(6) Confidential Landfill Leachate - Treatment Program 2013 - Tables 5,6,7. Concentrations represent average of 4 samples.
(7) Confidential Landfill Leachate - Leachate Treatment Program 2013 - Tables 5,6,7. Concentrations represent average of 3 samples.
(8) Concentration represents average of 2 samples.

Table 9.2

HELP Model Results
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

	Daily Cover - New cell	Daily Cover	Intermediate Cover	Final Cover
		mm		
Jan	222.68	176.93	177.40	2.92
Feb	155.72	162.00	165.02	2.69
Mar	124.98	157.48	160.20	2.40
Apr	68.62	122.23	122.31	1.96
May	34.31	50.57	37.41	1.48
Jun	26.80	26.91	13.18	0.91
Jul	22.54	22.34	10.61	0.62
Aug	18.67	18.87	8.44	0.43
Sep	27.85	26.60	13.98	0.29
Oct	108.64	59.91	46.16	0.12
Nov	187.21	117.04	110.28	0.20
Dec	209.02	162.09	160.08	1.81
Total:	**1207.05**	**1102.97**	**1025.06**	**15.82**
Peak Daily:	**20.56**	**14.79**	**14.76**	**0.21**

Table 9.3

Cover Areas
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

	Areas (m^2)			
Stage	**New Cell**	**Daily Cover**	**Intermediate Cover**	**Final Cover**
1 East - Half	6,882	0	0	0
1 East	6,882	6,882	0	0
1 West - Half	4,559	3,053	10,710	0
1 West	4,559	7,612	7,710	3,720
2A	10,590	0	10,217	9,050
2B	0	10,160	10,647	9,050
2C	0	7,047	13,854	9,050
3A	3,212	13,583	207	16,235
3B	0	8,393	8,609	16,235
3C	0	0	0	34,145

Table 9.4

Estimated Leachate Generation Per Stage
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

	Days in Month	Stage 1 East Half Cell w Rain Flap	Stage 1 East	Stage 1 West Half Cell w Rain Flap	Stage 1 West	Stage 2A	Stage 2B	Stage 2C	Stage 3A	Stage 3B	Stage 3C
						m^3					
January	31	1532	2,750.0	3,455.2	3,740.4	4,197.1	3,712.8	3,731.0	3,202.6	3,059.6	99.6
February	28	1072	2,186.4	2,971.8	3,225.2	3,359.4	3,427.2	3,452.1	2,778.4	2,824.0	91.8
March	31	860	1,943.8	2,766.3	3,012.5	2,982.0	3,327.4	3,350.9	2,612.6	2,739.9	81.8
April	30	472	1,313.4	1,995.9	2,193.4	1,994.1	2,561.8	2,573.5	1,937.8	2,110.6	66.9
May	31	236	584.1	711.5	835.3	759.0	925.5	888.1	828.9	770.6	50.6
June	30	184	369.6	345.5	431.9	426.7	421.9	380.4	469.0	354.0	31.0
July	31	155	308.8	284.5	356.9	352.7	345.5	310.0	388.0	288.8	21.1
August	31	129	258.4	233.2	295.5	287.9	285.5	253.9	325.1	238.1	14.7
September	30	192	374.7	357.9	438.3	440.4	421.8	383.8	458.3	348.3	9.9
October	31	748	1,159.9	1,172.5	1,307.6	1,623.2	1,101.2	1,062.7	1,174.2	902.1	4.0
November	30	1288	2,093.7	2,391.8	2,595.3	3,111.1	2,365.1	2,354.4	2,217.1	1,935.0	6.8
December	31	1438	2,553.8	3,162.1	3,427.5	3,865.4	3,367.5	3,376.3	2,935.5	2,767.9	61.8
Annual Leachate		8,306.3	15,896.4	19,848.2	21,859.7	23,398.9	22,263.2	22,117.0	19,327.7	18,338.8	540.1
Peak Daily Rate		141.5	243.3	297.0	320.1	370.4	309.4	310.6	273.4	254.6	7.2
Average Daily Rate		22.8	43.6	54.4	59.9	64.1	61.0	60.6	53.0	50.2	1.5
+ 5.2% Climate Change Factor											
Annual Leachate		**8,738**	**16,723**	**20,880**	**22,996**	**24,616**	**23,421**	**23,267**	**20,333**	**19,292**	**568**
Peak Daily Rate		**149**	**256**	**312**	**337**	**390**	**325**	**327**	**288**	**268**	**8**
Average Daily Rate		**24**	**46**	**57**	**63**	**67**	**64**	**64**	**56**	**53**	**2**

Table 10.1

Waste Characterization
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

Waste Type	Percent of Total Waste Composition	Percent Relatively Inert	Percent Moderately Decomposable	Percent Decomposable
Waste Soil	50%	100%	0%	0%
Construction, Demolition and Land Clearing Debris	50%	50%	50%	0%
Total	**100%**	**75%**	**25%**	**0%**

Table 10.2

Landfill Gas Generation Summary
2021 Design, Operations and Closure Plan
New Landfill (Northwin Landfill)
Upland Excavating Ltd.
Campbell River, British Columbia

Year	Annual Waste Tonnage (tonnes)	Methane Generation (tonnes CH4/year)	Total Waste in Place (tonnes)
2022	138,238	0	138,238
2023	45,000	186	183,238
2024	45,000	236	228,238
2025	45,000	285	273,238
2026	45,000	330	318,238
2027	45,000	373	363,238
2028	45,000	414	408,238
2029	45,000	453	453,238
2030	45,000	490	498,238
2031	45,000	525	543,238
2032	45,000	559	588,238
2033	45,000	590	633,238
2034	45,000	620	678,238
2035	13,836	649	692,075
2036	0	634	692,075
2037	0	602	692,075
2038	0	571	692,075
2039	0	542	692,075
2040	0	515	692,075
2041	0	489	692,075
2042	0	464	692,075
2043	0	441	692,075
2044	0	419	692,075
2045	0	399	692,075
2046	0	379	692,075
2047	0	361	692,075
2048	0	343	692,075
2049	0	327	692,075
2050	0	311	692,075
2051	0	297	692,075
2052	0	283	692,075
2053	0	269	692,075
2054	0	257	692,075
2055	0	245	692,075
2056	0	234	692,075
2057	0	223	692,075
2058	0	213	692,075
2059	0	204	692,075
2060	0	195	692,075
2061	0	186	692,075
2062	0	178	692,075
2063	0	170	692,075
2064	0	163	692,075

Note:
This table presents the results of the landfill gas (LFG) assessment from the anticipated year where waste placement will begin to the estimated year of closure with anticipated annual waste tonnages.

Table 10.3

Landfill Gas Generation Results
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

	Relatively Inert	Moderately Decomposable	Decomposable	
Gas Production potential, Lo =	20	120	160	m^3 CH_4/tonne
Waste Composition (2006 SWMP)	75.0%	25.0%	0.0%	
lag time before start of gas production, lag =	1 years			
Historical Data Used (years)	30			
1st Year of Historical Data Used	2021			
Proposed year of closure	2033			
methane (by volume)	50%			
carbon dioxide (by volume)	50%			
methane (density)	0.6557 kg/m^3		(25°C,1ATM)	
carbon dioxide (density)	1.7988 kg/m^3		(25°C,1ATM)	

Year	Annual Tonnage (tonnes)	Cumulative Waste-in-place (tonnes)	Waste Tonnage: Relatively Inert (tonnes)	Waste Tonnage: Moderately Decomposable (tonnes)	Waste Tonnage: Decomposable (tonnes)	Methane Generation Rate, k: Relatively Inert ($year^{-1}$)	Methane Generation Rate, k: Moderately Decomposable ($year^{-1}$)	Methane Generation Rate, k: Decomposable ($year^{-1}$)	Annual Methane Production (tonnes/yr)	Landfill Gas Production (m^3/hr)	Greenhouse Gas Emissions (as CO_2e/year)
2022	138,238	138,238	103,679	34,560	0	0.02	0.06	0.11	185.8	64.7	3,901
2023	45,000	183,238	33,750	11,250	0	0.02	0.06	0.11	236.5	82.3	4,966
2024	45,000	228,238	33,750	11,250	0	0.02	0.06	0.11	284.5	99.1	5,975
2025	45,000	273,238	33,750	11,250	0	0.02	0.06	0.11	330.1	114.9	6,932
2026	45,000	318,238	33,750	11,250	0	0.02	0.06	0.11	373.3	130.0	7,840
2027	45,000	363,238	33,750	11,250	0	0.02	0.06	0.11	414.3	144.3	8,701
2028	45,000	408,238	33,750	11,250	0	0.02	0.06	0.11	453.2	157.8	9,518
2029	45,000	453,238	33,750	11,250	0	0.02	0.06	0.11	490.2	170.7	10,293
2030	45,000	498,238	33,750	11,250	0	0.02	0.06	0.11	525.2	182.9	11,030
2031	45,000	543,238	33,750	11,250	0	0.02	0.06	0.11	558.5	194.5	11,729
2032	45,000	588,238	33,750	11,250	0	0.02	0.06	0.11	590.1	205.5	12,393
2033	45,000	633,238	33,750	11,250	0	0.02	0.06	0.11	620.2	215.9	13,024
2034	45,000	678,238	33,750	11,250	0	0.02	0.06	0.11	648.7	225.9	13,623
2035	13,836	692,075	10,377	3,459	0	0.02	0.06	0.11	634.0	220.8	13,314
2036	0	692,075	0	0	0	0.02	0.06	0.11	601.5	209.4	12,632
2037	0	692,075	0	0	0	0.02	0.06	0.11	570.9	198.8	11,989
2038	0	692,075	0	0	0	0.02	0.06	0.11	541.9	188.7	11,380
2039	0	692,075	0	0	0	0.02	0.06	0.11	514.6	179.2	10,806
2040	0	692,075	0	0	0	0.02	0.06	0.11	488.7	170.2	10,263
2041	0	692,075	0	0	0	0.02	0.06	0.11	464.3	161.7	9,750
2042	0	692,075	0	0	0	0.02	0.06	0.11	441.2	153.6	9,266
2043	0	692,075	0	0	0	0.02	0.06	0.11	419.4	146.0	8,808
2044	0	692,075	0	0	0	0.02	0.06	0.11	398.8	138.9	8,375
2045	0	692,075	0	0	0	0.02	0.06	0.11	379.3	132.1	7,965
2046	0	692,075	0	0	0	0.02	0.06	0.11	360.9	125.6	7,578
2047	0	692,075	0	0	0	0.02	0.06	0.11	343.4	119.6	7,212
2048	0	692,075	0	0	0	0.02	0.06	0.11	326.9	113.8	6,866
2049	0	692,075	0	0	0	0.02	0.06	0.11	311.3	108.4	6,538
2050	0	692,075	0	0	0	0.02	0.06	0.11	296.6	103.3	6,228
2051	0	692,075	0	0	0	0.02	0.06	0.11	282.6	98.4	5,935
2052	0	692,075	0	0	0	0.02	0.06	0.11	269.4	93.8	5,657
2053	0	692,075	0	0	0	0.02	0.06	0.11	256.9	89.4	5,395
2054	0	692,075	0	0	0	0.02	0.06	0.11	245.0	85.3	5,146
2055	0	692,075	0	0	0	0.02	0.06	0.11	233.8	81.4	4,910
2056	0	692,075	0	0	0	0.02	0.06	0.11	223.2	77.7	4,687
2057	0	692,075	0	0	0	0.02	0.06	0.11	213.1	74.2	4,476
2058	0	692,075	0	0	0	0.02	0.06	0.11	203.6	70.9	4,276
2059	0	692,075	0	0	0	0.02	0.06	0.11	194.6	67.7	4,086
2060	0	692,075	0	0	0	0.02	0.06	0.11	186.0	64.8	3,906
2061	0	692,075	0	0	0	0.02	0.06	0.11	177.9	61.9	3,735
2062	0	692,075	0	0	0	0.02	0.06	0.11	170.2	59.2	3,573
2063	0	692,075	0	0	0	0.02	0.06	0.11	162.9	56.7	3,420
2064	0	692,075	0	0	0	0.02	0.06	0.11	155.9	54.3	3,274

Sources:
-Landfill Gas Generation Assessment Procedure Guidance Report, Conestoga-Rovers & Associates, March 2009
-Annual waste tonnage data is estimated.

Table 13.1 A
Groundwater Compliance Forecast
Scenario 1 - Liner Failure
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

Parameters	Units	Average Pre-Landfilling Concentrations (1) 2015 - 2017	Forecasted Upland Landfill Leachate Concentrations	Forecasted Upland Landfill Treated Leachate Concentrations	Contaminant Masses & Source Volumes (2)						Final Forecasted Groundwater Concentrations (3)	BC Contaminated Site Regulation Schedule 3.2, Nov. 2017	BC Contaminated Site Regulation Schedule 3.2, Nov. 2017
						Flux into Landfill Footprint Area (minimum)	Landfill Leakage (primary liner failure with leak detection system)	Treated Leachate Infiltration (Designed)	Infiltration of Runoff and Lateral Drainage from Landfill Cap (dry periods)	Infiltration Downgradient of Landfill (5) (dry periods)			
			Maximum	Maximum	Units						liner failure (with leak detection system), max. mass loading (leachate & effluent), min. upgradient flux, dry season runoff & downgradient infiltration	Drinking Water (DW)	Aquatic Life (AW)
			mg/L	mg/L	m3/day	500	0.00010	67	1.0	73	Scenario	(mg/L)	(mg/L)
					L/day	500,000	0.10	67,000	1750.0	73,000	Liner Failure		
GENERAL CHEMISTRY							Contaminant Masses				(mg/L)		
							Maximum	Maximum					
Alkalinity (total)	mg/L	54.7	2500	250	mg/day	27350000	250	16750000	95725	3993100	75.1	-	-
Ammonia-N	mg/L	0.08	30	3	mg/day	40000	3.0	201000	140	5840	0.38	-	11.3 [a]
BOD	mg/L	2.07	50	17.5	mg/day	1035000	5.0	1172500	3622.5	151110	3.68	-	-
Chloride (Cl) (dissolved)	mg/L	4.15	1500	250	mg/day	2075000	150	16750000	7262.5	302950	29.82	250	1500
COD	mg/L	39.1	500	150	mg/day	19550000	50	10050000	68425	2854300	50.68	-	-
Conductivity(4)	us/cm	137	7500	7500	us/cm	-	-	-	-	-	846	-	-
Hardness	mg/L	60	2500	2500	mg/day	30000000	250	167500000	105000	4380000	315	-	-
pH(4)	pH units	7.86	8	8	std. units	-	-	-	-	-	7-8	-	-
Phenols	mg/L	0.0	0.1	0.01	mg/day	0	0.01	670	0	0	0.00104	1	2
Sulphate (S042-)	mg/L	5.72	1000	500	mg/day	2860000	100	33500000	10010	417560	57.32	500	2180 - 4290 [b]
Sulphide	mg/L	0.006	5	0.05	mg/day	3000	0.50	3350	10.5	438	0.0106	0.05	0.02
Total Suspended Solids (TSS)	mg/L	390	150	75	mg/day	1.95E+08	15.0	5025000	682500	28470000	357	-	-
Total Dissolved Solids (TDS)	mg/L	31	10000	5000	mg/day	15500000	1000	335000000	54250	2263000	550	-	-
Total Kjeldahl Nitrogen (TKN)	mg/L	0.143	60	21	mg/day	71500	6.00	1407000	250.25	10439	2.321	-	-
Phosphorus	mg/L	0.551	0.5	0.5	mg/day	275500	0.05	33500	964.25	40223	0.546	-	-
HYDROCARBONS													
HEPH	mg/L	0.0	2	2	mg/day	0	0.20	134000	0	0	0.2088	-	-
LEPH	mg/L	0.0	2	0.5	mg/day	0	0.20	33500	0	0	0.0522	-	0.5
METALS													
Aluminum	mg/L	-	1	1		-	0.100	67000				-	-
Aluminum (Dissolved)	mg/L	0.00737	0.1	0.1	mg/day	3685	0.010	6700	12.8975	538.01	0.02	9.5	-
Arsenic	mg/L	-	0.04	0.01	mg/day	-	0.004	670				-	-
Arsenic (Dissolved)	mg/L	0.00014	0.04	0.01	mg/day	70	0.004	670	0.245	10.22	0.0012	0.01	0.05
Barium	mg/L	-	0.7	0.7	mg/day	-	0.070	46900				-	-
Barium (Dissolved)	mg/L	0.0014	0.7	0.7	mg/day	700	0.07	46900	2.45	102.2	0.074	1	10
Boron	mg/L	-	10	5	mg/day	-	1.00	335000				-	-
Boron (Dissolved)	mg/L	0.0	10	5	mg/day	0	1.00	335000	0	0	0.522	5	12
Cadmium	mg/L	-	0.0003	0.0003	mg/day	-	3.0E-05	20.1				-	-
Cadmium (Dissolved)	mg/L	0.00001	0.0003	0.0003	mg/day	5.0	3.0E-05	20.1	0.0175	0.73	0.00004	0.005	0.0015 - 0.004 [b]
Calcium	mg/L	-	700	700	mg/day	-	70.00	46900000				-	-
Calcium (Dissolved)	mg/L	18.842	700	700	mg/day	9421000	70	46900000	32973.5	1375466	89.96	-	-
Chromium	mg/L	-	0.05	0.05	mg/day	-	0.005	3350				-	-
Chromium (Dissolved)	mg/L	0.0	0.05	0.05	mg/day	0	0.005	3350	0	0	0.00522	0.05	0.01 [c]
Cobalt	mg/L	-	0.01	0.01	mg/day	-	0.0010	670				-	-
Cobalt (Dissolved)	mg/L	0.0	0.01	0.01	mg/day	0	0.0010	670	0	0	0.0010	0.001	0.04
Copper	mg/L	-	0.05	0.05	mg/day	-	0.0050	3350				-	-
Copper (Dissolved)	mg/L	0.0008	0.05	0.05	mg/day	400	0.005	3350	1.4	58.4	0.0059	1.5	0.03-0.09 [b]
Iron	mg/L	-	70	6.5	mg/day	-	7.0	435500				-	-
Iron (Dissolved)	mg/L	0.056	7	6.5	mg/day	28000	0.7	435500	98	4088	0.73	6.5	-
Lead	mg/L	-	0.01	0.01	mg/day	-	0.0010	670				-	-
Lead (Dissolved)	mg/L	0.0	0.01	0.01	mg/day	0	0.0010	670	0	0	0.0010	0.01	0.05 - 0.16 [b]
Magnesium	mg/L	-	300	100	mg/day	-	30.0	6700000				-	-
Magnesium (Dissolved)	mg/L	3.28	300	100	mg/day	1640000	30.0	6700000	5740	239440	13.38	-	-
Manganese	mg/L	-	5	0.55	mg/day	-	0.5	36850				-	-
Manganese (Dissolved)	mg/L	0.03	5	0.55	mg/day	15000	0.5	36850	52.5	2190	0.084	1.5	-
Mercury	mg/L	-	0.00003	0.00003	mg/day	-	3.0E-06	2.01				-	-
Mercury (Dissolved)	mg/L	0.0	0.00001	0.00001	mg/day	0	1.0E-06	0.67	0	0	0.000001	0.001	0.00025
Molybdenum	mg/L	-	0.002	0.002	mg/day	-	0.0002	134				-	-
Molybdenum (Dissolved)	mg/L	0.0	0.002	0.002	mg/day	0	0.0002	134	0	0	0.0002	0.25	10
Nickel	mg/L	-	0.02	0.02	mg/day	-	0.002	1340				-	-
Nickel (Dissolved)	mg/L	0.0	0.02	0.02	mg/day	0	0.002	1340	0	0	0.0021	0.08	0.65-1.5 [b]
Selenium	mg/L	-	0.005	0.005	mg/day	-	0.0005	335				-	-
Selenium (Dissolved)	mg/L	0.0002	0.005	0.005	mg/day	100	0.001	335	0.35	14.6	0.0007	0.01	0.02
Silver	mg/L	-	0.00002	0.00002	mg/day	-	2.0E-06	1.34				-	-
Silver (Dissolved)	mg/L	0.0	0.0002	0.0002	mg/day	0	2.0E-05	13.4	0	0	0.00002	0.02	0.0005-0.015
Sodium	mg/L	-	1000	200	mg/day	-	100	13400000				-	-
Sodium (Dissolved)	mg/L	3.89	1000	200	mg/day	1945000	100	13400000	6807.5	283970	24.36	200	-
Zinc	mg/L	-	2	2	mg/day	-	0.20	134000				-	-
Zinc (Dissolved)	mg/L	0.002	1	1	mg/day	1000	0.10	67000	3.5	146	0.106	3	0.075-2.4 [b]

Notes:
(1) Concentrations have been calculated using the average concentration of each sample collected from the overburden, sand and gravel aquifer between 2015 and 2017.
For the purposes of predicting the mass inputs, concentrations of 0.0 mg/L have been used whereever samples were below detection limits (ND or less than the reporting limit).
(2) Contaminant masses are calculated by multipling the forcasted concentration by the volume of the respective source
(3) Final Forecasted Groundwater Concentrations = (sum of masses)/(sum of source volumes)
(4) The forecasted concentration approach is inappropriate for pH and conductivity.
conductivity is estimated as TDS/0.67; pH is expected to fall within the min. and max. range in pre-Landfill, leachate, or effluent.
(5) Infiltation rates used are 72% in the pit (with no vegetation) and 50% for above the pit (with vegetation) - derived from HELP modeling.
\- not analyzed or no standard/criteria available.
ND - not detected above the respective laboratory reporting limit
[a] - Limit varies with pH. Ranges are calculated using average pre-landfilling and final predicted concentrations
[b] - Limit varies with Hardness. Ranges are calculated using average pre-landfilling and final predicted concentrations
[c] - Limit is set for hexavalent chromium
(SAD)/(WAD) - strong acid dissolvable/weak acid dissolvable

(pink)	exceeds the BC CSR Drinking Water (DW) Standards
(yellow)	exceeds the BC CSR Aquatic Life (AW) Standards

Table 13.1 B
Groundwater Compliance Forecast
Scenario 2 - Base Case
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

Parameters	Units	Average Pre-Landfilling Concentrations [1] 2015 - 2017	Forecasted Upland Landfill Leachate Concentrations			Forecasted Upland Landfill Treated Leachate Concentrations			Contaminant Masses & Source Volumes [2]						Final Forecasted Groundwater Concentrations [3]	BC Contaminated Site Regulation Schedule 3.2, Nov. 2017	BC Contaminated Site Regulation Schedule 3.2, Nov. 2017
										Flux into Landfill Footprint Area (average)	Landfill Leakage (primary liner only)	Treated Leachate Infiltration (Designed)	Infiltration of Runoff and Lateral Drainage from Landfill Cap (average)	Infiltration Downgradient of Landfill [5] (average)			
			Minimum	Average	Maximum	Minimum	Average	Maximum	Units						max mass loading (leachate & effluent), average upgradient flux, average runoff & downgradient infiltration	Drinking Water (DW)	Aquatic Life (AW)
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	m3/day	640	0.00032	67	4.8	225		(mg/L)	(mg/L)
									L/day	640,000	0.32	67,000	4,800	225,000	Scenario Base Case		
GENERAL CHEMISTRY									Contaminant Masses						(mg/L)		
											Maximum	Maximum					
Alkalinity (total)	mg/L	54.7	500	1500	2500	50	150	250	mg/day	35008000	826	16750000	191450	12307500	68.6	-	-
Ammonia-N	mg/L	0.08	1	15.5	30	0.10	1.55	3	mg/day	51200	9.9	201000	280	18000	0.29	-	11.3 [a]
BOD	mg/L	2.07	10	30	50	3.5	10.5	17.5	mg/day	1324800	16.5	1172500	7245	465750	3.17	-	-
Chloride (Cl) (dissolved)	mg/L	4.15	100	800	1500	16.7	133.3	250	mg/day	2656000	495	16750000	14525	933750	21.73	250	1500
COD	mg/L	39.1	50	275	500	15	82.5	150	mg/day	25024000	165	10050000	136850	8797500	46.98	-	-
Conductivity[4]	us/cm	137	200	3850	7500	200	3850	7500	us/cm	-	-	-	-	-	595.20	-	-
Hardness	mg/L	60	750	1625	2500	750	1625	2500	mg/day	38400000	826	167500000	210000	13500000	234	-	-
pH[4]	pH units	7.86	6	7	8	6	7	8	std. units	-	-	-	-	-	7-8	-	-
Phenols	mg/L	0.0	0.005	0.0525	0.1	0.0005	0.00525	0.01	mg/day	0	0.03	670	0	0	0.00072	1	2
Sulphate (S042-)	mg/L	5.72	50	525	1000	25	263	500	mg/day	3660800	330	33500000	20020	1287000	41.06	500	2180 - 4290 [b]
Sulphide	mg/L	0.006	0.1	2.55	5	0.001	0.026	0.05	mg/day	3840	1.65	3350	21	1350	0.0091	0.05	0.02
Total Suspended Solids (TSS)	mg/L	390	10	80	150	5	40	75	mg/day	2.50E+08	49.5	5025000	1365000	87750000	367	-	-
Total Dissolved Solids (TDS)	mg/L	31	2000	6000	10000	1000	3000	5000	mg/day	19840000	3302	335000000	108500	6975000	386	-	-
Total Kjeldahl Nitrogen (TKN)	mg/L	0.143	3	31.5	60	1.05	11.03	21	mg/day	91520	19.81	1407000	501	32175	1.635	-	-
Phosphorus	mg/L	0.551	0.1	0.3	0.5	0.1	0.3	0.5	mg/day	352640	0.17	33500	1928.5	123975	0.547	-	-
HYDROCARBONS																	
HEPH	mg/L	0.0	0.5	1.25	2	0.5	1.25	2	mg/day	0	0.66	134000	0	0	0.1430	-	-
LEPH	mg/L	0.0	0.5	1.25	2	0.125	0.313	0.5	mg/day	0	0.66	33500	0	0	0.0358	-	0.5
METALS																	
Aluminum	mg/L	-	0.1	0.55	1	0.1	0.55	1		-	0.330	67000			0.07	-	-
Aluminum (Dissolved)	mg/L	0.00737	0.01	0.055	0.1	0.01	0.055	0.1	mg/day	4717	0.033	6700	25.8	1658	0.01	9.5	-
Arsenic	mg/L	-	0.001	0.0205	0.04	0.00025	0.005	0.01	mg/day	-	0.013	670				-	-
Arsenic (Dissolved)	mg/L	0.00014	0.001	0.0205	0.04	0.00025	0.005	0.01	mg/day	90	0.013	670	0.49	32	0.0008	0.01	0.05
Barium	mg/L	-	0.05	0.375	0.7	0.05	0.375	0.7	mg/day	-	0.231	46900				-	-
Barium (Dissolved)	mg/L	0.0014	0.05	0.375	0.7	0.05	0.375	0.7	mg/day	896	0.23	46900	5	315	0.051	1	10
Boron	mg/L	-	5	7.5	10	2.5	3.75	5	mg/day	-	3.30	335000				-	-
Boron (Dissolved)	mg/L	0.0	5	7.5	10	2.5	3.75	5	mg/day	0	3.30	335000	0	0	0.358	5	12
Cadmium	mg/L	-	0.0001	0.0002	0.0003	0.0001	0.0002	0.0003	mg/day	-	9.9E-05	20.1				-	-
Cadmium (Dissolved)	mg/L	0.00001	0.0001	0.0002	0.0003	0.0001	0.0002	0.0003	mg/day	6.4	9.9E-05	20.1	0.04	2	0.00003	0.005	0.0015 - 0.004 [b]
Calcium	mg/L	-	200	450	700	200	450	700	mg/day	-	231.15	46900000				-	-
Calcium (Dissolved)	mg/L	18.842	200	450	700	200	450	700	mg/day	12058880	231	46900000	65947	4239450	67.53	-	-
Chromium	mg/L	-	0.005	0.0275	0.05	0.005	0.03	0.05	mg/day	-	0.017	3350				-	-
Chromium (Dissolved)	mg/L	0.0	0.005	0.0275	0.05	0.005	0.03	0.05	mg/day	0	0.017	3350	0	0	0.00358	0.05	0.01 [c]
Cobalt	mg/L	-	0.001	0.0055	0.01	0.001	0.006	0.01	mg/day	-	0.0033	670				-	-
Cobalt (Dissolved)	mg/L	0.0	0.001	0.0055	0.01	0.001	0.006	0.01	mg/day	0	0.0033	670	0	0	0.0007	0.001	0.04
Copper	mg/L	-	0.005	0.0275	0.05	0.005	0.03	0.05	mg/day	-	0.0165	3350				-	-
Copper (Dissolved)	mg/L	0.0008	0.005	0.0275	0.05	0.005	0.03	0.05	mg/day	512	0.017	3350	2.8	180	0.0043	1.5	0.03-0.09 [b]
Iron	mg/L	-	1	35.5	70	0.09	3.3	6.5	mg/day	-	23.1	435500				-	-
Iron (Dissolved)	mg/L	0.056	0.1	3.55	7	0.09	3.3	6.5	mg/day	35840	2.3	435500	196	12600	0.52	6.5	-
Lead	mg/L	-	0.001	0.0055	0.01	0.001	0.006	0.01	mg/day	-	0.0033	670				-	-
Lead (Dissolved)	mg/L	0.0	0.001	0.0055	0.01	0.001	0.006	0.01	mg/day	0	0.0033	670	0	0	0.0007	0.01	0.05 - 0.16 [b]
Magnesium	mg/L	-	30	165	300	10	55	100	mg/day	-	99.1	6700000				-	-
Magnesium (Dissolved)	mg/L	3.28	30	165	300	10	55	100	mg/day	2099200	99.1	6700000	11480	738000	10.19	-	-
Manganese	mg/L	-	1	3	5	0.11	0.33	0.55	mg/day	-	1.7	36850				-	-
Manganese (Dissolved)	mg/L	0.03	1	3	5	0.11	0.33	0.55	mg/day	19200	1.7	36850	105	6750	0.067	1.5	-
Mercury	mg/L	-	0.00001	0.00002	0.00003	0.00001	0.00002	0.00003	mg/day	-	9.9E-06	2.01				-	-
Mercury (Dissolved)	mg/L	0.0	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	mg/day	0	3.3E-06	0.67	0.0	0	0.000001	0.001	0.00025
Molybdenum	mg/L	-	0.001	0.0015	0.002	0.001	0.0015	0.002	mg/day	-	0.0007	134				-	-
Molybdenum (Dissolved)	mg/L	0.0	0.001	0.0015	0.002	0.001	0.0015	0.002	mg/day	0	0.0007	134	0.0	0	0.0001	0.25	10
Nickel	mg/L	-	0.0075	0.01375	0.02	0.0075	0.014	0.02	mg/day	-	0.007	1340				-	-
Nickel (Dissolved)	mg/L	0.0	0.0075	0.01375	0.02	0.0075	0.014	0.02	mg/day	0	0.007	1340	0.0	0	0.0014	0.08	0.65-1.5 [b]
Selenium	mg/L	-	0.001	0.003	0.005	0.001	0.003	0.005	mg/day	-	0.0017	335				-	-
Selenium (Dissolved)	mg/L	0.0002	0.001	0.003	0.005	0.001	0.003	0.005	mg/day	128	0.002	335	0.70	45	0.0005	0.01	0.02
Silver	mg/L	-	0.0001	0.00006	0.00002	0.0001	0.00006	0.00002	mg/day	-	6.6E-06	1.34				-	-
Silver (Dissolved)	mg/L	0.0	0.0001	0.00015	0.0002	0.0001	0.00015	0.0002	mg/day	0	6.6E-05	13.4	0	0	0.00001	0.02	0.0005-0.015
Sodium	mg/L	-	100	550	1000	20	110	200	mg/day	-	330	13400000				-	-
Sodium (Dissolved)	mg/L	3.89	100	550	1000	20	110	200	mg/day	2489600	330	13400000	13615	875250	17.91	200	-
Zinc	mg/L	-	0.05	1.025	2	0.05	1.03	2	mg/day	-	0.66	134000				-	-
Zinc (Dissolved)	mg/L	0.002	0.025	0.5125	1	0.025	0.51	1	mg/day	1280	0.33	67000	7	450	0.073	3	0.075-2.4 [b]

Notes:
(1) Concentrations have been calculated using the average concentration of each sample collected from the overburden, sand and gravel aquifer between 2015 and 2017.
For the purposes of predicting the mass inputs, concentrations of 0.0 mg/L have been used whereever samples were below detection limits (ND or less than the reporting limit).
(2) Contaminant masses are calculated by multiplying the forcasted concentration by the volume of the respective source
(3) Final Forecasted Groundwater Concentrations = (sum of masses)/(sum of source volumes)
(4) The forecasted concentration approach is inappropriate for pH and conductivity.
conductivity is estimated as TDS/0.67; pH is expected to fall within the min. and max. range in pre-Landfill, leachate, or effluent.
(5) Infiltation rates used are 72% in the pit (with no vegetation) and 50% for above the pit (with vegetation) - derived from HELP modeling.
\- not analyzed or no standard/criteria available.
ND - not detected above the respective laboratory reporting limit
[a] - Limit varies with pH. Ranges are calculated using average pre-landfilling and final predicted concentrations
[b] - Limit varies with Hardness. Ranges are calculated using average pre-landfilling and final predicted concentrations
[c] - Limit is set for hexavalent chromium
(SAD)/(WAD) - strong acid dissolvable/weak acid dissolvable

exceeds the BC CSR Drinking Water (DW) Standards
exceeds the BC CSR Aquatic Life (AW) Standards

Table 13.1 C
Groundwater Compliance Forecast
Scenario 3 - Dry Season
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

Parameters	Units	Average Pre-Landfilling Concentrations (1) 2015 - 2017	Forecasted Upland Landfill Leachate Concentrations			Forecasted Upland Landfill Treated Leachate Concentrations			Contaminant Masses & Source Volumes (2)	Flux into Landfill Footprint Area (minimum)	Landfill Leakage (primary liner only)	Treated Leachate Infiltration (Designed)	Infiltration of Runoff and Lateral Drainage from Landfill Cap (dry periods)	Infiltration Downgradient of Landfill (5) (dry periods)	Final Forecasted Groundwater Concentrations (3)	BC Contaminated Site Regulation Schedule 3.2, Nov. 2017	BC Contaminated Site Regulation Schedule 3.2, Nov. 2017
			Minimum	Average	Maximum	Minimum	Average	Maximum	Units						min. upgradient flux, average mass loading (leachate & effluent), dry season runoff & downgradient infiltration	Drinking Water (DW)	Aquatic Life (AW)
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	m3/day	500	0.00032	67	1.0	73		(mg/L)	(mg/L)
									L/day	500,000	0.32	67,000	1049	73,000	Scenario Dry Season		
GENERAL CHEMISTRY										Contaminant Masses	Maximum	Maximum			(mg/L)		
Alkalinity (total)	mg/L	54.7	500	1500	2500	50	150	250	mg/day	27350000	826	16750000	95725	3993100	75.2	-	-
Ammonia-N	mg/L	0.08	1	15.5	30	0.10	1.55	3	mg/day	40000	9.9	201000	140	5840	0.39	-	11.3 [a]
BOD	mg/L	2.07	10	30	50	3.5	10.5	17.5	mg/day	1035000	16.5	1172500	3622.5	151110	3.68	-	-
Chloride (Cl) (dissolved)	mg/L	4.15	100	800	1500	16.7	133.3	250	mg/day	2075000	495	16750000	7262.5	302950	29.85	250	1500
COD	mg/L	39.1	50	275	500	15	82.5	150	mg/day	19550000	165	10050000	68425	2854300	50.73	-	-
Conductivity(4)	us/cm	137	200	3850	7500	200	3850	7500	us/cm	-	-	-	-	-	845.81	-	-
Hardness	mg/L	60	750	1625	2500	750	1625	2500	mg/day	30000000	826	167500000	105000	4380000	315.09	-	-
pH(4)	pH units	7.86	6	7	8	6	7	8	std. units	-	-	-	-	-	7-8	-	-
Phenols	mg/L	0.0	0.005	0.0525	0.1	0.0005	0.00525	0.01	mg/day	0	0.03	670	0	0	0.00105	1	2
Sulphate (S042-)	mg/L	5.72	50	525	1000	25	263	500	mg/day	2860000	330	33500000	10010	417560	57.39	500	2180 - 4290 [b]
Sulphide	mg/L	0.006	0.1	2.55	5	0.001	0.026	0.05	mg/day	3000	1.65	3350	10.5	438	0.0106	0.05	0.02
Total Suspended Solids (TSS)	mg/L	390	10	80	150	5	40	75	mg/day	1.95E+08	49.5	5025000	682500	28470000	358	-	-
Total Dissolved Solids (TDS)	mg/L	31	2000	6000	10000	1000	3000	5000	mg/day	15500000	3302	335000000	54250	2263000	550	-	-
Total Kjeldahl Nitrogen (TKN)	mg/L	0.143	3	31.5	60	1.05	11.03	21	mg/day	71500	19.81	1407000	250.25	10439	2.323	-	-
Phosphorus	mg/L	0.551	0.1	0.3	0.5	0.1	0.3	0.5	mg/day	275500	0.17	33500	964.25	40223	0.546	-	-
HYDROCARBONS																	
HEPH	mg/L	0.0	0.5	1.25	2	0.5	1.25	2	mg/day	0	0.66	134000	0	0	0.2090	-	-
LEPH	mg/L	0.0	0.5	1.25	2	0.125	0.313	0.5	mg/day	0	0.66	33500	0	0	0.0523	-	0.5
METALS																	
Aluminum	mg/L	-	0.1	0.55	1	0.1	0.55	1		-	0.330	67000				-	-
Aluminum (Dissolved)	mg/L	0.00737	0.01	0.055	0.1	0.01	0.055	0.1	mg/day	3685	0.033	6700	12.8975	538.01	0.02	9.5	-
Arsenic	mg/L	-	0.001	0.0205	0.04	0.00025	0.005	0.01	mg/day	-	0.013	670				-	-
Arsenic (Dissolved)	mg/L	0.00014	0.001	0.0205	0.04	0.00025	0.005	0.01	mg/day	70	0.013	670	0.245	10.22	0.0012	0.01	0.05
Barium	mg/L	-	0.05	0.375	0.7	0.05	0.375	0.7	mg/day	-	0.231	46900				-	-
Barium (Dissolved)	mg/L	0.0014	0.05	0.375	0.7	0.05	0.375	0.7	mg/day	700	0.23	46900	2.45	102.2	0.074	1	10
Boron	mg/L	-	5	7.5	10	2.5	3.75	5	mg/day	-	3.30	335000				-	-
Boron (Dissolved)	mg/L	0.0	5	7.5	10	2.5	3.75	5	mg/day	0	3.30	335000	0	0	0.523	5	12
Cadmium	mg/L	-	0.0001	0.0002	0.0003	0.0001	0.0002	0.0003	mg/day	-	9.9E-05	20.1				-	-
Cadmium (Dissolved)	mg/L	0.00001	0.0001	0.0002	0.0003	0.0001	0.0002	0.0003	mg/day	5.0	9.9E-05	20.1	0.0175	0.73	0.00004	0.005	0.0015 - 0.004 [b]
Calcium	mg/L	-	200	450	700	200	450	700	mg/day	-	231.15	46900000				-	-
Calcium (Dissolved)	mg/L	18.842	200	450	700	200	450	700	mg/day	9421000	231	46900000	32973.5	1375466		-	-
Chromium	mg/L	-	0.005	0.0275	0.05	0.005	0.03	0.05	mg/day	-	0.017	3350				-	-
Chromium (Dissolved)	mg/L	0.0	0.005	0.0275	0.05	0.005	0.03	0.05	mg/day	0	0.017	3350	0	0	0.00523	0.05	0.01 [c]
Cobalt	mg/L	-	0.001	0.0055	0.01	0.001	0.006	0.01	mg/day	-	0.0033	670				-	-
Cobalt (Dissolved)	mg/L	0.0	0.001	0.0055	0.01	0.001	0.006	0.01	mg/day	0	0.0033	670	0	0	0.0010	0.001	0.04
Copper	mg/L	-	0.005	0.0275	0.05	0.005	0.03	0.05	mg/day	-	0.0165	3350				-	-
Copper (Dissolved)	mg/L	0.0008	0.005	0.0275	0.05	0.005	0.03	0.05	mg/day	400	0.017	3350	1.4	58.4	0.0059	1.5	0.03-0.09 [b]
Iron	mg/L	-	1	35.5	70	0.09	3.3	6.5	mg/day	-	23.1	435500				-	-
Iron (Dissolved)	mg/L	0.056	0.1	3.55	7	0.09	3.3	6.5	mg/day	28000	2.3	435500	98	4088	0.73	6.5	-
Lead	mg/L	-	0.001	0.0055	0.01	0.001	0.006	0.01	mg/day	-	0.0033	670				-	-
Lead (Dissolved)	mg/L	0.0	0.001	0.0055	0.01	0.001	0.006	0.01	mg/day	0	0.0033	670	0	0	0.0010	0.01	0.05 - 0.16 [b]
Magnesium	mg/L	-	30	165	300	10	55	100	mg/day	-	99.1	6700000				-	-
Magnesium (Dissolved)	mg/L	3.28	30	165	300	10	55	100	mg/day	1640000	99.1	6700000	5740	239440	13.39	-	-
Manganese	mg/L	-	1	3	5	0.11	0.33	0.55	mg/day	-	1.7	36850				-	-
Manganese (Dissolved)	mg/L	0.03	1	3	5	0.11	0.33	0.55	mg/day	15000	1.7	36850	52.5	2190	0.084	1.5	-
Mercury	mg/L	-	0.00001	0.00002	0.00003	0.00001	0.00002	0.00003	mg/day	-	9.9E-06	2.01				-	-
Mercury (Dissolved)	mg/L	0.0	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	mg/day	0	3.3E-06	0.67	0	0	0.000001	0.001	0.00025
Molybdenum	mg/L	-	0.001	0.0015	0.002	0.001	0.0015	0.002	mg/day	-	0.0007	134				-	-
Molybdenum (Dissolved)	mg/L	0.0	0.001	0.0015	0.002	0.001	0.0015	0.002	mg/day	0	0.0007	134	0	0	0.0002	0.25	10
Nickel	mg/L	-	0.0075	0.01375	0.02	0.0075	0.014	0.02	mg/day	-	0.007	1340				-	-
Nickel (Dissolved)	mg/L	0.0	0.0075	0.01375	0.02	0.0075	0.014	0.02	mg/day	0	0.007	1340	0	0	0.0021	0.08	0.65-1.5 [b]
Selenium	mg/L	-	0.001	0.003	0.005	0.001	0.003	0.005	mg/day	-	0.0017	335				-	-
Selenium (Dissolved)	mg/L	0.0002	0.001	0.003	0.005	0.001	0.003	0.005	mg/day	100	0.002	335	0.35	14.6	0.0007	0.01	0.02
Silver	mg/L	-	0.0001	0.00006	0.00002	0.0001	0.00006	0.00002	mg/day	-	6.6E-06	1.34				-	-
Silver (Dissolved)	mg/L	0.0	0.0001	0.00015	0.0002	0.0001	0.00015	0.0002	mg/day	0	6.6E-05	13.4	0	0	0.00002	0.02	0.0005-0.015
Sodium	mg/L	-	100	550	1000	20	110	200	mg/day	-	330	13400000				-	-
Sodium (Dissolved)	mg/L	3.89	100	550	1000	20	110	200	mg/day	1945000	330	13400000	6807.5	283970	24.39	200	-
Zinc	mg/L	-	0.05	1.025	2	0.05	1.03	2	mg/day	-	0.66	134000				-	-
Zinc (Dissolved)	mg/L	0.002	0.025	0.5125	1	0.025	0.51	1	mg/day	1000	0.33	67000	3.5	146	0.106	3	0.075-2.4 [b]

Notes:
(1) Concentrations have been calculated using the average concentration of each sample collected from the overburden, sand and gravel aquifer between 2015 and 2017.
For the purposes of predicting the mass inputs, concentrations of 0.0 mg/L have been used whereever samples were below detection limits (ND or less than the reporting limit).
(2) Contaminant masses are calculated by multipling the forcasted concentration by the volume of the respective source
(3) Final Forecasted Groundwater Concentrations = (sum of masses)/(sum of source volumes)
(4) The forecasted concentration approach is inappropriate for pH and conductivity.
conductivity is estimated as TDS/0.67; pH is expected to fall within the min. and max. range in pre-Landfill, leachate, or effluent.
(5) Infiltation rates used are 72% in the pit (with no vegetation) and 50% for above the pit (with vegetation) - derived from HELP modeling.
\- not analyzed or no standard/criteria available.
ND - not detected above the respective laboratory reporting limit
[a] - Limit varies with pH. Ranges are calculated using average pre-landfilling and final predicted concentrations
[b] - Limit varies with Hardness. Ranges are calculated using average pre-landfilling and final predicted concentrations
[c] - Limit is set for hexavalent chromium
(SAD)/(WAD) - strong acid dissolvable/weak acid dissolvable

(pink)	exceeds the BC CSR Drinking Water (DW) Standards
(yellow)	exceeds the BC CSR Aquatic Life (AW) Standards

Table 13.1 D
Groundwater Compliance Forecast
Scenario 4 - Wet Season
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

Parameters	Units	Average Pre-Landfilling Concentrations (1) 2015 - 2017	Forecasted Upland Landfill Leachate Concentrations			Forecasted Upland Landfill Treated Leachate Concentrations			Contaminant Masses & Source Volumes (2)						Final Forecasted Groundwater Concentrations (3)	BC Contaminated Site Regulation Schedule 3.2, Nov. 2017	BC Contaminated Site Regulation Schedule 3.2, Nov. 2017
										Flux into Landfill Footprint Area (maximum)	Landfill Leakage (primary liner only)	Treated Leachate Infiltration (Designed)	Infiltration of Runoff and Lateral Drainage from Landfill Cap (wet periods)	Infiltration Downgradient of Landfill (5) (wet periods)			
			Minimum	Average	Maximum	Minimum	Average	Maximum	Units						max. upgradient flux, average mass loading (leachate & effluent), wet season runoff & downgradient infiltration	Drinking Water (DW)	Aquatic Life (AW)
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	m3/day	860	0.00032	67	6.6	430		(mg/L)	(mg/L)
									L/day	860,000	0.32	67,000	6,640	430,000	Scenario Wet Season		
GENERAL CHEMISTRY									Contaminant Masses						(mg/L)		
											Maximum	Maximum					
Alkalinity (total)	mg/L	54.7	500	1500	2500	50	150	250	mg/day	47042000	826	16750000	363208	23521000	64.3	-	-
Ammonia-N	mg/L	0.08	1	15.5	30	0.10	1.55	3	mg/day	68800	9.9	201000	531	34400	0.22	-	11.3 [a]
BOD	mg/L	2.07	10	30	50	3.5	10.5	17.5	mg/day	1780200	16.5	1172500	13744.8	890100	2.83	-	-
Chloride (Cl) (dissolved)	mg/L	4.15	100	800	1500	16.7	133.3	250	mg/day	3569000	495	16750000	27556	1784500	16.23	250	1500
COD	mg/L	39.1	50	275	500	15	82.5	150	mg/day	33626000	165	10050000	259624	16813000	44.55	-	-
Conductivity(4)	us/cm	137	200	3850	7500	200	3850	7500	us/cm	-	-	-	-	-	423.30	-	-
Hardness	mg/L	60	750	1625	2500	750	1625	2500	mg/day	51600000	826	167500000	398400	25800000	180	-	-
pH(4)	pH units	7.86	6	7	8	6	7	8	std. units	-	-	-	-	-	7-8	-	-
Phenols	mg/L	0.0	0.005	0.0525	0.1	0.0005	0.00525	0.01	mg/day	0	0.03	670	0	0	0.00049	1	2
Sulphate (S042-)	mg/L	5.72	50	525	1000	25	263	500	mg/day	4919200	330	33500000	37980.8	2459600	30.01	500	2180 - 4290 [b]
Sulphide	mg/L	0.006	0.1	2.55	5	0.001	0.026	0.05	mg/day	5160	1.65	3350	40	2580	0.0082	0.05	0.02
Total Suspended Solids (TSS)	mg/L	390	10	80	150	5	40	75	mg/day	3.35E+08	49.5	5025000	2589600	167700000	375	-	-
Total Dissolved Solids (TDS)	mg/L	31	2000	6000	10000	1000	3000	5000	mg/day	26660000	3302	335000000	205840	13330000	275	-	-
Total Kjeldahl Nitrogen (TKN)	mg/L	0.143	3	31.5	60	1.05	11.03	21	mg/day	122980	19.81	1407000	950	61490	1.168	-	-
Phosphorus	mg/L	0.551	0.1	0.3	0.5	0.1	0.3	0.5	mg/day	473860	0.17	33500	3658.64	236930	0.548	-	-
HYDROCARBONS																	
HEPH	mg/L	0.0	0.5	1.25	2	0.5	1.25	2	mg/day	0	0.66	134000	0	0	0.0983	-	-
LEPH	mg/L	0.0	0.5	1.25	2	0.125	0.313	0.5	mg/day	0	0.66	33500	0	0	0.0246	-	0.5
METALS																	
Aluminum	mg/L	-	0.1	0.55	1	0.1	0.55	1		-	0.330	67000				-	-
Aluminum (Dissolved)	mg/L	0.00737	0.01	0.055	0.1	0.01	0.055	0.1	mg/day	6338.2	0.033	6700	48.9	3169	0.01	9.5	-
Arsenic	mg/L	-	0.001	0.0205	0.04	0.00025	0.005	0.01	mg/day	-	0.013	670				-	-
Arsenic (Dissolved)	mg/L	0.00014	0.001	0.0205	0.04	0.00025	0.005	0.01	mg/day	120.4	0.013	670	0.93	60	0.0006	0.01	0.05
Barium	mg/L	-	0.05	0.375	0.7	0.05	0.375	0.7	mg/day	-	0.231	46900				-	-
Barium (Dissolved)	mg/L	0.0014	0.05	0.375	0.7	0.05	0.375	0.7	mg/day	1204	0.23	46900	9	602	0.036	1	10
Boron	mg/L	-	5	7.5	10	2.5	3.75	5	mg/day	-	3.30	335000				-	-
Boron (Dissolved)	mg/L	0.0	5	7.5	10	2.5	3.75	5	mg/day	0	3.30	335000	0	0	0.246	5	12
Cadmium	mg/L	-	0.0001	0.0002	0.0003	0.0001	0.0002	0.0003	mg/day	-	9.9E-05	20.1				-	-
Cadmium (Dissolved)	mg/L	0.00001	0.0001	0.0002	0.0003	0.0001	0.0002	0.0003	mg/day	8.6	9.9E-05	20.1	0.07	4	0.00002	0.005	0.0015 - 0.004 [b]
Calcium	mg/L	-	200	450	700	200	450	700	mg/day	-	231.15	46900000				-	-
Calcium (Dissolved)	mg/L	18.842	200	450	700	200	450	700	mg/day	16204120	231	46900000	125111	8102060	52.31	-	-
Chromium	mg/L	-	0.005	0.0275	0.05	0.005	0.03	0.05	mg/day	-	0.017	3350				-	-
Chromium (Dissolved)	mg/L	0.0	0.005	0.0275	0.05	0.005	0.03	0.05	mg/day	0	0.017	3350	0	0	0.00246	0.05	0.01 [c]
Cobalt	mg/L	-	0.001	0.0055	0.01	0.001	0.006	0.01	mg/day	-	0.0033	670				-	-
Cobalt (Dissolved)	mg/L	0.0	0.001	0.0055	0.01	0.001	0.006	0.01	mg/day	0	0.0033	670	0	0	0.0005	0.001	0.04
Copper	mg/L	-	0.005	0.0275	0.05	0.005	0.03	0.05	mg/day	-	0.0165	3350				-	-
Copper (Dissolved)	mg/L	0.0008	0.005	0.0275	0.05	0.005	0.03	0.05	mg/day	688	0.017	3350	5.3	344	0.0032	1.5	0.03-0.09 [b]
Iron	mg/L	-	1	35.5	70	0.09	3.3	6.5	mg/day	-	23.1	435500				-	-
Iron (Dissolved)	mg/L	0.056	0.1	3.55	7	0.09	3.3	6.5	mg/day	48160	2.3	435500	372	24080	0.37	6.5	-
Lead	mg/L	-	0.001	0.0055	0.01	0.001	0.006	0.01	mg/day	-	0.0033	670				-	-
Lead (Dissolved)	mg/L	0.0	0.001	0.0055	0.01	0.001	0.006	0.01	mg/day	0	0.0033	670	0	0	0.0005	0.01	0.05 - 0.16 [b]
Magnesium	mg/L	-	30	165	300	10	55	100	mg/day	-	99.1	6700000				-	-
Magnesium (Dissolved)	mg/L	3.28	30	165	300	10	55	100	mg/day	2820800	99.1	6700000	21779	1410400	8.03	-	-
Manganese	mg/L	-	1	3	5	0.11	0.33	0.55	mg/day	-	1.7	36850				-	-
Manganese (Dissolved)	mg/L	0.03	1	3	5	0.11	0.33	0.55	mg/day	25800	1.7	36850	199	12900	0.056	1.5	-
Mercury	mg/L	-	0.00001	0.00002	0.00003	0.00001	0.00002	0.00003	mg/day	-	9.9E-06	2.01				-	-
Mercury (Dissolved)	mg/L	0.0	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	mg/day	0	3.3E-06	0.67	0.0	0	0.000000	0.001	0.00025
Molybdenum	mg/L	-	0.001	0.0015	0.002	0.001	0.0015	0.002	mg/day	-	0.0007	134				-	-
Molybdenum (Dissolved)	mg/L	0.0	0.001	0.0015	0.002	0.001	0.0015	0.002	mg/day	0	0.0007	134	0.0	0	0.0001	0.25	10
Nickel	mg/L	-	0.0075	0.01375	0.02	0.0075	0.014	0.02	mg/day	-	0.007	1340				-	-
Nickel (Dissolved)	mg/L	0.0	0.0075	0.01375	0.02	0.0075	0.014	0.02	mg/day	0	0.007	1340	0.0	0	0.0010	0.08	0.65-1.5 [b]
Selenium	mg/L	-	0.001	0.003	0.005	0.001	0.003	0.005	mg/day	-	0.0017	335				-	-
Selenium (Dissolved)	mg/L	0.0002	0.001	0.003	0.005	0.001	0.003	0.005	mg/day	172	0.002	335	1.33	86	0.0004	0.01	0.02
Silver	mg/L	-	0.0001	0.00006	0.00002	0.0001	0.00006	0.00002	mg/day	-	6.6E-06	1.34				-	-
Silver (Dissolved)	mg/L	0.0	0.0001	0.00015	0.0002	0.0001	0.00015	0.0002	mg/day	0	6.6E-05	13.4	0	0	0.00001	0.02	0.0005-0.015
Sodium	mg/L	-	100	550	1000	20	110	200	mg/day	-	330	13400000				-	-
Sodium (Dissolved)	mg/L	3.89	100	550	1000	20	110	200	mg/day	3345400	330	13400000	25830	1672700	13.53	200	-
Zinc	mg/L	-	0.05	1.025	2	0.05	1.03	2	mg/day	-	0.66	134000				-	-
Zinc (Dissolved)	mg/L	0.002	0.025	0.5125	1	0.025	0.51	1	mg/day	1720	0.33	67000	13	860	0.051	3	0.075-2.4 [b]

Notes:
(1) Concentrations have been calculated using the average concentration of each sample collected from the overburden, sand and gravel aquifer between 2015 and 2017.
For the purposes of predicting the mass inputs, concentrations of 0.0 mg/L have been used whereever samples were below detection limits (ND or less than the reporting limit).
(2) Contaminant masses are calculated by multipling the forcasted concentration by the volume of the respective source
(3) Final Forecasted Groundwater Concentrations = (sum of masses)/(sum of source volumes)
(4) The forecasted concentration approach is inappropriate for pH and conductivity.
conductivity is estimated as TDS/0.67; pH is expected to fall within the min. and max. range in pre-Landfill, leachate, or effluent.
(5) Infiltation rates used are 72% in the pit (with no vegetation) and 50% for above the pit (with vegetation) - derived from HELP modeling.
\- not analyzed or no standard/criteria available.
ND - not detected above the respective laboratory reporting limit
[a] - Limit varies with pH. Ranges are calculated using average pre-landfilling and final predicted concentrations
[b] - Limit varies with Hardness. Ranges are calculated using average pre-landfilling and final predicted concentrations
[c] - Limit is set for hexavalent chromium
(SAD)/(WAD) - strong acid dissolvable/weak acid dissolvable
exceeds the BC CSR Drinking Water (DW) Standards
exceeds the BC CSR Aquatic Life (AW) Standards

Table 14.1

Well, Borehole and Test Pit Completion Details
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

Monitoring ID	Installation Date	Completed By	Borehole Depth (mBGS)	Easting	Northing	2015 Reference Elevation Ground Surface (mAMSL)[2]	2015 Reference Elevation TOR (mAMSL)[2]	2017 Reference Elevation Ground Surface (mAMSL)[1]	2017 Reference Elevation TOR (mAMSL)[1]	Stick-up (m)	Screened Interval (mBGS)		Screen Interval (mAMSL)		Screen Length (m)	Well Diameter (mm)	Primary Constinuent of Completed Unit
Date:																	
MW1-14	12/4/2014	RWD	10.97	330788.539	5541791.638	154.5	172.9	-	-	1.1	11.0	4.9	160.8	149.6	6.1	50.8	Sand/gravel
MW2-14	12/4/2014	RWD	21.64	330961.402	5541591.181	155.8	156.5	-	-	0.8	21.6	15.5	151.4	140.2	6.1	50.8	Sand/gravel
MW2A-16	1/27/2016	Drillwell	45.42	330964.560	5541591.419	155.8	156.6	173.1	173.9	0.8	40.5	37.5	132.6	118.3	6.1	50.8	Sand
MW3-14	12/4/2014	RWD	18.59	330885.439	5541429.793	150.3	151.3	-	-	1.0	17.4	11.3	150.2	139.0	6.1	50.8	Sand/gravel
MW4A-15	8/5/2015	Blue Max	21.33	330737.351	5541583.042	151.2	152.0	-	-	0.8	21.4	19.8	147.2	131.4	1.5	50.8	Bedrock
MW4B-15	8/5/2015	Blue Max	18.28	330743.926	5541575.024	151.1	152.0	-	-	0.9	18.3	15.2	150.1	135.9	3.0	50.8	Sand
MW5A-15	8/7/2015	Blue Max	10.66	330675.167	5541325.831	174.0	174.6	-	-	0.6	10.7	9.1	180.6	164.8	1.5	50.8	Bedrock
MW5B-15	8/7/2015	Blue Max	8.23	330685.323	5541325.831	191.3	174.7	-	-	1.7	7.9	4.9	182.4	186.4	3.0	50.8	Sand/Silt with clay
MW6-17	3/22/2017	Drillwell	11.89	330407.086	5541753.092	-	-	185.5	185.4	-0.1	11.3	9.8	174.2	175.7	1.5	50.8	Sand
MW7-17	3/14/2017	Drillwell	5.03	330266.457	5541691.359	-	-	186.9	187.5	0.7	4.3	2.7	182.6	184.1	1.5	50.8	Gravel
MW8-17	2/22/2017	Blue Max	28.96	330544.895	5541828.138	-	-	191.3	192.5	1.2	18.8	15.8	172.5	175.5	3.0	50.8	Gravel
MW9-17	3/14/2017	Drillwell	33.53	330744.892	5541911.675	-	-	190.9	191.7	0.8	33.5	30.5	157.3	160.4	3.0	50.8	Sand/gravel
MW10-17	3/27/2017	Drillwell	47.87	331208.625	5541441.665	-	-	188.2	189.1	0.8	46.3	43.2	142.0	145.0	3.0	50.8	Sand
RW-98020	5/13/2008	RWD	60.96	330012.000	5541724.000	178.3	179.6	-	-	1.3	61.0	1.8	134.7	176.5	41.8	152.4	Bedrock
BH1-16	1/27/2016	Drillwell	24.08	330846.010	5541551.180	168.41	-	-	-	-	-	-	-	-	-	-	Bedrock
BH2-16	1/28/2016	Drillwell	16.46	330839.010	5541470.180	167.83	-	-	-	-	-	-	-	-	-	-	Bedrock
BH5-15	8/6/2015	Blue Max	24.38	330765.701	5541327.331	ns	-	-	-	-	-	-	-	-	-	-	Sand/gravel
TP1-17	3/23/2017	Upland	4.57	330375.872	5541665.807	-	-	182.14	-	-	-	-	-	-	-	-	Sand with gravel
TP2-17	3/23/2017	Upland	2.44	330340.223	5541649.458	-	-	182.78	-	-	-	-	-	-	-	-	Bedrock
TP3-17	3/23/2017	Upland	5.49	330445.9487	5541608.703	-	-	182.61	-	-	-	-	-	-	-	-	Bedrock
TP4-17	3/23/2017	Upland	4.11	330471.1766	5541750.688	-	-	191.23	-	-	-	-	-	-	-	-	Sand with gravel
TP5-17	3/23/2017	Upland	5.64	330467.1592	5541418.59	-	-	189.44	-	-	-	-	-	-	-	-	Silty Sand
TP6-17	3/24/2017	Upland	5.79	330407.0856	5541753.092	-	-	191.89	-	-	-	-	-	-	-	-	Sand with gravel
TP7-17	3/24/2017	Upland	6.40	330509.0192	5541457.215	-	-	191.82	-	-	-	-	-	-	-	-	Sand with gravel
TP8-17	3/24/2017	Upland	3.35	330492.9906	5541417.832	-	-	192.15	-	-	-	-	-	-	-	-	Bedrock
TP9-17	3/24/2017	Upland	0.61	330535.6659	5541369.794	-	-	191.99	-	-	-	-	-	-	-	-	Bedrock

Notes:
1 - Surveys completed by McElhanney on April 6, 2016 and March 16 and 31, 2017
2 - Survey completed by Upland Excavating Ltd. on January 29th, 2015, March 8, 2016 and April 6th, 2016. Elevations measured with respect to AMSL.
mBGS - metres below ground surface
mAMSL - metres above mean sea level
TOR - top of riser
ns - not surveyed
RWD - Red Williams Well Drilling Ltd.
Upland - Upland Excavating Ltd.
Drillwell - Drillwell Enterprises Ltd.
Blue Max - Blue Max Drilling Inc.

Table 14.2

Hydraulic Monitoring Results
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

Monitoring ID	Borehole Depth (m BGS)	2015/2016 Reference Elevation TOR (m AMSL)[2]	2017 Reference Elevation TOR (m AMSL)[1]	Depth to Water (m BTOR)									Water Elevation (m AMSL)											Hydraulic Conductivity (cm/s)	Screened Unit/Aquifer
Date:				**11-Sep-15**	**17-Sep-15**	**5-Oct-15**	**25-Jan-16**	**29-Jan-16**	**15-Feb-16**	**8-Mar-16**	**15-Mar-17**	**6-Apr-17**	**11-Sep-15**	**17-Sep-15**	**5-Oct-15**	**25-Jan-16**	**29-Jan-16**	**15-Feb-16**	**8-Mar-16**	**6-Apr-16**	**15-Mar-17**	**6-Apr-17**		**Primary Constituent**
MW1-14	10.97	172.9	-	5.6	6.3	6.1	6.0	-	-	-	8.1	7.7	167.3	166.6	166.9	166.9	-	-	-	-	164.8	165.2	-	Sand/gravel (S&G Aquifer
MW2-14	21.64	173.8	-	14.5	14.7	15.2	14.7	-	14.6	-	15.9	15.8	159.4	159.1	158.6	159.1	-	159.3	-	-	158.0	158.0	-	Sand/gravel (S&G Aquifer)
MW2A-16	45.42	173.9	173.9	-	-	-	14.5	-	14.5	-	15.9	15.8	-	-	-	159.3	-	159.3	-	-	158.0	158.1	-	Sand (S&G Aquifer)
MW3-14	18.59	168.6	-	12.8	12.7	12.8	11.3	-		-	12.1	12.1	155.8	155.9	155.8	157.2	-	-	-	-	156.5	156.4	-	Sand/gravel (S&G Aquifer)
MW4A-15	21.33	169.3	-	3.9	4.3	4.9	4.0	-	-	-	5.7	3.4	165.4	165.0	164.4	165.3	-	-	-	-	163.6	165.9	2.2×10^{-2}	Bedrock (S&G Aquifer)
MW4B-15	18.28	169.3	-	4.1	4.5	5.1	4.2	-	-	-	5.9	5.7	165.2	164.8	164.1	165.0	-	-	-	-	163.3	163.6	2.0×10^{-2}	Sand (S&G Overburden)
MW5A-15	10.66	191.9	-	9.0	9.0	8.3	7.3	-	-	-	8.1	7.7	182.9	182.9	183.6	184.6	-	-	-	-	183.8	184.2	1.4×10^{-5}	Bedrock Ridge (S&G Aquifer)
MW5B-15	8.22	192.0	-	7.1	7.2	7.0	5.4	-	-	-	7.1	6.1	184.9	184.9	185.0	186.6	-	-	-	-	184.9	185.9	-	Sand/Silt with clay (S&G Aquifer)
MW6-17	11.28	-	185.4	-	-	-	-	-	-	-	-	7.5	-	-	-	-	-	-	-	-	-	177.9	-	Sand (S&G Aquifer)
MW7-17	4.29	-	187.5	-	-	-	-	-	-	-	3.3	2.9	-	-	-	-	-	-	-	-	184.2	184.6	-	Gravel (Shallow Aquifer)
MW8-17	18.80	-	192.5	-	-	-	-	-	-	-	19.7	19.7	-	-	-	-	-	-	-	-	172.8	172.8	-	Gravel (S&G Aquifer)
MW9-17	33.54	-	191.7	-	-	-	-	-	-	-	24.8	24.4	-	-	-	-	-	-	-	-	166.8	167.2	-	Sand/gravel (S&G Aquifer)
MW10-17	46.25	-	189.1	-	-	-	-	-	-	-	-	39.0	-	-	-	-	-	-	-	-	-	150.1	-	Sand (S&G Aquifer)
RW-98020	60.96	196.9	-	-	-	-	-	-	17.1	-	-	-	-	-	-	-	-	179.9	-	-	-	-	-	Bedrock Ridge
McIvor Lake	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	177.5[3]	-	177.9[2]	177.0[2]	177.6[3]	177.6[3]	-	-
SW15-02 Rico Lake	-	180.33*		-	-	-	-	0.88	-	0.91	0.06	0.09	-	-	-	-	181.2	-	181.2[2]	180.8[2]	180.4	180.4	-	-

Notes:
1 - Surveys completed by McElhanney on April 6, 2016 and March 16 and 31, 2017
2 - Survey completed by Upland Excavating Ltd. on January 29th, 2015, March 8, 2016 and April 6th, 2016. Elevations measured with respect to AMSL.
3 - Based on BC Hydro record of water elevations at Ladore Dam recorded every three hours. (https://www.bchydro.com/energy-in-bc/our_system/transmission_reservoir_data/previous_reservoir_elevations/vancouver_island/ladore_ldr.html)

* Surface water gauge reference elevation refers to the bottom of the gauge. (0 m on gauge = 180.33 m amsl)
m BGS - metres below ground surface
m AMSL - metres above mean sea level (WGS1984)
TOR - top of riser
S&G - Sand and gravel

Drawings

UPLAND EXCAVATING LTD.
CAMPBELL RIVER, B.C.

NORTHWIN LANDFILL
2021 DESIGN, OPERATIONS AND CLOSURE PLAN
JUNE 2021

LOCATION MAP

DRAWING LIST

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N
0 250 500 750m

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CAMPBELL RIVER, B.C.

Project
2021 DESIGN, OPERATIONS, AND CLOSURE PLAN

No.	Issue	Drawn	Approved	Date
1	ISSUED FOR REVIEW	D.C.	D.L.	06-08-2020

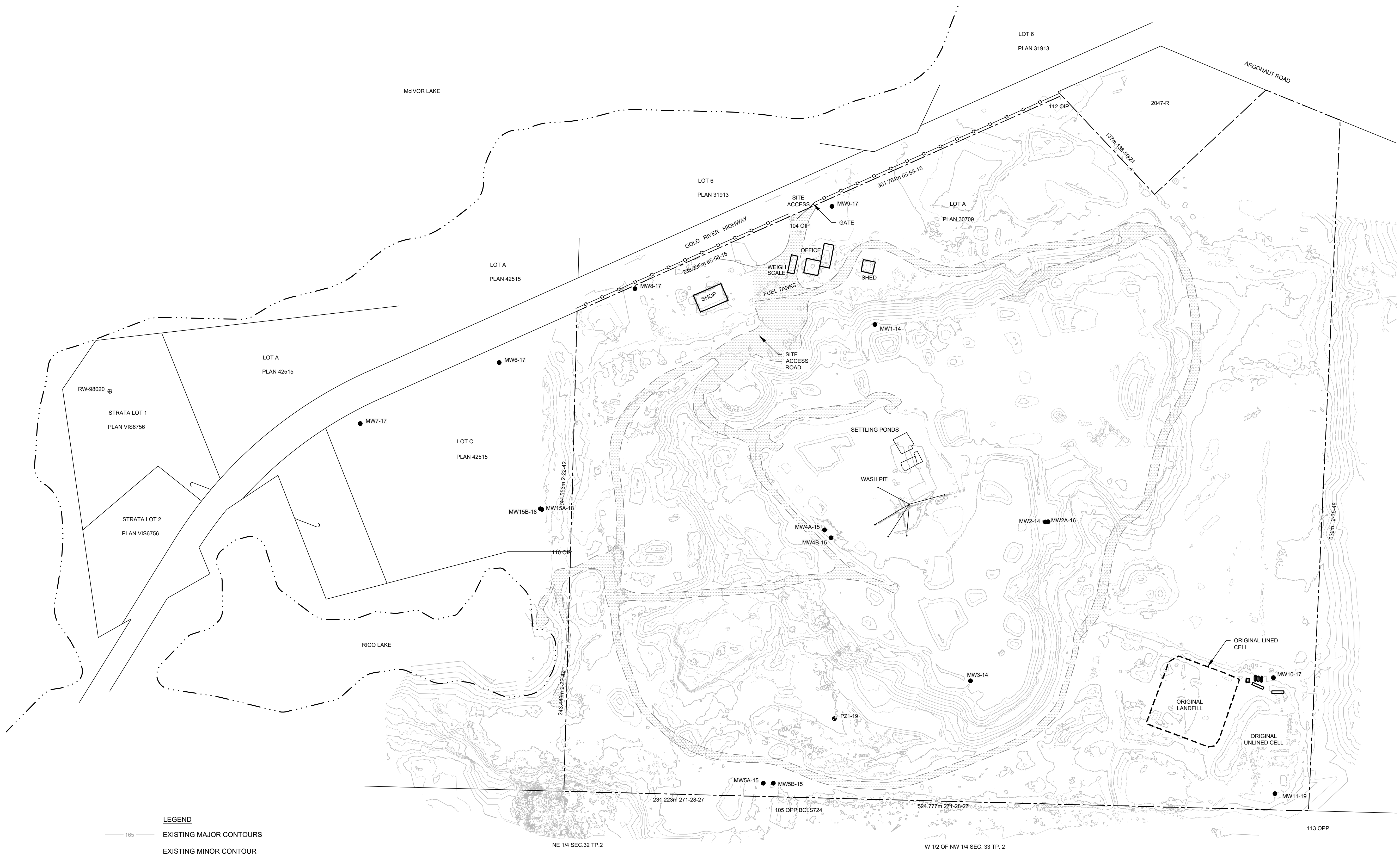
Drawn T.WAGSTAFF	Designer R. HASIOR
Drafting Check	Design Check
Project Manager D. LIDDY	Date Jun 10, 2016
This document shall not be used for construction unless signed and sealed for construction.	Scale 1:25000
Original Size ANSI D	Bar is 20mm on original size drawing 0 20mm

Project No. 88877-11

Title
COVER

Sheet No.
G-01

Sheet 1 of 20



LEGEND

- 165 — EXISTING MAJOR CONTOURS
- EXISTING MINOR CONTOUR
- PROPERTY LINE
- EXISTING LAKE SHORELINE
- EXISTING FENCELINE
- EXISTING ACCESS ROADWAY
- MW3-14 EXISTING MONITORING WELLS

SOURCE: TOPOGRAPHICAL SURVEY CONDUCTED BY McELHANNEY ASSOCIATES LAND SURVEYING LTD. ,MARCH 2020 AND SEPTEMBER 2020.

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CAMPBELL RIVER, B.C.**

Project
2021 DESIGN, OPERATIONS AND CLOSURE PLAN

No.	Issue	Drawn	Approved	Date
1	ISSUED FOR REVIEW	D.C.	D.L.	06-08-2020

Drawn	T. WAGSTAFF	Designer	R. HASIOR
Drafting Check		Design Check	
Project Manager	D. LIDDY	Date	July 2, 2021
This document shall not be used for construction unless signed and sealed for construction.		Scale	1:2000
Original Size	ANSI D	Bar is 20mm on original size drawing 0 20mm	

Project No. 88877-11

Title

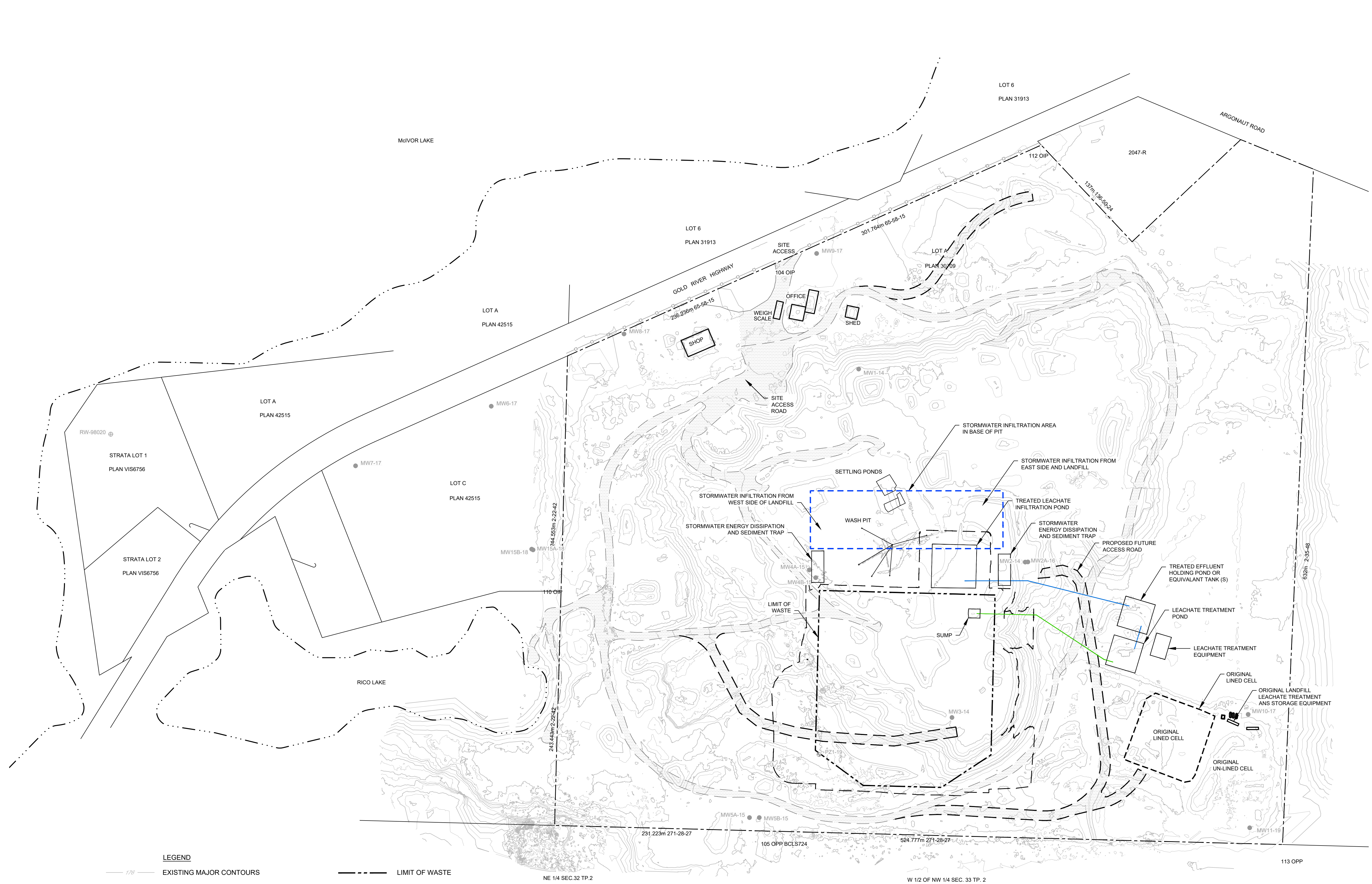
EXISTING CONDITIONS

Sheet No.

C-01

Sheet 2 of 20

Plot Date: 2 July 2021 - 9:25 AM Plotted By: Tyler Wagstaff CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-11(014)\88877-11(014)CI\88877-11(014)CI-WA001.dwg



LEGEND

	EXISTING MAJOR CONTOURS		LIMIT OF WASTE
	EXISTING MINOR CONTOUR		LIMIT OF EXCAVATION
	PROPERTY LINE		LEACHATE CONVEYANCE PIPE
	EXISTING LAKE SHORELINE		TREATED EFFLUENT CONVEYANCE PIPE
	EXISTING ACCESS ROADWAY		EXISTING FENCELINE
	PROPOSED FUTURE ACCESS ROADWAY	MW3-14	EXISTING MONITORING WELL
		PZ1-19	EXISTING PIEZOMETER

SOURCE: TOPOGRAPHICAL SURVEY CONDUCTED BY McELHANNEY ASSOCIATES LAND SURVEYING LTD. ,MARCH 2020 AND SEPTEMBER 2020.

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PROVINCE OF
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33360
BRITISH COLUMBIA
ENGINEER
2021-07-08

0 20 40 60m

Client
UPLAND EXCAVATING LTD.
CAMPBELL RIVER, B.C.

Project
2021 DESIGN, OPERATIONS AND CLOSURE PLAN

No.	Issue	Drawn	Approved	Date
1	ISSUED FOR REVIEW	D.C.	D.L.	06-08-2020

Drawn	T. WAGSTAFF	Designer	R. HASIOR
Drafting Check		Design Check	
Project Manager	D. LIDDY	Date	July 2, 2021
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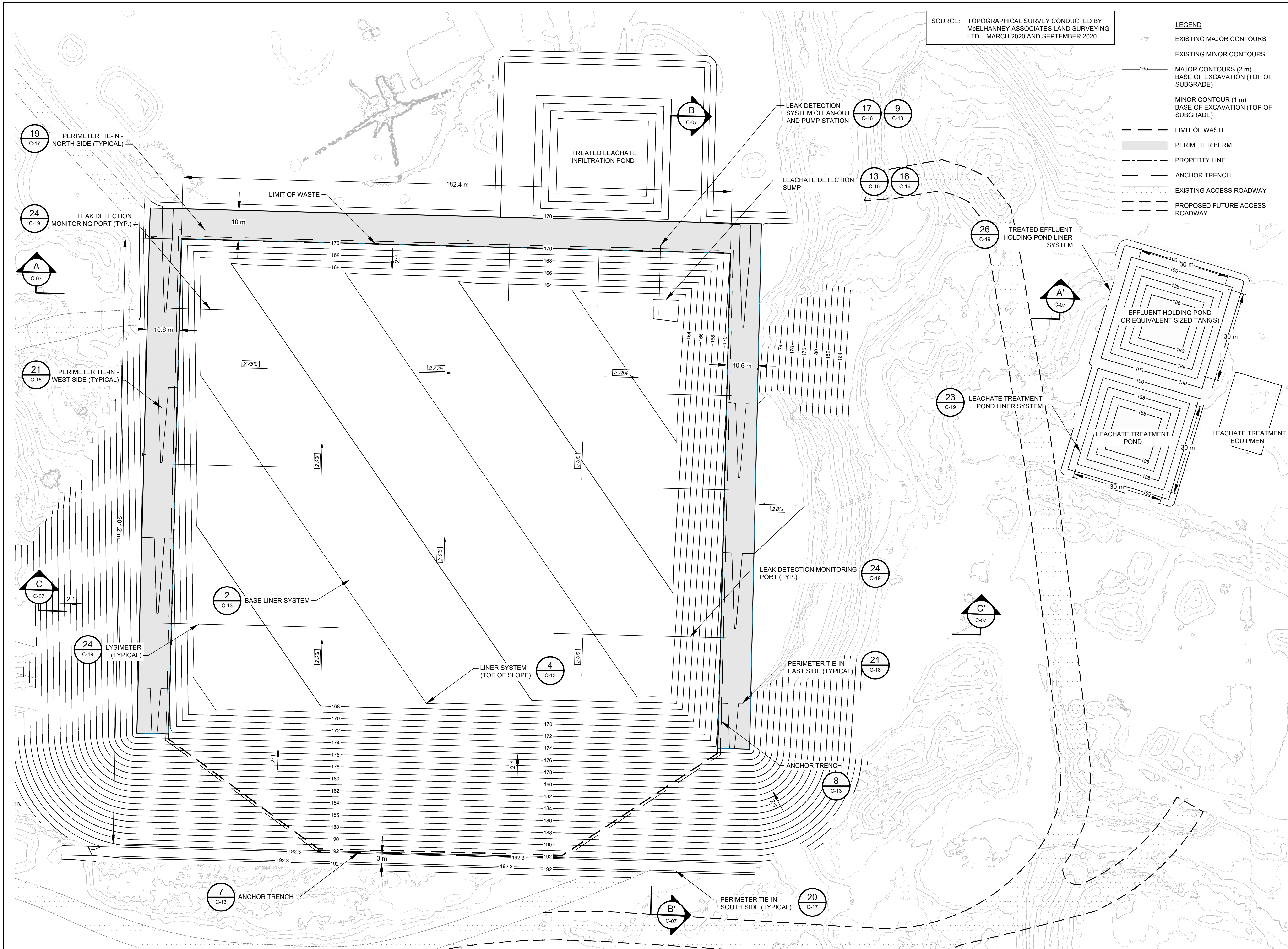
Original Size	ANSI D	Bar is 20mm on original size drawing 0 20mm	

Project No. 88877-11

Title
SITE OPERATIONS

Sheet No.
C-02

Sheet 3 of 20



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PROVINCE OF BRITISH COLUMBIA
D. J. LIDDY
33360
2021-07-08

Client
UPLAND EXCAVATING LTD.
CAMPBELL RIVER, B.C.

Project
2021 DESIGN, OPERATIONS AND CLOSURE PLAN

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1	ISSUED FOR REVIEW	D.C.	D.L.	06-08-2020

Drawn T.WAGSTAFF — Designer R. HASIOR
Drafting Check — Design Check
Project Manager D. LIDDY — Date July 5, 2021
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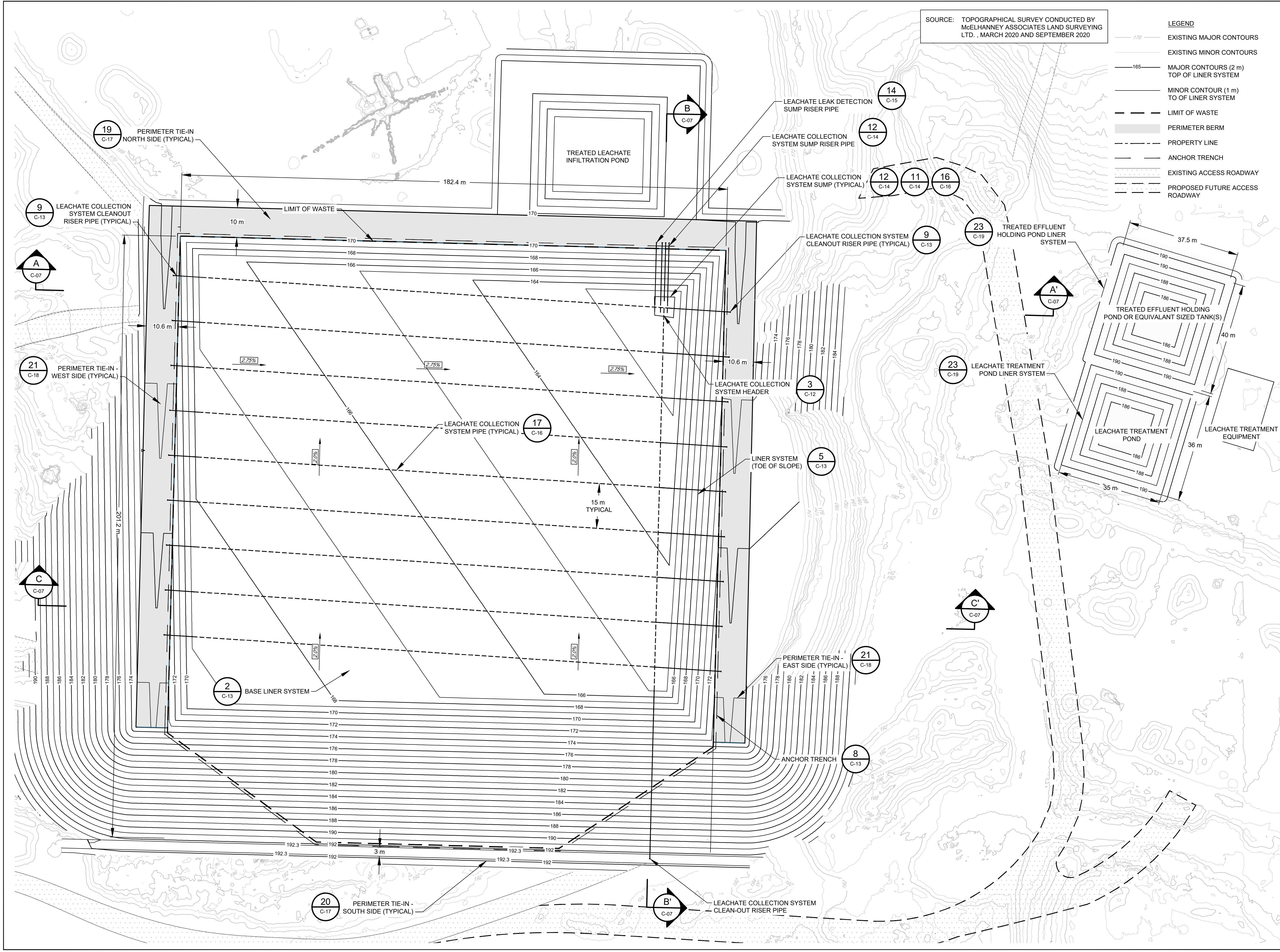
Project No. 88877-11

Title
BASE GRADES AND LEAK DETECTION SYSTEM

Sheet No.
C-03

Plot Date: 5 July 2021 - 5:09 PM Plotted By: Tyler Wagstaff CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-11(014)\88877-11(014)CI\88877-11(014)CI-WA003.dwg



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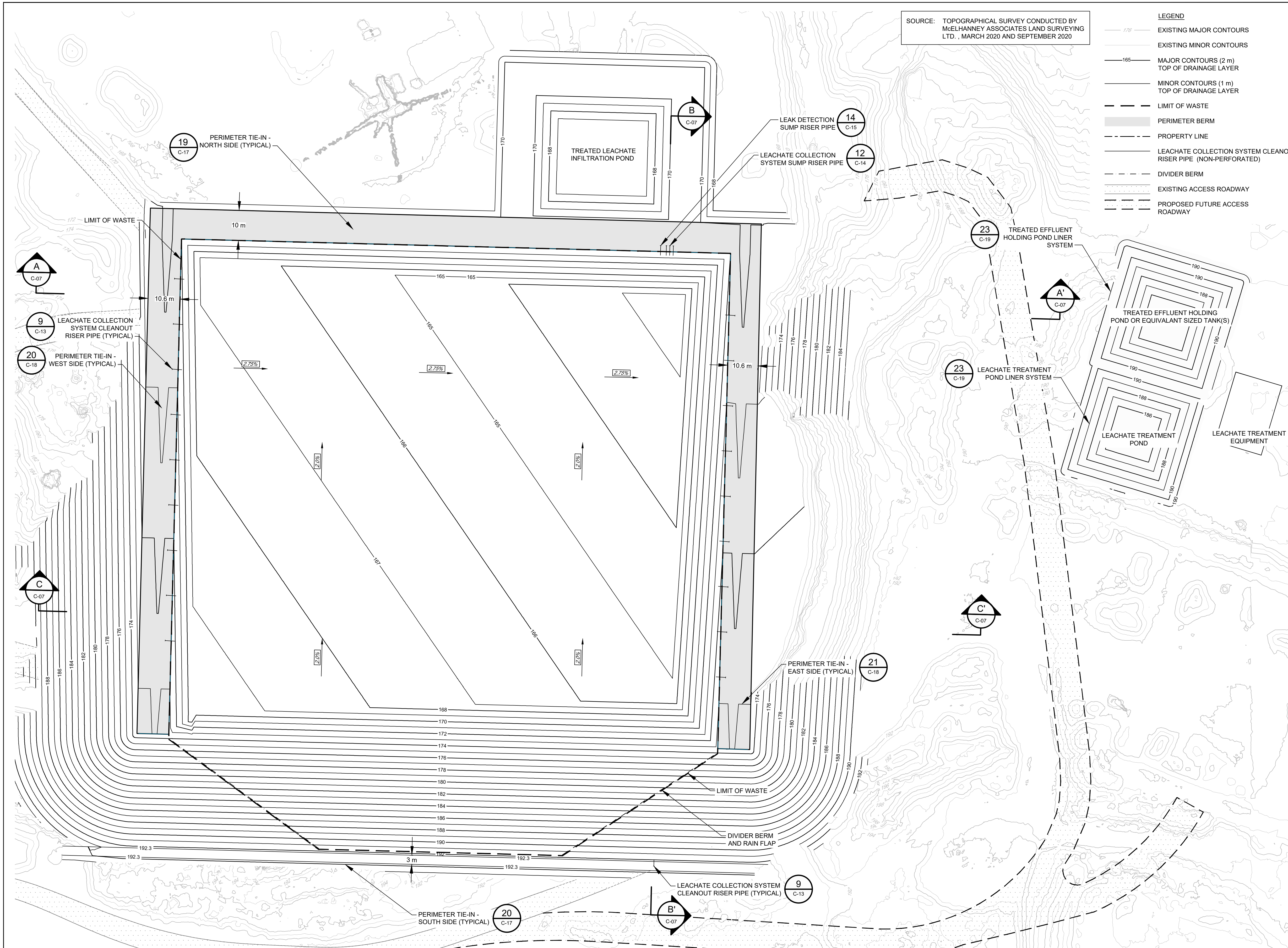
Project No. 88877-11

Title
LEACHATE COLLECTION SYSTEM

Sheet No.
C-04

Sheet 5 of 20

Plot Date: 5 July 2021 - 5:12 PM Plotted By: Tyler Wagstaff CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-11(014)\88877-11(014)CI\88877-11(014)CI-WA004.dwg



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2021 DESIGN, OPERATIONS AND CLOSURE PLAN

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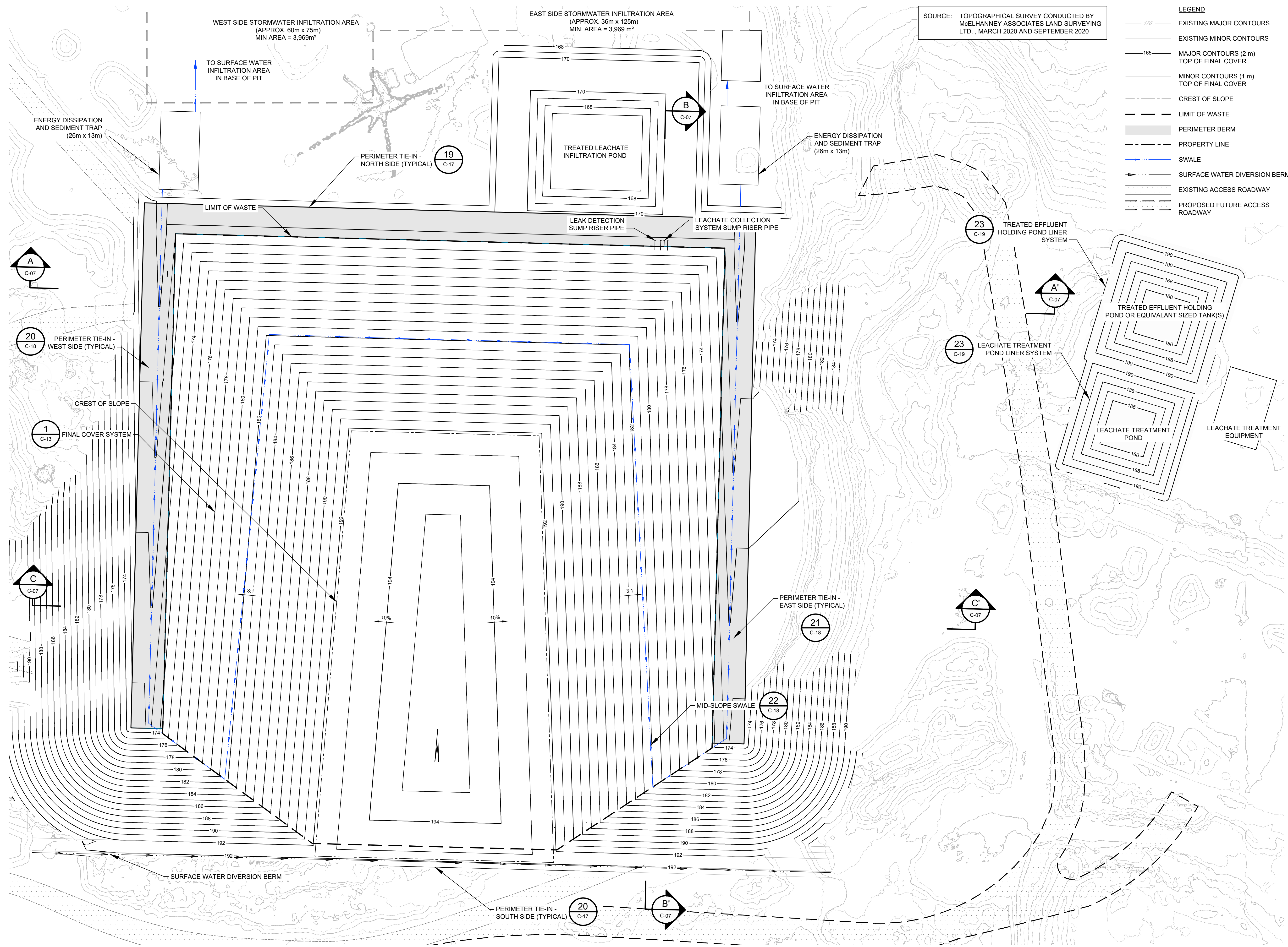
Project No. 88877-11

Title
LEACHATE COLLECTION SYSTEM TOP OF DRAINAGE LAYER

Sheet No.
C-05

Sheet 6 of 20

Plot Date: 5 July 2021 - 5:16 PM Plotted By: Tyler Wagstaff CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-11(014)\88877-11(014)CI\88877-11(014)CI-WA005.dwg



SOURCE: TOPOGRAPHICAL SURVEY CONDUCTED BY McELHANNEY ASSOCIATES LAND SURVEYING LTD. , MARCH 2020 AND SEPTEMBER 2020

LEGEND

- EXISTING MAJOR CONTOURS
- EXISTING MINOR CONTOURS
- MAJOR CONTOURS (2 m) TOP OF FINAL COVER
- MINOR CONTOURS (1 m) TOP OF FINAL COVER
- CREST OF SLOPE
- LIMIT OF WASTE
- PERIMETER BERM
- PROPERTY LINE
- SWALE
- SURFACE WATER DIVERSION BERM
- EXISTING ACCESS ROADWAY
- PROPOSED FUTURE ACCESS ROADWAY

0 6 12 18m

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Project
2021 DESIGN, OPERATIONS, AND CLOSURE PLAN

No.	Issue	Drawn	Approved	Date
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Project Manager	D. LIDDY	Date	July 5, 2021
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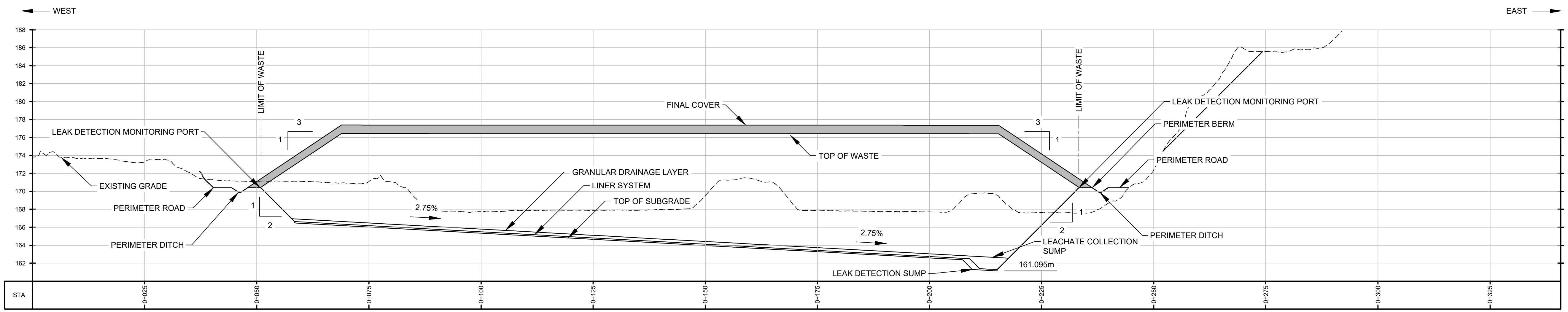
Project No. 88877-11

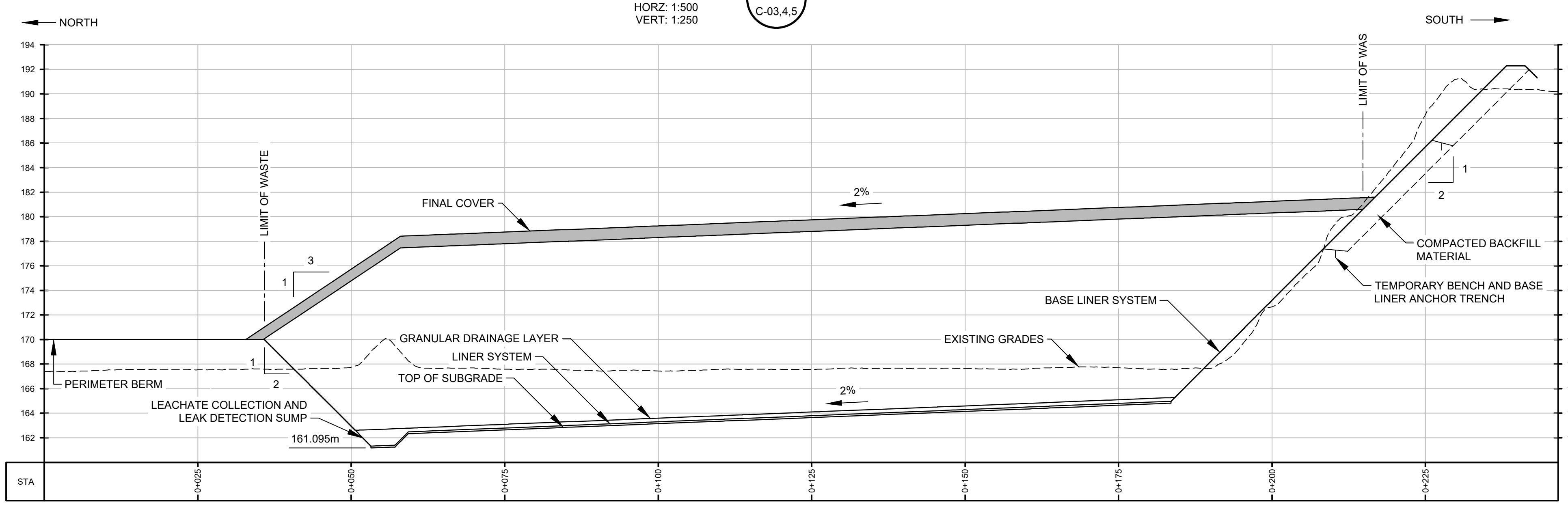
Title
FINAL GRADES (TOP OF FINAL COVER)

Sheet No.
C-06

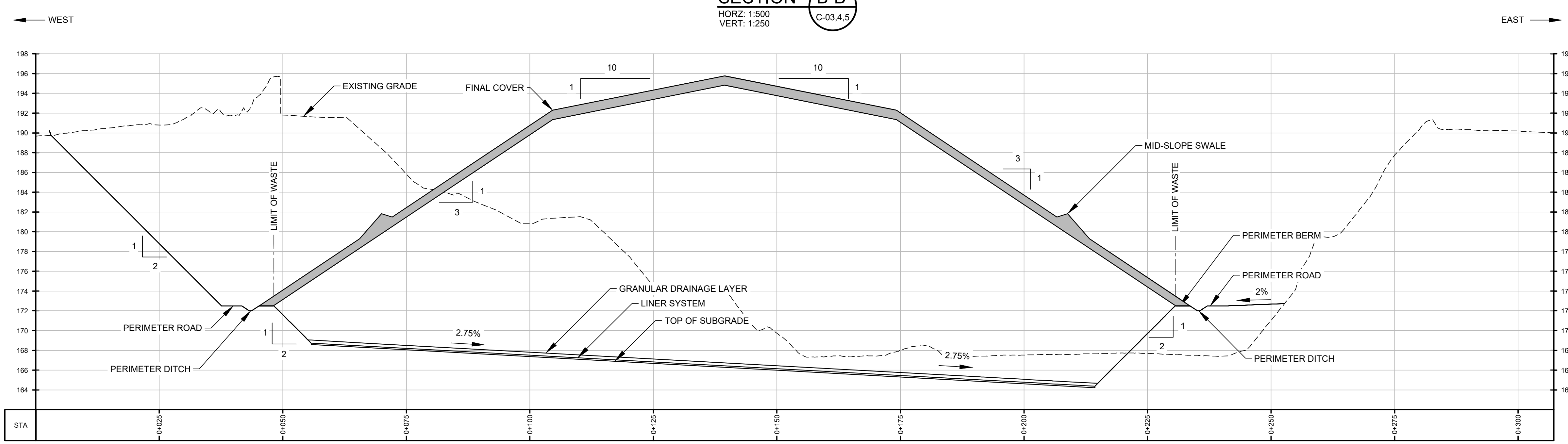
Sheet 7 of 20



SECTION A-A'
HORZ: 1:500
VERT: 1:250
C-03,4,5



SECTION B-B'
HORZ: 1:500
VERT: 1:250
C-03,4,5



SECTION C-C'
HORZ: 1:500
VERT: 1:250
C-03,4,5

SOURCE: TOPOGRAPHICAL SURVEY CONDUCTED BY McELHANNEY ASSOCIATES LAND SURVEYING LTD. , DECEMBER 18, 2018.

Plot Date: 5 July 2021 - 5:38 PM   Plotted By: Tyler Wagstaff   CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-11(014)\88877-11(014)CI\88877-11(014)CI-WA007.dwg

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Client
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Project
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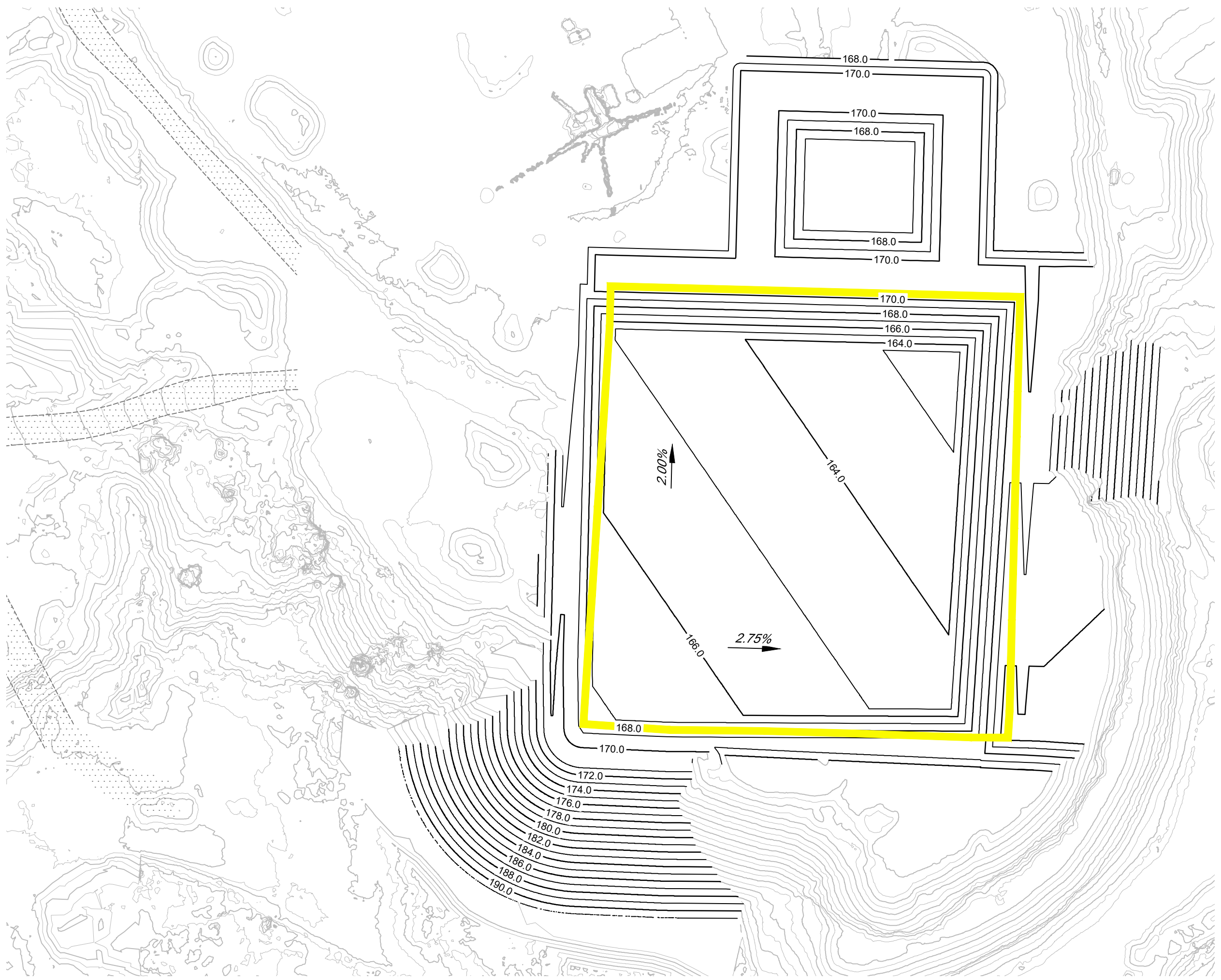
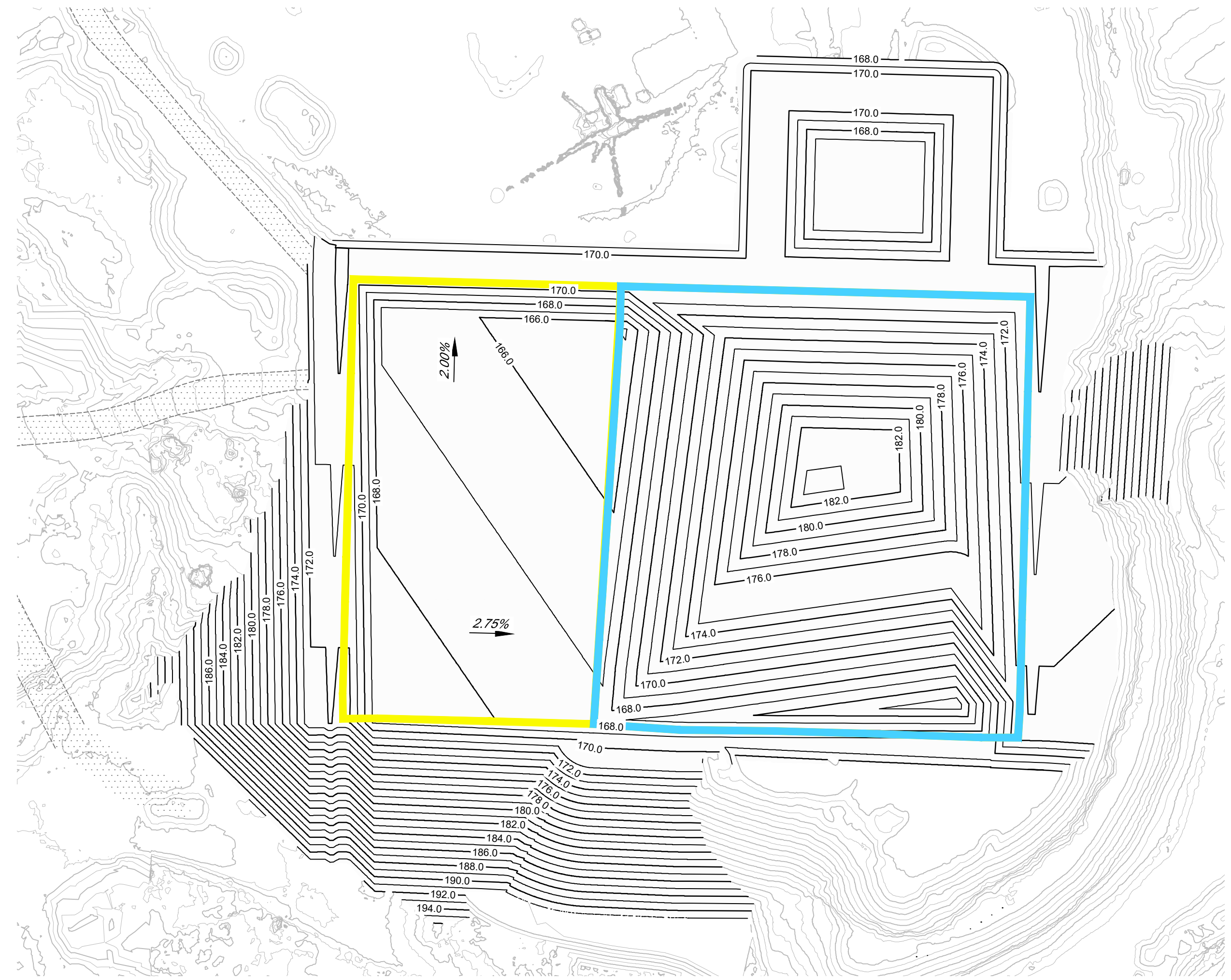
Project No. 88877-11

Title
**CROSS-SECTIONS
A-A', B-B' AND C-C'**

Sheet No.
C-07



STAGE 1 EAST BASE LINER INSTALLATION



PHASE I: STAGE 1 EAST
(INCLUDING RELOCATION OF WASTE FROM ORIGINAL LANDFILL)
FILL VOLUME = 106,337 m³

LEGEND

- BASE LINER PREPARATION / CONSTRUCTION FOR NEXT STAGE
- DAILY COVER AREA
- INTERMEDIATE COVER AREA

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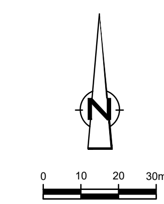

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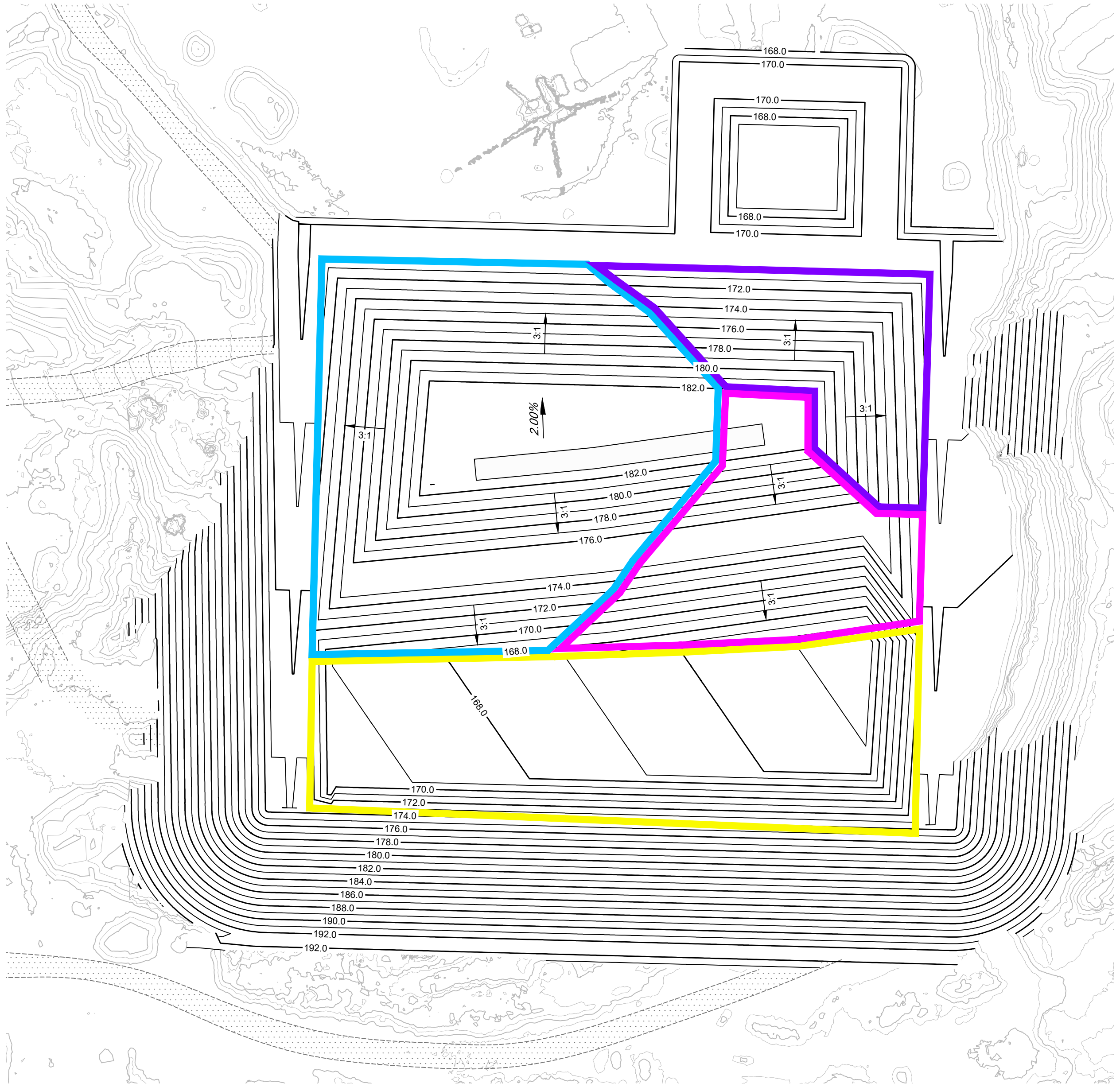
Project No. 88877-11

Title
FILL PLAN
STAGE 1 EAST

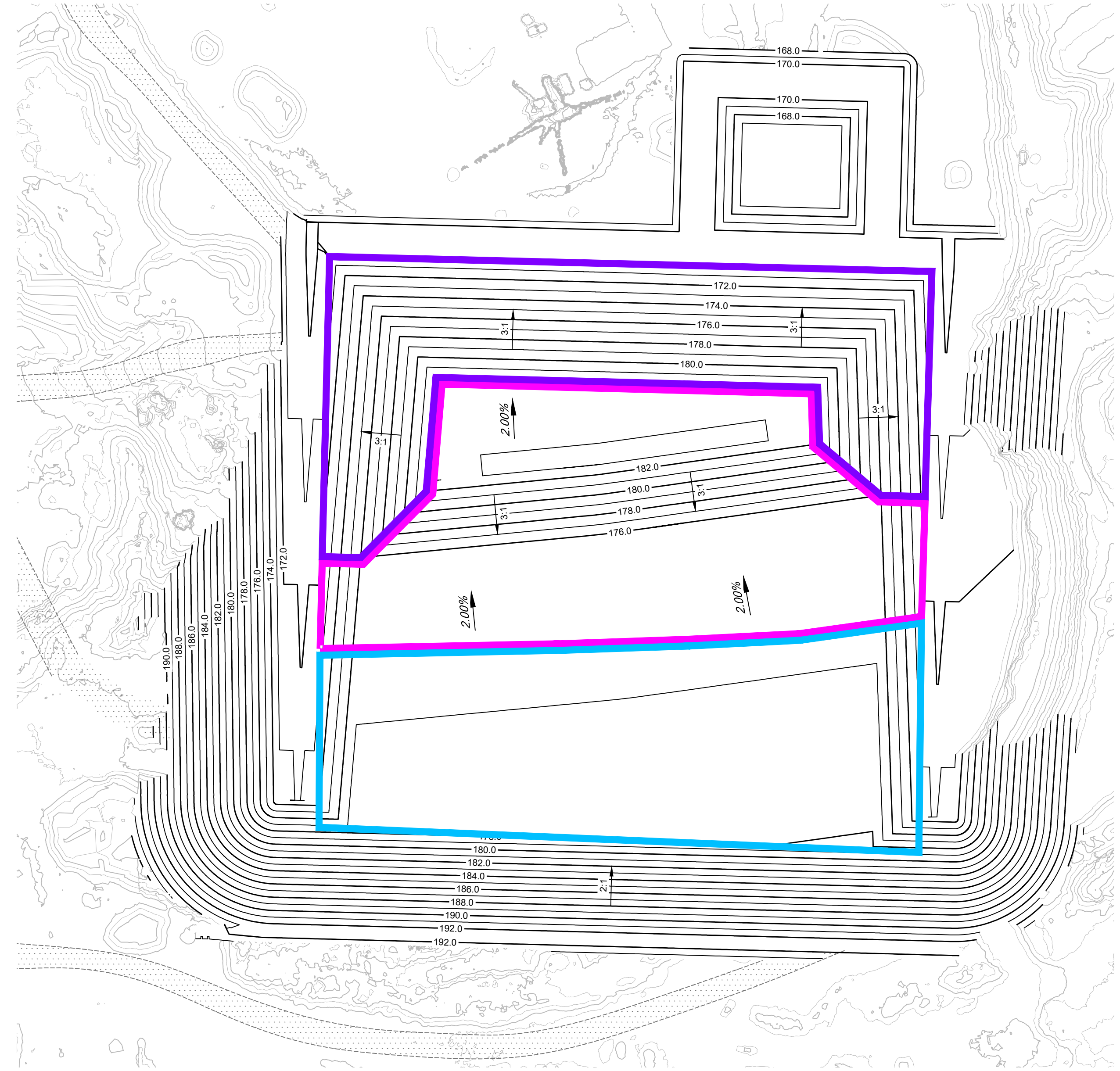
Sheet No.
C-08

Sheet 9 of 20

Plot Date: 2 July 2021 - 10:09 AM   Plotted By: Tyler Wagstaff   CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-11(014)\88877-11(014)CI\88877-11(014)CI-WA008.dwg



PHASE I: STAGE 1 WEST
FILL VOLUME = 101,447 m³



PHASE II: STAGE 2A
FILL VOLUME = 106,823 m³

LEGEND

- BASE LINER PREPARATION / CONSTRUCTION FOR NEXT STAGE
- DAILY COVER AREA
- INTERMEDIATE COVER AREA
- FINAL COVER AREA

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Project
2021 DESIGN, OPERATIONS, AND CLOSURE PLAN

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Project No. **88877-11**

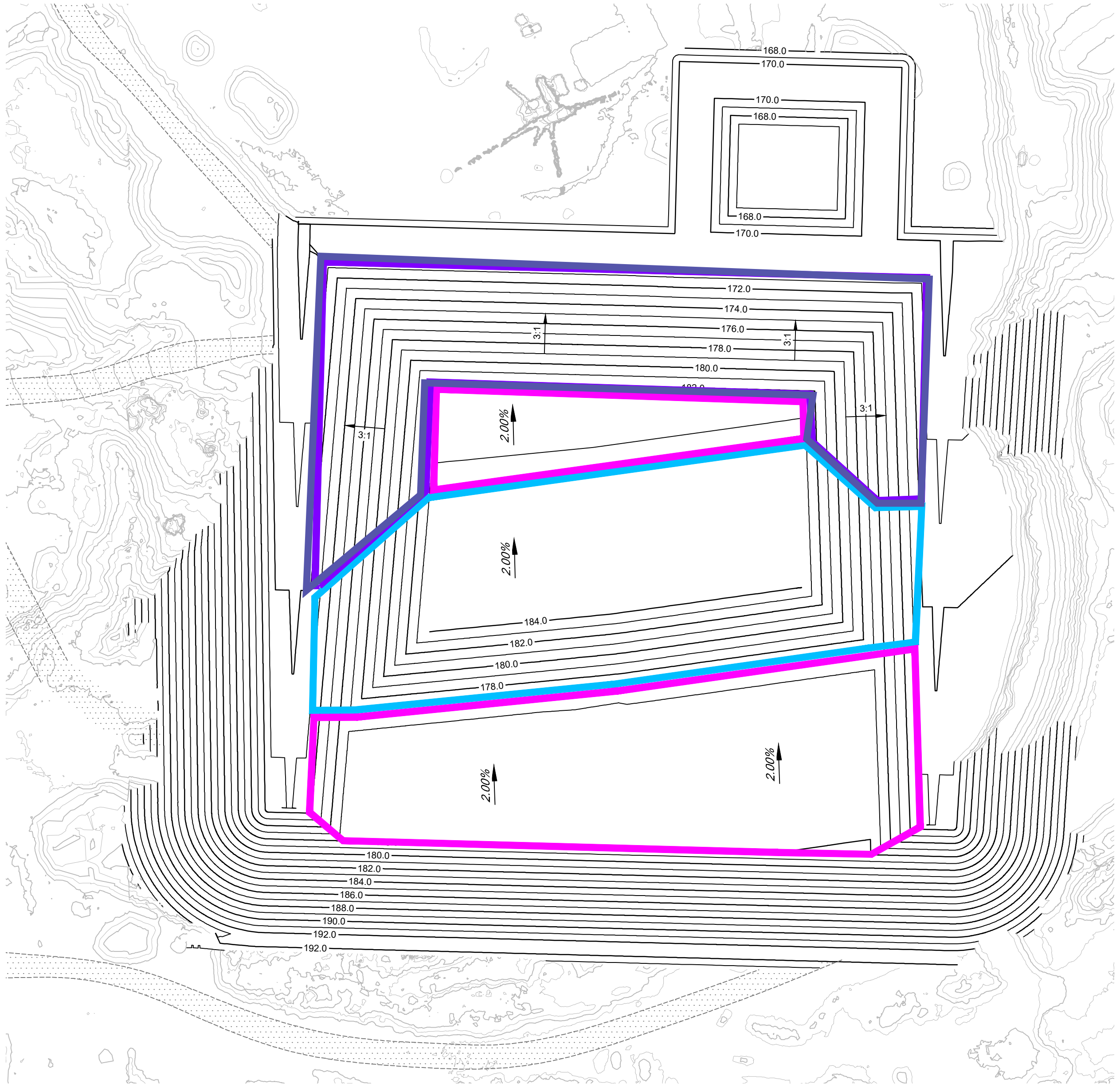
Title

**FILL PLAN
STAGE 1 WEST & STAGE 2A**

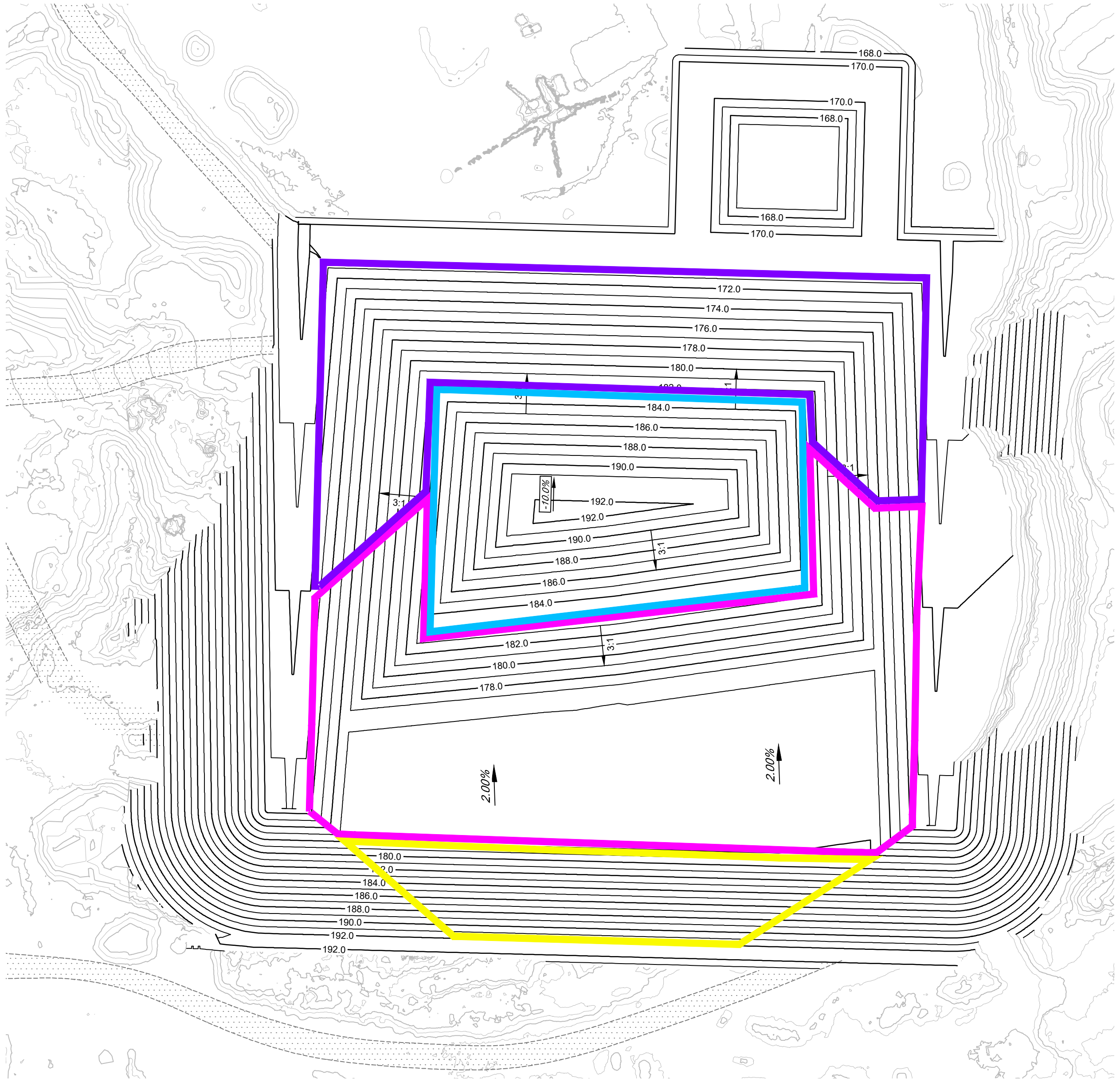
Sheet No.

C-09

Sheet **10** of **20**



PHASE II: STAGE 2B
FILL VOLUME = 44,912 m³



PHASE II: STAGE 2C
FILL VOLUME = 27,085 m³

LEGEND

- BASE LINER PREPARATION / CONSTRUCTION FOR NEXT STAGE
- DAILY COVER AREA
- INTERMEDIATE COVER AREA
- FINAL COVER AREA

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Drafting Check	Design Check
Project Manager D. LIDDY	Date July 2, 2021
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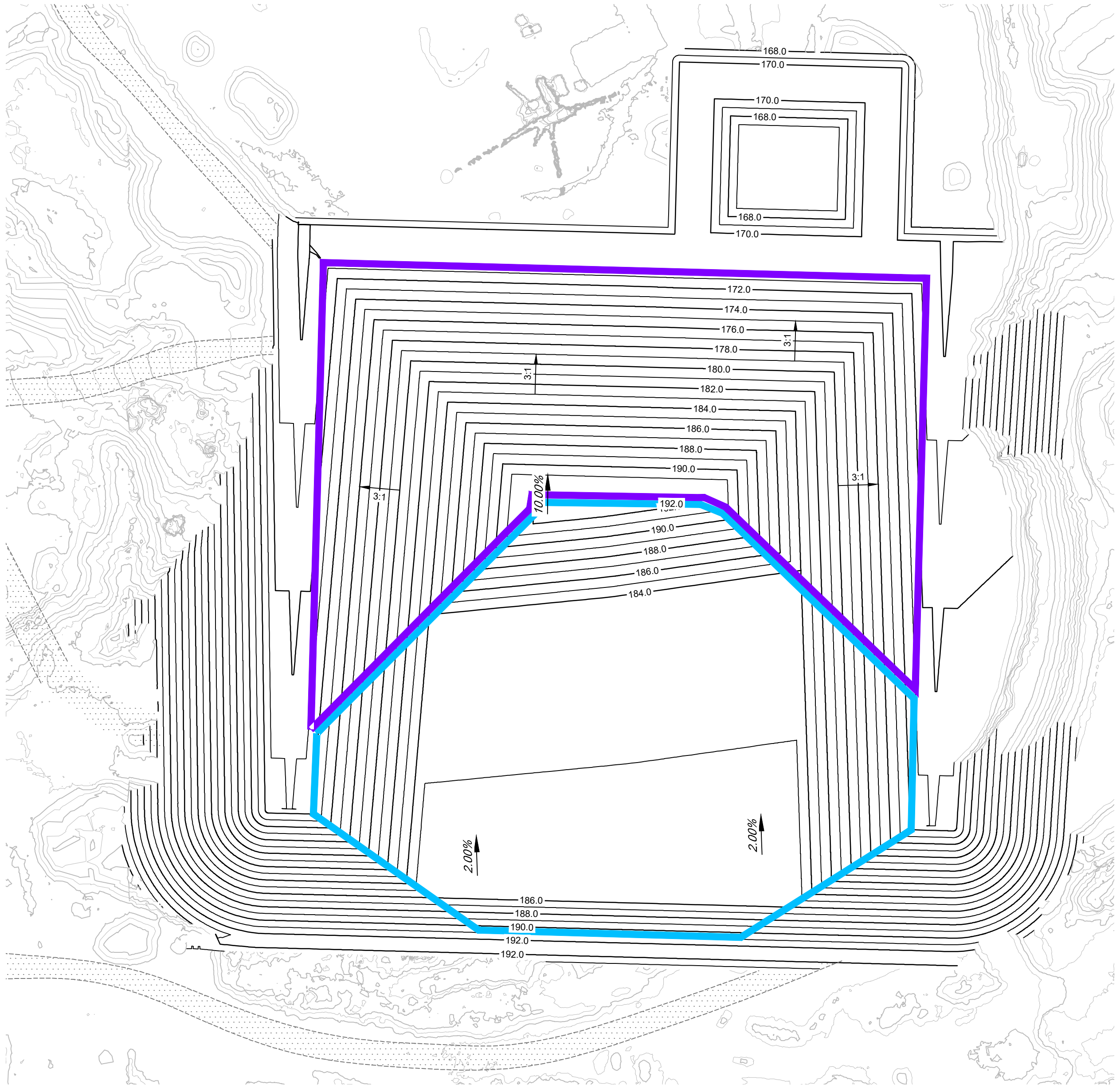
Project No. 88877-11

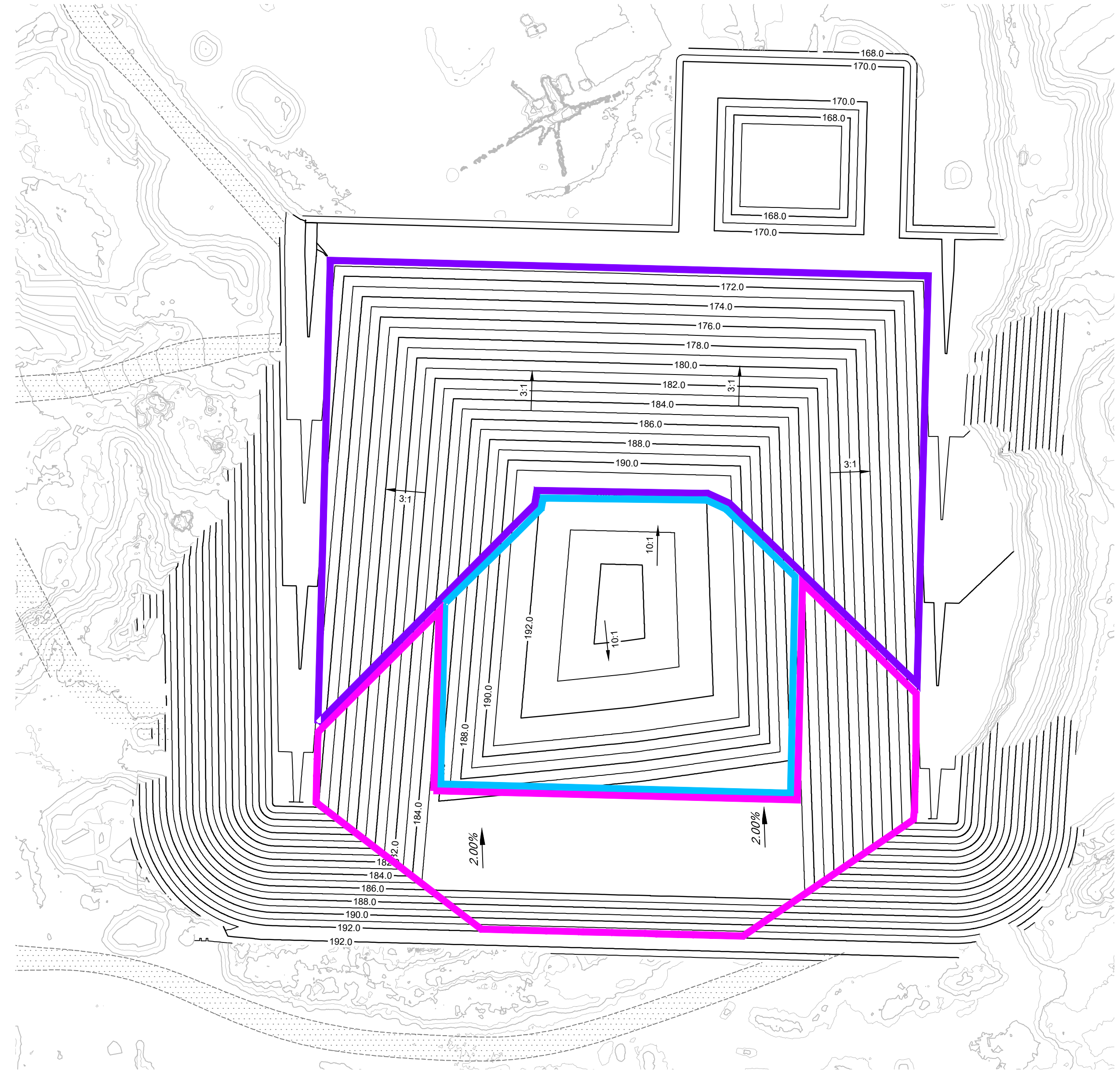
Title
**FILL PLAN
STAGE 2B & STAGE 2C**

Sheet No.
C-10

Plot Date: 2 July 2021 - 10:13 AM Plotted By: Tyler Wagstaff CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-11(014)\88877-11(014)CI\88877-11(014)CI-WA010.dwg



PHASE III: STAGE 3A
FILL VOLUME = 67,949 m³



PHASE III: STAGE 3B
FILL VOLUME = 44,266 m³

LEGEND

- DAILY COVER AREA
- INTERMEDIATE COVER AREA
- FINAL COVER AREA

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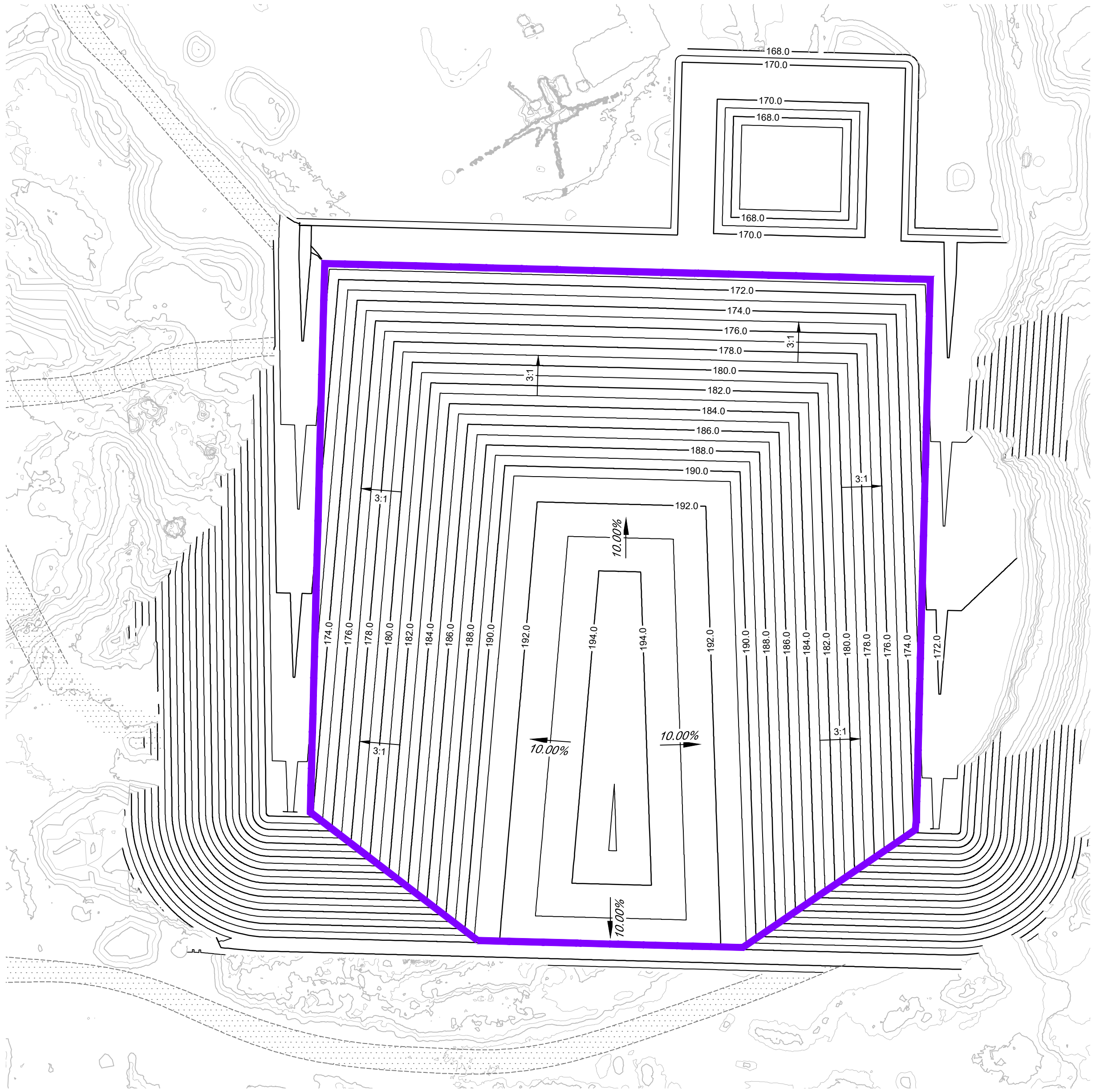
Project No. 88877-11

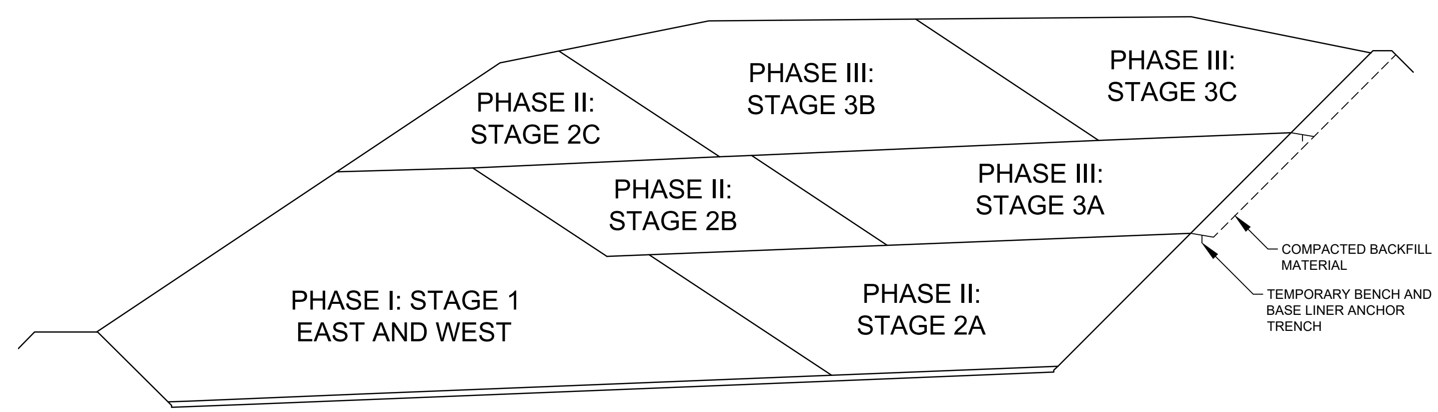
Title
**FILL PLAN
STAGE 3A & STAGE 3B**

Sheet No.
C-11

Sheet 12 of 20



PHASE III: STAGE 3C
FILL VOLUME = 33,546 m³



FILL SEQUENCE
HOR. SCALE 1:600
VERT. SCALE 1:300

LEGEND

- DAILY COVER AREA
- INTERMEDIATE COVER AREA
- FINAL COVER AREA

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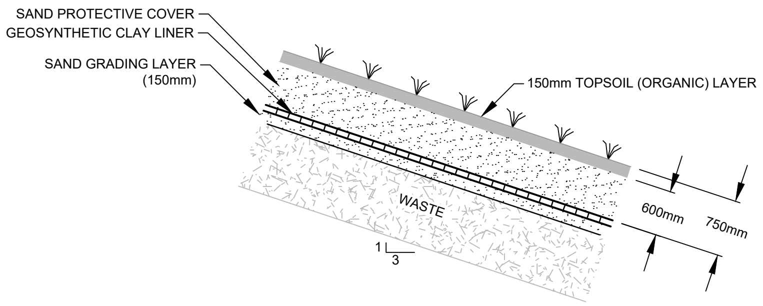
Project No. 88877-11

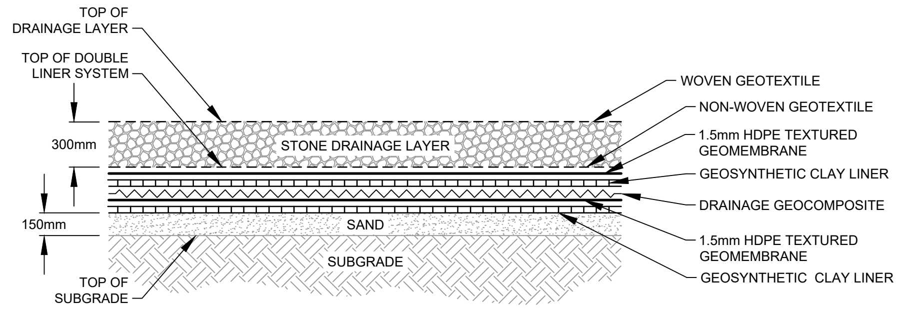
Title
FILL PLAN
STAGE 3C

Sheet No.
C-12

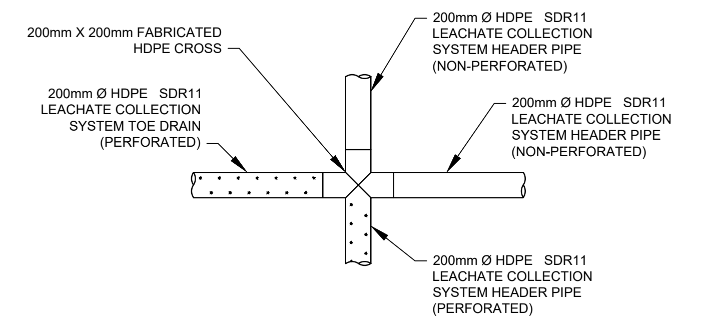
Sheet 13 of 20



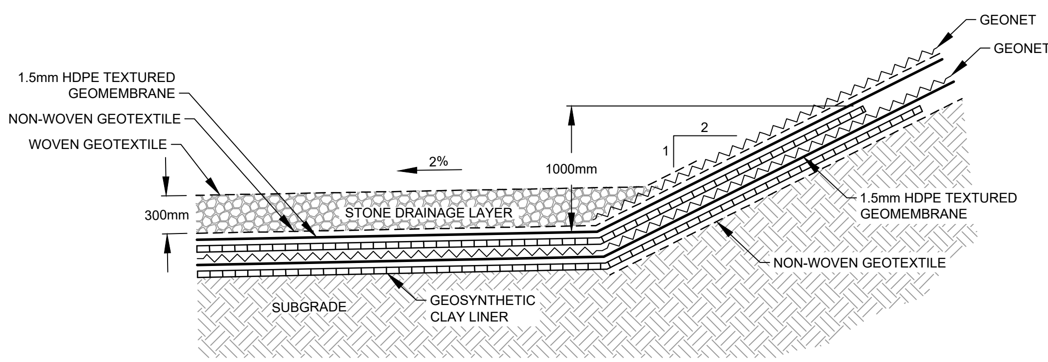
DETAIL 1 FINAL COVER SYSTEM
1:50 C-06,17



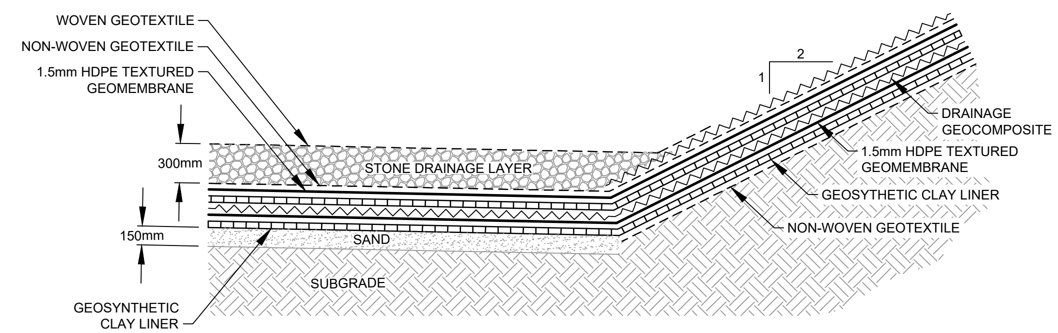
DETAIL 2 BASE LINER AND LEAK DETECTION SYSTEM
1:25 C-03,04,13



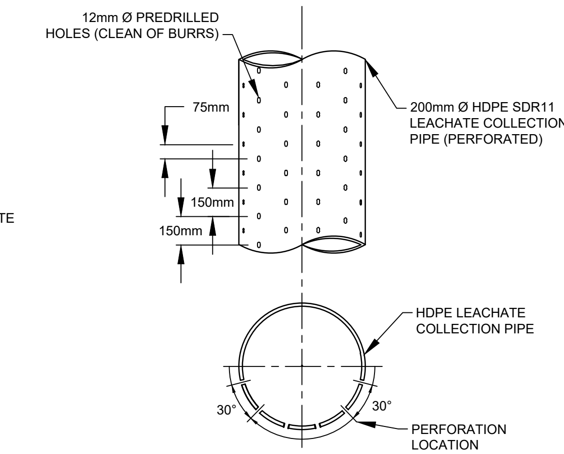
DETAIL 3 LEACHATE COLLECTION SYSTEM TOE DRAIN / LEACHATE COLLECTION SYSTEM PIPE CONNECTION
1:30 C-04



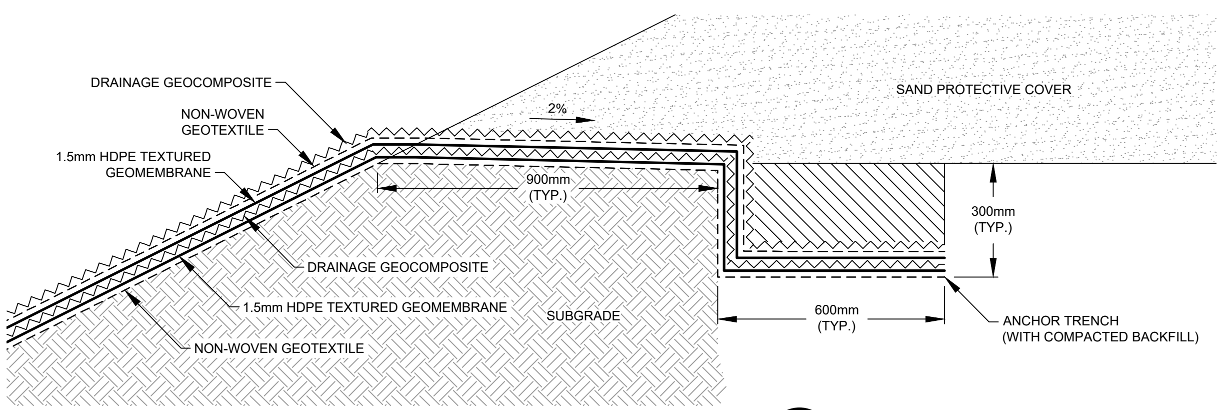
DETAIL 4 LINER SYSTEM (TOE OF SLOPE) SOUTH (TYP.)
1:30 C-03



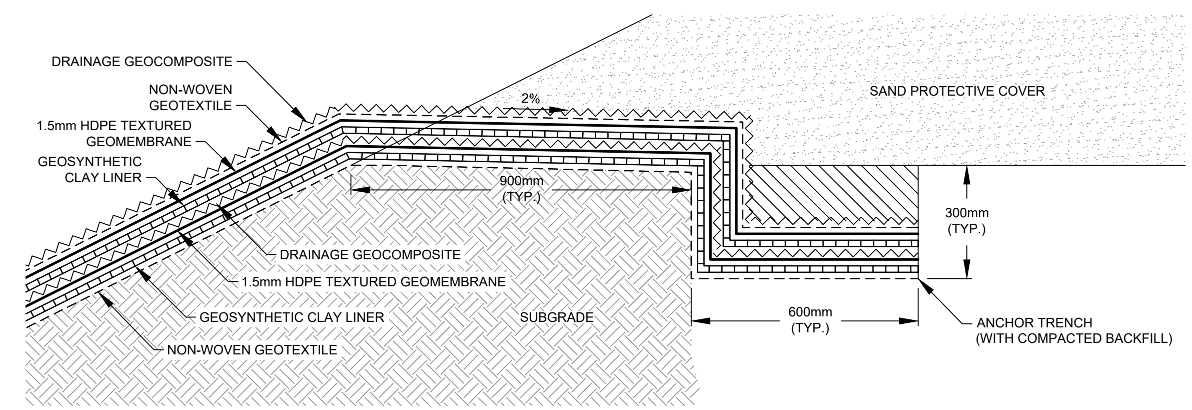
DETAIL 5 LINER SYSTEM (TOE OF SLOPE) NORTH, WEST AND EAST (TYP.)
1:30 C-04



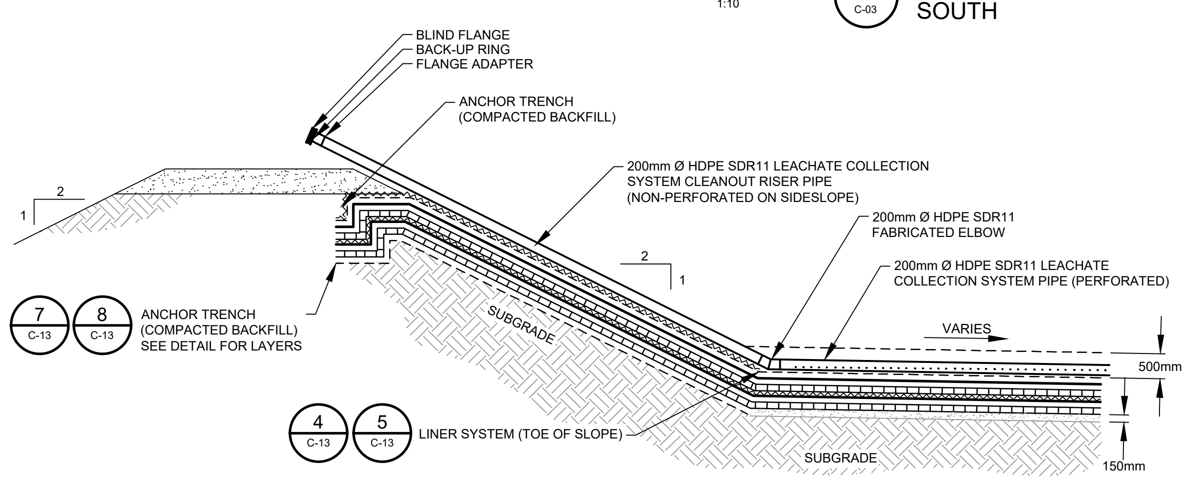
DETAIL 6 LEACHATE COLLECTION SYSTEM TOE DRAIN / LEACHATE COLLECTION SYSTEM PIPE PERFORATIONS
N.T.S. C-04



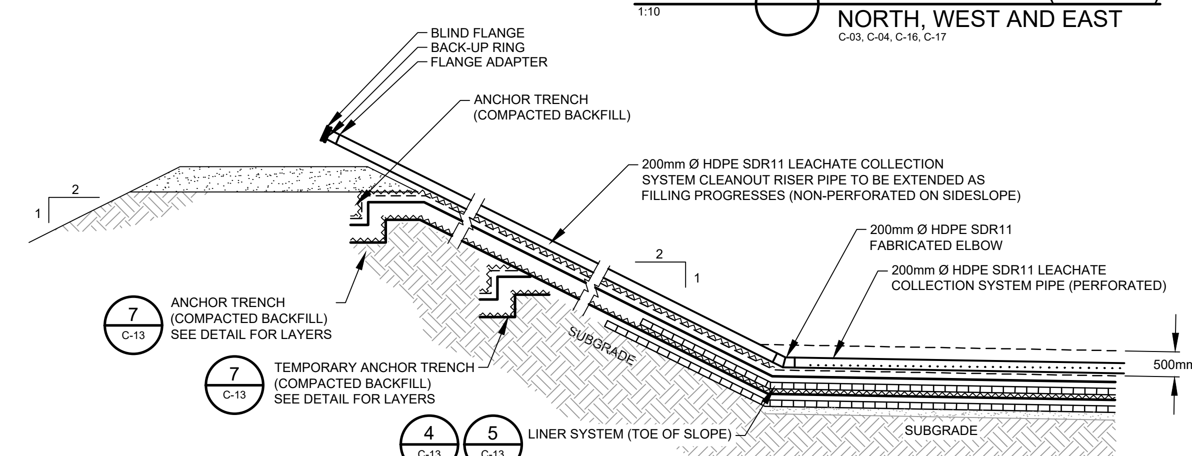
DETAIL 7 ANCHOR TRENCH (TYPICAL) SOUTH
1:10 C-03



DETAIL 8 ANCHOR TRENCH (TYPICAL) NORTH, WEST AND EAST
1:10 C-03, C-04, C-16, C-17



DETAIL 9 LEACHATE COLLECTION SYSTEM CLEANOUT RISER PIPE (TYPICAL) NORTH
1:75 C-04,05



DETAIL 10 LEACHATE COLLECTION SYSTEM CLEANOUT RISER PIPE (TYPICAL) SOUTH
1:75 C-04,05

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Client
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Project
2021 DESIGN, OPERATIONS, AND CLOSURE PLAN

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Project Manager	D. LIDDY	Date	July 5, 2021
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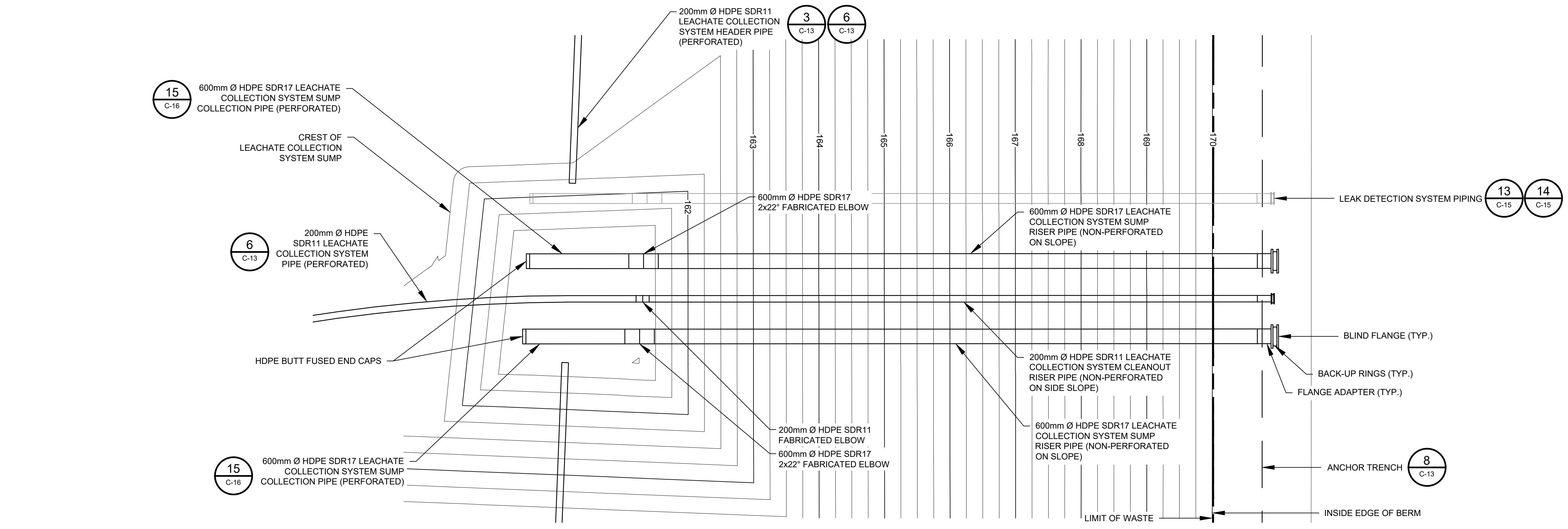
Project No. 88877-11

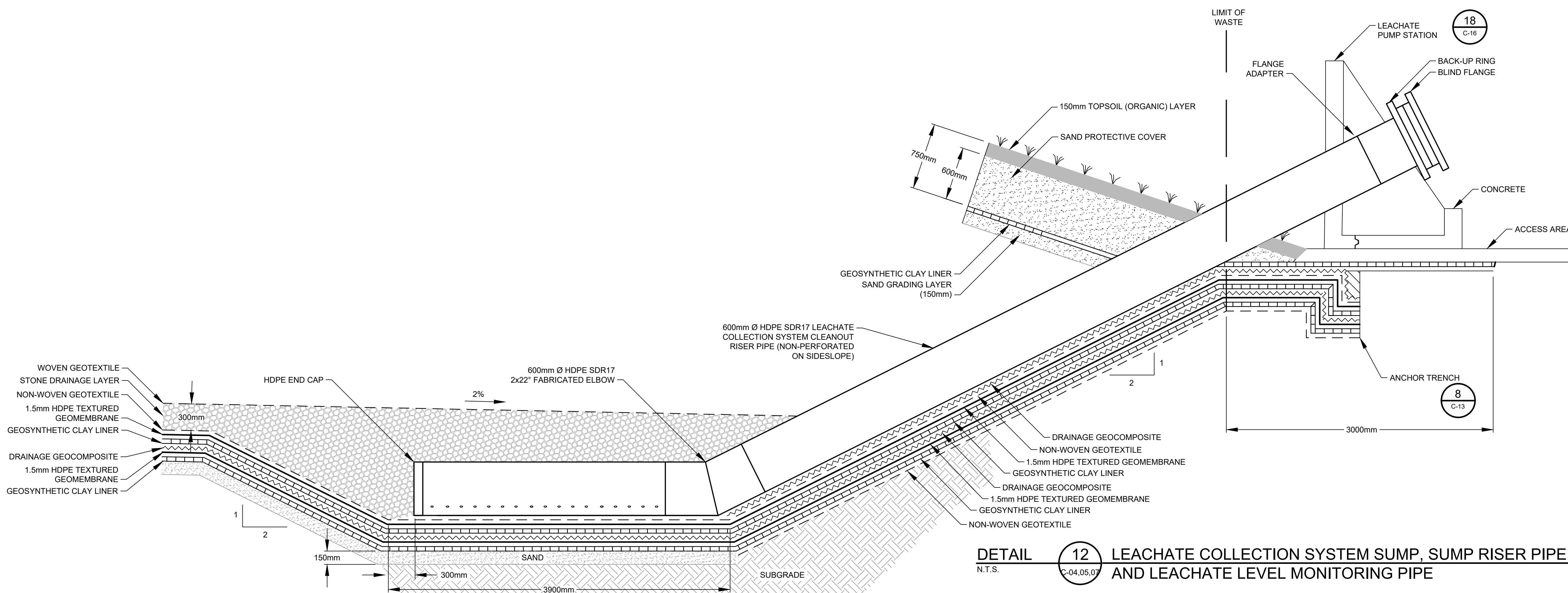
Title
DETAILS LINER DETAILS

Sheet No.
C-13

Plot Date: 5 July 2021 - 5:54 PM Plotted By: Tyler Wagstaff CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-11(014)\88877-11(014)CI\88877-11(014)CI-WA013.dwg



DETAIL 11 C-04 LEACHATE COLLECTION SYSTEM SUMP (TOP OF LINER)
1:75



DETAIL 12 C-04,05,07 LEACHATE COLLECTION SYSTEM SUMP, SUMP RISER PIPE, AND LEACHATE LEVEL MONITORING PIPE
N.T.S.

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PROFESSIONAL ENGINEER, PROVINCE OF BRITISH COLUMBIA
D. J. LIDDY
33360
2021-07-08

Client
UPLAND EXCAVATING LTD.
CAMPBELL RIVER, B.C.

Project
2021 DESIGN, OPERATIONS, AND CLOSURE PLAN

No.	Issue	Drawn	Approved	Date
1	ISSUED FOR REVIEW	D.C.	D.L.	06-08-2020

Drawn	T.WAGSTAFF	Designer	R. HASIOR
Drafting Check		Design Check	
Project Manager	D. LIDDY	Date	July 2, 2021
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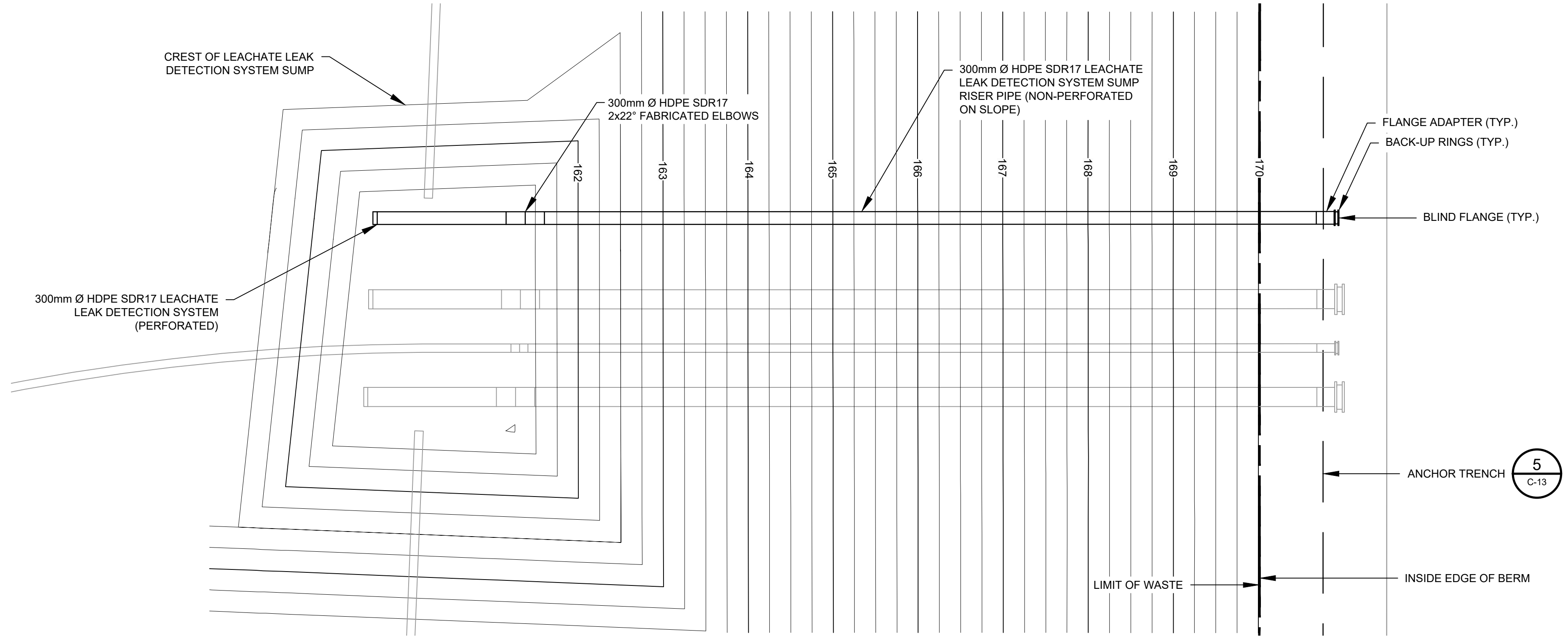
Original Size	ANSI D	Bar is 20mm on original size drawing	0 20mm

Project No. 88877-11

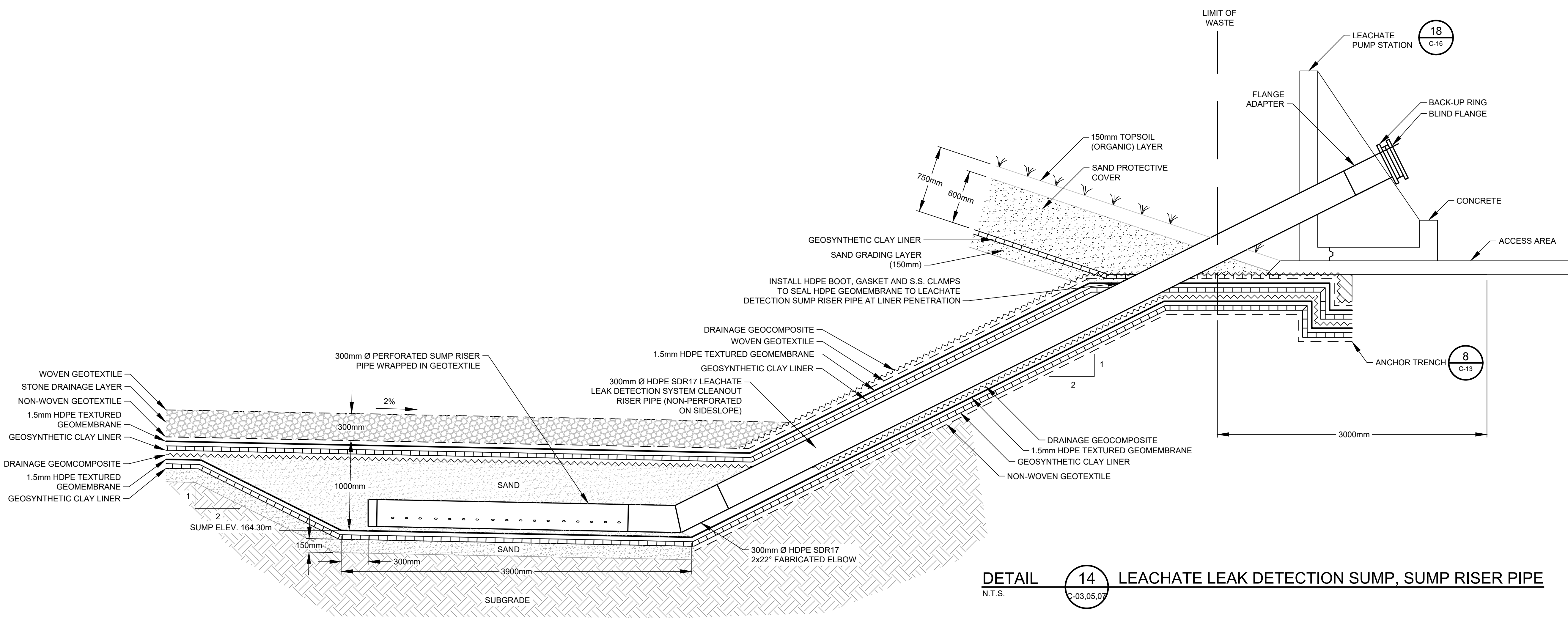
Title
DETAILS LEACHATE COLLECTION SUMP

Sheet No.
C-14

Sheet 15 of 20



DETAIL 13 (C-03) LEACHATE LEAK DETECTION SUMP
1:75



DETAIL 14 (C-03,05,07) LEACHATE LEAK DETECTION SUMP, SUMP RISER PIPE
N.T.S.

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PROFESSIONAL ENGINEER — PROVINCE OF BRITISH COLUMBIA — D. J. LIDDY # 33360 — 2021-07-08

Client
UPLAND EXCAVATING LTD.
CAMPBELL RIVER, B.C.

Project
2021 DESIGN, OPERATIONS, AND CLOSURE PLAN

No.	Issue	Drawn	Approved	Date
1	ISSUED FOR REVIEW	D.C.	D.L.	06-08-2020

Drawn	T.WAGSTAFF	Designer	R. HASIOR
Drafting Check		Design Check	
Project Manager	D. LIDDY	Date	July 2, 2021
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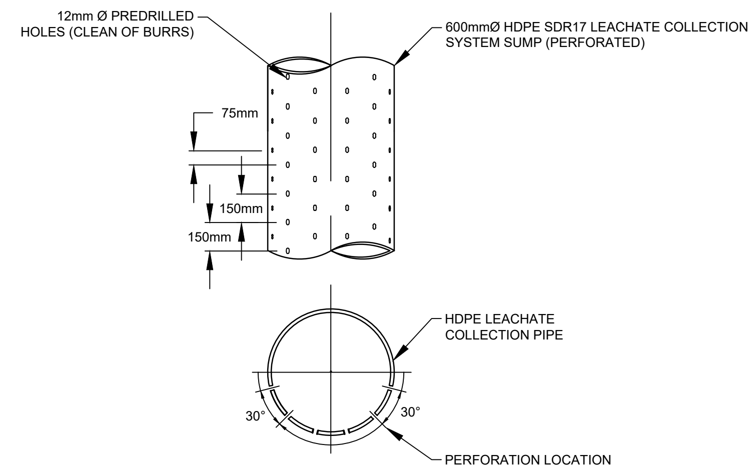
Original Size	ANSI D	Bar is 20mm on original size drawing	0 — 20mm

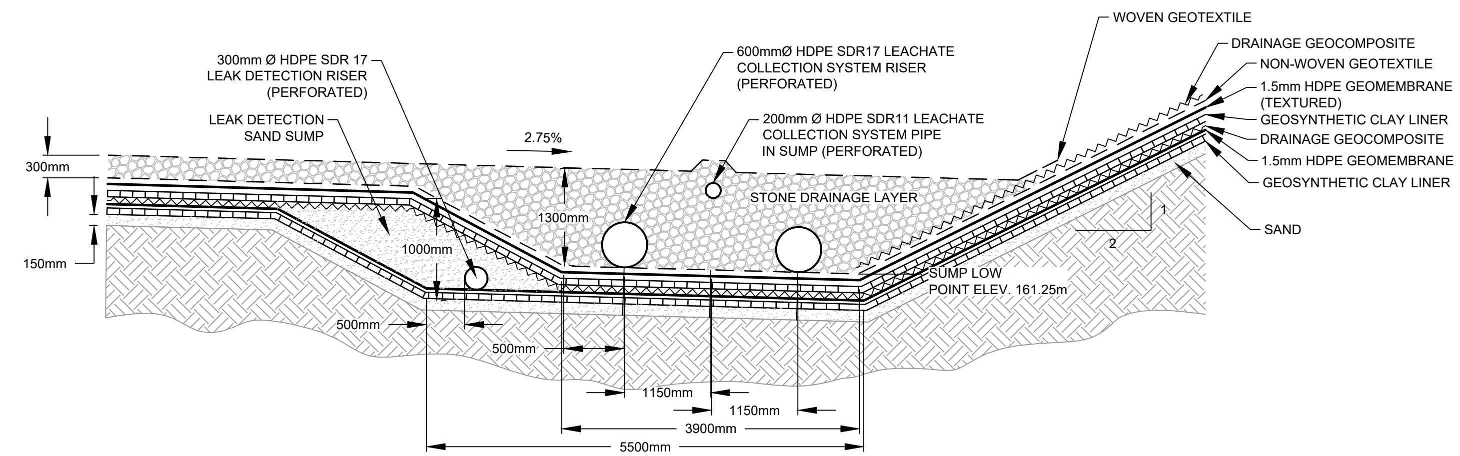
Project No. 88877-11

Title
DETAILS LEACHATE LEAK DETECTION SUMP

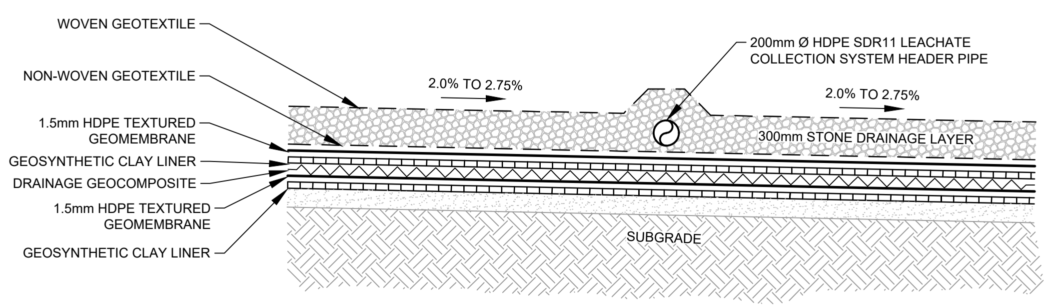
Sheet No.
C-15



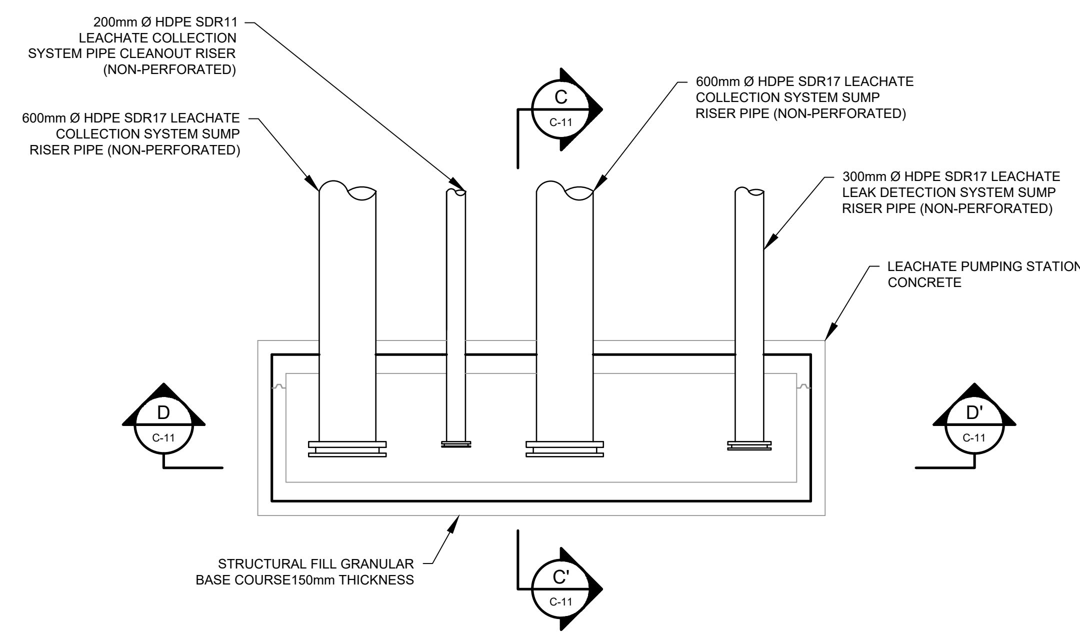
DETAIL 15 NTS C-04 600mmØ LEACHATE COLLECTION SYSTEM SUMP PIPE PERFORATIONS



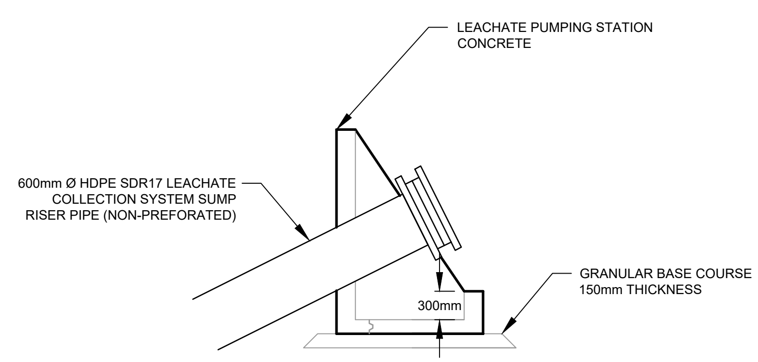
DETAIL 16 1:50 C-03,04,07 LEACHATE COLLECTION SYSTEM SUMP



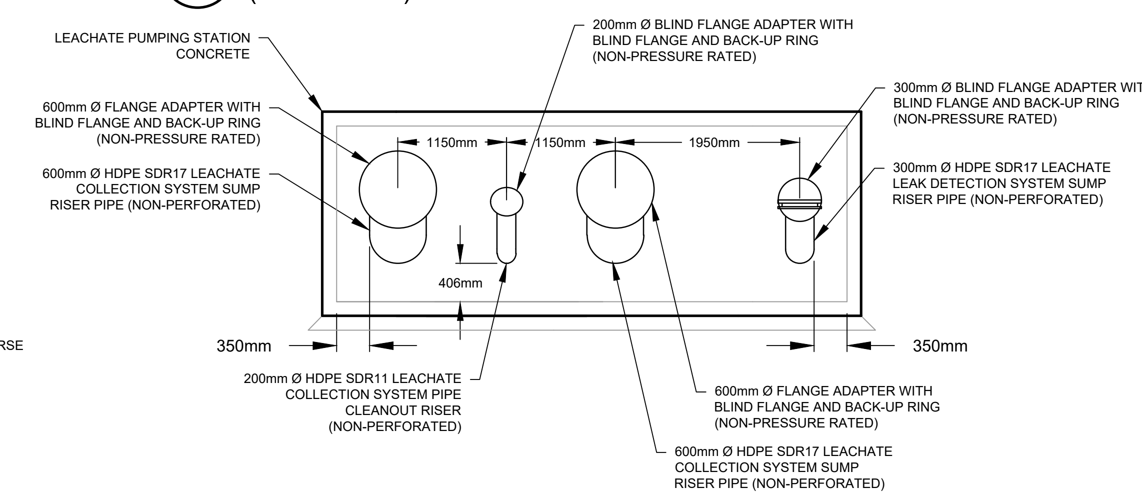
DETAIL 17 1:30 C-04 LEACHATE COLLECTION SYSTEM TOE DRAIN/ LEACHATE COLLECTION SYSTEM PIPE



DETAIL 18 1:40 C-03 LEACHATE PUMP STATION (PLAN VIEW)



SECTION C-C' 1:40 C-16



SECTION D-D' 1:40 C-16

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PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA
D. J. LIDDY
33360
2021-07-08

Client
UPLAND EXCAVATING LTD. CAMPBELL RIVER, B.C.

Project
2021 DESIGN, OPERATIONS, AND CLOSURE PLAN

No.	Issue	Drawn	Approved	Date
1	ISSUED FOR REVIEW	D.C.	D.L.	06-08-2020

Drawn T.WAGSTAFF — Designer R. HASIOR
Drafting Check — Design Check
Project Manager D. LIDDY — Date July 2, 2021
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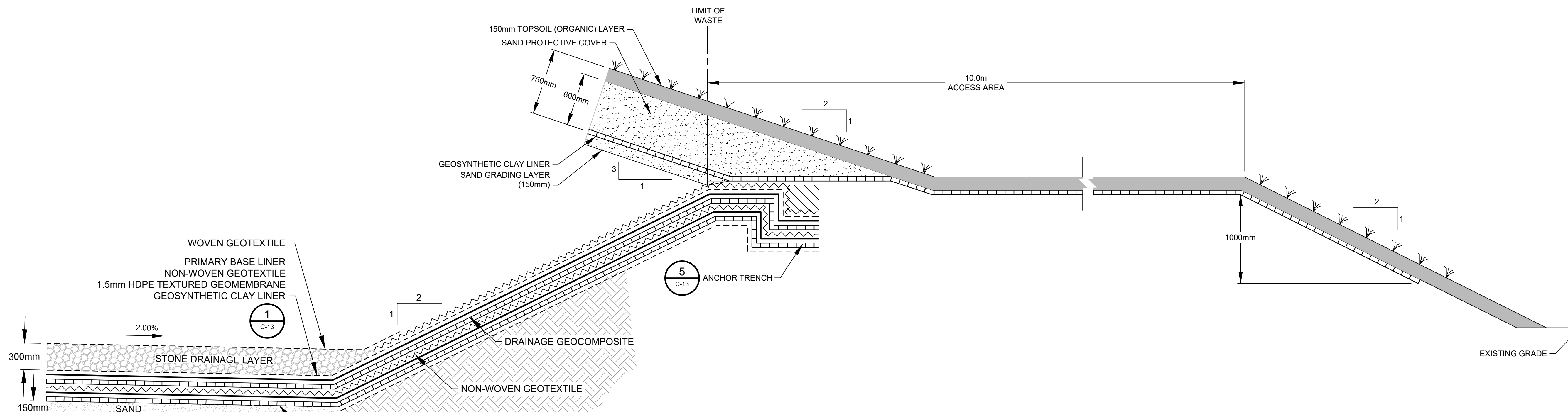
Project No. 88877-11

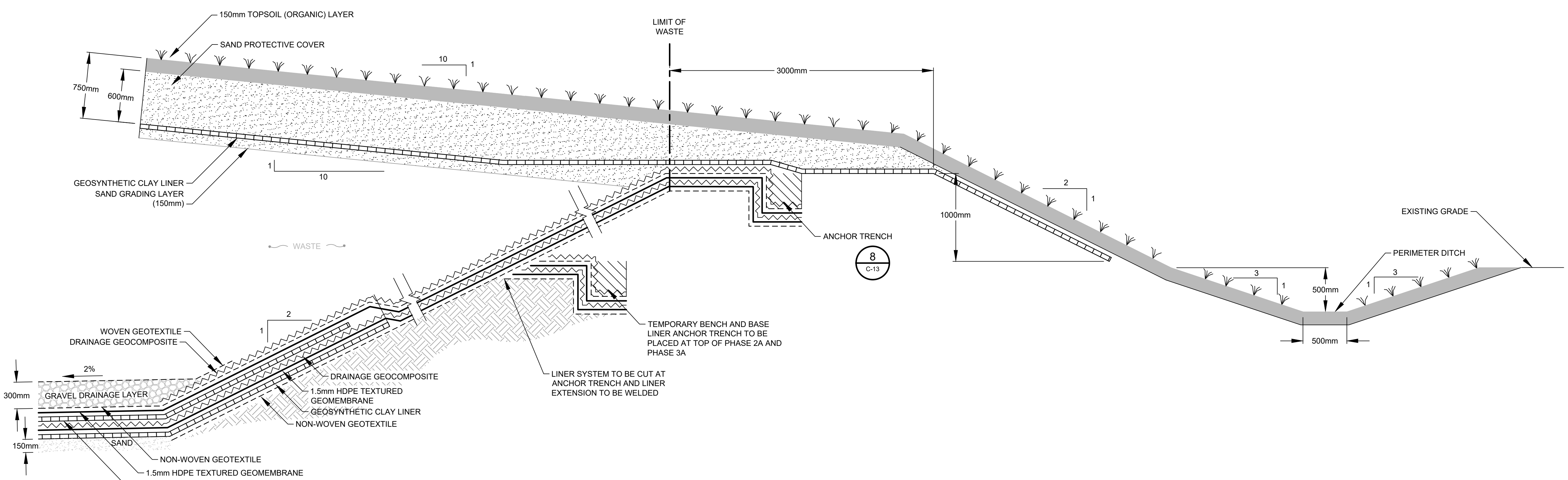
Title
DETAILS LEACHATE COLLECTION SYSTEM

Sheet No.
C-16

Plot Date: 2 July 2021 - 11:07 AM Plotted By: Tyler Wagstaff CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-11(014)\88877-11(014)CI\88877-11(014)CI-WA014.dwg



DETAIL 19 PERIMETER TIE-IN DETAIL ON NORTH SIDE (TYPICAL)
1:25
C-03, C-04, C-05, C-06



DETAIL 20 PERIMETER TIE-IN DETAIL ON SOUTH SIDE (TYPICAL)
1:25
C-03, C-04, C-05, C-06

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PROFESSIONAL ENGINEER — PROVINCE OF BRITISH COLUMBIA — D. J. LIDDY # 33360
2021-07-08

Client
UPLAND EXCAVATING LTD. CAMPBELL RIVER, B.C.

Project
2021 DESIGN, OPERATIONS, AND CLOSURE PLAN

No.	Issue	Drawn	Approved	Date
1	ISSUED FOR REVIEW	D.C.	D.L.	06-08-2020

Drawn	T.WAGSTAFF	Designer	R. HASIOR
Drafting Check		Design Check	
Project Manager	D. LIDDY	Date	July 2, 2021
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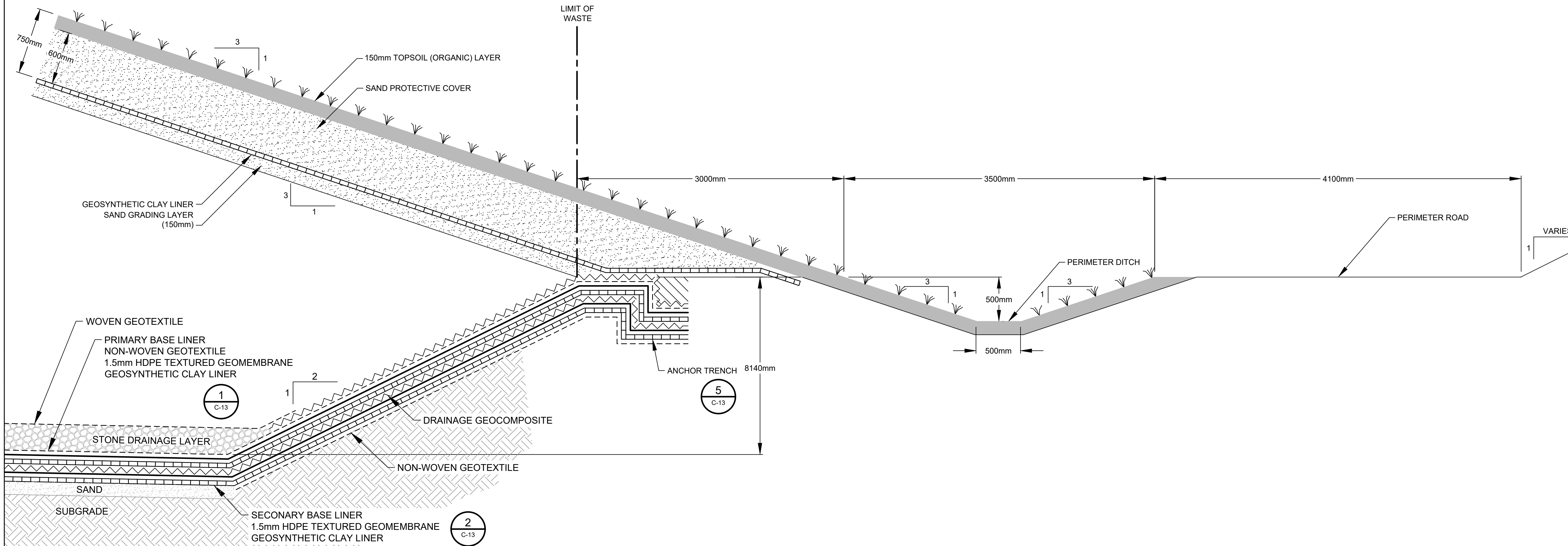
Original Size	ANSI D	Bar is 20mm on original size drawing 0 20mm	

Project No. 88877-11

Title
DETAILS PERIMETER TIE-IN DETAILS I

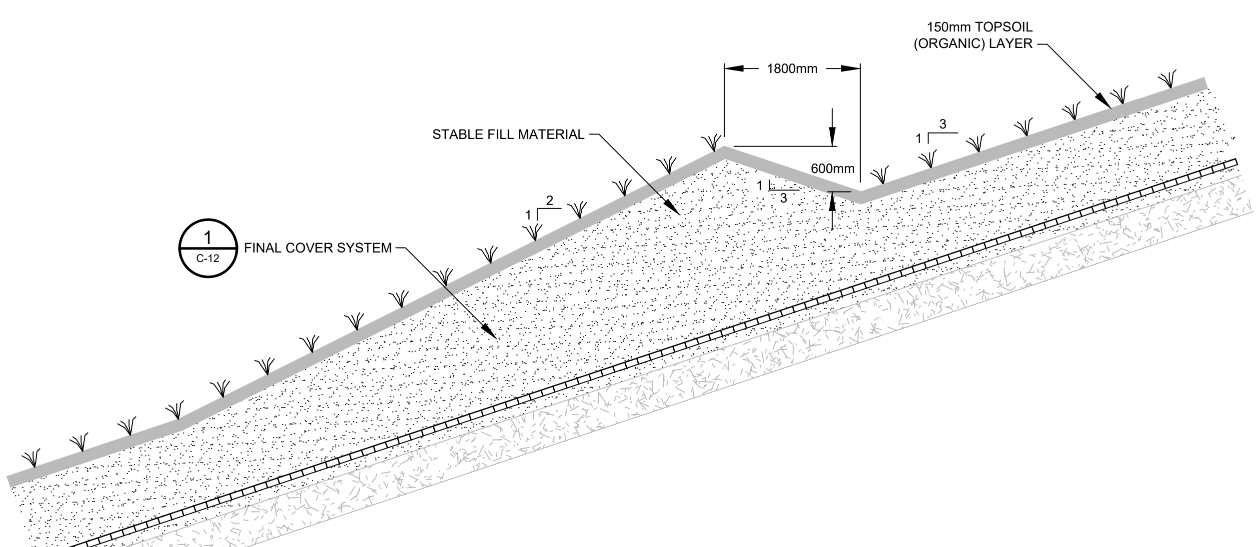
Sheet No.
C-17

Sheet 18 of 20



DETAIL 21 (C-03) PERIMETER TIE-IN DETAIL - EAST/WEST (TYPICAL)

1:25 C-03, C-04, C-05, C-06



DETAIL 22 (C-06,07) MID-SLOPE SWALE

1:50

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Client
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CAMPBELL RIVER, B.C.**

Project
2021 DESIGN, OPERATIONS, AND CLOSURE PLAN

No.	Issue	Drawn	Approved	Date
1	ISSUED FOR REVIEW	D.C.	D.L.	06-08-2020

Drawn T.WAGSTAFF	Designer R. HASIOR
Drafting Check	Design Check
Project Manager D. LIDDY	Date June 29, 2021
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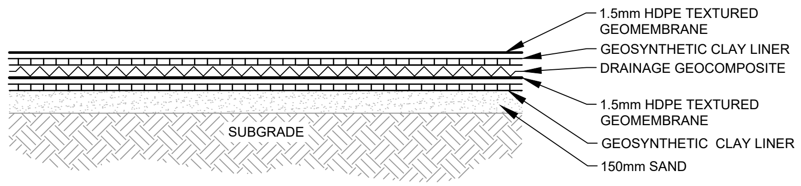
Original Size ANSI D	Bar is 20mm on original size drawing 0 20mm

Project No. 88877-11

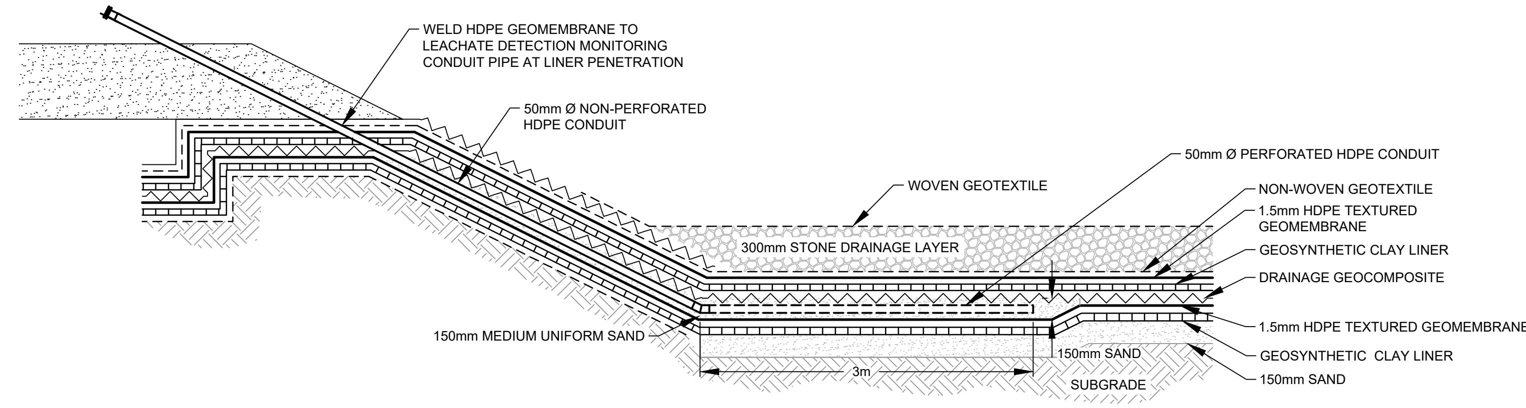
Title
**DETAILS
PERIMETER TIE-IN DETAILS II**

Sheet No.
C-18

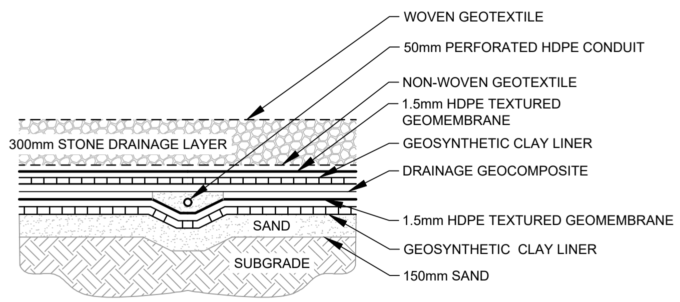
Sheet 19 of 20



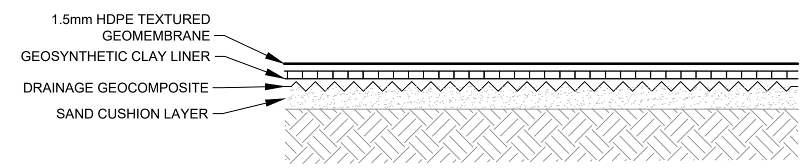
DETAIL 23 C-04 LEACHATE TREATMENT POND LINER SYSTEM
1:25



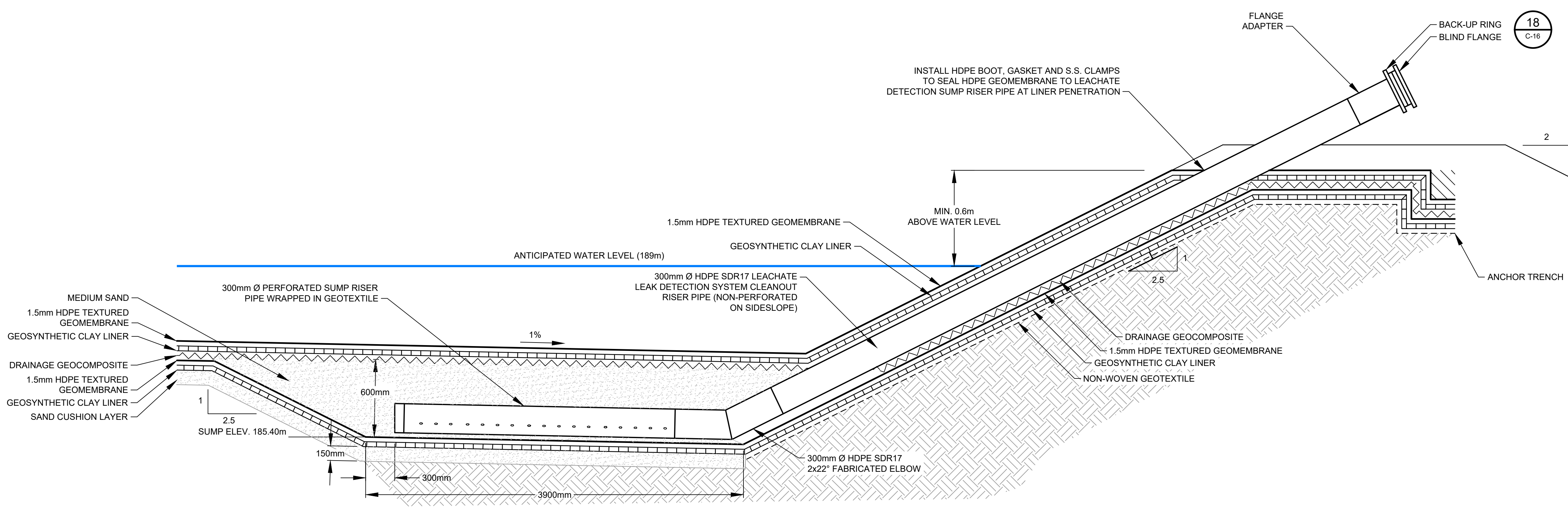
DETAIL 24 C-04 LEAK DETECTION LYSIMETER MONITORING PORT
1:25



DETAIL 25 C-18 LEAK DETECTION LYSIMETER MONITORING PORT CROSS-SECTION
1:25



DETAIL 26 C-04 TREATED EFFLUENT HOLDING POND LINER SYSTEM
1:25



DETAIL 27 LEACHATE TREATMENT POND LEAK DETECTION SUMP RISER PIPE
N.T.S.

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PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA
D. J. LIDDY
33360
2021-07-08

Client
UPLAND EXCAVATING LTD.
CAMPBELL RIVER, B.C.

Project
2020 DESIGN, OPERATIONS, AND CLOSURE PLAN

No.	Issue	Drawn	Approved	Date
1	ISSUED FOR REVIEW	D.C.	D.L.	06-08-2020

Drawn	T.WAGSTAFF	Designer	R. HASIOR
Drafting Check		Design Check	
Project Manager	D. LIDDY	Date	July 5, 2021
This document shall not be used for construction unless signed and sealed for construction.		Scale	AS SHOWN
Original Size	ANSI D	Bar is 20mm on original size drawing	0 20mm

Project No. 88877-11

Title
DETAILS
LEACHATE MANAGEMENT

Sheet No.
C-19

Sheet 20 of 20

Plot Date: 5 July 2021 - 5:58 PM Plotted By: Tyler Wagstaff CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-11(014)\88877-11(014)CI\88877-11(014)CI-WA016.dwg

about GHD

GHD is one of the world's leading professional services companies operating in the global markets of water, energy and resources, environment, property and buildings, and transportation. We provide engineering, environmental, and construction services to private and public sector clients.

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2021 Design, Operations and Closure Plan

Northwin Landfill
Upland Pit Property
Campbell River, British Columbia

Upland Excavating Ltd.

GHD | 138 East 7th Avenue Suite 100 Vancouver British Columbia V5T 1M6 Canada

088877 | Report No 14 | July 8, 2021

Appendices

Appendix A
Operational Certificate

August 1, 2019

Tracking Number: 335965
Authorization Number: 107689

REGISTERED MAIL

UPLAND EXCAVATING LTD.
#201-909 ISLAND HIGHWAY
CAMPBELL RIVER BC V9W 2C2

Dear operational certificate holder:

Enclosed is Operational Certificate 107689 issued under the provisions of the *Environmental Management Act*. Your attention is respectfully directed to the terms and conditions outlined in the operational certificate. An annual fee will be determined according to the Permit and Approval Fees and Charges Regulation.

This operational certificate does not authorize entry upon, crossing over, or use for any purpose of private or Crown lands or works, unless and except as authorized by the owner of such lands or works. The responsibility for obtaining such authority rests with the operational certificate holder. It is also the responsibility of the operational certificate holder to ensure that all activities conducted under this authorization are carried out with regard to the rights of third parties, and comply with other applicable legislation that may be in force.

Requirements may also be specified by the *Environmental Management Act* and regulations including, but not limited to, the Contaminated Sites Regulation, Environmental Data Quality Assurance Regulation, Hazardous Waste Regulation, Landfill Gas Management Regulation, Organic Matter Recycling Regulation, Ozone Depleting Substances and Other Halocarbons Regulation, Recycling Regulation, Spill Reporting Regulation, Storage of Recyclable Material Regulation, Waste Discharge Regulation and Codes of Practice.

This decision may be appealed to the Environmental Appeal Board in accordance with Part 8 of the *Environmental Management Act*. An appeal must be delivered within 30 days from the date that notice of this decision is given. For further information, please contact the Environmental Appeal Board at (250) 387-3464.

Administration of this operational certificate will be carried out by staff from the Environmental Protection Division's Regional Operations Branch. Documents pertinent to the operational certificate are to be submitted by email or electronic transfer to the director, in accordance with the ministry Data & Report Submissions website at: http://www2.gov.bc.ca/gov/content/environment/waste-management/waste-discharge-authorization/data-and-report-submissions, or as further instructed.

If you have any questions or concerns, please contact Authorizations - South at Authorizations.South@gov.bc.ca.

Yours truly,

Luc Lachance, P.Eng
for Director, *Environmental Management Act*
Authorizations - South Region

Enclosure

MINISTRY OF ENVIRONMENT &
CLIMATE CHANGE STRATEGY

OPERATIONAL CERTIFICATE

107689

Under the Provisions of the Environmental Management Act

Pursuant to the Approved

Comox Valley Regional District Solid Waste Management Plan

UPLAND EXCAVATING LTD.

#201-909 ISLAND HIGHWAY
CAMPBELL RIVER BC V9W 2C2

Is authorized to manage waste at the Facility located in Campbell River, British Columbia, subject to the requirements listed below. Contravention of any of these requirements is a violation of the *Environmental Management Act* and may lead to prosecution.

Pursuant to section 24(10) of the *Environmental Management Act*, this operational certificate supersedes and cancels Permit PR-10807 issued under section 14 of the *Environmental Management Act*.

1. <u>AUTHORIZED DISCHARGES, FACILITIES AND WORKS</u>

1.1 <u>Original Landfill</u>

This section applies to the Original Landfill.

1.1.1 The maximum rate of waste discharge to the Original Lined Cell is 45,000 tonnes per calendar year.

1.1.2 The characteristics of the waste discharge to the Original Lined Cell must be:
(a) demolition waste,
(b) construction waste,
(c) land clearing waste,
(d) soil in which the concentrations of all substances are less than the lowest applicable industrial land use standard specified for those substances in
(i) the generic numerical soil standards,
(ii) the matrix numerical soil standards, or

Date issued: August 1, 2019

Luc Lachance, P.Eng
for Director, *Environmental Management Act*
Authorizations - South Region

(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,
(e) sludge from the Original Leachate Management Works, or,
(f) other waste as authorized in writing by the director,
but does not include:
(g) hazardous waste except as authorized pursuant to the Hazardous Waste Regulation, controlled waste, Attractants, and,
(h) waste and/or recyclable material prohibited in writing by the director.

1.1.3 The waste discharge is authorized to the Original Lined Cell approximately located as shown on Site Plan A. Waste discharge to the Original Un-Lined Cell is not authorized.

1.1.4 Authorization to discharge waste to the Original Lined Cell ceases on the earlier of:
(i) the date the Original Lined Cell is filled to capacity with grades not steeper than 3H:1V (33%),
(ii) the date of commencement of waste discharge to the New Landfill.

1.1.5 The authorized works are:
(i) a lined landfill footprint with a maximum area of 0.72 ha (85 m x 85 m) including from bottom to top a base with perimeter berm, 0.3 m sand cushion layer, 0.5 mm thick coated woven polyethylene liner, 0.3 m granular leak detection layer, leak detection riser pipe, 0.5 mm thick coated woven polyethylene liner, 0.3 m sand protection layer, leachate extraction chamber, final cover, and,
(ii) an un-lined landfill footprint with an approximate area of 0.7 ha, final cover,
and related appurtenances, approximately located as shown on Site Plan A.

1.1.6 The operational certificate holder must ensure the Original Landfill, excluding final cover, is complete and fully operational on or before the date of issuance of this operational certificate, and at all times thereafter, until the Original Landfill is decommissioned in compliance with the plan referred to in section 2.9(a) (plan to remove all waste from the Original Landfill) of this operational certificate.

1.2 Original Leachate Management Works

This section applies to the management of leachate from the Original Lined Cell.

1.2.1 The operational certificate holder must convey the leachate from the Original Lined Cell, that is to be discharged on the Facility site, to the Original Leachate Management Works.

1.2.2 The maximum rate of treated leachate effluent discharge to the treated leachate infiltration pond is 7,139 m^3 per calendar year.

Date issued: August 1, 2019

Luc Lachance, P.Eng
for Director, *Environmental Management Act*
Authorizations - South Region

1.2.3 The concentration of any substance in the treated leachate effluent discharge to the treated leachate infiltration pond must not be greater than the Contaminated Sites Regulation Generic Numerical Water Standards for Drinking Water (DW), for that substance.

1.2.4 The treated leachate effluent is authorized to be discharged to the treated leachate infiltration pond and infiltrated into the ground. This authorization ceases on the date the Original Leachate Management Works are decommissioned in compliance with the plan referred to in section 2.9(a) (plan to remove all waste from the Original Landfill) of this operational certificate.

1.2.5 The authorized works are leachate conveyance, storage, treatment and discharge works including pumps, pipes, leachate storage and treatment tanks, treated leachate infiltration pond, flow monitoring works, and related appurtenances approximately located as shown on Site Plan A.

1.2.6 Minimum Freeboard must be maintained at all times as follows:
treated leachate infiltration pond: 0.6 m

1.2.7 The operational certificate holder must ensure the Original Leachate Management Works are complete and fully operational on or before the date of commencement of discharge to the treated leachate infiltration pond, and at all times thereafter, until the Original Leachate Management Works are decommissioned in compliance with the plan referred to in section 2.9(a) (plan to remove all waste from the Original Landfill) of this operational certificate.

1.3 **New Landfill**

This section applies to the New Landfill.

1.3.1 The maximum rate of waste discharge to the New Landfill is: (45,000 minus the waste discharge to the Original Lined Cell) tonnes per calendar year.

1.3.2 The characteristics of the waste discharge to the New Landfill must be:

(a) demolition waste,
(b) construction waste,
(c) land clearing waste,
(d) soil in which the concentrations of all substances are less than the lowest applicable industrial land use standard specified for those substances in
(i) the generic numerical soil standards,
(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,
(e) sludge from the New Leachate Management Works or the New Stormwater

Date issued: August 1, 2019

Luc Lachance, P.Eng
for Director, *Environmental Management Act*
Authorizations - South Region

Management Works, or,

(f) other waste as authorized in writing by the director,

but does not include:

(g) hazardous waste except as authorized pursuant to the Hazardous Waste Regulation, controlled waste, Attractants, and,

(h) waste and/or recyclable material prohibited in writing by the director.

1.3.3 The waste discharge is authorized to the New Landfill approximately located as shown on Site Plan A.

1.3.4 The authorized works are a lined landfill footprint with a maximum area of 3.60 ha including from bottom to top a base with perimeter berm, secondary base liner, leak detection drainage layer and leak collection pipes and sump, primary base liner, leachate collection drainage layer and leachate collection pipes and sump, pumps, pipes, final cover, and related appurtenances, approximately located as shown on Site Plan A.

1.3.5 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 1×10^{-7} cm/s. However, on the south slope of the base more than 1 m above the primary base liner, the geosynthetic clay liners are not required.

1.3.6 The operational certificate holder must ensure the New Landfill, excluding final cover, is complete and fully operational on or before the date of commencement of waste discharge to the New Landfill, and at all times thereafter.

1.4 New Leachate Management Works

This section applies to the management of leachate from the New Landfill.

1.4.1 The operational certificate holder must convey the leachate from the New Landfill, that is to be discharged on the Facility site, to the New Leachate Management Works.

1.4.2 The maximum rate of treated leachate effluent discharge to the treated leachate infiltration pond is 24,633 m^3 per calendar year.

1.4.3 The concentration of any substance in the treated leachate effluent discharge to the treated leachate infiltration pond must not be greater than the Contaminated Sites Regulation Generic Numerical Water Standards for Drinking Water (DW), for that substance.

1.4.4 The treated leachate effluent is authorized to be discharged to the treated leachate infiltration pond and infiltrated into the ground.

1.4.5 The authorized works are leachate conveyance, treatment and discharge works including pumps, pipes, leachate treatment pond(s), treated leachate infiltration pond, flow monitoring works, and related appurtenances approximately located as shown on Site Plan A.

1.4.6 The leachate treatment pond(s) 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 1×10^{-7} cm/s.

1.4.7 Minimum Freeboard must be maintained at all times as follows:
leachate treatment pond(s): 0.6 m
treated leachate infiltration pond: 0.6 m

1.4.8 The operational certificate holder must ensure the New Leachate Management Works are complete and fully operational on or before the date of commencement of waste discharge to the New Landfill, and at all times thereafter.

1.5 New Stormwater Management Works

This section applies to the management of stormwater from the New Landfill.

1.5.1 The operational certificate holder must manage stormwater from the New Landfill such that stormwater is infiltrated into the ground with the authorized works.

1.5.2 The stormwater must not include leachate and the concentration of any substance in the stormwater must not be greater than the Contaminated Sites Regulation Generic Numerical Water Standards for Drinking Water (DW), for that substance.

1.5.3 The authorized works are diversion berm, perimeter berm, mid slope swales, drop down channels, ditches, energy dissipation and sediment traps, stormwater infiltration area, and related appurtenances approximately located as shown on Site Plan A.

1.5.4 Minimum Freeboard must be maintained at all times as follows:
stormwater infiltration area: 0.6 m
all other authorized works: 0.3 m

1.5.5 The operational certificate holder must ensure that adequate authorized works to manage stormwater, such that stormwater is infiltrated into the ground with the authorized works, are complete and fully operational on or before the date of commencement of waste discharge to the New Landfill, and at all times thereafter.

1.6 **Facility Entrance**

This section applies to the Facility entrance.

1.6.1 The authorized works are sign(s), gate, fence, weigh scale, and related appurtenances approximately located as shown on Site Plan A.

1.6.2 The operational certificate holder must ensure the authorized works are complete and fully operational on or before the date of issuance of this operational certificate and at all times thereafter.

1.7 **Location of Facility**

This section applies to the location of the Facility.

1.7.1 The location of the Facility is PID 001-223-321, LOT A, DISTRICT LOT 85, SAYWARD DISTRICT, PLAN 30709 EXCEPT PART IN PLAN EPP15087, approximately located as shown on Site Plan A.

2. GENERAL REQUIREMENTS

2.1 **Glossary**

The following capitalized terms referred to in this authorization are defined in the Glossary below. Other terms used in this authorization have the same meaning as those defined in the *Environmental Management Act*, applicable regulations, and the Landfill Criteria;

“Attractant” means food or food waste, compost, carcass or part of an animal, fish, or other meat, or other waste or garbage, that could attract bears, birds, rodents, insects, vectors or wildlife, but does not include grass, leaves, weeds, branches and woodwaste;

“Facility” means the Original Landfill, Original Leachate Management Works, New Landfill, New Leachate Management Works, New Stormwater Management Works and the authorized works in section 1.6.1 (Facility Entrance) of this operational certificate;

“Freeboard” means the difference in elevation between the contained liquid level and the top of the containment works at its lowest point;

"Landfill Criteria" means the Landfill Criteria for Municipal Solid Waste Second Edition June 2016, as amended or replaced from time to time;

"New Landfill" means the authorized works in section 1.3.4 of this operational certificate;

"New Leachate Management Works" means the authorized works in section 1.4.5 of this operational certificate;

"New Stormwater Management Works" means the authorized works in section 1.5.3 of this operational certificate;

"Original Landfill" means the Original Lined Cell and the Original Un-Lined Cell;

"Original Leachate Management Works" means the authorized works in section 1.2.5 of this operational certificate;

"Original Lined Cell" means the authorized works in section 1.1.5(i) of this operational certificate;

"Original Un-Lined Cell" means the authorized works in section 1.1.5(ii) of this operational certificate;

"Province" means Her Majesty the Queen in right of British Columbia;

"Regulatory Document" means any document that the operational certificate holder is required to cause to be prepared, prepare or submit to the director or the Province, pursuant to: (i) this authorization; (ii) any regulation made under the *Environmental Management Act* that regulates the Facility described in this authorization or the discharge of waste from that Facility; or (iii) any order issued under the *Environmental Management Act* directed against the operational certificate holder that is related to the Facility described in this authorization or the discharge of waste from that Facility;

"Significant Works" means the Facility excluding the authorized works in section 1.6.1 (Facility Entrance) of this operational certificate.

2.2 Use of Qualified Professional(s)

The operational certificate holder must cause a Qualified Professional to:

(a) Design and inspect the construction of the Facility, and,

(b) Certify documents related to the Facility including plans, specifications, drawings, construction reports, assessments, reviews, investigations, studies, surveys, programs, reports and as-built record drawings.

(d) Submit a completed Declaration of Competency and a Conflict of Interest Disclosure Statement with each document.

2.3 **Operations and Closure Plan (OCP)**

(a) The operational certificate holder must cause a Qualified Professional to certify and submit an up to date OCP for the Original Landfill and the Original Leachate Management Works, to the director, on or before the earlier of:
(i) 30 days before the date of commencement of waste discharge to the Original Lined Cell,
(ii) 30 days after the date of issuance of this operational certificate.

(b) The OCP must comply with the requirements of this operational certificate, include information specified in relevant items listed in the Landfill Criteria Section 10.3 Design, Operations and Closure Plan including a site layout plan, a filling plan, a lifespan analysis table, a stormwater management plan, a leachate management plan, an environmental monitoring plan, an operations plan, a closure plan, and the information specified in the following sections of this operational certificate:
2.7(a) (soil acceptance plan), and,
2.10(a) (financial security plan).

(c) The operational certificate holder must carry out the most recent OCP and design, construct, operate, inspect, maintain, monitor and close the Original Landfill and the Original Leachate Management Works, in compliance with the most recent OCP and this operational certificate, until the Original Landfill and the Original Leachate Management Works are decommissioned in compliance with the plan referred to in section 2.9(a) (plan to remove all waste from the Original Landfill) of this operational certificate.

2.4 **Hydrogeology and Hydrology Characterization Report (HHCR)**

(a) The operational certificate holder must cause a Qualified Professional to certify and submit an up to date HHCR, to the director, on or before 90 days before the date of commencement of waste discharge to the New Landfill.

(b) The HHCR must include characterization of the geology, hydrogeology, and surface hydrology at and near the Facility site, and the information specified in all the items listed in the Landfill Criteria, section 10.1 Hydrogeology and Hydrology Characterization Report.

(c) The operational certificate holder must cause a Qualified Professional to certify and submit an updated HHCR to the director, at least once every five years after the date of commencement of waste discharge to the New Landfill.

2.5 **Design, Operations and Closure Plan (DOCP)**

(a) The operational certificate holder must cause a Qualified Professional to certify and submit an up to date DOCP, for the Facility, to the director, on or before 90 days before the date of commencement of waste discharge to the New Landfill.

(b) The DOCP must comply with the requirements of this operational certificate, include the information specified in all the items listed in the Landfill Criteria Section 10.3 Design, Operations and Closure Plan, and the information specified in the following sections of this operational certificate:

2.6(a) (New Leachate Management Works commissioning plan),
2.7(a) (soil acceptance plan),
2.8(a) (trigger level assessment plan),
2.9(a) (plan to remove all waste from the Original Landfill), and,
2.10(b) (financial security plan).

(c) The operational certificate holder must cause a Qualified Professional to certify and submit an updated DOCP to the director, as necessary to keep the DOCP up to date, at least once every five years after the date of commencement of waste discharge to the New Landfill.

(d) The operational certificate holder must carry out the most recent DOCP and design, construct, operate, inspect, maintain, monitor, and close the Facility, in compliance with most recent DOCP and this operational certificate.

2.6 **New Leachate Management Works Commissioning Plan and Report**

(a) The DOCP submitted pursuant to section 2.5 of this operational certificate must include a New Leachate Management Works commissioning plan that includes:

(i) the expected duration of the New Leachate Management Works commissioning period,
(ii) description of the New Leachate Management Works and design, including treatment of leachate from soil and treated leachate infiltration pond design and infiltration tests,
(iii) the monitoring, sampling and analyses that will be carried out during the New Leachate Management Works commissioning period including the quantity and quality of leachate and treated leachate effluent, and confirmatory sampling before the discharge of any treated leachate effluent to the treated leachate infiltration pond,
(iv) operating procedures that will be carried out during the New Leachate Management Works commissioning period including review of confirmatory sampling results before the discharge of any treated leachate effluent to the treated leachate infiltration pond,
(v) contingency measures that will be carried out during the New Leachate Management Works

commissioning period if the treated leachate effluent quality does not comply with this operational certificate, including storage, retreatment, and transport to an off-site authorized treatment facility,

(vi) New Leachate Management Works commissioning report description, table of contents and summary of contents.

(b) The operational certificate holder must cause a Qualified Professional to certify and submit a New Leachate Management Works commissioning report, that includes the information contemplated in section 2.6(a)(vi) of this operational certificate, to the director, on or before 30 days after the completion of the New Leachate Management Works commissioning period, or as specified by the director.

2.7 **Soil Acceptance Plan**

(a) The OCP submitted pursuant to section 2.3, and the DOCP submitted pursuant to section 2.5, of this operational certificate, must include a soil acceptance plan that includes procedures that will be carried out before soil is accepted at the Facility including receipt and review of documents required by section 2.7(b) of this operational certificate, and consideration of the applicable Original Leachate Management Works or New Leachate Management Works adequacy to treat leachate from the soil.

(b) Before a specific quantity of soil is accepted at the Facility, the operational certificate holder must cause a Qualified Professional to certify and submit to the operational certificate holder, a document pertaining to the specific quantity of soil that includes:

(i) the soil tonnage(s) and soil quality class(es) as described in the most recent version of Technical Guidance 1 on Contaminated Sites Site Characterization and Confirmation Testing,

(ii) the soil origin including applicable civic address, site identification number, parcel identifier, parcel identification number, legal description, and,

(iii) characterization of the soil in accordance with ministry procedures and applicable Contaminated Sites Regulation Guidance, Protocols and Procedures.

2.8 **Trigger Level Assessment Plan**

(a) The DOCP submitted pursuant to section 2.5 of this operational certificate must include a trigger level assessment plan that includes:

(i) Description of the routine monitoring of the quantity and quality of leachate leakage through the primary liner and into the leak detection layer for the New Landfill, and for the leachate treatment pond(s), and related leachate leakage quantities and qualities that will trigger corresponding described increased monitoring, investigations, contingency measures and actions.

(ii) Description of the routine monitoring of groundwater quality immediately downgradient of the New Landfill, the leachate treatment pond(s), and the treated leachate infiltration pond, and related groundwater substance concentrations that will trigger corresponding described increased monitoring, investigations, contingency measures and actions.

2.9 Plan to Remove all Waste from the Original Landfill

(a) 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.

(b) Subject to section 1.3.2 of this operational certificate, waste removed from the Original Landfill is authorized to be discharged to the New Landfill. The tonnage of such waste must not be included for the purpose of determining compliance with section 1.3.1 of this operational certificate.

(c) The director may require the operational certificate holder to carry out and complete the plan referred to in section 2.9(a) of this operational certificate, in accordance with the director's requirements.

(d) If the plan referred to in section 2.9(a) of this operational certificate is carried out, the operational certificate holder must cause a Qualified Professional to certify and submit a report to the director that confirms that the plan has been carried out and completed in accordance with the director's requirements, describes the plan implementation, describes and provides the waste categorization, describes and provides the sampling and results, describes the decommissioning of the Original Landfill and the Original Leachate Management Works, provides photos documenting the implementation of the plan referred to in section 2.9(a) of this operational certificate, and lists the tonnages or volumes, and categories of waste removed and discharged to the New Landfill and to other identified and authorized waste management facility(ies), on or before 60 days after the plan referred to in section 2.9(a) of this operational certificate has been carried out and completed.

2.10 Financial Security

(a) The OCP submitted pursuant to section 2.3 of this operational certificate must include a financial security plan that includes:
   (i) the calculations of the amounts of financial security and time periods for each phase of development for the Original Landfill in accordance with the Landfill Criteria Section 8.0 Financial Security, and,
   (ii) the amounts of financial security for the corresponding time periods.

(b) The DOCP submitted pursuant to section 2.5 of this operational certificate must include a financial security plan that includes:
   (i) the tasks, estimated costs, contingency costs, calculations of the amounts of financial security

and time periods, to carry out and complete the plan referred to in section 2.9(a) of this operational certificate (plan to remove all waste from the Original Landfill),
(ii) the calculations of the amounts of financial security and time periods for each phase of development for the New Landfill in accordance with the Landfill Criteria Section 8.0 Financial Security, and,
(iii) the amounts of financial security for the corresponding time periods.

(c) The operational certificate holder must provide the director with financial security, on or before the earlier of:
(i) 30 days before the date of commencement of waste discharge to the Original Lined Cell,
(ii) 30 days after the date of issuance of this operational certificate,
(iii) 90 days before the date of commencement of waste discharge to the New Landfill,
and at all times thereafter.

(d) The amount of financial security at any time must be equal to or greater than:
(i) Before the report referred to in section 2.9(d) (report that confirms that the plan referred to in section 2.9(a) of this operational certificate has been carried out and completed) of this operational certificate is submitted to the director, the greater amount specified for the corresponding time period in:
- the financial security plan in the most recent OCP,
- the financial security plan in the most recent DOCP.
(ii) On and after the report referred to in section 2.9(d) (report that confirms that the plan referred to in section 2.9(a) of this operational certificate has been carried out and completed) of this operational certificate is submitted to the director, the amount specified for the corresponding time period in the financial security plan in the most recent DOCP.

(e) The form of financial security must be satisfactory to the director.

(f) At the discretion of the director, such financial security may be used among other things:
(i) to correct any inadequacy of the Facility relating to its design, construction, operation, inspection, maintenance, monitoring, closure, and post-closure;
(ii) to correct any default in compliance with this operational certificate or the *Environmental Management Act*; and,
(iii) for remediation of the Facility.

(g) The operational certificate holder must replenish any amounts drawn from the posted financial security within 60 days of such amounts being drawn or as otherwise specified by the director.

2.11 **<u>Construction Report(s)</u>**

(a) The operational certificate holder must cause a Qualified Professional to carry out inspections before and during the construction or modification of Significant Works, and, after the completion of construction or modification of Significant Works, to certify and submit construction report(s) to the director:

(i) for construction of the New Landfill and the New Leachate Management Works, on or before 30 days before the date of commencement of waste discharge to those new Significant Works, and,
(ii) for all Significant Works, on or before 60 days after the completion of construction or modification of the Significant Works.

(b) The construction report(s) must demonstrate that the Significant Works have been constructed in accordance with this operational certificate and the applicable most recent OCP or DOCP, describe any technical concerns that arose from the inspections and testing and how they were addressed, and include as-built record drawings of the constructed Significant Works, all the inspection and testing reports and results including geologic inspection report, quality control and quality assurance testing, soil test data including field and laboratory data, as described in the Landfill Criteria section 10.2 Construction Report(s).

2.12 **Notification of Commencement of Waste Discharge**

The operational certificate holder must notify the director of:
(a) the date of commencement of waste discharge to the Original Lined Cell, on that date,
(b) the date of commencement of waste discharge to the New Landfill, on that date,
(c) the date the Original Lined Cell has reached capacity, on that date, and,
(d) the date the plan referred to in section 2.9(a) of this operational certificate has been carried out and completed, on that date.

2.13 **Buffer Zone**

The operational certificate holder must ensure that the New Landfill, New Leachate Management Works, and New Stormwater Management Works, are located a minimum of 50 m from the Facility site boundary.

2.14 **Depth to Groundwater**

The operational certificate holder must ensure that the New Landfill secondary base liner, and the New Leachate Management Works leachate treatment pond(s) secondary base liner, are a minimum of 1.5 m above groundwater at all times.

2.15 **Covenant**

On or before the date of commencement of waste discharge to the New Landfill, the operational certificate holder must register a covenant under section 219 (1) of the *Land Title Act*, in a form acceptable to the director, that binds successors in title to uphold the continued implementation of the closure plan in the most recent DOCP, and prohibits development of the Facility other than as contemplated by this operational certificate or approved by the director. Such covenant must include an acknowledgement that the property was used for the purpose of waste disposal, must be registered as a charge against title to the property on which the facility is located and must be registered in priority to all charges except charges which do not give the holders any rights which might conflict with the covenant.

2.16 Additional Requirements

The director may require the operational certificate holder to:

(a) Cause a Qualified Professional to certify and submit to the director additional, amended or improved documents of the Facility including plans, specifications, drawings, construction reports, assessments, reviews, investigations, studies, surveys, programs, reports and as-built record drawings.

(b) Carry out actions in accordance with the additional, amended or improved documents submitted, and additional actions as specified.

(c) Repair, alter, remove, improve or add to existing facilities and works, or construct new facilities and works, at the Facility.

(d) Temporarily or permanently cease waste discharge to the Original Lined Cell and/or the New Landfill, cover part(s) or all of the Original Landfill and/or the New Landfill with final cover, and close and decommission the Facility, as specified.

2.17 Authorization Requirements

Where this authorization provides that the director may specify a matter or require an action to be carried out, the operational certificate holder must comply with the specification and carry out the action in accordance with the requirements of the director.

3. OPERATING AND PERFORMANCE REQUIREMENTS

3.1 Multiple and/or Spare Works and Auxiliary Power Facilities

The operational certificate holder must provide and install multiple and/or spare works and auxiliary power facilities to ensure the Original Lined Cell, Original Leachate Management Works, New Landfill, New Leachate Management Works, and New Stormwater Management Works, are complete and fully operational as specified in this operational certificate, including during maintenance, breakdowns and electrical power outages.

3.2 Maintenance of the Facility

(a) The operational certificate holder must cause persons that are qualified and trained to operate, regularly inspect, and maintain the Facility, in good working order. If components of the Facility have a manufacturer's recommended maintenance schedule, then those components must, at a minimum, be maintained in accordance with that schedule.

(b) The operational certificate holder must prepare documents of the qualification and training of the persons operating, inspecting and maintaining the Facility, and of Facility inspections, operation and maintenance.

3.3 Facility Manager and Operator Certification

(a) The operational certificate holder must ensure that at least one person responsible for the management of the Facility is certified, and maintains certification, by The Solid Waste Association of North America (SWANA) as a Manager of Landfill Operations, and at least one person responsible for the operation of the Facility has, within the preceding five years, successfully completed the SWANA Landfill Operations Basics course, on or before the earlier of:

(i) the date of commencement of waste discharge to the Original Lined Cell,

(ii) the date of commencement of waste discharge to the New Landfill,

and at all times thereafter.

(b) The operational certificate holder must prepare documents of the SWANA certification and training of the person(s) responsible for the management and operation of the Facility.

3.4 New Leachate Management Works Classification and Operator Certification

(a) The operational certificate holder must have the New Leachate Management Works classified by the Environmental Operators Certification Program (EOCP), on or before the date of commencement of waste discharge to the New Landfill, and at all times thereafter.

(b) The operational certificate holder must ensure that the person(s) responsible for the operation and maintenance of the New Leachate Management Works is(are) certified at an EOCP certification level equivalent to or higher than the EOCP classification level of the New Leachate Management Works, on or before the date of commencement of waste discharge to the New Landfill, and at all times thereafter.

(c) The operational certificate holder must prepare documents of the EOCP classification level of the New Leachate Management Works and the EOCP certification level(s) of the person(s) responsible for the operation and maintenance of the New Leachate Management Works.

3.5 Groundwater Quality

(a) The operational certificate holder must ensure that the Facility does not cause the concentration of any substance in groundwater flowing from the Facility site boundary to be greater than:

(i) the Contaminated Sites Regulation Generic Numerical Water Standards for Drinking Water (DW), for that substance,

or,

(ii) if the local background concentration of any substance is greater than (i), the local background concentration of that substance.

(b) If section 3.5(a)(ii) of this operational certificate is being used, the operational certificate holder must cause a Qualified Professional to determine the local background concentration of substance(s) in (a), in accordance with the latest approved version of Protocol 9 for Contaminated Sites, Determining Background Groundwater Quality, and include such determination(s) in the Annual Operations and Monitoring Report.

(c) The director may specify more stringent groundwater quality standards than those set out in this section.

3.6 Landfill Gas Management

The operational certificate holder must ensure that:

(a) The Facility does not cause:

(i) combustible gas concentrations to exceed the lower explosive limit of methane (5 percent by volume), or a lower concentration specified by the director, in soil at the Facility site boundary;
(ii) combustible gas concentrations to exceed 20 percent of the lower explosive limit of methane (1 percent by volume) in any building; and
(iii) federal, provincial, or local ambient air quality objectives and standards to be exceeded in air at the Facility site boundary.

(b) Landfill gas is managed in accordance with all migration and health and safety requirements.

3.7 Nuisance

The operational certificate holder must ensure that the Facility does not cause a nuisance including with regard to birds, rodents, insects, odour, noise, dust, litter, vector and wildlife attraction.

3.8 Complaints

The operational certificate holder must prepare documents of complaints with regard to matters relevant to this operational certificate, including environmental and nuisance complaints. These documents must include the source and nature of the complaint, actions, responses, and corresponding dates and times.

3.9 **Regulatory Documents**

(a) The operational certificate holder must retain all Regulatory Documents.

(b) The operational certificate holder must retain all Regulatory Documents for the last seven years at the Facility and such documents must be available for immediate inspection at the Facility by a director or an officer.

(c) If requested by a director or an officer, the operational certificate holder must submit the requested Regulatory Documents to the director or officer within 14 days of the request.

4. **SAMPLING REQUIREMENTS**

4.1 **Sampling Procedures**

The operational certificate holder must carry out required sampling in accordance with the procedures described in the "British Columbia Field Sampling Manual for Continuous Monitoring and the Collection of Air, Air-Emission, Water, Wastewater, Soil, Sediment, and Biological Samples, 2013 Edition (Permittee)" or most recent edition, or by alternative procedures as authorized by the director. A copy of the above manual is available on the Ministry web page at https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/laboratory-standards-quality-assurance.

4.2 **Analytical Procedures**

The operational certificate holder must carry out required analyses in accordance with procedures described in the "British Columbia Laboratory Manual (2015 Permittee Edition)", or the most recent edition or by alternative procedures as authorized by the director. A copy of the above manual is available on the Ministry web page at https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/laboratory-standards-quality-assurance.

4.3 **Quality Assurance**

(a) The operational certificate holder must obtain from the analytical laboratory(ies) their precision, accuracy and blank data for each sample set submitted by the operational certificate holder and an evaluation of the data acceptability, based on criteria set by such laboratory.

(b) The operational certificate holder must submit samples to analytical laboratory(ies) that meet the definition of a qualified laboratory under the Environmental Data Quality Assurance Regulation.

(c) The operational certificate holder must collect, prepare and submit for analysis by the analytical laboratory(ies) quality control (QC) samples for each parameter. As a minimum,

(i) The number of QC samples should be 20% of all samples collected (environmental + QC samples) within 48 hours of each other, and

(ii) Include duplicate, field and trip blank samples for each parameter.

5. REPORTING REQUIREMENTS

5.1 Routine Reporting

The operational certificate holder must submit all routine Regulatory Documents required by this operational certificate by email to the Ministry's Routine Environmental Reporting Submission Mailbox at EnvAuthorizationsReporting@gov.bc.ca or as otherwise instructed by the director. For guidelines on how to properly name the files and email subject lines or for more information visit the Ministry website http://www2.gov.bc.ca/gov/content/environment/waste-management/waste-discharge-authorization/data-and-report-submissions/routine-environmental-reporting-submission-mailbox.

5.2 Non-compliance Notification

(a) The operational certificate holder must immediately notify the director or designate by email at EnvironmentalCompliance@gov.bc.ca, or as otherwise instructed by the director of any non-compliance with the requirements of this authorization by the operational certificate holder and must take remedial action to remedy any effects of such non-compliance.

(b) The operational certificate holder must provide the director with written confirmation of all such non-compliance events, including available test results within 24 hours of the original notification by email at EnvironmentalCompliance@gov.bc.ca, or as otherwise instructed by the director.

5.3. Non-compliance Reporting

(a) If the operational certificate holder fails to comply with any of the requirements of this authorization, the operational certificate holder must, within 30 days of such non-compliance, submit to the director a written report that is satisfactory to the director and includes, but is not necessarily limited to, the following:

(i) all relevant test results obtained by the operational certificate holder related to the non-compliance,

(ii) an explanation of the most probable cause(s) of the non-compliance, and
(iii) a description of remedial action planned and/or taken by the operational certificate holder to prevent similar non-compliance(s) in the future.

(b) The operational certificate holder must submit all non-compliance reporting required to be submitted under this section by email to the Ministry's Compliance Reporting Submission Mailbox at EnvironmentalCompliance@gov.bc.ca or as otherwise instructed by the director. For guidelines on how to report a non-compliance or for more information visit the Ministry website http://www2.gov.bc.ca/gov/content/environment/waste-management/waste-discharge-authorization/data-and-report-submissions/non-compliance-reporting-mailbox.

5.4 **Annual Operations and Monitoring Report**

(a) The operational certificate holder must cause a Qualified Professional to certify and submit an Annual Operations and Monitoring Report in a format suitable for public release, for the preceding calendar year, to the director on or before March 31 of each year. On or before March 31 of each year, the operational certificate holder must post a copy of the Annual Operations and Monitoring Report online, on a website accessible to the public, and in accordance with any requirements of the director.

(b) The Annual Operations and Monitoring Report must include the following information:
Operations Report:

(i) Summary of OCP implementation that addresses the information in section 2.3(b), and summary of DOCP implementation that addresses the information in 2.5(b), of this operational certificate,
(ii) Summary of construction report(s),
(iii) Annual and cumulative tonnages and categories of waste including soil tonnage(s) and soil quality class(es) discharged to the Original Lined Cell and to the New Landfill,
(iv) Remaining volume and life of the Original Lined Cell and of the New Landfill,
(v) Summary of treated leachate effluent quantity and quality discharged to the treated leachate infiltration pond,
(vi) Summary of complaints and nuisances and description of remedial action planned and/or taken by the operational certificate holder to prevent similar complaints and nuisances in the future,
(vii) Summary of non-compliance notifications and non-compliance reporting and description of remedial action planned and/or taken by the operational certificate holder to prevent similar non-compliance(s) in the future ,
(viii) Annual status form in accordance with the instructions and template at the ministry website https://www2.gov.bc.ca/gov/content/environment/waste-management/waste-discharge-authorization/data-and-report-submissions/annual-status-form
(ix) Summary of OCP and DOCP implementation, and construction of Significant Works, planned for the next calendar year,

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for Director, *Environmental Management Act*
Authorizations - South Region

Environmental Monitoring Plan Report:

(x) Site plan(s), sampling locations, stormwater flow paths, groundwater elevations, gradients and flow directions,
(xi) Sampling facilities, frequencies, substances, sampling and analytical procedures,
(xii) Data including laboratory analysis and quality assurance and quality control results,
(xiii) Data tabulation, trend analysis, graphs, diagrams, and interpretation,
(xiv) Trigger level assessment plan monitoring, data, results and interpretation,
(xv) Any determination(s) of the local background concentration of substance(s) in accordance with section 3.5 of this operational certificate,
(xvi) Comparison of the data with the standards for treated leachate effluent discharge, stormwater quality, groundwater quality, and landfill gas management, specified in sections 1.2, 1.4, 1.5, 3.5 and 3.6 of this operational certificate, and identification of any non-compliance and predicted future non-compliance,
(xvii) Results, conclusions, recommendations and changes to the environmental monitoring plan.

(c) The operational certificate holder must upload monitoring data associated with this operational certificate to the Ministry's Environmental Monitoring System (EMS) database, within 45 days of the end of the 3 month period in which the data is collected.

5.5 **Licence to Publish Documents**

(a) Subject to paragraph (b), the operational certificate holder authorizes the Province to publish on the Ministry of Environment and Climate Change Strategy website the entirety of any Regulatory Document.

(b) The Province will not publish any information that could not, if it were subject to a request under section 5 of the *Freedom of Information and Protection of Privacy Act*, be disclosed under that Act.

(c) The operational certificate holder will indemnify and save harmless the Province and the Province's employees and agents from any claim for infringement of copyright or other intellectual property rights that the Province or any of the Province's employees or agents may sustain, incur, suffer or be put to at any time that arise from the publication of a Regulatory Document.

Date issued: August 1, 2019

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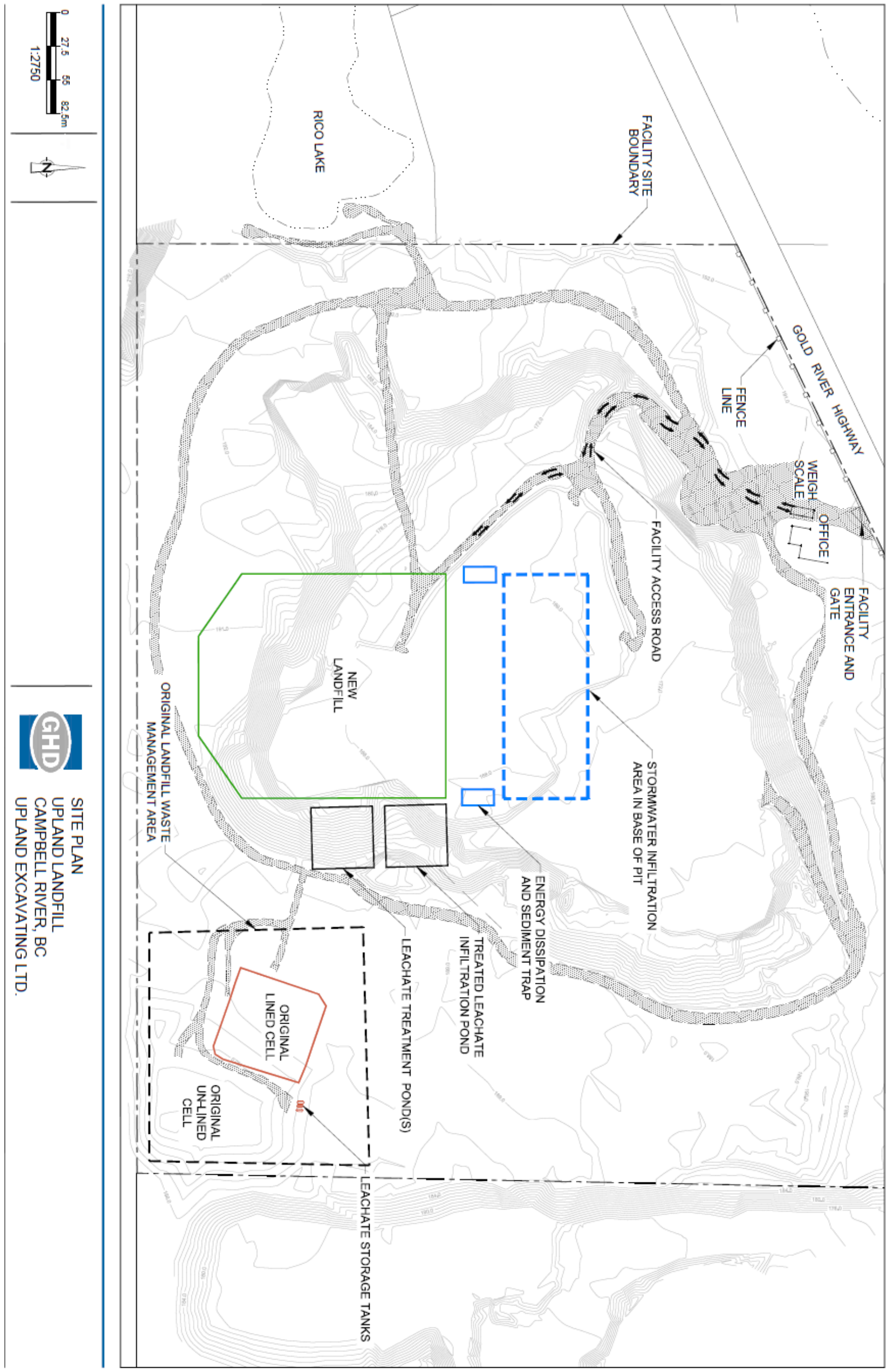
for Director, *Environmental Management Act*
Authorizations - South Region

Site Plan A



Date issued: August 1, 2019

Luc Lachance, P.Eng
for Director, *Environmental Management Act*
Authorizations - South Region

 Operational Certificate Number: 107689

Appendix B
HDPE Geomembrane Liner Performance Review

Appendix B Liner Performance Review

1. Liner Performance Review

High-density polyethylene (HDPE) geomembranes have very high performance in containing common leachate constituents at concentrations found in landfill leachate. Geomembranes are an excellent barrier to ionic contaminants such as chloride and heavy metals, and when used in composite liners, the secondary layer provides resistance to diffusive transport of vapour phase contaminants (Rowe et al. 2004). The use of HDPE geomembranes in composite liner systems is an industry standard for all types of landfills, worldwide.

The United States Environmental Protection Agency (USEPA) promotes the use of HDPE geomembranes in composite liner systems for both hazardous and non-hazardous waste landfills (Resource Conservation and Recovery Act (RCRA) Subtitle C and Subtitle D regulations) (USOFR, 2006). The Canadian Council of Ministers of the Environment (CCME) National Guidelines for Hazardous Waste Landfills, 2006 specifies the use of HDPE geomembranes in combination with a clay layer or GCL for the containment of hazardous wastes due the complimentary properties of the two different liner materials. Many North American regulatory jurisdictions generically accept the performance life of HDPE membranes in landfill liner systems as being over 100 years, well beyond the contaminating life span of most landfills.

The Landfill has an estimated operating site life of 13 years. The Contaminating Lifespan (CLS) Assessment for the landfill as presented in the DOCP, is estimated to be 28 years and rounded up to 30 years per the Landfill Criteria requirements. The CLS is the period of time during which the Site could produce leachate contaminants at concentrations that could have an unacceptable impact if they were discharged from the Site.

1.1 Expected Leachate Quality

As in the 2020 DOCP, the Landfill will accept waste select municipal solid waste, as defined by the Environmental Management Act, and will include the following:

- Construction and demolition waste
- Land clearing debris
- Soil meeting Industrial land use standards, per the BC CSR
- Waste asbestos containing materials (ACM), managed according to Section 40 of the HWR

The Landfill leachate is expected to be characteristic of demolition, land clearing and construction (DLC) waste landfills (C&D landfills). Typically, the most potentially prominent contaminants in the leachate from C&D landfills are sulphate, arsenic, iron, manganese, and total dissolved solids (TDS). Non-hazardous contaminated soil may contain a 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). The leachability of the contaminants in non-hazardous contaminated soil is low compared to hazardous waste that may contain elevated concentrations and potentially include free-product. Soil must meet Industrial land use standards per the CSR to be accepted at the Site. 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 distinguish hazardous chemicals, identified in the HWR. Once landfilled ACM is an inert material.

HDPE geomembranes are used in landfill applications, especially for bottom liners, because of their relatively high resistance to aggressive leachate components (Rowe, 2001). However, unlike putrescible municipal solid waste (MSW), DLC waste consists largely of inorganic components and organic matter with a low degree of biodegradability. Typical concentration ranges of leachate parameters for DLC landfills are lower than for MSW (Weber et al., 2002).

Based on accepted waste management practices, and forecasted leachate quality, a composite liner consisting of an HDPE geomembrane and a GCL is an appropriate base liner for the Landfill.

1.2 HDPE Geomembrane Durability

Examinations of both laboratory and field data available in the literature indicate that the projected service lives of HDPE geomembranes may range depending on the material and exposure conditions. HDPE liner durability or lifetime is typically described as the material half-life, the time at which design properties have been reduced to 50%. The ageing process of HDPE geomembranes involves a combination of physical and chemical ageing that will, over time, eventually lead to material degradation. This sub-section describes the structure of HDPE and its potential failure mechanisms and reviews the predicted durability of the HDPE liner system in the context of the Site life and contaminating lifespan of the Landfill.

1.3 Structure of HDPE

HDPE is formulated by percentage based on weight 95 - 98% resin, 2- 3% carbon black (colourant) and 0.25 – 1% additives, such as antioxidants and other stabilizers (Rowe and Sangam, 2001). If the formulation changes (particularly the additives), the predicted lifetime will also change. The typical structure of a polyethylene consists of linked carbon atoms that are bonded to hydrogen with the molecular chains folded together to form ordered regions called lamellae (Rowe and Sangam, 2001). HDPE is defined as a semi-crystalline polymer with partially aligned molecular chains. Some of the inherent properties of HDPE depend on its molecular packing structure and therefore, changes at the molecular level many alter the durability and the overall field performance of the geomembrane (Tarnowski and Baldauf, 2006).

1.4 Failure Mechanisms

HDPE can be degraded to only a limited extent by most inorganic and organic chemicals (Tarnowski and Baldauf, 2006). Photo and/or thermo-oxidative ageing, depending on the application, is the primary cause of degradation of the polymer (Tarnowski and Baldauf, 2006). Under covered conditions in medium temperature and in the absence of UV radiation, oxidation takes place very slowly. The failure mechanisms that are potentially applicable for buried HDPE geomembranes include:

- Oxidation – is the major mechanisms of degradation in polyethylenes, including HDPE under all conditions. The polymer chains undergo reactions with oxygen leading eventually to changes in molecular structure and in morphology.
- Chemical – can occur when one or more components are removed from the material due to long-term exposure to chemicals or liquids (Rowe and Sangam, 2001). In HDPE geomembranes, the additives incorporated in the polymer formation may be susceptible to extraction, which would leave the geomembrane unprotected and susceptible to subsequent oxidative degradation (Koerner et al., 2005).
- Temperature – the higher the temperature the more rapid the degradation via the oxidation and chemical mechanisms described above.
- Stress state – typically geomembranes are subjected to vertical compressive stress but actual stress is site-specific. The presence of tensile stresses less than the short-term mechanical strength of the material lead to environmental stress cracking (Koerner et al., 2005). The presence of chemicals may accelerate cracking (Koerner et al., 2005).

1.5 Lifetime Stages of HDPE

Hsuan and Koerner (1998) describe that the oxidative degradation of HDPE geomembrane can be divided into three distinct stages:

- Stage A – Antioxidant depletion time.
- Stage B – Induction Time to the Onset of Degradation.
- Stage C – Time to reach 50% Degradation (Half-life), based on change of the molecular structure accompanied by a deterioration of the decisive mechanical properties.

The duration of the antioxidant depletion stage (Stage A) is dependent on both the type and amount of various antioxidants used in the precise formulation of the HDPE, the service temperature and the nature of the site-specific environment (Rowe and Sangam, 2001). The depletion of anti-oxidants is a consequence of chemical reactions with oxygen diffusing into the geomembrane and the physical loss of anti-oxidants from the geomembrane. The physical loss of anti-oxidants is related to their physical distribution in the geomembrane and their volatility and extractability in the in-situ environment (Koerner et al., 2005).

Once anti-oxidants are depleted, the rate of oxidation follows an S-shaped curve: the initial rate of oxidation is very slow, followed by an accelerated period and then the rate slows again. The initial period of slow oxidation is referred to as induction time or Stage B (Hsuan and Koerner, 1998). During Stage B the polymer reacts with oxygen forming hydroperoxide (ROOH), however the amount of ROOH formed is very small and the compound does not decompose further into other free radicals at this stage. As oxidation continues and ROOH is being formed, the concentration of ROOH will eventually reach a critical level at which ROOH begins to decompose into other free radicals. The presence of additional free radicals causes an increased rate of oxidation, which signifies the end of Stage B.

In Stage C oxidation continues and the polymer begins to degrade with noticeable change in the physical properties, including decreases in both tensile strength and break strain until the material reaches the limit of service life (half-life) (Hsuan and Koerner, 1998).

1.6 Service Life Estimate

Sangam (2001) examined the service lives of HDPE geomembranes under various exposure condition scenarios that the geomembranes may be subjected to when used as bottom liners for MSW landfills. For the typical groundwater temperature range of 7–10°C, Sangam (2001) estimated that the geomembrane used as a secondary liner will last at least 400 years provided that it has a suitable antioxidant package, is not subjected to significant tensile stress and is covered by an adequate protection layer. Koerner, Hsuan and Koerner (2005) used test-derived data and modeling to estimate that the total predicted half-life (Stages A, B and C) of HDPE is between 446 years at 20°C and 69 years at 40°C. The predicated time of Stage C was based on Arrhenius modeling and is dependent on the activation energy.

The average annual surface temperature in Campbell River, BC is 9.0°C and ranges from a daily average of 2.1°C in December to 17.3°C in July (Government of Canada, 2018). Due the nature of the waste, being DLC and not containing significant volumes of putrescible waste, biological activity will not be significant, therefore the temperature on the liner is not expected to be elevated. Based on the preceding, the HDPE geomembrane will be exposed to temperatures below or within the range of 20°C resulting in a service life well beyond the estimated CLS of the Landfill.

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Appendix C
Soil Acceptance Plan

Northwin Landfill
#210-909 Island Highway
Campbell River, BC
V9W 2C2
Phone (250) 286-1148
Fax (250) 286-3546

Soil Screening Process

Upland staff will complete the following steps prior to the acceptance of soil and during discharge at the Original Landfill lined cell.

Phase 1 – Prior to Discharge

Ask the Company the following questions and confirm their responses by visual inspection.

1. Is the soil generated from a site that may be contaminated? Y/N
2. Does the soil contain or is intermixed with waste including but not limited to plastic, metal debris, PVC pipe, or insulation? Y/N
3. Does the soil have any visible stains? Y/N
4. Is the soil odorous? Y/N
5. Does the soil comply with the OCP Soil Acceptance Plan? Y/N

The generating company must sign the Soil Acceptance Agreement, answered No to Questions 1 to 4, and answered Yes to Question 5, before proceeding with soil discharge to the Original Landfill lined cell.

If the answer to Question 1 is yes, the soil characterization must be certified by Qualified Professional.

Phase 2 – During/Following Discharge

During discharge (i.e., dumping) at the lined cell, confirm that the soil does not contain any waste material including but not limited to:

1. Plastic
2. Metal debris
3. PVC pipe
4. Insulation
5. Asbestos Containing Material
6. Other waste material
7. Staining
8. Odorous soil (i.e., gasoline, chemical, paint; etc. odour)

If the soil contains one or more waste materials, isolate the soil for testing or removal. Record non-compliant or rejected loads on the corresponding Soil Acceptance Agreement and contact your supervisor for further direction.

Northwin Landfill
#210-909 Island Highway
Campbell River, BC
V9W 2C2
Phone (250) 286-1148 Fax (250) 286-3546

Soil Acceptance Agreement

This Agreement must be executed before any soil can be accepted by Upland Excavating Ltd. at the Northwin Landfill located at 7295 Gold River Highway (Northwin Landfill). The Northwin Landfill requires this agreement to be executed by an authorized signatory of your firm (the “Company”).

By signing this agreement, the Company represents and warrants to Northwin Landfill that none of the soil delivered to Northwin Landfill by the Company is hazardous waste and does not contain any hazardous waste constituents as defined by the Qualified Professional for the Northwin Landfill (the “Criteria”) or any other criteria stipulated by Northwin Landfill and which may be amended from time to time at its sole discretion upon notice to the Company.

Northwin Landfill further serves the right to inspect and sample and/or may require the Company to sample any and all soil before accepting the soil. The right of Northwin Landfill to inspect or sample the soil does not reduce, restrict or otherwise affect the Company’s liability in relation to soil that that contains any waste material or does not meet the Criteria. Any soil that contains waste material or does not meet the Criteria may be rejected by Northwin Landfill acting in its discretion and Northwin Landfill may request the Company to remove and dispose of such soil/material, such removal and disposal being the sole cost, risk and responsibility of the Company. If after acceptance by Northwin Landfill, the soil is discovered to include waste material or not meet the Criteria, Northwin Landfill will notify the Company. If requested the Company shall remove the soil/material within 24 hours of notification and dispose of the same in accordance with all applicable laws.

The Company agrees to defend, indemnify and hold Northwin Landfill harmless from and against any and all claims, demands, orders, causes of action, damages, liabilities, losses, expenses, penalties and all costs of defense relative thereto, including legal fees, caused by or resulting from the Company’s breach of this agreement, including without limitation, any breach of the Company’s obligation to deliver only soil and meets the Criteria.

This Agreement does not confer a right on the Company to deliver soil to the Northwin Landfill. Northwin Landfill reserves the right to reject for any reason, any and all deliveries of soil made by or desired to be made by the Company.

This Agreement commences effective as of the first day on which the Company delivers soil to the Northwin Landfill.

Any waiver of any provisions of this Agreement must be in writing signed by the Northwin Landfill.

Name:	Title:
Company:	Company Address:
Site Name:	Site Address:
Signature:	Date:

Appendix D
Surface Water Management Plan Supporting Documents

Environment and Climate Change Canada
Environnement et Changement climatique Canada

Short Duration Rainfall Intensity-Duration-Frequency Data
Données sur l'intensité, la durée et la fréquence des chutes de pluie de courte durée

Gumbel - Method of moments/Méthode des moments

2021/03/26

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CAMPBELL RIVER A BC 1021261
(composite)
Latitude: 49 57'N Longitude: 125 16'W Elevation/Altitude: 108 m

Years/Années : 1970 - 2002 # Years/Années : 21

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Table 1 : Annual Maximum (mm)/Maximum annuel (mm)

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Year Année	5 min	10 min	15 min	30 min	1 h	2 h	6 h	12 h	24 h
1970	-99.9	-99.9	-99.9	-99.9	9.4	16.0	25.7	43.7	55.1
1971	-99.9	-99.9	-99.9	-99.9	9.1	15.5	29.2	46.0	57.7
1972	-99.9	-99.9	-99.9	-99.9	15.5	22.9	38.9	57.9	73.9
1973	-99.9	-99.9	-99.9	-99.9	9.1	14.0	26.2	39.4	53.3
1974	-99.9	-99.9	-99.9	-99.9	8.1	12.4	26.4	39.9	65.5
1975	-99.9	-99.9	-99.9	-99.9	18.3	20.6	41.9	44.2	59.7
1976	-99.9	-99.9	-99.9	-99.9	8.1	15.7	41.1	45.7	48.5
1981	-99.9	-99.9	-99.9	-99.9	12.4	18.6	33.4	39.8	63.2
1982	3.3	5.2	7.8	13.7	17.7	19.6	32.4	49.2	62.9
1983	2.8	3.9	4.7	7.4	10.9	17.7	33.6	53.1	79.6
1984	4.2	5.6	6.9	12.3	20.2	29.6	48.6	59.3	62.0
1985	2.6	2.9	3.6	6.3	9.0	12.0	21.4	24.7	36.8
1986	5.1	5.9	6.1	7.3	7.8	13.9	27.5	40.7	56.1
1987	2.4	3.2	3.7	4.6	8.5	16.4	39.0	43.6	65.7
1988	1.8	2.2	3.0	4.9	8.6	16.9	36.1	45.7	50.5
1989	4.6	7.1	9.0	13.0	14.5	14.6	18.5	29.2	39.2
1990	5.2	7.7	9.6	12.9	15.8	16.2	24.7	45.9	69.8
1991	1.7	2.8	3.9	5.9	9.6	16.9	42.5	64.1	72.3
1992	3.1	4.3	6.1	8.6	11.4	13.6	28.6	-99.9	61.6
1993	2.1	3.6	4.1	6.5	9.3	16.0	36.2	61.9	97.4
1994	3.6	4.8	5.3	6.8	9.7	15.3	31.9	49.6	58.3

1995	7.4	10.4	11.6	12.4	14.1	19.5	34.8	53.6	68.1
1996	5.5	5.9	6.1	8.0	11.5	14.9	27.6	39.9	50.9
1997	4.9	5.8	7.0	9.5	10.9	13.5	35.1	41.6	63.6
1998	5.5	8.8	10.3	13.1	15.3	18.8	32.5	-99.9	61.0
1999	2.2	3.6	4.5	6.0	9.1	17.2	33.2	63.6	81.0
2000	5.5	8.4	10.2	13.1	14.7	14.7	20.2	28.4	37.8
2001	3.5	4.8	5.4	8.9	13.5	18.1	32.3	38.3	46.8
2002	3.9	4.9	6.2	6.9	9.7	13.1	26.1	43.5	55.7
# Yrs. Années	21	21	21	21	29	29	29	27	29
Mean Moyenne	3.9	5.3	6.4	9.0	11.8	16.7	31.9	45.6	60.5
Std. Dev. Écart-type	1.5	2.2	2.5	3.1	3.5	3.6	7.1	10.1	13.2
Skew. Dissymétrie	0.45	0.75	0.62	0.35	0.86	1.84	0.21	0.06	0.50
Kurtosis	3.03	3.42	2.78	1.93	2.98	8.31	3.13	3.19	4.36

*-99.9 Indicates Missing Data/Données manquantes

Warning: annual maximum amount greater than 100-yr return period amount
Avertissement : la quantité maximale annuelle excède la quantité pour une période de retour de 100 ans

Year/Année	Duration/Durée	Data/Données	100-yr/ans
1984	2 h	29.6	27.8

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Table 2a : Return Period Rainfall Amounts (mm)
Quantité de pluie (mm) par période de retour

****

Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années
5 min	3.6	4.9	5.8	7.0	7.8	8.6	21
10 min	5.0	6.9	8.1	9.7	10.9	12.1	21
15 min	6.0	8.2	9.7	11.5	12.9	14.2	21
30 min	8.4	11.2	13.0	15.3	17.0	18.7	21
1 h	11.2	14.3	16.3	18.9	20.8	22.6	29
2 h	16.1	19.3	21.3	24.0	25.9	27.8	29
6 h	30.8	37.0	41.2	46.4	50.3	54.2	29
12 h	44.0	52.9	58.9	66.3	71.9	77.4	27
24 h	58.3	70.0	77.7	87.5	94.7	101.9	29

****

Table 2b :

Return Period Rainfall Rates (mm/h) - 95% Confidence limits
Intensité de la pluie (mm/h) par période de retour - Limites de confiance de 95%

****

Duration/Durée		2 yr/ans		5 yr/ans		10 yr/ans		25 yr/ans		50 yr/ans		100 yr/ans	#Years Années
5 min		43.2		59.4		70.1		83.6		93.6		103.5	21
	+/-	7.2	+/-	12.1	+/-	16.3	+/-	22.0	+/-	26.3	+/-	30.7	21
10 min		29.8		41.3		48.9		58.4		65.5		72.6	21
	+/-	5.1	+/-	8.6	+/-	11.6	+/-	15.6	+/-	18.7	+/-	21.8	21
15 min		24.1		32.9		38.7		46.0		51.5		56.9	21
	+/-	3.9	+/-	6.6	+/-	8.9	+/-	12.0	+/-	14.3	+/-	16.7	21
30 min		16.9		22.4		26.0		30.6		34.1		37.4	21
	+/-	2.4	+/-	4.1	+/-	5.6	+/-	7.5	+/-	9.0	+/-	10.4	21
1 h		11.2		14.3		16.3		18.9		20.8		22.6	29
	+/-	1.2	+/-	1.9	+/-	2.6	+/-	3.5	+/-	4.2	+/-	4.9	29
2 h		8.1		9.6		10.7		12.0		13.0		13.9	29
	+/-	0.6	+/-	1.0	+/-	1.4	+/-	1.8	+/-	2.2	+/-	2.5	29
6 h		5.1		6.2		6.9		7.7		8.4		9.0	29
	+/-	0.4	+/-	0.7	+/-	0.9	+/-	1.2	+/-	1.4	+/-	1.7	29
12 h		3.7		4.4		4.9		5.5		6.0		6.5	27
	+/-	0.3	+/-	0.5	+/-	0.7	+/-	0.9	+/-	1.1	+/-	1.2	27
24 h		2.4		2.9		3.2		3.6		3.9		4.2	29
	+/-	0.2	+/-	0.3	+/-	0.4	+/-	0.6	+/-	0.7	+/-	0.8	29

****

Table 3 : Interpolation Equation / Équation d'interpolation: R = A*T^B

R = Interpolated Rainfall rate (mm/h)/Intensité interpolée de la pluie (mm/h)
RR = Rainfall rate (mm/h) / Intensité de la pluie (mm/h)
T = Rainfall duration (h) / Durée de la pluie (h)

****

Statistics/Statistiques	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans
Mean of RR/Moyenne de RR	16.1	21.5	25.1	29.6	33.0	36.3
Std. Dev. /Écart-type (RR)	13.9	19.4	23.1	27.8	31.2	34.7
Std. Error/Erreur-type	0.7	1.1	1.4	1.7	2.0	2.3
Coefficient (A)	12.0	15.5	17.7	20.6	22.7	24.7
Exponent/Exposant (B)	-0.499	-0.529	-0.543	-0.556	-0.563	-0.569
Mean % Error/% erreur moyenne	3.3	4.2	4.9	5.5	5.8	6.1

Design Calculations - Forebay Desgin
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbiaa

Task: Design forebay for the inlet of Infiltration Pond

In accordance with "Best Management Practices Guide for Stormwater", Sedimentation forebay should provide 10% volume of total design storage volume for pond.

Infiltration Basin Volume=	3313	m^3
Sediment Forebay Volume=	10% of Infiltration Basin Volume	
Sediment Forebay Volume=	331	m^3
Forebay Length to width ratio=	2:1	
Forebay Depth=	1	m
Forebay Length=	**26**	m
Forebay Width=	**13**	m
Forebay Depth=	**1**	m

Reference: Allan Gibb, Harlan Kelly, and Thomas Schueler, 1999, Best Management Practices Guide for Stormwater, Prepared for Greater Vancouver Sewerage and Drainage District.

Appendix D

Design Calculations - Infiltration Pond
2021 Design, Operations and Closure Plan
Northwin Landfill
Upland Excavating Ltd.
Campbell River, British Columbia

East and West Infiltration Pond
Stage/Storage Relationship

Elevation		Area		Depth		Total Storage	
(m)	(ft)	(m^2)	(ft^2)	(m)	(ft)	(m^3)	(ft^3)
150	492.1	2930	31533	0			
150.20	492.8	3078	33128	0.2	0.7	601	21214
150.40	493.4	3228	34751	0.4	1.3	1232	43493
150.60	494.1	3382	36401	0.6	2.0	1893	66864
150.80	494.8	3538	38080	0.8	2.6	2587	91356
151.00	495.4	3696	39787	1	3.3	3313	116994

Note:

* Volume for an interval calculated by Average End Area Method.
* Length to width ratio of infiltration pond assumed as 3:1.
* Assume vertical to horizontal slope of 1:3 on all sides of infiltration pond
*Area calculated for 1m depth assumes 10% goes into sedimentation bay so uses 0.9 fac

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.010)

****
Element Count
****

Number of rain gages 4
Number of subcatchments ... 15
Number of nodes 14
Number of links 12
Number of pollutants 0
Number of land uses 0

****
Raingage Summary
****

Name	Data Source	Data Type	Recording Interval
100yr_SCS_Type_IA_117.4mm	100yr_SCS_Type_IA_117.4mm	INTENSITY	15 min.
10yr_SCS_Type_IA_89.5mm	10yr_SCS_Type_IA_89.5mm	INTENSITY	15 min.
200yr_SCS_Type_IA_126.8mm	200yr_SCS_Type_IA_126.8mm	INTENSITY	15 min.
5yr_SCS_Type_IA_80.6mm	5yr_SCS_Type_IA_80.6mm	INTENSITY	15 min.

****
Subcatchment Summary
****

Name	Area	Width	%Imperv	%Slope	Rain Gage	Outlet
101	0.79	196.75	0.00	45.0000	5yr_SCS_Type_IA_80.6mm	J5
102	0.08	21.05	0.00	45.0000	5yr_SCS_Type_IA_80.6mm	J5
103	0.13	33.30	0.00	45.0000	5yr_SCS_Type_IA_80.6mm	J4
104	1.35	245.89	0.00	35.0000	5yr_SCS_Type_IA_80.6mm	J8
105	0.20	67.73	0.00	20.0000	5yr_SCS_Type_IA_80.6mm	J7
106	0.95	146.54	0.00	22.0000	5yr_SCS_Type_IA_80.6mm	J2
107	0.51	146.63	0.00	30.0000	5yr_SCS_Type_IA_80.6mm	J5
108	0.53	150.14	0.00	30.0000	5yr_SCS_Type_IA_80.6mm	J8
109	0.92	141.63	0.00	22.0000	5yr_SCS_Type_IA_80.6mm	J3
110	0.18	40.56	0.00	22.0000	5yr_SCS_Type_IA_80.6mm	J1
111	0.19	42.33	0.00	22.0000	5yr_SCS_Type_IA_80.6mm	J1
112	0.46	185.00	100.00	15.0000	5yr_SCS_Type_IA_80.6mm	POND_East
113	0.29	82.37	0.00	30.0000	5yr_SCS_Type_IA_80.6mm	J9
114	0.50	200.56	100.00	15.0000	5yr_SCS_Type_IA_80.6mm	POND_West
115	0.28	81.14	0.00	30.0000	5yr_SCS_Type_IA_80.6mm	J6

****
Node Summary
****

Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
J1	JUNCTION	164.50	0.60	0.0	
J10	JUNCTION	164.50	0.60	0.0	
J2	JUNCTION	164.30	0.60	0.0	
J3	JUNCTION	164.30	0.60	0.0	
J4	JUNCTION	164.00	0.60	0.0	
J5	JUNCTION	156.00	0.60	0.0	
J6	JUNCTION	153.00	0.50	0.0	
J7	JUNCTION	164.00	0.60	0.0	
J8	JUNCTION	156.00	0.60	0.0	
J9	JUNCTION	153.00	0.50	0.0	
OF1	OUTFALL	149.50	0.00	0.0	
OF2	OUTFALL	149.50	0.00	0.0	
POND_East	STORAGE	150.00	1.00	0.0	
POND_West	STORAGE	150.00	1.00	0.0	

****
Link Summary
****

Name	From Node	To Node	Type	Length	%Slope	Roughness
D101	J1	J2	CONDUIT	57.9	0.3454	0.0300
D102	J2	J4	CONDUIT	146.4	0.2050	0.0300
D103	J4	J5	CONDUIT	31.7	26.0720	0.0300
D104	J5	J6	CONDUIT	174.8	1.7166	0.0300
D105	J10	J3	CONDUIT	59.2	0.3376	0.0300
D106	J3	J7	CONDUIT	149.5	0.2006	0.0300
D107	J7	J8	CONDUIT	34.2	24.0519	0.0300
D108	J8	J9	CONDUIT	180.0	1.6664	0.0300
D109	J6	POND_West	CONDUIT	53.0	4.7258	0.0300
D110	J9	POND_East	CONDUIT	42.9	5.8372	0.0300
OL1	POND_West	OF1	OUTLET			
OL2	POND_East	OF2	OUTLET			

****
Cross Section Summary
****

Conduit	Shape	Full Depth	Full Area	Hyd. Rad.	Max. Width	No. of Barrels	Full Flow
D101	TRIANGULAR	0.60	1.08	0.28	3.60	1	0.92
D102	TRIANGULAR	0.60	1.08	0.28	3.60	1	0.71
D103	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	7.16
D104	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	1.84
D105	TRIANGULAR	0.60	1.08	0.28	3.60	1	0.91
D106	TRIANGULAR	0.60	1.08	0.28	3.60	1	0.70
D107	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	6.88
D108	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	1.81
D109	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	3.05
D110	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	3.39

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****

```
Flow Units ............... CMS
Process Models:
  Rainfall/Runoff ........ YES
  RDII ................... NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Infiltration Method ...... HORTON
Flow Routing Method ...... DYNWAVE
Starting Date ............ JAN-19-2016 00:00:00
Ending Date .............. JAN-25-2016 00:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:05:00
Wet Time Step ............ 00:00:01
Dry Time Step ............ 00:00:01
Routing Time Step ........ 1.00 sec
Variable Time Step ....... YES
Maximum Trials ........... 8
Number of Threads ........ 1
Head Tolerance ........... 0.001500 m
```

Runoff Quantity Continuity	Volume hectare-m	Depth mm
Total Precipitation	0.595	80.600
Evaporation Loss	0.000	0.000
Infiltration Loss	0.055	7.446
Surface Runoff	0.539	73.029
Final Storage	0.001	0.124

Continuity Error (%) 0.000

**************************	Volume	Volume
Flow Routing Continuity	hectare-m	10^6 ltr
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.539	5.390
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	0.000	0.000
External Outflow	0.560	5.600
Flooding Loss	0.000	0.000
Evaporation Loss	0.000	0.000
Exfiltration Loss	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.000	0.000
Continuity Error (%)	-3.899	

****
Highest Continuity Errors
****
Node POND_West (-4.00%)
Node POND_East (-3.80%)

****
Time-Step Critical Elements
****
None

****
Highest Flow Instability Indexes
****
Link OL1 (4)
Link OL2 (3)

****
Routing Time Step Summary
****

Minimum Time Step	:	0.50 sec
Average Time Step	:	1.00 sec
Maximum Time Step	:	1.00 sec
Percent in Steady State	:	0.00
Average Iterations per Step	:	2.00
Percent Not Converging	:	0.00

****
Subcatchment Runoff Summary
****

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
101	80.60	0.00	0.00	7.91	72.69	0.57	0.03	0.902
102	80.60	0.00	0.00	7.91	72.69	0.06	0.00	0.902
103	80.60	0.00	0.00	7.91	72.69	0.10	0.00	0.902
104	80.60	0.00	0.00	7.94	72.66	0.98	0.05	0.902
105	80.60	0.00	0.00	7.92	72.68	0.15	0.01	0.902
106	80.60	0.00	0.00	9.05	71.55	0.68	0.03	0.888

107	80.60	0.00	0.00	8.92	71.68	0.37	0.02
0.889							
108	80.60	0.00	0.00	8.92	71.68	0.38	0.02
0.889							
109	80.60	0.00	0.00	9.05	71.55	0.66	0.03
0.888							
110	80.60	0.00	0.00	8.98	71.62	0.13	0.01
0.889							
111	80.60	0.00	0.00	8.98	71.62	0.14	0.01
0.889							
112	80.60	0.00	0.00	0.00	79.65	0.37	0.02
0.988							
113	80.60	0.00	0.00	8.92	71.68	0.21	0.01
0.889							
114	80.60	0.00	0.00	0.00	79.65	0.40	0.02
0.988							
115	80.60	0.00	0.00	8.92	71.68	0.20	0.01
0.889							

****
Node Depth Summary
****

Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Time of Max Occurrence days hr:min	Reported Max Depth Meters
J1	JUNCTION	0.01	0.14	164.64	0 08:00	0.04
J10	JUNCTION	0.00	0.10	164.60	0 08:01	0.03
J2	JUNCTION	0.04	0.33	164.63	0 08:00	0.10
J3	JUNCTION	0.03	0.30	164.60	0 08:00	0.09
J4	JUNCTION	0.00	0.04	164.04	0 08:00	0.01
J5	JUNCTION	0.01	0.13	156.13	0 08:00	0.04
J6	JUNCTION	0.01	0.10	153.10	0 08:00	0.03
J7	JUNCTION	0.00	0.04	164.04	0 08:00	0.01
J8	JUNCTION	0.01	0.14	156.14	0 08:00	0.04
J9	JUNCTION	0.01	0.10	153.10	0 08:00	0.03
OF1	OUTFALL	0.00	0.00	149.50	0 00:00	0.00
OF2	OUTFALL	0.00	0.00	149.50	0 00:00	0.00
POND_East	STORAGE	0.01	0.14	150.14	0 09:41	0.04
POND_West	STORAGE	0.00	0.13	150.13	0 09:36	0.04

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CMS	Maximum Total Inflow CMS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 ltr	Total Inflow Volume 10^6 ltr	Flow Balance Error Percent
J1	JUNCTION	0.013	0.013	0 08:00	0.267	0.267	-0.084
J10	JUNCTION	0.000	0.001	0 07:15	0	0.00178	1.356
J2	JUNCTION	0.033	0.046	0 08:00	0.681	0.949	0.030
J3	JUNCTION	0.032	0.032	0 08:00	0.659	0.66	0.010
J4	JUNCTION	0.005	0.050	0 08:00	0.0968	1.05	-0.004
J5	JUNCTION	0.048	0.098	0 08:00	1	2.05	-0.003
J6	JUNCTION	0.010	0.108	0 08:00	0.204	2.25	0.002
J7	JUNCTION	0.007	0.038	0 08:00	0.148	0.806	-0.009
J8	JUNCTION	0.065	0.104	0 08:00	1.36	2.17	-0.004
J9	JUNCTION	0.010	0.114	0 08:00	0.207	2.37	0.003
OF1	OUTFALL	0.000	0.049	0 04:11	0	2.76	0.000
OF2	OUTFALL	0.000	0.049	0 04:08	0	2.84	0.000
POND_East	STORAGE	0.016	0.130	0 08:00	0.368	2.74	-3.665
POND_West	STORAGE	0.018	0.126	0 08:00	0.399	2.65	-3.842

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Storage Volume Summary
****

Storage Unit	Average Volume 1000 m3	Avg Pcnt Full	Evap Pcnt Loss	Exfil Pcnt Loss	Maximum Volume 1000 m3	Max Pcnt Full	Time of Max Occurrence days hr:min	Maximum Outflow CMS
POND_East	0.016	0	0	0	0.404	12	0 09:41	0.049
POND_West	0.014	0	0	0	0.375	11	0 09:36	0.049

****
Outfall Loading Summary
****

Outfall Node	Flow Freq Pcnt	Avg Flow CMS	Max Flow CMS	Total Volume 10^6 ltr
OF1	14.78	0.036	0.049	2.755
OF2	14.94	0.037	0.049	2.845
System	14.86	0.073	0.098	5.600

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CMS	Time of Max Occurrence days hr:min	Maximum |Veloc| m/sec	Max/ Full Flow	Max/ Full Depth
D101	CONDUIT	0.013	0 08:00	0.10	0.01	0.40
D102	CONDUIT	0.046	0 08:00	0.42	0.06	0.32
D103	CONDUIT	0.050	0 08:00	0.75	0.01	0.18
D104	CONDUIT	0.098	0 08:00	0.96	0.05	0.24
D105	CONDUIT	0.001	0 07:15	0.01	0.00	0.33
D106	CONDUIT	0.031	0 08:00	0.38	0.05	0.28
D107	CONDUIT	0.038	0 08:00	0.57	0.01	0.18
D108	CONDUIT	0.104	0 08:00	0.99	0.06	0.24
D109	CONDUIT	0.108	0 08:00	1.27	0.04	0.21
D110	CONDUIT	0.114	0 08:00	1.39	0.03	0.20
OL1	DUMMY	0.049	0 04:11			
OL2	DUMMY	0.049	0 04:08			

****
Flow Classification Summary
****

Conduit	Adjusted /Actual Length	Fraction of Time in Flow Class: Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Norm Ltd	Inlet Ctrl
D101	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.97	0.00
D102	1.00	0.02	0.01	0.00	0.98	0.00	0.00	0.00	0.00	0.00
D103	1.00	0.48	0.21	0.00	0.31	0.00	0.00	0.00	0.37	0.00
D104	1.00	0.48	0.00	0.00	0.50	0.02	0.00	0.00	0.08	0.00
D105	1.00	0.02	0.02	0.00	0.96	0.00	0.00	0.00	0.93	0.00
D106	1.00	0.02	0.01	0.00	0.98	0.00	0.00	0.00	0.00	0.00
D107	1.00	0.48	0.21	0.00	0.31	0.00	0.00	0.00	0.38	0.00

D108	1.00	0.48	0.00	0.00	0.49	0.03	0.00	0.00	0.03	0.00
D109	1.00	0.68	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00
D110	1.00	0.69	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00

****
Conduit Surcharge Summary
****

No conduits were surcharged.

Analysis begun on: Mon Jun 28 15:51:36 2021
Analysis ended on: Mon Jun 28 15:51:43 2021
Total elapsed time: 00:00:07

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.010)

****
Element Count
****

Number of rain gages 4
Number of subcatchments ... 15
Number of nodes 14
Number of links 12
Number of pollutants 0
Number of land uses 0

****
Raingage Summary
****

Name	Data Source	Data Type	Recording Interval
100yr_SCS_Type_IA_117.4mm	100yr_SCS_Type_IA_117.4mm	INTENSITY	15 min.
10yr_SCS_Type_IA_89.5mm	10yr_SCS_Type_IA_89.5mm	INTENSITY	15 min.
200yr_SCS_Type_IA_126.8mm	200yr_SCS_Type_IA_126.8mm	INTENSITY	15 min.
5yr_SCS_Type_IA_80.6mm	5yr_SCS_Type_IA_80.6mm	INTENSITY	15 min.

****
Subcatchment Summary
****

Name	Area	Width	%Imperv	%Slope	Rain Gage	Outlet
101	0.79	196.75	0.00	45.0000	10yr_SCS_Type_IA_89.5mm	J5
102	0.08	21.05	0.00	45.0000	10yr_SCS_Type_IA_89.5mm	J5
103	0.13	33.30	0.00	45.0000	10yr_SCS_Type_IA_89.5mm	J4
104	1.35	245.89	0.00	35.0000	10yr_SCS_Type_IA_89.5mm	J8
105	0.20	67.73	0.00	20.0000	10yr_SCS_Type_IA_89.5mm	J7
106	0.95	146.54	0.00	22.0000	10yr_SCS_Type_IA_89.5mm	J2
107	0.51	146.63	0.00	30.0000	10yr_SCS_Type_IA_89.5mm	J5
108	0.53	150.14	0.00	30.0000	10yr_SCS_Type_IA_89.5mm	J8
109	0.92	141.63	0.00	22.0000	10yr_SCS_Type_IA_89.5mm	J3
110	0.18	40.56	0.00	22.0000	10yr_SCS_Type_IA_89.5mm	J1
111	0.19	42.33	0.00	22.0000	10yr_SCS_Type_IA_89.5mm	J1
112	0.46	185.00	100.00	15.0000	10yr_SCS_Type_IA_89.5mm	POND_East
113	0.29	82.37	0.00	30.0000	10yr_SCS_Type_IA_89.5mm	J9
114	0.50	200.56	100.00	15.0000	10yr_SCS_Type_IA_89.5mm	POND_West
115	0.28	81.14	0.00	30.0000	10yr_SCS_Type_IA_89.5mm	J6

****
Node Summary
****

Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
J1	JUNCTION	164.50	0.60	0.0	
J10	JUNCTION	164.50	0.60	0.0	
J2	JUNCTION	164.30	0.60	0.0	
J3	JUNCTION	164.30	0.60	0.0	
J4	JUNCTION	164.00	0.60	0.0	
J5	JUNCTION	156.00	0.60	0.0	
J6	JUNCTION	153.00	0.50	0.0	
J7	JUNCTION	164.00	0.60	0.0	
J8	JUNCTION	156.00	0.60	0.0	
J9	JUNCTION	153.00	0.50	0.0	
OF1	OUTFALL	149.50	0.00	0.0	
OF2	OUTFALL	149.50	0.00	0.0	
POND_East	STORAGE	150.00	1.00	0.0	
POND_West	STORAGE	150.00	1.00	0.0	

****
Link Summary
****

```
Name             From Node        To Node          Type            Length    %Slope Roughness
---------------------------------------------------------------------------------------------
D101             J1               J2               CONDUIT           57.9    0.3454    0.0300
D102             J2               J4               CONDUIT          146.4    0.2050    0.0300
D103             J4               J5               CONDUIT           31.7   26.0720    0.0300
D104             J5               J6               CONDUIT          174.8    1.7166    0.0300
D105             J10              J3               CONDUIT           59.2    0.3376    0.0300
D106             J3               J7               CONDUIT          149.5    0.2006    0.0300
D107             J7               J8               CONDUIT           34.2   24.0519    0.0300
D108             J8               J9               CONDUIT          180.0    1.6664    0.0300
D109             J6               POND_West        CONDUIT           53.0    4.7258    0.0300
D110             J9               POND_East        CONDUIT           42.9    5.8372    0.0300
OL1              POND_West        OF1              OUTLET
OL2              POND_East        OF2              OUTLET


*********************
Cross Section Summary
*********************
                                        Full     Full     Hyd.     Max.   No. of     Full
Conduit          Shape                 Depth     Area     Rad.    Width  Barrels     Flow
---------------------------------------------------------------------------------------
D101             TRIANGULAR             0.60     1.08     0.28     3.60        1     0.92
D102             TRIANGULAR             0.60     1.08     0.28     3.60        1     0.71
D103             TRAPEZOIDAL            0.50     1.00     0.27     3.50        1     7.16
D104             TRAPEZOIDAL            0.50     1.00     0.27     3.50        1     1.84
D105             TRIANGULAR             0.60     1.08     0.28     3.60        1     0.91
D106             TRIANGULAR             0.60     1.08     0.28     3.60        1     0.70
D107             TRAPEZOIDAL            0.50     1.00     0.27     3.50        1     6.88
D108             TRAPEZOIDAL            0.50     1.00     0.27     3.50        1     1.81
D109             TRAPEZOIDAL            0.50     1.00     0.27     3.50        1     3.05
D110             TRAPEZOIDAL            0.50     1.00     0.27     3.50        1     3.39


*********************************************************
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
*********************************************************

****************
Analysis Options
****************
Flow Units ............... CMS
Process Models:
  Rainfall/Runoff ........ YES
  RDII ................... NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Infiltration Method ...... HORTON
Flow Routing Method ...... DYNWAVE
Starting Date ............ JAN-19-2016 00:00:00
Ending Date .............. JAN-25-2016 00:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:05:00
Wet Time Step ............ 00:00:01
Dry Time Step ............ 00:00:01
Routing Time Step ........ 1.00 sec
Variable Time Step ....... YES
Maximum Trials ........... 8
Number of Threads ........ 1
Head Tolerance ........... 0.001500 m

**************************        Volume         Depth
Runoff Quantity Continuity     hectare-m            mm
**************************     ---------       -------
Total Precipitation ......         0.661        89.503
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........         0.055         7.454
Surface Runoff ...........         0.605        81.924
Final Storage ............         0.001         0.124
```

```
  Continuity Error (%) .....         0.000


  **************************        Volume        Volume
  Flow Routing Continuity        hectare-m      10^6 ltr
  **************************     ---------     ---------
  Dry Weather Inflow .......         0.000         0.000
  Wet Weather Inflow .......         0.605         6.047
  Groundwater Inflow .......         0.000         0.000
  RDII Inflow ..............         0.000         0.000
  External Inflow ..........         0.000         0.000
  External Outflow .........         0.613         6.131
  Flooding Loss ............         0.000         0.000
  Evaporation Loss .........         0.000         0.000
  Exfiltration Loss ........         0.000         0.000
  Initial Stored Volume ....         0.000         0.000
  Final Stored Volume ......         0.000         0.000
  Continuity Error (%) .....        -1.395


  *************************
  Highest Continuity Errors
  *************************
  Node POND_East (-1.53%)
  Node POND_West (-1.25%)


  ***************************
  Time-Step Critical Elements
  ***************************
  None


  ********************************
  Highest Flow Instability Indexes
  ********************************
  Link OL1 (4)
  Link OL2 (3)


  *************************
  Routing Time Step Summary
  *************************
  Minimum Time Step           :     0.50 sec
  Average Time Step           :     1.00 sec
  Maximum Time Step           :     1.00 sec
  Percent in Steady State     :     0.00
  Average Iterations per Step :     2.00
  Percent Not Converging      :     0.00


  ***************************
  Subcatchment Runoff Summary
  ***************************
```

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
101	89.50	0.00	0.00	7.92	81.58	0.64	0.03	0.912
102	89.50	0.00	0.00	7.92	81.58	0.07	0.00	0.912
103	89.50	0.00	0.00	7.92	81.58	0.11	0.01	0.912
104	89.50	0.00	0.00	7.95	81.55	1.10	0.05	0.911
105	89.50	0.00	0.00	7.93	81.58	0.17	0.01	0.911
106	89.50	0.00	0.00	9.06	80.44	0.77	0.04	0.899

107	89.50	0.00	0.00	8.92	80.58	0.41	0.02	0.900
108	89.50	0.00	0.00	8.92	80.58	0.42	0.02	0.900
109	89.50	0.00	0.00	9.06	80.44	0.74	0.04	0.899
110	89.50	0.00	0.00	8.99	80.51	0.15	0.01	0.900
111	89.50	0.00	0.00	8.99	80.51	0.15	0.01	0.900
112	89.50	0.00	0.00	0.00	88.55	0.41	0.02	0.989
113	89.50	0.00	0.00	8.92	80.58	0.23	0.01	0.900
114	89.50	0.00	0.00	0.00	88.55	0.44	0.02	0.989
115	89.50	0.00	0.00	8.92	80.58	0.23	0.01	0.900

****
Node Depth Summary
****

Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Time of Max Occurrence days hr:min	Reported Max Depth Meters
J1	JUNCTION	0.01	0.15	164.65	0 08:00	0.05
J10	JUNCTION	0.00	0.11	164.61	0 08:01	0.03
J2	JUNCTION	0.04	0.35	164.65	0 08:00	0.11
J3	JUNCTION	0.03	0.31	164.61	0 08:00	0.09
J4	JUNCTION	0.00	0.05	164.05	0 08:00	0.01
J5	JUNCTION	0.01	0.14	156.14	0 08:00	0.04
J6	JUNCTION	0.01	0.11	153.11	0 08:00	0.03
J7	JUNCTION	0.00	0.04	164.04	0 08:00	0.01
J8	JUNCTION	0.01	0.15	156.15	0 08:00	0.05
J9	JUNCTION	0.01	0.11	153.11	0 08:00	0.03
OF1	OUTFALL	0.00	0.00	149.50	0 00:00	0.00
OF2	OUTFALL	0.00	0.00	149.50	0 00:00	0.00
POND_East	STORAGE	0.01	0.17	150.17	0 10:02	0.05
POND_West	STORAGE	0.01	0.16	150.16	0 09:58	0.05

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CMS	Maximum Total Inflow CMS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 ltr	Total Inflow Volume 10^6 ltr	Flow Balance Error Percent
J1	JUNCTION	0.014	0.014	0 08:00	0.3	0.3	-0.078
J10	JUNCTION	0.000	0.001	0 07:15	0	0.00208	1.072
J2	JUNCTION	0.037	0.051	0 08:00	0.766	1.07	0.028
J3	JUNCTION	0.035	0.035	0 08:00	0.741	0.743	0.011
J4	JUNCTION	0.005	0.056	0 08:00	0.109	1.18	-0.004
J5	JUNCTION	0.054	0.109	0 08:00	1.12	2.3	-0.003
J6	JUNCTION	0.011	0.120	0 08:00	0.229	2.53	0.002
J7	JUNCTION	0.008	0.043	0 08:00	0.166	0.906	-0.009
J8	JUNCTION	0.073	0.115	0 08:00	1.53	2.43	-0.004
J9	JUNCTION	0.011	0.127	0 08:00	0.232	2.67	0.003
OF1	OUTFALL	0.000	0.049	0 04:01	0	3.01	0.000
OF2	OUTFALL	0.000	0.049	0 03:56	0	3.12	0.000
POND_East	STORAGE	0.018	0.144	0 08:00	0.41	3.07	-1.510
POND_West	STORAGE	0.020	0.140	0 08:00	0.444	2.97	-1.236

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Storage Volume Summary
****

Storage Unit	Average Volume 1000 m3	Avg Pcnt Full	Evap Pcnt Loss	Exfil Pcnt Loss	Maximum Volume 1000 m3	Max Pcnt Full	Time of Max Occurrence days hr:min	Maximum Outflow CMS
POND_East	0.026	1	0	0	0.520	16	0 10:02	0.049
POND_West	0.022	1	0	0	0.481	15	0 09:58	0.049

****
Outfall Loading Summary
****

Outfall Node	Flow Freq Pcnt	Avg Flow CMS	Max Flow CMS	Total Volume 10^6 ltr
OF1	15.03	0.039	0.049	3.009
OF2	15.32	0.039	0.049	3.122
System	15.18	0.078	0.098	6.131

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CMS	Time of Max Occurrence days hr:min	Maximum |Veloc| m/sec	Max/ Full Flow	Max/ Full Depth
D101	CONDUIT	0.014	0 08:00	0.10	0.02	0.42
D102	CONDUIT	0.051	0 08:00	0.44	0.07	0.33
D103	CONDUIT	0.056	0 08:00	0.78	0.01	0.19
D104	CONDUIT	0.109	0 08:00	0.99	0.06	0.25
D105	CONDUIT	0.001	0 07:15	0.01	0.00	0.34
D106	CONDUIT	0.035	0 08:00	0.39	0.05	0.29
D107	CONDUIT	0.043	0 08:00	0.59	0.01	0.19
D108	CONDUIT	0.115	0 08:00	1.02	0.06	0.26
D109	CONDUIT	0.120	0 08:00	1.31	0.04	0.22
D110	CONDUIT	0.126	0 08:00	1.43	0.04	0.21
OL1	DUMMY	0.049	0 04:01			
OL2	DUMMY	0.049	0 03:56			

****
Flow Classification Summary
****

Conduit	Adjusted /Actual Length	---------- Fraction of Time in Flow Class ---------- Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Norm Ltd	Inlet Ctrl
D101	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.97	0.00
D102	1.00	0.01	0.00	0.00	0.98	0.00	0.00	0.00	0.00	0.00
D103	1.00	0.48	0.21	0.00	0.31	0.00	0.00	0.00	0.37	0.00
D104	1.00	0.48	0.00	0.00	0.50	0.02	0.00	0.00	0.08	0.00
D105	1.00	0.02	0.02	0.00	0.97	0.00	0.00	0.00	0.93	0.00
D106	1.00	0.01	0.00	0.00	0.98	0.00	0.00	0.00	0.00	0.00
D107	1.00	0.48	0.21	0.00	0.31	0.00	0.00	0.00	0.38	0.00

D108	1.00	0.48	0.00	0.00	0.49	0.04	0.00	0.00	0.03	0.00
D109	1.00	0.68	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00
D110	1.00	0.69	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00

****
Conduit Surcharge Summary
****

No conduits were surcharged.

Analysis begun on: Mon Jun 28 15:50:23 2021
Analysis ended on: Mon Jun 28 15:50:30 2021
Total elapsed time: 00:00:07

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.010)

****
Element Count
****

Number of rain gages 4
Number of subcatchments ... 15
Number of nodes 14
Number of links 12
Number of pollutants 0
Number of land uses 0

****
Raingage Summary
****

Name	Data Source	Data Type	Recording Interval
100yr_SCS_Type_IA_117.4mm	100yr_SCS_Type_IA_117.4mm	INTENSITY	15 min.
10yr_SCS_Type_IA_89.5mm	10yr_SCS_Type_IA_89.5mm	INTENSITY	15 min.
200yr_SCS_Type_IA_126.8mm	200yr_SCS_Type_IA_126.8mm	INTENSITY	15 min.
5yr_SCS_Type_IA_80.6mm	5yr_SCS_Type_IA_80.6mm	INTENSITY	15 min.

****
Subcatchment Summary
****

Name	Area	Width	%Imperv	%Slope	Rain Gage	Outlet
101	0.79	196.75	0.00	45.0000	100yr_SCS_Type_IA_117.4mm	J5
102	0.08	21.05	0.00	45.0000	100yr_SCS_Type_IA_117.4mm	J5
103	0.13	33.30	0.00	45.0000	100yr_SCS_Type_IA_117.4mm	J4
104	1.35	245.89	0.00	35.0000	100yr_SCS_Type_IA_117.4mm	J8
105	0.20	67.73	0.00	20.0000	100yr_SCS_Type_IA_117.4mm	J7
106	0.95	146.54	0.00	22.0000	100yr_SCS_Type_IA_117.4mm	J2
107	0.51	146.63	0.00	30.0000	100yr_SCS_Type_IA_117.4mm	J5
108	0.53	150.14	0.00	30.0000	100yr_SCS_Type_IA_117.4mm	J8
109	0.92	141.63	0.00	22.0000	100yr_SCS_Type_IA_117.4mm	J3
110	0.18	40.56	0.00	22.0000	100yr_SCS_Type_IA_117.4mm	J1
111	0.19	42.33	0.00	22.0000	100yr_SCS_Type_IA_117.4mm	J1
112	0.46	185.00	100.00	15.0000	100yr_SCS_Type_IA_117.4mm	POND_East
113	0.29	82.37	0.00	30.0000	100yr_SCS_Type_IA_117.4mm	J9
114	0.50	200.56	100.00	15.0000	100yr_SCS_Type_IA_117.4mm	POND_West
115	0.28	81.14	0.00	30.0000	100yr_SCS_Type_IA_117.4mm	J6

****
Node Summary
****

Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
J1	JUNCTION	164.50	0.60	0.0	
J10	JUNCTION	164.50	0.60	0.0	
J2	JUNCTION	164.30	0.60	0.0	
J3	JUNCTION	164.30	0.60	0.0	
J4	JUNCTION	164.00	0.60	0.0	
J5	JUNCTION	156.00	0.60	0.0	
J6	JUNCTION	153.00	0.50	0.0	
J7	JUNCTION	164.00	0.60	0.0	
J8	JUNCTION	156.00	0.60	0.0	
J9	JUNCTION	153.00	0.50	0.0	
OF1	OUTFALL	149.50	0.00	0.0	
OF2	OUTFALL	149.50	0.00	0.0	
POND_East	STORAGE	150.00	1.00	0.0	
POND_West	STORAGE	150.00	1.00	0.0	

****
Link Summary
****

Name	From Node	To Node	Type	Length	%Slope	Roughness
D101	J1	J2	CONDUIT	57.9	0.3454	0.0300
D102	J2	J4	CONDUIT	146.4	0.2050	0.0300
D103	J4	J5	CONDUIT	31.7	26.0720	0.0300
D104	J5	J6	CONDUIT	174.8	1.7166	0.0300
D105	J10	J3	CONDUIT	59.2	0.3376	0.0300
D106	J3	J7	CONDUIT	149.5	0.2006	0.0300
D107	J7	J8	CONDUIT	34.2	24.0519	0.0300
D108	J8	J9	CONDUIT	180.0	1.6664	0.0300
D109	J6	POND_West	CONDUIT	53.0	4.7258	0.0300
D110	J9	POND_East	CONDUIT	42.9	5.8372	0.0300
OL1	POND_West	OF1	OUTLET			
OL2	POND_East	OF2	OUTLET			

****
Cross Section Summary
****

Conduit	Shape	Full Depth	Full Area	Hyd. Rad.	Max. Width	No. of Barrels	Full Flow
D101	TRIANGULAR	0.60	1.08	0.28	3.60	1	0.92
D102	TRIANGULAR	0.60	1.08	0.28	3.60	1	0.71
D103	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	7.16
D104	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	1.84
D105	TRIANGULAR	0.60	1.08	0.28	3.60	1	0.91
D106	TRIANGULAR	0.60	1.08	0.28	3.60	1	0.70
D107	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	6.88
D108	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	1.81
D109	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	3.05
D110	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	3.39

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****

```
Flow Units ............... CMS
Process Models:
  Rainfall/Runoff ........ YES
  RDII ................... NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Infiltration Method ...... HORTON
Flow Routing Method ...... DYNWAVE
Starting Date ............ JAN-19-2016 00:00:00
Ending Date .............. JAN-25-2016 00:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:05:00
Wet Time Step ............ 00:00:01
Dry Time Step ............ 00:00:01
Routing Time Step ........ 1.00 sec
Variable Time Step ....... YES
Maximum Trials ........... 8
Number of Threads ........ 1
Head Tolerance ........... 0.001500 m
```

Runoff Quantity Continuity	Volume hectare-m	Depth mm
Total Precipitation	0.867	117.399
Evaporation Loss	0.000	0.000
Infiltration Loss	0.055	7.470
Surface Runoff	0.810	109.804
Final Storage	0.001	0.124

Continuity Error (%) 0.000

```
**************************        Volume         Volume
Flow Routing Continuity          hectare-m      10^6 ltr
**************************       ---------      ---------
Dry Weather Inflow .......           0.000          0.000
Wet Weather Inflow .......           0.810          8.105
Groundwater Inflow .......           0.000          0.000
RDII Inflow ..............           0.000          0.000
External Inflow ..........           0.000          0.000
External Outflow .........           0.811          8.115
Flooding Loss ............           0.000          0.000
Evaporation Loss .........           0.000          0.000
Exfiltration Loss ........           0.000          0.000
Initial Stored Volume ....           0.000          0.000
Final Stored Volume ......           0.000          0.000
Continuity Error (%) .....          -0.129


***************************
Time-Step Critical Elements
***************************
None


********************************
Highest Flow Instability Indexes
********************************
Link OL1 (1)
Link OL2 (1)


*************************
Routing Time Step Summary
*************************
Minimum Time Step           :     0.50 sec
Average Time Step           :     1.00 sec
Maximum Time Step           :     1.00 sec
Percent in Steady State     :     0.00
Average Iterations per Step :     2.00
Percent Not Converging      :     0.00


***************************
Subcatchment Runoff Summary
***************************
```

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
101	117.40	0.00	0.00	7.94	109.46	0.86	0.04	0.932
102	117.40	0.00	0.00	7.94	109.46	0.09	0.00	0.932
103	117.40	0.00	0.00	7.94	109.46	0.15	0.01	0.932
104	117.40	0.00	0.00	7.97	109.42	1.48	0.07	0.932
105	117.40	0.00	0.00	7.95	109.45	0.22	0.01	0.932
106	117.40	0.00	0.00	9.08	108.32	1.03	0.05	0.923
107	117.40	0.00	0.00	8.94	108.46	0.56	0.03	0.924
108	117.40	0.00	0.00	8.94	108.46	0.57	0.03	0.924
109	117.40	0.00	0.00	9.08	108.32	1.00	0.05	0.923

110	117.40	0.00	0.00	9.00	108.39	0.20	0.01
0.923							
111	117.40	0.00	0.00	9.00	108.39	0.21	0.01
0.923							
112	117.40	0.00	0.00	0.00	116.45	0.54	0.02
0.992							
113	117.40	0.00	0.00	8.94	108.46	0.31	0.01
0.924							
114	117.40	0.00	0.00	0.00	116.45	0.58	0.03
0.992							
115	117.40	0.00	0.00	8.94	108.46	0.31	0.01
0.924							

****
Node Depth Summary
****

Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Time of Max Occurrence days hr:min	Reported Max Depth Meters
J1	JUNCTION	0.01	0.18	164.68	0 08:00	0.06
J10	JUNCTION	0.00	0.14	164.64	0 08:00	0.04
J2	JUNCTION	0.04	0.38	164.68	0 08:00	0.12
J3	JUNCTION	0.04	0.34	164.64	0 08:00	0.10
J4	JUNCTION	0.00	0.05	164.05	0 08:00	0.02
J5	JUNCTION	0.01	0.16	156.16	0 08:00	0.05
J6	JUNCTION	0.01	0.13	153.13	0 08:00	0.04
J7	JUNCTION	0.00	0.05	164.05	0 08:00	0.01
J8	JUNCTION	0.01	0.17	156.17	0 08:00	0.05
J9	JUNCTION	0.01	0.12	153.12	0 08:00	0.04
OF1	OUTFALL	0.00	0.00	149.50	0 00:00	0.00
OF2	OUTFALL	0.00	0.00	149.50	0 00:00	0.00
POND_East	STORAGE	0.03	0.32	150.32	0 11:45	0.10
POND_West	STORAGE	0.03	0.30	150.30	0 11:34	0.09

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CMS	Maximum Total Inflow CMS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 ltr	Total Inflow Volume 10^6 ltr	Flow Balance Error Percent
J1	JUNCTION	0.019	0.019	0 08:00	0.404	0.404	-0.066
J10	JUNCTION	0.000	0.001	0 07:14	0	0.00299	0.689
J2	JUNCTION	0.048	0.067	0 08:00	1.03	1.44	0.024
J3	JUNCTION	0.047	0.047	0 08:00	0.997	1	0.011
J4	JUNCTION	0.007	0.074	0 08:00	0.146	1.58	-0.004
J5	JUNCTION	0.070	0.144	0 08:00	1.51	3.09	-0.003
J6	JUNCTION	0.014	0.159	0 08:00	0.308	3.4	0.002
J7	JUNCTION	0.010	0.057	0 08:00	0.222	1.22	-0.008
J8	JUNCTION	0.095	0.152	0 08:00	2.05	3.27	-0.003
J9	JUNCTION	0.015	0.167	0 08:00	0.313	3.58	0.002
OF1	OUTFALL	0.000	0.049	0 02:50	0	3.99	0.000
OF2	OUTFALL	0.000	0.049	0 02:37	0	4.12	0.000
POND_East	STORAGE	0.024	0.190	0 08:00	0.539	4.12	-0.076
POND_West	STORAGE	0.026	0.184	0 08:00	0.584	3.98	-0.184

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Storage Volume Summary
****

Storage Unit	Average Volume 1000 m3	Avg Pcnt Full	Evap Pcnt Loss	Exfil Pcnt Loss	Maximum Volume 1000 m3	Max Pcnt Full	Time of Max Occurrence days hr:min	Maximum Outflow CMS
POND_East	0.089	3	0	0	0.975	29	0 11:45	0.049
POND_West	0.077	2	0	0	0.902	27	0 11:34	0.049

****
Outfall Loading Summary
****

Outfall Node	Flow Freq Pcnt	Avg Flow CMS	Max Flow CMS	Total Volume 10^6 ltr
OF1	16.47	0.047	0.049	3.991
OF2	16.96	0.047	0.049	4.124
System	16.71	0.094	0.098	8.115

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CMS	Time of Max Occurrence days hr:min	Maximum |Veloc| m/sec	Max/ Full Flow	Max/ Full Depth
D101	CONDUIT	0.019	0 08:00	0.11	0.02	0.47
D102	CONDUIT	0.067	0 08:00	0.48	0.10	0.36
D103	CONDUIT	0.074	0 08:00	0.84	0.01	0.22
D104	CONDUIT	0.144	0 08:00	1.06	0.08	0.29
D105	CONDUIT	0.001	0 07:14	0.01	0.00	0.39
D106	CONDUIT	0.046	0 08:00	0.42	0.07	0.32
D107	CONDUIT	0.057	0 08:00	0.64	0.01	0.22
D108	CONDUIT	0.152	0 08:00	1.10	0.08	0.29
D109	CONDUIT	0.158	0 08:00	1.41	0.05	0.25
D110	CONDUIT	0.167	0 08:00	1.54	0.05	0.25
OL1	DUMMY	0.049	0 02:50			
OL2	DUMMY	0.049	0 02:37			

****
Flow Classification Summary
****

Conduit	Adjusted /Actual Length	Fraction of Time in Flow Class: Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Norm Ltd	Inlet Ctrl
D101	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.97	0.00
D102	1.00	0.01	0.00	0.00	0.98	0.00	0.00	0.00	0.00	0.00
D103	1.00	0.47	0.21	0.00	0.32	0.00	0.00	0.00	0.38	0.00
D104	1.00	0.47	0.00	0.00	0.50	0.03	0.00	0.00	0.08	0.00
D105	1.00	0.02	0.01	0.00	0.97	0.00	0.00	0.00	0.91	0.00
D106	1.00	0.01	0.00	0.00	0.98	0.00	0.00	0.00	0.00	0.00
D107	1.00	0.47	0.21	0.00	0.32	0.00	0.00	0.00	0.38	0.00
D108	1.00	0.47	0.00	0.00	0.46	0.07	0.00	0.00	0.03	0.00
D109	1.00	0.68	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00
D110	1.00	0.69	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00

****

```
Conduit Surcharge Summary
*************************

No conduits were surcharged.


Analysis begun on:  Mon Jun 28 15:49:00 2021
Analysis ended on:  Mon Jun 28 15:49:06 2021
Total elapsed time: 00:00:06
```

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.010)

****
Element Count
****

Number of rain gages 4
Number of subcatchments ... 15
Number of nodes 14
Number of links 12
Number of pollutants 0
Number of land uses 0

****
Raingage Summary
****

Name	Data Source	Data Type	Recording Interval
100yr_SCS_Type_IA_117.4mm	100yr_SCS_Type_IA_117.4mm	INTENSITY	15 min.
10yr_SCS_Type_IA_89.5mm	10yr_SCS_Type_IA_89.5mm	INTENSITY	15 min.
200yr_SCS_Type_IA_126.8mm	200yr_SCS_Type_IA_126.8mm	INTENSITY	15 min.
5yr_SCS_Type_IA_80.6mm	5yr_SCS_Type_IA_80.6mm	INTENSITY	15 min.

****
Subcatchment Summary
****

Name	Area	Width	%Imperv	%Slope	Rain Gage	Outlet
101	0.79	196.75	0.00	45.0000	200yr_SCS_Type_IA_126.8mm	J5
102	0.08	21.05	0.00	45.0000	200yr_SCS_Type_IA_126.8mm	J5
103	0.13	33.30	0.00	45.0000	200yr_SCS_Type_IA_126.8mm	J4
104	1.35	245.89	0.00	35.0000	200yr_SCS_Type_IA_126.8mm	J8
105	0.20	67.73	0.00	20.0000	200yr_SCS_Type_IA_126.8mm	J7
106	0.95	146.54	0.00	22.0000	200yr_SCS_Type_IA_126.8mm	J2
107	0.51	146.63	0.00	30.0000	200yr_SCS_Type_IA_126.8mm	J5
108	0.53	150.14	0.00	30.0000	200yr_SCS_Type_IA_126.8mm	J8
109	0.92	141.63	0.00	22.0000	200yr_SCS_Type_IA_126.8mm	J3
110	0.18	40.56	0.00	22.0000	200yr_SCS_Type_IA_126.8mm	J1
111	0.19	42.33	0.00	22.0000	200yr_SCS_Type_IA_126.8mm	J1
112	0.46	185.00	100.00	15.0000	200yr_SCS_Type_IA_126.8mm	POND_East
113	0.29	82.37	0.00	30.0000	200yr_SCS_Type_IA_126.8mm	J9
114	0.50	200.56	100.00	15.0000	200yr_SCS_Type_IA_126.8mm	POND_West
115	0.28	81.14	0.00	30.0000	200yr_SCS_Type_IA_126.8mm	J6

****
Node Summary
****

Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
J1	JUNCTION	164.50	0.60	0.0	
J10	JUNCTION	164.50	0.60	0.0	
J2	JUNCTION	164.30	0.60	0.0	
J3	JUNCTION	164.30	0.60	0.0	
J4	JUNCTION	164.00	0.60	0.0	
J5	JUNCTION	156.00	0.60	0.0	
J6	JUNCTION	153.00	0.50	0.0	
J7	JUNCTION	164.00	0.60	0.0	
J8	JUNCTION	156.00	0.60	0.0	
J9	JUNCTION	153.00	0.50	0.0	
OF1	OUTFALL	149.50	0.00	0.0	
OF2	OUTFALL	149.50	0.00	0.0	
POND_East	STORAGE	150.00	1.00	0.0	
POND_West	STORAGE	150.00	1.00	0.0	

****
Link Summary
****

Name	From Node	To Node	Type	Length	%Slope	Roughness
D101	J1	J2	CONDUIT	57.9	0.3454	0.0300
D102	J2	J4	CONDUIT	146.4	0.2050	0.0300
D103	J4	J5	CONDUIT	31.7	26.0720	0.0300
D104	J5	J6	CONDUIT	174.8	1.7166	0.0300
D105	J10	J3	CONDUIT	59.2	0.3376	0.0300
D106	J3	J7	CONDUIT	149.5	0.2006	0.0300
D107	J7	J8	CONDUIT	34.2	24.0519	0.0300
D108	J8	J9	CONDUIT	180.0	1.6664	0.0300
D109	J6	POND_West	CONDUIT	53.0	4.7258	0.0300
D110	J9	POND_East	CONDUIT	42.9	5.8372	0.0300
OL1	POND_West	OF1	OUTLET			
OL2	POND_East	OF2	OUTLET			

****
Cross Section Summary
****

Conduit	Shape	Full Depth	Full Area	Hyd. Rad.	Max. Width	No. of Barrels	Full Flow
D101	TRIANGULAR	0.60	1.08	0.28	3.60	1	0.92
D102	TRIANGULAR	0.60	1.08	0.28	3.60	1	0.71
D103	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	7.16
D104	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	1.84
D105	TRIANGULAR	0.60	1.08	0.28	3.60	1	0.91
D106	TRIANGULAR	0.60	1.08	0.28	3.60	1	0.70
D107	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	6.88
D108	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	1.81
D109	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	3.05
D110	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	3.39

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****

```
Flow Units ............... CMS
Process Models:
  Rainfall/Runoff ........ YES
  RDII ................... NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Infiltration Method ...... HORTON
Flow Routing Method ...... DYNWAVE
Starting Date ............ JAN-19-2016 00:00:00
Ending Date .............. JAN-25-2016 00:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:05:00
Wet Time Step ............ 00:00:01
Dry Time Step ............ 00:00:01
Routing Time Step ........ 1.00 sec
Variable Time Step ....... YES
Maximum Trials ........... 8
Number of Threads ........ 1
Head Tolerance ........... 0.001500 m
```

Runoff Quantity Continuity	Volume hectare-m	Depth mm
Total Precipitation	0.936	126.800
Evaporation Loss	0.000	0.000
Infiltration Loss	0.055	7.474
Surface Runoff	0.880	119.202
Final Storage	0.001	0.124

```
  Continuity Error (%) .....         0.000


  **************************        Volume         Volume
  Flow Routing Continuity        hectare-m      10^6 ltr
  **************************     ---------     ---------
  Dry Weather Inflow .......         0.000         0.000
  Wet Weather Inflow .......         0.880         8.798
  Groundwater Inflow .......         0.000         0.000
  RDII Inflow ..............         0.000         0.000
  External Inflow ..........         0.000         0.000
  External Outflow .........         0.880         8.802
  Flooding Loss ............         0.000         0.000
  Evaporation Loss .........         0.000         0.000
  Exfiltration Loss ........         0.000         0.000
  Initial Stored Volume ....         0.000         0.000
  Final Stored Volume ......         0.000         0.000
  Continuity Error (%) .....        -0.040


  ***************************
  Time-Step Critical Elements
  ***************************
  None


  ********************************
  Highest Flow Instability Indexes
  ********************************
  Link OL2 (1)
  Link OL1 (1)


  *************************
  Routing Time Step Summary
  *************************
  Minimum Time Step           :     0.50 sec
  Average Time Step           :     1.00 sec
  Maximum Time Step           :     1.00 sec
  Percent in Steady State     :     0.00
  Average Iterations per Step :     2.00
  Percent Not Converging      :     0.00


  ***************************
  Subcatchment Runoff Summary
  ***************************
```

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
101	126.80	0.00	0.00	7.95	118.85	0.94	0.04	0.937
102	126.80	0.00	0.00	7.95	118.85	0.10	0.00	0.937
103	126.80	0.00	0.00	7.95	118.85	0.16	0.01	0.937
104	126.80	0.00	0.00	7.98	118.82	1.61	0.07	0.937
105	126.80	0.00	0.00	7.95	118.85	0.24	0.01	0.937
106	126.80	0.00	0.00	9.08	117.72	1.12	0.05	0.928
107	126.80	0.00	0.00	8.94	117.86	0.60	0.03	0.929
108	126.80	0.00	0.00	8.94	117.86	0.62	0.03	0.929
109	126.80	0.00	0.00	9.08	117.72	1.08	0.05	0.928

110	126.80	0.00	0.00	9.01	117.79	0.21	0.01	0.929
111	126.80	0.00	0.00	9.01	117.79	0.22	0.01	0.929
112	126.80	0.00	0.00	0.00	125.85	0.58	0.03	0.992
113	126.80	0.00	0.00	8.94	117.86	0.34	0.02	0.929
114	126.80	0.00	0.00	0.00	125.85	0.63	0.03	0.992
115	126.80	0.00	0.00	8.94	117.86	0.33	0.02	0.929

****
Node Depth Summary
****

Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Time of Max Occurrence days hr:min	Reported Max Depth Meters
J1	JUNCTION	0.01	0.19	164.69	0 08:00	0.06
J10	JUNCTION	0.00	0.14	164.64	0 08:00	0.04
J2	JUNCTION	0.04	0.39	164.69	0 08:00	0.12
J3	JUNCTION	0.04	0.34	164.64	0 08:00	0.10
J4	JUNCTION	0.00	0.06	164.06	0 08:00	0.02
J5	JUNCTION	0.01	0.17	156.17	0 08:00	0.05
J6	JUNCTION	0.01	0.13	153.13	0 08:00	0.04
J7	JUNCTION	0.00	0.05	164.05	0 08:00	0.02
J8	JUNCTION	0.01	0.18	156.18	0 08:00	0.05
J9	JUNCTION	0.01	0.13	153.13	0 08:00	0.04
OF1	OUTFALL	0.00	0.00	149.50	0 00:00	0.00
OF2	OUTFALL	0.00	0.00	149.50	0 00:00	0.00
POND_East	STORAGE	0.04	0.38	150.38	0 12:32	0.12
POND_West	STORAGE	0.04	0.35	150.35	0 11:53	0.11

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CMS	Maximum Total Inflow CMS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 ltr	Total Inflow Volume 10^6 ltr	Flow Balance Error Percent
J1	JUNCTION	0.021	0.021	0 08:00	0.439	0.439	-0.063
J10	JUNCTION	0.000	0.002	0 07:14	0	0.00328	0.652
J2	JUNCTION	0.052	0.073	0 08:00	1.12	1.56	0.023
J3	JUNCTION	0.051	0.051	0 08:00	1.08	1.09	0.010
J4	JUNCTION	0.007	0.080	0 08:00	0.158	1.72	-0.004
J5	JUNCTION	0.076	0.156	0 08:00	1.64	3.36	-0.003
J6	JUNCTION	0.016	0.171	0 08:00	0.335	3.69	0.002
J7	JUNCTION	0.011	0.061	0 08:00	0.241	1.33	-0.008
J8	JUNCTION	0.103	0.164	0 08:00	2.23	3.55	-0.003
J9	JUNCTION	0.016	0.180	0 08:00	0.34	3.89	0.002
OF1	OUTFALL	0.000	0.049	0 02:37	0	4.33	0.000
OF2	OUTFALL	0.000	0.049	0 02:23	0	4.47	0.000
POND_East	STORAGE	0.026	0.206	0 08:00	0.582	4.47	-0.005
POND_West	STORAGE	0.028	0.199	0 08:00	0.631	4.32	-0.076

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Storage Volume Summary
****

Storage Unit	Average Volume 1000 m3	Avg Pcnt Full	Evap Pcnt Loss	Exfil Pcnt Loss	Maximum Volume 1000 m3	Max Pcnt Full	Time of Max Occurrence days hr:min	Maximum Outflow CMS
POND_East	0.122	4	0	0	1.164	35	0 12:32	0.049
POND_West	0.107	3	0	0	1.082	33	0 11:53	0.049

****
Outfall Loading Summary
****

Outfall Node	Flow Freq Pcnt	Avg Flow CMS	Max Flow CMS	Total Volume 10^6 ltr
OF1	17.72	0.047	0.049	4.328
OF2	18.27	0.047	0.049	4.473
System	18.00	0.094	0.098	8.802

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CMS	Time of Max Occurrence days hr:min	Maximum |Veloc| m/sec	Max/ Full Flow	Max/ Full Depth
D101	CONDUIT	0.020	0 08:00	0.11	0.02	0.48
D102	CONDUIT	0.073	0 08:00	0.49	0.10	0.37
D103	CONDUIT	0.080	0 08:00	0.86	0.01	0.23
D104	CONDUIT	0.156	0 08:00	1.09	0.08	0.30
D105	CONDUIT	0.002	0 07:14	0.02	0.00	0.41
D106	CONDUIT	0.050	0 08:00	0.43	0.07	0.33
D107	CONDUIT	0.061	0 08:00	0.66	0.01	0.23
D108	CONDUIT	0.164	0 08:00	1.13	0.09	0.31
D109	CONDUIT	0.171	0 08:00	1.44	0.06	0.26
D110	CONDUIT	0.180	0 08:00	1.58	0.05	0.26
OL1	DUMMY	0.049	0 02:37			
OL2	DUMMY	0.049	0 02:23			

****
Flow Classification Summary
****

Conduit	Adjusted /Actual Length	Fraction of Time in Flow Class								
		Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Norm Ltd	Inlet Ctrl
D101	1.00	0.01	0.00	0.00	0.99	0.00	0.00	0.00	0.97	0.00
D102	1.00	0.01	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00
D103	1.00	0.48	0.20	0.00	0.32	0.00	0.00	0.00	0.38	0.00
D104	1.00	0.48	0.00	0.00	0.49	0.03	0.00	0.00	0.08	0.00
D105	1.00	0.01	0.01	0.00	0.98	0.00	0.00	0.00	0.90	0.00
D106	1.00	0.01	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00
D107	1.00	0.48	0.20	0.00	0.32	0.00	0.00	0.00	0.38	0.00
D108	1.00	0.48	0.00	0.00	0.44	0.09	0.00	0.00	0.03	0.00
D109	1.00	0.68	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00
D110	1.00	0.69	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00

****

```
Conduit Surcharge Summary
*************************

No conduits were surcharged.


Analysis begun on:  Mon Jun 28 15:24:09 2021
Analysis ended on:  Mon Jun 28 15:24:15 2021
Total elapsed time: 00:00:06
```

Appendix E
Leachate Generation HELP Model Outputs

Appendix E - Leachate Generation HELP Model Input Parameters

Description of Cover System	Layer Type	Layer Decription
Daily Cover		
	Vegetative Coverage	Bare (Leaf Area Index 0)
	Evaporative Zone Depth	100 mm
	Slope	10 % slope
Sand-Daily Cover	Vertical Percolation Layer	100 mm of Sand (Soil Texture No. 2), Hyd.Cond. 5.8x10^{-3}cm/sec
Sand-Daily Cover	Barrier Soil	50 mm of Sand (Soil Texture No. 2), Hyd.Cond. 5.8x10^{-3}cm/sec
Municipal Waste	Vertical Percolation Layer	24 m of Municipal Solid Waste (Soil Texture No. 18), Hyd.Cond. 1x10^{-3}cm/sec
Geotextile	Flexible Membrane Liner	Drainage Net (model default, Soil Texture No. 20), Hyd.Cond. 10cm/sec
		Good placement quality, 2 pinholes/hectare, 6 installation defects/hectare
Drain Rock	Lateral Drainage Layer	300 mm of Gravel (Soil Texture No. 21), Hyd.Cond. 3x10^{-1}cm/sec
Intermediate Cover		
	Vegetative Coverage	Bare (Leaf Area Index 1)
	Evaporative Zone Depth	250 mm
	Slope	10 % slope
Sand-Intermediate Cover	Vertical Percolation Layer	300 mm of Sand (Soil Texture No. 2), Hyd.Cond. 5.8x10^{-3}cm/sec
Sand-Intermediate Cover	Barrier Soil	50 mm of Sand (Soil Texture No. 2), Hyd.Cond. 5.8x10^{-3}cm/sec
Municipal Waste	Vertical Percolation Layer	24 m of Municipal Solid Waste (Soil Texture No. 18), Hyd.Cond. 1x10^{-3}cm/sec
Geotextile	Flexible Membrane Liner	Drainage Net (model default, Soil Texture No. 20), Hyd.Cond. 10cm/sec
		Good placement quality, 2 pinholes/hectare, 6 installation defects/hectare
Drain Rock	Lateral Drainage Layer	300 mm of Gravel (Soil Texture No. 21), Hyd.Cond. 3x10^{-1}cm/sec
Final Cover		
	Vegetative Coverage	Good stand of grass
	Evaporative Zone Depth	300 mm
	Slope	10%
Topsoil	Vertical Percolation Layer	150 mm of Loamy Sand 9Soil Texture No. 4), Hyd.Cond. 1.7x10^{-3}cm/sec
Sand	Lateral Drainage Layer	600 mm of Sand (Soil Texture No. 2), Hyd.Cond. 5.8x10^{-3}cm/sec
Geosynthetic Clay Liner	Barrier Soil Liner	Bentonite Mat (model default, Soil Texture No. 17), Hyd.Con. 3x10^{-9}cm/sec
Sand	Vertical Percolation Layer	150 mm of Sand (Soil Texture No. 2), Hyd.Cond. 5.8x10^{-3}cm/sec
Municipal Waste	Vertical Percolation Layer	24 m of Municipal Solid Waste (Soil Texture No. 18), Hyd.Cond. 1x10^{-3}cm/sec
Geotextile	Flexible Membrane Liner	Drainage Net (model default, Soil Texture No. 20), Hyd.Cond. 10cm/sec
		Good placement quality, 2 pinholes/hectare, 6 installation defects/hectare
Drain Rock	Lateral Drainage Layer	300 mm of Gravel (Soil Texture No. 21), Hyd.Cond. 3x10^{-1}cm/sec

Daily Cover

	Lateral Drainage Collected from Layer 5	Run-off	
Jan	65.1089	34.035	
Feb	84.2772	26.786	
Mar	102.4533	5.216	
Apr	123.0865	0.55	
May	138.0491	0.336	
Jun	123.4093	0.253	
Jul	117.0968	0.335	
Aug	106.9451	0.489	
Sep	86.7352	0.129	
Oct	60.5727	6.234	
Nov	43.3287	11.463	
Dec	50.4224	20.108	
Sum:	1101.4852	105.934	1207.419

```
LATERAL DRAINAGE COLLECTED FROM LAYER  5
   ----------------------------------------
     TOTALS                65.1089  84.2772 102.4533 123.0865 138.04
                          117.0968 106.9451  86.7352  60.5727  43.32

     STD. DEVIATIONS       24.4978  28.8200  30.3134  31.9586  29.09
                           18.4311  17.3214  15.8749  16.8588  14.97

RUNOFF
   ------
     TOTALS                34.035   26.786    5.216    0.550    0.33
                            0.335    0.489    0.129    6.234   11.46

     STD. DEVIATIONS       67.175   67.695   13.713    1.344    1.12
                            1.002    2.820    0.565    7.952   13.01
```

Intermediate Cover

	Lateral Drainage from Layer 5
Jan	54.2613
Feb	73.35
Mar	92.706
Apr	117.4078
May	139.5856
Jun	122.926
Jul	112.8487
Aug	101.057
Sep	82.7143
Oct	54.8109
Nov	32.8243
Dec	39.5423
Sum:	1024.0342

```
   LATERAL DRAINAGE COLLECTED FROM LAYER  5
   ----------------------------------------
     TOTALS                54.2613  73.3592  92.7060 117.4078 139.58
                          112.8487 101.0570  82.7143  54.8109  32.82

     STD. DEVIATIONS       23.4180  26.8001  29.4715  31.4007  28.07
                           20.3881  21.6544  19.3005  17.9345  12.51
```

Final Cover

Jan	2.9168
Feb	2.6859
Mar	2.386
Apr	1.9599
May	1.4829
Jun	0.9079
Jul	0.6186
Aug	0.431
Sep	0.2893
Oct	0.1173
Nov	0.1984
Dec	1.808
Sum:	15.802

```
   LATERAL DRAINAGE COLLECTED FROM LAYER  7
   ----------------------------------------
     TOTALS                 2.9168   2.6859   2.3986   1.9599   1.48
                            0.6186   0.4310   0.2893   0.1173   0.19

     STD. DEVIATIONS        0.8955   0.8772   0.8500   0.5565   0.35
                            0.1340   0.1000   0.0949   0.0888   0.29
```

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\88877PD.D4
TEMPERATURE DATA FILE:      C:\HELP3\88877TD.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877SRD.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\88877ETD.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877DF8.D10
OUTPUT DATA FILE:           C:\HELP3\88877df8.OUT


TIME:  13:23     DATE:   5/28/2020


******************************************************************************

     TITLE:  Upland Landfill - Daily Cover HDPE Failure C&D

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   2
          THICKNESS                  =    10.00   CM
          POROSITY                   =     0.4370 VOL/VOL
          FIELD CAPACITY             =     0.0620 VOL/VOL
          WILTING POINT              =     0.0240 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.1434 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.579999993000E-02 CM/SEC
```

LAYER 2

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 2

THICKNESS	=	5.00	CM
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.0620	VOL/VOL
WILTING POINT	=	0.0240	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4370	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.579999993000E-02	CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 19

THICKNESS	=	2400.00	CM
POROSITY	=	0.1680	VOL/VOL
FIELD CAPACITY	=	0.0730	VOL/VOL
WILTING POINT	=	0.0190	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0838	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02	CM/SEC

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.50	CM
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000	CM/SEC
FML PINHOLE DENSITY	=	2.00	HOLES/HECTARE
FML INSTALLATION DEFECTS	=	6.00	HOLES/HECTARE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

THICKNESS	=	30.00	CM
POROSITY	=	0.3970	VOL/VOL

```
   FIELD CAPACITY             =     0.0320 VOL/VOL
   WILTING POINT              =     0.0130 VOL/VOL
   INITIAL SOIL WATER CONTENT =     0.1597 VOL/VOL
   EFFECTIVE SAT. HYD. COND.  = 0.300000012000     CM/SEC
   SLOPE                      =     1.00   PERCENT
   DRAINAGE LENGTH            =    80.0    METERS


                         LAYER  6
                         --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  17
   THICKNESS                  =     0.60   CM
   POROSITY                   =     0.7500 VOL/VOL
   FIELD CAPACITY             =     0.7470 VOL/VOL
   WILTING POINT              =     0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT =     0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.  = 0.300000003000E-08 CM/SEC


          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 2 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF 10.% AND
          A SLOPE LENGTH OF   35. METERS.

SCS RUNOFF CURVE NUMBER            =     81.70
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =      1.0000 HECTARES
EVAPORATIVE ZONE DEPTH             =     10.0    CM
INITIAL WATER IN EVAPORATIVE ZONE  =      1.434  CM
UPPER LIMIT OF EVAPORATIVE STORAGE =      4.370  CM
LOWER LIMIT OF EVAPORATIVE STORAGE =      0.240  CM
INITIAL SNOW WATER                 =      0.000  CM
INITIAL WATER IN LAYER MATERIALS   =    209.980  CM
TOTAL INITIAL WATER                =    209.980  CM
TOTAL SUBSURFACE INFLOW            =      0.00   MM/YR


          EVAPOTRANSPIRATION AND WEATHER DATA
          -----------------------------------

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          Campbell River        British Columbia

     STATION LATITUDE                        =  49.95 DEGREES
     MAXIMUM LEAF AREA INDEX                 =   0.00
```

START OF GROWING SEASON (JULIAN DATE) = 91
END OF GROWING SEASON (JULIAN DATE) = 305
EVAPORATIVE ZONE DEPTH = 10.0 CM
AVERAGE ANNUAL WIND SPEED = 8.00 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 84.10 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 72.47 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 71.95 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 87.08 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53

	28.36	30.28	30.04	68.74	74.24	69.47

RUNOFF

TOTALS	34.035	26.786	5.216	0.550	0.336	0.253
	0.335	0.489	0.129	6.234	11.463	20.108
STD. DEVIATIONS	67.175	67.695	13.713	1.344	1.127	0.629
	1.002	2.820	0.565	7.952	13.010	40.118

EVAPOTRANSPIRATION

TOTALS	7.270	10.909	32.661	50.909	38.585	34.688
	19.103	18.345	23.951	19.526	8.926	6.344
STD. DEVIATIONS	2.877	4.501	6.050	12.277	16.674	16.545
	13.384	13.132	11.467	4.334	1.619	2.045

PERCOLATION/LEAKAGE THROUGH LAYER 2

TOTALS	184.9617	124.8822	110.9308	54.5503	29.5131	27.0398
	20.0543	19.7217	28.2646	134.8827	186.5648	187.1910
STD. DEVIATIONS	82.3606	64.2705	45.3760	29.2116	20.9264	19.1694
	18.4242	18.2704	20.5887	61.0835	63.2804	71.2859

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	180.9979	156.5872	156.9727	111.9285	40.3257	26.9729
	21.2218	18.5651	29.2020	73.4767	126.3587	168.5397
STD. DEVIATIONS	63.5396	64.1078	51.8090	49.4760	27.7111	19.9570
	21.7540	16.4440	20.3996	26.8081	40.0389	46.5411

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	176.9316	162.1197	157.4841	122.2302	50.5715	26.9056
	22.3385	18.8743	26.5993	59.9102	117.0397	162.0860
STD. DEVIATIONS	55.2198	60.7850	53.8837	46.7045	31.7294	18.2236
	18.9747	16.8879	18.4590	22.3651	35.4900	42.5217

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	1.2600	1.1540	1.1304	0.8927	0.4175	0.2560
	0.2259	0.1974	0.2513	0.4793	0.8581	1.1611
STD. DEVIATIONS	0.3681	0.4049	0.3593	0.3114	0.2116	0.1233
	0.1304	0.1212	0.1277	0.1497	0.2366	0.2834

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.1754	0.1345	0.1128	0.0588	0.0295	0.0299
	0.0207	0.0206	0.0312	0.1313	0.1855	0.1773
STD. DEVIATIONS	0.0790	0.0695	0.0476	0.0312	0.0224	0.0239
	0.0196	0.0180	0.0240	0.0619	0.0683	0.0707

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.7718	0.7304	0.6655	0.4914	0.1730	0.1189
	0.0908	0.0794	0.1289	0.3097	0.5510	0.7141
STD. DEVIATIONS	0.2726	0.3011	0.2218	0.2170	0.1180	0.0872
	0.0927	0.0705	0.0897	0.1133	0.1775	0.2009

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	8.8090	8.8574	7.8410	6.2886	2.5179	1.3843
	1.1122	0.9397	1.3685	2.9829	6.0216	8.0699
STD. DEVIATIONS	2.7489	3.3251	2.6828	2.4029	1.5798	0.9376
	0.9447	0.8408	0.9497	1.1135	1.8259	2.1166

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	105.931	(128.5090)	1059.31	7.129
EVAPOTRANSPIRATION	271.217	(37.8267)	2712.17	18.252
PERCOLATION/LEAKAGE THROUGH LAYER 2	1108.55688	(180.96466)	11085.568	74.60322
AVERAGE HEAD ON TOP OF LAYER 2	0.923	(0.156)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	1111.14868	(193.93793)	11111.486	74.77763
AVERAGE HEAD ON TOP OF LAYER 4	4.021	(0.714)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	1103.09058	(192.71375)	11030.906	74.23534
PERCOLATION/LEAKAGE THROUGH LAYER 6	8.28386	(1.28800)	82.839	0.55748

AVERAGE HEAD ON TOP OF LAYER 6	46.827 (8.247)		
CHANGE IN WATER STORAGE	-2.586 (4.3345)	-25.86	-0.174

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(MM)	(CU. METERS)
PRECIPITATION	128.90	1289.000
RUNOFF	87.653	876.5259
PERCOLATION/LEAKAGE THROUGH LAYER 2	60.615021	606.15021
AVERAGE HEAD ON TOP OF LAYER 2	25.039	
PERCOLATION/LEAKAGE THROUGH LAYER 4	19.712858	197.12859
AVERAGE HEAD ON TOP OF LAYER 4	26.039	
DRAINAGE COLLECTED FROM LAYER 5	14.79354	147.93542
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.099692	0.99692
AVERAGE HEAD ON TOP OF LAYER 6	224.771	
MAXIMUM HEAD ON TOP OF LAYER 6	286.035	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	29.9 METERS	
SNOW WATER	341.73	3417.2583

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4370
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0240

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	3.7450	0.3745
2	2.1850	0.4370
3	175.2000	0.0730
4	0.0000	0.0000
5	2.5355	0.0845
6	0.4500	0.7500
SNOW WATER	0.000	

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                 **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************
```

```
PRECIPITATION DATA FILE:    C:\HELP3\88877PD.D4
TEMPERATURE DATA FILE:      C:\HELP3\88877TD.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877SRD.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\88877ETD.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877DF7.D10
OUTPUT DATA FILE:           C:\HELP3\88877df7.OUT
```

TIME: 15:58   DATE: 5/26/2020

****

TITLE: Upland Landfill - Daily Cover HDPE Failure C&D

****

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 2

```
THICKNESS                  =     10.00   CM
POROSITY                   =      0.4370 VOL/VOL
FIELD CAPACITY             =      0.0620 VOL/VOL
WILTING POINT              =      0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.1434 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.579999993000E-02 CM/SEC
```

LAYER 2

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 2

```
THICKNESS                    =      5.00   CM
POROSITY                     =      0.4370 VOL/VOL
FIELD CAPACITY               =      0.0620 VOL/VOL
WILTING POINT                =      0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.4370 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.579999993000E-02 CM/SEC
```

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 19

```
THICKNESS                    =    240.00   CM
POROSITY                     =      0.1680 VOL/VOL
FIELD CAPACITY               =      0.0730 VOL/VOL
WILTING POINT                =      0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0776 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC
```

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 20

```
THICKNESS                    =      0.50   CM
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   10.0000000000     CM/SEC
FML PINHOLE DENSITY          =      2.00   HOLES/HECTARE
FML INSTALLATION DEFECTS     =      6.00   HOLES/HECTARE
FML PLACEMENT QUALITY        =  3 - GOOD
```

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

```
THICKNESS                    =     30.00   CM
POROSITY                     =      0.3970 VOL/VOL
```

```
FIELD CAPACITY              =     0.0320 VOL/VOL
WILTING POINT               =     0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.2717 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.300000012000     CM/SEC
SLOPE                       =     1.00   PERCENT
DRAINAGE LENGTH             =    80.0    METERS
```

LAYER 6

```
              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  17
THICKNESS                   =     0.60   CM
POROSITY                    =     0.7500 VOL/VOL
FIELD CAPACITY              =     0.7470 VOL/VOL
WILTING POINT               =     0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.300000003000E-08 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

```
NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE # 2 WITH BARE
         GROUND CONDITIONS, A SURFACE SLOPE OF 10.% AND
         A SLOPE LENGTH OF   35. METERS.

SCS RUNOFF CURVE NUMBER              =     81.70
FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =      1.0000 HECTARES
EVAPORATIVE ZONE DEPTH               =     10.0    CM
INITIAL WATER IN EVAPORATIVE ZONE    =      1.434  CM
UPPER LIMIT OF EVAPORATIVE STORAGE   =      4.370  CM
LOWER LIMIT OF EVAPORATIVE STORAGE   =      0.240  CM
INITIAL SNOW WATER                   =      0.000  CM
INITIAL WATER IN LAYER MATERIALS     =     30.855  CM
TOTAL INITIAL WATER                  =     30.855  CM
TOTAL SUBSURFACE INFLOW              =      0.00   MM/YR
```

EVAPOTRANSPIRATION AND WEATHER DATA

```
NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         Campbell River        British Columbia

   STATION LATITUDE                       =  49.95 DEGREES
   MAXIMUM LEAF AREA INDEX                =   0.00
```

START OF GROWING SEASON (JULIAN DATE) = 91
END OF GROWING SEASON (JULIAN DATE) = 305
EVAPORATIVE ZONE DEPTH = 10.0 CM
AVERAGE ANNUAL WIND SPEED = 8.00 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 84.10 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 72.47 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 71.95 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 87.08 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

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17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79

STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53
	28.36	30.28	30.04	68.74	74.24	69.47

RUNOFF

TOTALS	34.035	26.786	5.216	0.550	0.336	0.253
	0.335	0.489	0.129	6.234	11.463	20.108
STD. DEVIATIONS	67.175	67.695	13.713	1.344	1.127	0.629
	1.002	2.820	0.565	7.952	13.010	40.118

EVAPOTRANSPIRATION

TOTALS	7.270	10.909	32.661	50.909	38.585	34.688
	19.103	18.345	23.951	19.526	8.926	6.344
STD. DEVIATIONS	2.877	4.501	6.050	12.277	16.674	16.545
	13.384	13.132	11.467	4.334	1.619	2.045

PERCOLATION/LEAKAGE THROUGH LAYER 2

TOTALS	184.9617	124.8822	110.9308	54.5503	29.5131	27.0398
	20.0543	19.7217	28.2646	134.8827	186.5648	187.1910
STD. DEVIATIONS	82.3606	64.2705	45.3760	29.2116	20.9264	19.1694
	18.4242	18.2704	20.5887	61.0835	63.2804	71.2859

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	186.7819	125.4513	113.2133	58.6388	30.8218	26.7040
	20.9745	18.0658	29.6386	126.4795	184.1192	187.7798
STD. DEVIATIONS	80.2050	63.7018	46.5574	30.0269	19.8723	18.7225
	19.8969	15.6496	20.6210	56.9506	63.5764	66.5428

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	188.6486	128.9355	119.7612	68.0736	33.9717	26.5464
	22.2037	18.1844	27.7207	102.4087	175.7489	188.9156
STD. DEVIATIONS	77.3292	63.2177	46.8353	31.0103	18.5991	17.8725
	19.4788	16.0282	19.5871	47.7744	59.0323	59.0145

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	1.3349	0.9319	0.8788	0.5316	0.3067	0.2530
	0.2249	0.1920	0.2587	0.7622	1.2482	1.3379
STD. DEVIATIONS	0.5111	0.4207	0.3121	0.2068	0.1243	0.1221
	0.1338	0.1161	0.1352	0.3182	0.3916	0.3906

-

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

-

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.1754	0.1345	0.1128	0.0588	0.0295	0.0299
	0.0207	0.0206	0.0312	0.1313	0.1855	0.1773
STD. DEVIATIONS	0.0790	0.0695	0.0476	0.0312	0.0224	0.0239
	0.0196	0.0180	0.0240	0.0619	0.0683	0.0707

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.7943	0.5852	0.4853	0.2626	0.1344	0.1208
	0.0919	0.0795	0.1330	0.5385	0.8090	0.7990
STD. DEVIATIONS	0.3393	0.2970	0.1996	0.1318	0.0860	0.0840
	0.0878	0.0694	0.0929	0.2413	0.2828	0.2805

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	9.3680	7.0421	5.9621	3.5023	1.6914	1.3658
	1.1055	0.9054	1.4262	5.0953	9.0314	9.3906
STD. DEVIATIONS	3.8164	3.4486	2.3307	1.5954	0.9260	0.9195
	0.9698	0.7980	1.0077	2.3729	3.0217	2.9170

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

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	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	105.931	(128.5090)	1059.31	7.129
EVAPOTRANSPIRATION	271.217	(37.8267)	2712.17	18.252
PERCOLATION/LEAKAGE THROUGH LAYER 2	1108.55688	(180.96466)	11085.568	74.60322
AVERAGE HEAD ON TOP OF LAYER 2	0.923 (	0.156)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	1108.66833	(182.04721)	11086.684	74.61072
AVERAGE HEAD ON TOP	4.028 (	0.658)		

```
   OF LAYER  4

 LATERAL DRAINAGE COLLECTED   1101.11902 (183.70462)     11011.190   74.10267
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH     8.26081 (  1.22634)        82.608    0.55593
   LAYER  6

 AVERAGE HEAD ON TOP            46.572 (    7.806)
   OF LAYER  6

 CHANGE IN WATER STORAGE        -0.592   (  2.3864)         -5.92    -0.040

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```

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            PEAK DAILY VALUES FOR YEARS    1 THROUGH  100
  ------------------------------------------------------------------------
                                               (MM)        (CU. METERS)
                                            ----------    ------------
    PRECIPITATION                            128.90          1289.000

    RUNOFF                                    87.653          876.5259

    PERCOLATION/LEAKAGE THROUGH LAYER  2      60.615021       606.15021

    AVERAGE HEAD ON TOP OF LAYER  2           25.039

    PERCOLATION/LEAKAGE THROUGH LAYER  4      50.805981       508.05981

    AVERAGE HEAD ON TOP OF LAYER  4           75.712

    DRAINAGE COLLECTED FROM LAYER  5          20.55753        205.57533

    PERCOLATION/LEAKAGE THROUGH LAYER  6       0.132190         1.32190

    AVERAGE HEAD ON TOP OF LAYER  6          300.000

    MAXIMUM HEAD ON TOP OF LAYER  6          367.829

    LOCATION OF MAXIMUM HEAD IN LAYER  5
          (DISTANCE FROM DRAIN)               33.6 METERS

    SNOW WATER                               341.73          3417.2583


    MAXIMUM VEG. SOIL WATER (VOL/VOL)                  0.4370

    MINIMUM VEG. SOIL WATER (VOL/VOL)                  0.0240


     ***  Maximum heads are computed using McEnroe's equations.  ***

          Reference:  Maximum Saturated Depth over Landfill Liner
                      by Bruce M. McEnroe, University of Kansas
                      ASCE Journal of Environmental Engineering
                      Vol. 119, No. 2, March 1993, pp. 262-270.

******************************************************************************
```

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	3.7450	0.3745
2	2.1850	0.4370
3	17.5200	0.0730
4	0.0000	0.0000
5	1.0381	0.0346
6	0.4500	0.7500
SNOW WATER	0.000	

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****

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******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
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PRECIPITATION DATA FILE:    C:\HELP3\88877PI.D4
TEMPERATURE DATA FILE:      C:\HELP3\88877TI.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877SRI.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\88877ETI.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877IF6.D10
OUTPUT DATA FILE:           C:\HELP3\88877if6.OUT


TIME:  13: 1     DATE:   5/28/2020


******************************************************************************

     TITLE:  Upland Landfill - Intermediate Cover HDPE Failure C&D

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER   2
          THICKNESS                  =     25.00   CM
          POROSITY                   =      0.4370 VOL/VOL
          FIELD CAPACITY             =      0.0620 VOL/VOL
          WILTING POINT              =      0.0240 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.1416 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.579999993000E-02 CM/SEC
```

LAYER 2

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 2

```
THICKNESS                    =     5.00   CM
POROSITY                     =     0.4370 VOL/VOL
FIELD CAPACITY               =     0.0620 VOL/VOL
WILTING POINT                =     0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.4370 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.579999993000E-02 CM/SEC
```

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 19

```
THICKNESS                    =  2400.00   CM
POROSITY                     =     0.1680 VOL/VOL
FIELD CAPACITY               =     0.0730 VOL/VOL
WILTING POINT                =     0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.0845 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC
```

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 20

```
THICKNESS                    =     0.50   CM
POROSITY                     =     0.0000 VOL/VOL
FIELD CAPACITY               =     0.0000 VOL/VOL
WILTING POINT                =     0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   10.0000000000     CM/SEC
FML PINHOLE DENSITY          =     2.00   HOLES/HECTARE
FML INSTALLATION DEFECTS     =     6.00   HOLES/HECTARE
FML PLACEMENT QUALITY        =  3 - GOOD
```

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

```
THICKNESS                    =    30.00   CM
POROSITY                     =     0.3970 VOL/VOL
```

```
    FIELD CAPACITY              =      0.0320 VOL/VOL
    WILTING POINT               =      0.0130 VOL/VOL
    INITIAL SOIL WATER CONTENT  =      0.1493 VOL/VOL
    EFFECTIVE SAT. HYD. COND.   =  0.300000012000     CM/SEC
    SLOPE                       =      1.00   PERCENT
    DRAINAGE LENGTH             =     80.0    METERS
```

LAYER 6

```
                 TYPE 3 - BARRIER SOIL LINER
                 MATERIAL TEXTURE NUMBER  17
    THICKNESS                   =      0.60   CM
    POROSITY                    =      0.7500 VOL/VOL
    FIELD CAPACITY              =      0.7470 VOL/VOL
    WILTING POINT               =      0.4000 VOL/VOL
    INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
    EFFECTIVE SAT. HYD. COND.   =  0.300000003000E-08 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

```
 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 2 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF 10.% AND
          A SLOPE LENGTH OF   35. METERS.

   SCS RUNOFF CURVE NUMBER               =     81.70
   FRACTION OF AREA ALLOWING RUNOFF      =    100.0    PERCENT
   AREA PROJECTED ON HORIZONTAL PLANE    =      1.0000 HECTARES
   EVAPORATIVE ZONE DEPTH                =     25.0    CM
   INITIAL WATER IN EVAPORATIVE ZONE     =      3.540  CM
   UPPER LIMIT OF EVAPORATIVE STORAGE    =     10.925  CM
   LOWER LIMIT OF EVAPORATIVE STORAGE    =      0.600  CM
   INITIAL SNOW WATER                    =      0.000  CM
   INITIAL WATER IN LAYER MATERIALS      =    213.377  CM
   TOTAL INITIAL WATER                   =    213.377  CM
   TOTAL SUBSURFACE INFLOW               =      0.00   MM/YR
```

EVAPOTRANSPIRATION AND WEATHER DATA

```
 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          Campbell River        British Columbia

      STATION LATITUDE                        =  49.95 DEGREES
      MAXIMUM LEAF AREA INDEX                 =   0.00
```

START OF GROWING SEASON (JULIAN DATE) = 91
END OF GROWING SEASON (JULIAN DATE) = 305
EVAPORATIVE ZONE DEPTH = 25.0 CM
AVERAGE ANNUAL WIND SPEED = 8.00 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 84.10 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 72.47 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 71.95 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 87.08 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OLYMPIA WASHINGTON AND STATION LATITUDE = 49.95 DEGREES

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AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53

	28.36	30.28	30.04	68.74	74.24	69.47

RUNOFF

TOTALS	31.887	24.870	4.887	0.496	0.262	0.200
	0.222	0.399	0.102	6.164	11.299	18.928
STD. DEVIATIONS	62.872	63.609	12.642	1.150	0.918	0.540
	0.761	2.229	0.500	8.004	12.912	37.191

EVAPOTRANSPIRATION

TOTALS	7.259	10.995	36.327	65.831	57.276	48.516
	31.708	27.282	34.370	21.141	8.928	6.318
STD. DEVIATIONS	2.842	4.575	6.141	11.974	20.883	21.160
	20.687	19.099	17.596	4.743	1.608	2.028

PERCOLATION/LEAKAGE THROUGH LAYER 2

TOTALS	186.6601	125.6402	111.8985	45.9513	15.3922	12.4864
	10.1460	8.7020	15.9593	123.3714	185.9916	187.6318
STD. DEVIATIONS	81.1768	64.1526	46.8856	29.5841	15.6416	14.4724
	13.5229	12.9562	16.5228	60.4221	63.0770	70.4321

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	181.7890	159.4316	160.1953	110.0303	25.7250	12.9628
	10.3462	8.2745	15.9669	60.2012	120.0866	167.5739
STD. DEVIATIONS	64.0056	63.7747	51.0165	53.3308	26.3330	16.5620
	16.0027	12.9388	17.0056	26.7836	40.0943	47.3464

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	177.4010	165.0154	160.2038	122.3063	37.4109	13.1796
	10.6072	8.4422	13.9848	46.1568	110.2817	160.0766
STD. DEVIATIONS	55.6627	60.3891	52.6477	48.6307	32.3400	15.5460
	14.3900	12.5511	14.9529	21.9186	34.9547	43.6375

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	1.2631	1.1723	1.1483	0.8933	0.3287	0.1537
	0.1359	0.1071	0.1549	0.3833	0.8131	1.1476
STD. DEVIATIONS	0.3711	0.4049	0.3514	0.3243	0.2168	0.1125
	0.1065	0.1010	0.1112	0.1506	0.2331	0.2908

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.1967	0.1453	0.1275	0.0505	0.0167	0.0135
	0.0106	0.0087	0.0175	0.1250	0.1970	0.1944
STD. DEVIATIONS	0.0803	0.0779	0.0588	0.0325	0.0168	0.0157
	0.0140	0.0149	0.0184	0.0620	0.0702	0.0736

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.7717	0.7442	0.6801	0.4846	0.1104	0.0574
	0.0443	0.0354	0.0704	0.2524	0.5214	0.7095
STD. DEVIATIONS	0.2734	0.3001	0.2163	0.2344	0.1129	0.0726
	0.0683	0.0556	0.0743	0.1131	0.1758	0.2046

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	8.8321	9.0153	7.9764	6.2925	1.8627	0.6781
	0.5281	0.4203	0.7195	2.2981	5.6739	7.9697
STD. DEVIATIONS	2.7706	3.3036	2.6212	2.5020	1.6102	0.7998
	0.7165	0.6249	0.7693	1.0913	1.7984	2.1718

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	99.716	(120.3010)	997.16	6.711
EVAPOTRANSPIRATION	355.950	(51.2605)	3559.50	23.955
PERCOLATION/LEAKAGE THROUGH LAYER 2	1029.83081	(173.63248)	10298.309	69.30514
AVERAGE HEAD ON TOP OF LAYER 2	0.919	(0.145)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	1032.58350	(187.03522)	10325.835	69.49039
AVERAGE HEAD ON TOP OF LAYER 4	3.735	(0.687)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	1025.06604	(185.51189)	10250.660	68.98448
PERCOLATION/LEAKAGE THROUGH LAYER 6	7.70132	(1.25354)	77.013	0.51828

```
 AVERAGE HEAD ON TOP              43.556 (    7.941)
   OF LAYER  6

 CHANGE IN WATER STORAGE          -2.497   (  4.3731)          -24.97     -0.168

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(MM)	(CU. METERS)
PRECIPITATION	128.90	1289.000
RUNOFF	86.028	860.2754
PERCOLATION/LEAKAGE THROUGH LAYER 2	69.487221	694.87219
AVERAGE HEAD ON TOP OF LAYER 2	53.465	
PERCOLATION/LEAKAGE THROUGH LAYER 4	19.819096	198.19095
AVERAGE HEAD ON TOP OF LAYER 4	26.185	
DRAINAGE COLLECTED FROM LAYER 5	14.76017	147.60168
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.099524	0.99524
AVERAGE HEAD ON TOP OF LAYER 6	224.383	
MAXIMUM HEAD ON TOP OF LAYER 6	285.534	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	29.9 METERS	
SNOW WATER	341.73	3417.2583

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3710
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0240

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	7.9385	0.3175
2	2.1850	0.4370
3	175.2000	0.0730
4	0.0000	0.0000
5	2.6365	0.0879
6	0.4500	0.7500
SNOW WATER	0.000	

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
******************************************************************************
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PRECIPITATION DATA FILE:    C:\HELP3\88877PF.D4
TEMPERATURE DATA FILE:      C:\HELP3\88877TF.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877SRF.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\88877ETF.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877FF6.D10
OUTPUT DATA FILE:           C:\HELP3\88877ff6.OUT


TIME:  14:32     DATE:   5/28/2020


******************************************************************************

     TITLE:  Upland Landfill - Final Cover HDPE Failure C&D

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER   4
           THICKNESS                  =     15.00   CM
           POROSITY                   =      0.4370 VOL/VOL
           FIELD CAPACITY             =      0.1050 VOL/VOL
           WILTING POINT              =      0.0470 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1785 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.170000002000E-02 CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

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                    LAYER  2
                    --------

             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   2
THICKNESS                   =    60.00   CM
POROSITY                    =     0.4370 VOL/VOL
FIELD CAPACITY              =     0.0620 VOL/VOL
WILTING POINT               =     0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.3227 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC
SLOPE                       =    10.00   PERCENT
DRAINAGE LENGTH             =    35.0    METERS


                    LAYER  3
                    --------

               TYPE 3 - BARRIER SOIL LINER
               MATERIAL TEXTURE NUMBER  17
THICKNESS                   =     0.60   CM
POROSITY                    =     0.7500 VOL/VOL
FIELD CAPACITY              =     0.7470 VOL/VOL
WILTING POINT               =     0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.300000003000E-08 CM/SEC


                    LAYER  4
                    --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER   2
THICKNESS                   =    15.00   CM
POROSITY                    =     0.4370 VOL/VOL
FIELD CAPACITY              =     0.0620 VOL/VOL
WILTING POINT               =     0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.1250 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC


                    LAYER  5
                    --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER  19
THICKNESS                   =  2400.00   CM
```

```
POROSITY                      =      0.1680 VOL/VOL
FIELD CAPACITY                =      0.0730 VOL/VOL
WILTING POINT                 =      0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.0730 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.100000005000E-02 CM/SEC


                        LAYER  6
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  20
THICKNESS                     =      0.50   CM
POROSITY                      =      0.0000 VOL/VOL
FIELD CAPACITY                =      0.0000 VOL/VOL
WILTING POINT                 =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =   10.0000000000     CM/SEC
FML PINHOLE DENSITY           =      2.00   HOLES/HECTARE
FML INSTALLATION DEFECTS      =      6.00   HOLES/HECTARE
FML PLACEMENT QUALITY         =  3 - GOOD


                        LAYER  7
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER  21
THICKNESS                     =     30.00   CM
POROSITY                      =      0.3970 VOL/VOL
FIELD CAPACITY                =      0.0320 VOL/VOL
WILTING POINT                 =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.0336 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.300000012000     CM/SEC
SLOPE                         =      1.00   PERCENT
DRAINAGE LENGTH               =     80.0    METERS


                        LAYER  8
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  17
THICKNESS                     =      0.60   CM
POROSITY                      =      0.7500 VOL/VOL
FIELD CAPACITY                =      0.7470 VOL/VOL
WILTING POINT                 =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.300000003000E-08 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 4 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 10.% AND A SLOPE LENGTH OF 35. METERS.

SCS RUNOFF CURVE NUMBER	=	56.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.0000	HECTARES
EVAPORATIVE ZONE DEPTH	=	30.0	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	5.060	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13.110	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.065	CM
INITIAL SNOW WATER	=	0.000	CM
INITIAL WATER IN LAYER MATERIALS	=	201.028	CM
TOTAL INITIAL WATER	=	201.028	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM Campbell River British Columbia

STATION LATITUDE	=	49.95	DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50	
START OF GROWING SEASON (JULIAN DATE)	=	91	
END OF GROWING SEASON (JULIAN DATE)	=	305	
EVAPORATIVE ZONE DEPTH	=	30.0	CM
AVERAGE ANNUAL WIND SPEED	=	8.00	KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	84.10	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.47	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.95	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	87.08	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53
	28.36	30.28	30.04	68.74	74.24	69.47
RUNOFF						
TOTALS	21.382	20.117	3.223	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.140	8.023
STD. DEVIATIONS	61.417	62.057	12.268	0.000	0.000	0.000
	0.000	0.000	0.000	0.003	0.842	33.796
EVAPOTRANSPIRATION						
TOTALS	6.991	10.459	35.089	66.199	66.348	57.095
	36.757	32.885	36.444	17.871	7.401	5.790
STD. DEVIATIONS	2.382	4.007	5.824	10.244	20.874	24.694
	24.988	20.829	18.091	3.718	1.437	1.722
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	198.2982	143.5541	130.1599	73.7398	27.9560	10.4772
	5.3721	4.0402	6.3776	70.6105	170.1666	196.9461

```
  STD. DEVIATIONS       73.5734  59.6388  42.8260  29.5571  15.4583  11.1173
                         7.3795   9.0126  10.6322  41.1663  57.6571  56.0787

PERCOLATION/LEAKAGE THROUGH LAYER  3
------------------------------------
  TOTALS                 3.1005   2.2607   2.0637   1.2014   0.5063   0.2374
                         0.1622   0.1412   0.1732   1.1557   2.6706   3.0813

  STD. DEVIATIONS        1.1182   0.9087   0.6526   0.4504   0.2356   0.1694
                         0.1124   0.1378   0.1632   0.6281   0.8784   0.8543

PERCOLATION/LEAKAGE THROUGH LAYER  6
------------------------------------
  TOTALS                 3.1054   2.6921   2.4105   1.9812   1.4585   0.9155
                         0.6563   0.4892   0.3439   0.1257   0.3705   2.2315

  STD. DEVIATIONS        0.9461   0.8941   0.8601   0.5131   0.3294   0.1857
                         0.1275   0.1010   0.1021   0.1032   0.4572   1.0633

LATERAL DRAINAGE COLLECTED FROM LAYER  7
----------------------------------------
  TOTALS                 2.9175   2.6867   2.3969   1.9595   1.4814   0.9074
                         0.6181   0.4307   0.2890   0.1172   0.1999   1.8106

  STD. DEVIATIONS        0.8955   0.8763   0.8482   0.5565   0.3509   0.2053
                         0.1336   0.0999   0.0949   0.0890   0.2910   1.0083

PERCOLATION/LEAKAGE THROUGH LAYER  8
------------------------------------
  TOTALS                 0.0998   0.0911   0.0958   0.0908   0.0902   0.0838
                         0.0845   0.0828   0.0782   0.0490   0.0328   0.0870

  STD. DEVIATIONS        0.0060   0.0060   0.0077   0.0037   0.0023   0.0014
                         0.0009   0.0029   0.0068   0.0204   0.0224   0.0174


-------------------------------------------------------------------------------
                 AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)
-------------------------------------------------------------------------------


DAILY AVERAGE HEAD ON TOP OF LAYER  3
-------------------------------------
  AVERAGES              22.5526  17.9315  14.8102   8.6702   3.1810   1.2319
                         0.6113   0.4597   0.7499   8.0344  20.0066  22.4089

  STD. DEVIATIONS        8.3496   7.4634   4.8729   3.4753   1.7589   1.3071
                         0.8397   1.0255   1.2501   4.6841   6.7776   6.3795

DAILY AVERAGE HEAD ON TOP OF LAYER  6
-------------------------------------
  AVERAGES               0.0133   0.0127   0.0103   0.0088   0.0063   0.0041
                         0.0029   0.0022   0.0016   0.0006   0.0016   0.0095

  STD. DEVIATIONS        0.0040   0.0042   0.0037   0.0023   0.0014   0.0008
                         0.0005   0.0004   0.0005   0.0005   0.0020   0.0045
```

DAILY AVERAGE HEAD ON TOP OF LAYER 8

AVERAGES	0.1453	0.1468	0.1193	0.1008	0.0738	0.0467
	0.0308	0.0214	0.0149	0.0058	0.0103	0.0902
STD. DEVIATIONS	0.0446	0.0480	0.0422	0.0286	0.0175	0.0106
	0.0066	0.0050	0.0049	0.0044	0.0150	0.0502

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	52.886	(114.1105)	528.86	3.559
EVAPOTRANSPIRATION	379.329	(55.0845)	3793.29	25.528
LATERAL DRAINAGE COLLECTED FROM LAYER 2	1037.69824	(180.34677)	10376.982	69.83460
PERCOLATION/LEAKAGE THROUGH LAYER 3	16.75417	(2.74737)	167.542	1.12752
AVERAGE HEAD ON TOP OF LAYER 3	100.540	(17.590)		
PERCOLATION/LEAKAGE THROUGH LAYER 6	16.78042	(2.82040)	167.804	1.12928
AVERAGE HEAD ON TOP OF LAYER 6	0.062	(0.010)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	15.81481	(2.77546)	158.148	1.06430
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.96599	(0.03470)	9.660	0.06501
AVERAGE HEAD ON TOP OF LAYER 8	0.672	(0.119)		
CHANGE IN WATER STORAGE	-0.757	(2.5400)	-7.57	-0.051

****

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*******************************************************************************

             PEAK DAILY VALUES FOR YEARS    1 THROUGH  100
  ------------------------------------------------------------------------
                                                (MM)        (CU. METERS)
                                             ----------     ------------
    PRECIPITATION                            128.90          1289.000

    RUNOFF                                    84.875          848.7458

    DRAINAGE COLLECTED FROM LAYER  2          22.22717        222.27165

    PERCOLATION/LEAKAGE THROUGH LAYER  3       0.320248         3.20248

    AVERAGE HEAD ON TOP OF LAYER  3          735.327

    MAXIMUM HEAD ON TOP OF LAYER  3          985.790

    LOCATION OF MAXIMUM HEAD IN LAYER  2
          (DISTANCE FROM DRAIN)               11.3 METERS

    PERCOLATION/LEAKAGE THROUGH LAYER  6       0.257808         2.57808

    AVERAGE HEAD ON TOP OF LAYER  6            0.343

    DRAINAGE COLLECTED FROM LAYER  7           0.20964          2.09641

    PERCOLATION/LEAKAGE THROUGH LAYER  8       0.003990         0.03990

    AVERAGE HEAD ON TOP OF LAYER  8            3.236

    MAXIMUM HEAD ON TOP OF LAYER  8            6.271

    LOCATION OF MAXIMUM HEAD IN LAYER  7
          (DISTANCE FROM DRAIN)                2.5 METERS

    SNOW WATER                               341.73          3417.2583


    MAXIMUM VEG. SOIL WATER (VOL/VOL)                  0.4370

    MINIMUM VEG. SOIL WATER (VOL/VOL)                  0.0355


     ***  Maximum heads are computed using McEnroe's equations.  ***

          Reference:  Maximum Saturated Depth over Landfill Liner
                      by Bruce M. McEnroe, University of Kansas
                      ASCE Journal of Environmental Engineering
                      Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	6.5550	0.4370
2	8.1823	0.1364
3	0.4500	0.7500
4	1.6144	0.1076
5	175.2018	0.0730
6	0.0000	0.0000
7	1.0044	0.0335
8	0.4500	0.7500
SNOW WATER	0.000	

****
****

Appendix F
Leachate Treatment Facility Commissioning Plan

Appendix F Leachate Treatment Facility Commissioning Plan

1. Description of Leachate Treatment Works and Design

Leachate will be collected by a series of perforated pipes installed at the base of each landfill cell that discharge to a sump. Leachate will be stored temporarily in the Landfill and pumped from the sump to the Leachate Treatment Facility (LTF). Leachate will be pumped from the Landfill to the LTF for batch treatment on an as-needed basis.

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 leachate generation rate, an average batch size is considered to be 625 m^3. A batch size may vary, requiring operational adjustments to the treatment system. Based on the pond sizing described below, the maximum batch size is 1,400 m^3.

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

- Perforated leachate collection pipes (LCP) with minimum diameter of 150 mm wrapped in protective geotextile layers within the stone drainage blanket
- A 2.75 percent slope along primary flow path and 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 along the east side of the Landfill sloping at 2 percent towards a leachate collection sump located at the north east corner of the Landfill footprint
- A sump with bottom dimension of 3,900 mm^2
- Two leachate sump riser pipes with minimum diameters of 450 mm
- Manually operated submersible leachate pump housed in one of the two sump riser pipes

The detailed design of the treatment system will be based on process modeling results and refined based on site-specific leachate chemistry. The conceptual design is described herein. The LTF consists of an aerated equalization system, solids removal, chemical addition, further solids removal, an effluent holding pond, a granular activated carbon (GAC) filter, and an infiltration pond.

The conceptual design features of the aerated equalization pond include:

- 2.5H:1V side walls double lined with 60-mil HDPE liner overlying a GCL
- A submerged coarse bubble aeration system
- Positive displacement blowers sized to provide the required air demand
- Decant pump
- Approximate bottom dimensions of the aeration pond will be 15 metres (m) by 15 m. The approximate top dimensions of the aeration pond will be 34 m by 32 m.
- Approximate depth of 3 m with a 0.6 m freeboard

- Resulting available volume is approximately 1,400 m^3
- 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.
- 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 2.4 litres per second (L/s) (38 gallons per minute [gpm]) for an average size batch and 5.4 L/s (86 gpm) for a maximum size batch.

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 will be accomplished through settling in a clarifier or filtration.

Clarification or filtration will require a capacity of 7.2 L/s (115 gpm) for an average size batch and 16 L/s (259 gpm) for a maximum size batch to complete solids removal within one day.

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 inline mixer.

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

Effluent from the chemical addition and solids removal step will be collected in a holding pond or tank. The effluent holding pond or tank will therefore have the necessary capacity to store a full batch with 0.6 m of freeboard.

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.

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.

The infiltration pond will be used to infiltrate treated leachate and some of the collected 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 Hydrology and Hydrogeology Characterization Report (HHCR).

Discharge to the infiltration pond will meet the British Columbia (BC) Contaminated Sites Regulation (CSR) Schedule 3.2 Drinking Water (DW) Criteria. The location of the infiltration pond has been selected to allow for further 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 design and construction of the infiltration pond is supported by the results of the HHCR, and includes:

- 2:5H:1V side walls
- Maximum draining time is 48 hours
- Maximum water ponding depth is 0.3 m
- Infiltration capacity between 13 mm/hr (minimum) and 61 mm/hr (maximum)
- Minimum 600 mm free board

1.1 Treatment Process

The leachate treatment system will reduce the concentration of leachate constituents by the processes described below:

- Aeration oxidizes dissolved metals such as iron and manganese to less soluble forms and produces flocs that will be filtered. 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.
- Hydrocarbons and volatile organic compounds will be readily volatized in an aeration lagoon thereby reducing the concentration. If concentrations of organic compounds are required to be further reduced, the effluent will be filtered through a GAC filter.
- The dissolved metals will be removed, if required by chemical precipitation, by adding a volume of chemicals (i.e., mild acids or bases) that will cause an increase or decrease of pH of the leachate to facilitate the formation of an insoluble salt.

Should leachate quality change over time and additional leachate constituents require treatment, the process is capable of including a polishing step to continue to meet the BC CSR Schedule 3.2 Criteria.

The forecasted treated leachate quality is presented in the DOCP. Further studies will be performed on the actual leachate during the commissioning and operation of the LTF to ensure adequate level 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.

2. Commissioning Period Operating Procedures

This LTF Commissioning Plan provides for a commissioning period during which initial leachate characterization and confirmation of treatment process capabilities is conducted. The LTF will be constructed and operational prior to landfilling in Stage 1 East. The anticipated commissioning period schedule is outlined in Section 2.4.

Initial leachate batches are expected to have low concentrations of leachate parameters derived from newly placed waste as well as waste relocated from the former on-site landfill. The commissioning period operating procedure will support leachate quality characterization, and ensure that only treated leachate meeting the discharge criteria is decanted to the infiltration pond. The following sections describe the commissioning period operating procedures.

2.1 Clean Water Testing

Clean water testing is the initial step in the LTF commissioning. The hydraulic integrity of all major process ponds, tanks, pumps, piping, and appurtenance will be verified via clean water testing prior to the commencement of start-up and commissioning activities. The process equipment (blowers, pumps and aeration system) shall also be commissioned by manufacturer representatives prior to start-up activities. All necessary process chemicals must be delivered to Site prior to commissioning. Testing of all control systems should be executed to verify automatic control functions prior to initiating start-up activities.

2.2 Chemical Jar Testing

To optimize chemical dosing to suit the influent leachate characteristics, a period of on-site jar testing will be conducted at the same time as clean water testing. Influent samples will be collected to create an initial leachate profile. Chemical manufacturer's representatives or LTF operators will conduct jar tests with various chemicals and dosages to evaluate the effectiveness and appropriate dose conditions for removal of target parameters. The jar tests will be used to set initial batch volume chemical dosage rates.

2.3 Initial Batch Treatment

Initial batches will be kept small. The objective of introducing small initial batches of leachate is to develop a relationship between initial leachate quality, the effectiveness of the aeration system, the chemical dosage required to achieve effluent criteria, and the need for the GAC system. Based on the leachate quantity modeling described in the DOCP, the anticipated average volume of leachate to be treated in a batch is 625 m^3, which results in 100 percent excess capacity in the treatment system. The modeling considered the landfill stage with the highest leachate generation potential (Stage 2A). The initial small batch runs will introduce approximately 25% of the anticipated average volume of leachate. This allows for excess capacity in the LTF in the event that initial batches do not pass discharge criteria and need to be recirculated along with additional leachate.

Approximately 150 m^3 of leachate will be pumped in the aeration pond for treatment. The influent will be allowed to aerate for 2 days. The mixed liquor will then be pumped through a solids removal process, a chemical dosing/mixing tank, and a second solids removal process prior to discharging into the lined effluent holding pond. The treatment times for small initial batch treatment process will mirror the regular treatment cycle, which will be typically completed in 7 days, as follows:

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				

Collected leachate will be sampled, according to the commissioning period sampling program described in Section 3.0. Dependent on the analytical sampling results, leachate will either be recirculated back into the landfill for additional treatment or, if the effluent meets CSR Schedule 3.2 DW criteria, discharged into the infiltration pond.

2.4 Schedule

As previously stated, the leachate commissioning process will provide for leachate characterization and chemical dosage optimization that will allow the treatment process to be refined. Adjustments to the treatment process will be made from time to time as the leachate profile changes, though these changes are expected to occur over months and years, not days. The initial commissioning procedure described in Sections 2.1 and 2.3 is anticipated to be completed in the following timeframe:

- Clean water testing and equipment commissioning – 7 days
- Influent testing and chemical jar testing – within above 7 days
- 3 cycles of initial small batches (150 m^3 each) with sampling of influent and effluent – 21 days, with adjustments in operation to refine optimized conditions.

The anticipated duration of the commissioning period is 4 weeks.

3. Commissioning Plan

The Commissioning Plan has been developed to outline the framework for required monitoring, sampling and analysis that will be carried out during the commissioning period of the leachate treatment works.

3.1 Commissioning Period Sampling Program

During the LTF commissioning period, untreated leachate and treated leachate will be sampled regularly to develop a relationship between the parameters of concern within the leachate and the batch treatment sampling program and well to monitor the performance of the leachate treatment system and chemical dosage.

3.1.1 Raw Leachate Sampling

During the commissioning period, untreated leachate samples will be collected from the collection sump prior to discharge into the aerated equalization pond. Samples will be analyzed for the comprehensive set of parameters presented in the attached Table 1 to confirm the parameters of concern within the leachate. The raw leachate samples will aid in leachate characterization and establish a baseline for determining the effectiveness of the leachate treatment process.

3.1.2 Effluent Quality Sampling

During the commissioning period, each batch of effluent will be sampled from the effluent holding pond and analyzed for a comprehensive set of parameters to determine if a batch can be discharged to the infiltration pond. The effluent will only be discharged to the infiltration pond if the effluent meets the CSR Schedule 3.2 DW criteria. As such, timely analytical results/provision for on-site analytical testing will be critical to the successful commissioning of the LTF.

The commissioning period effluent sampling results will be used to establish the parameter list for compliance sampling throughout the operation of LTF. Based on leachate quality forecasting discussed in the DOCP, the key leachate parameters will be chemical constituents commonly found in C&D and contaminated soil leachate, including:

- Chloride
- Sulphate
- Sulphide
- Arsenic

- Boron
- Iron
- Manganese
- Sodium
- PAHs

3.1.3 Start-Up Treatment Performance Monitoring

In addition to sampling to meet discharge quality objectives, leachate will also be sampled to monitor the performance of the treatment process and to observe changes to leachate quality over time as additional waste is added to the landfill. The following parameters will be used to develop an understanding of the system performance and to assist in the operation and maintenance of the LTF:

- COD
- Alkalinity
- pH
- CSR metals
- Hardness
- TDS
- TSS

The sampling results allow the process to be refined over time in comparison to the process modeling completed during the LTF detailed design and identify trends in changes in leachate quality. Necessary changes or additions to the treatment process will be identified based on the results of this analysis.

3.2 Leachate Batch Sampling and Leachate Monitoring

Subsequent to the completion of the start-up phase, a regular leachate batch sampling program will be implemented. The program will be developed based on the results of the start-up phase sampling program and will outline the parameters to be sampled in every batch to indicate the effectiveness of the treatment process, as well as the confirmatory sampling required at the quarterly environmental monitoring events. Treated leachate batch samples will be collected from the effluent holding pond to verify compliance with the discharge criteria prior to discharge to the infiltration pond.

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 LTF.

4. Commissioning Report

A report summarizing the LTF commissioning activities and the results of analytical sampling will be prepared and submitted to the Director subsequent the completion of the commissioning period (outlined in Section 2.4). In general, the commissioning report will include the following information:

- Summary of commission activities including sampling activities.
- Summary of analytical results of influent leachate and effluent sampling.
- Copy of all calibration reports and laboratory analytical reports.
- Comments on any observed deficiencies in the LTF design or performance, and a plan for addressing any such deficiencies.
- Maintenance and performance monitoring plan.

5. Contingency Measures

Contingency measures are practical and implementable measures that can put in place in the event of a failure or non-compliance with site performance criteria. The following is a list of potential LTF conditions and associated potential contingency measures that could be implemented:

- Treated leachate effluent does not meet CSR Schedule 3.2 DW standards:
  - Re-circulate batch into the Landfill for retreatment in the LTF
  - Pump and haul to an off-site authorized treatment facility
- Volume of leachate exceeds forecasted treatment capacity:
  - Store leachate in approved leachate containment tanks on-site
  - Evaluate if increased volume is expected long-term and necessitates an expansion of the LTF
- Worsening trend observed in leachate effluent quality:
  - Review leachate process modeling and refine treatment process with addition of chemical
  - Modify/upgrade the leachate treatment process
  - Pre-treat and haul to an off-site authorized treatment facility
- Worsening trend observed in influent leachate quality and/or identification of new parameters of concern:
  - Review leachate process modeling and refine treatment process with addition of chemical
  - Modify/upgrade the leachate treatment process
  - Pre-treat and haul to an off-site authorized treatment facility

Appendix F-Table 1

Analytical Parameters for Leachate
Leachate Treatment Facility Commissioning Plan
Northwin Landfill
Upland Contracting Ltd.

Field Parameters
Conductivity (field)
Dissolved oxygen
Oxidation reduction potential
pH (field)
Temperature
Total dissolved solids (TDS)
Turbidity

General Chemistry
Alkalinity (speciated)
Chemical oxygen demand (COD)
Chloride (dissolved)
Conductivity
Hardness
Hardness (dissolved)
Hydrogen sulfide
pH
Sulfate (dissolved)
Sulfide
Total dissolved solids (TDS)
Total suspended solids (TSS)

Nutrients
Ammonia-N
Nitrate (as N)
Nitrite (as N)
Nitrite/Nitrate
Total Kjeldahl Nitrogen (TKN)
Orthophosphate
Total Phosphorous (P)

Dissolved CSR Metals

Total CSR Metals

Polycyclic Aromatic Hydrocarbons

BTEX/Volatile Petroleum Hydrocarbons

Extractable petroleum hydrocarbons (EPH)

Appendix G
Contaminating Lifespan Assessment Calculations

Appendix G

Chloride (1st Order)
British Columbia CSR Contaminating Life Span of Chloride

Drinking Water Land Use
Maximum Anticipated Concentration

C_t	250	mg/L	
C_B	1500	mg/L	
λ	0.065	y^{-1}	
t	27.57	y	Time to reduce below Criteria
t	28	y	Time, rounded up
C_o	243.04	mg/L	Check at t (rounded up)

Note: This calculation uses the average concentration from the investigated Sites listed in the Leachate Profile tab.

Note: First order decay rate obtained from Lu et al., 1981, Leachate Production and Management from Municipal Landfill: Summary and Assessment, Land Disposal: Municipal Solid Waste – Proceedings of the Seventh Annual Research Symposium, EPA 600/9 81, pp. 1 17, 1981.

Appendix G

Chloride - Rowe Model
British Columbia CSR Contaminating Life Span of Chloride

Drinking Water Land Use

	Scenario 1	Scenario 2	Units	Comments
C_t	250	250	mg/L	Target concentration
C_t	0.25	0.25	kg/m^3	Target concentration
q_o	0.017	0.017	m/y	Average rate of infiltration
p	0.0004	0.00064	-	Proportion of total waste mass that is chloride
A_o	36,000	36,000	m^2	Unit area[2]
V_o	532,365	532,365	m^3	Volume of landfill
C_o	1500	1500	mg/L	Chloride concentration (peak or average)
C_o	1.5	1.5	kg/m^3	Chloride concentration (peak or average)
r_{dw}	1300	1300	kg/m^3	Dry density of waste
M_o	692,074,500	692,074,500	kg	
H_r	5.13	8.20	m	Reference height of leachate
λ	0.065	0.065	y^{-1}	First Order decay constant
k	0.0683	0.0671	y^{-1}	
k	0.0033	0.0021	y^{-1}	
t	**26.23**	**26.71**	**years**	
t			years	
q_o			m/y	Infiltration rate required to achieve CLS = 30 years

Scenario 1 — Maximum chloride concentration, average proportion of chloride in waste
Scenario 2 — Maximum chloride concentration, maximum proportion of chloride in waste

Notes

1. The Modified Rowe Model calculates the contaminating life span using a unit area of 1 sq. m. at the highest point of the landfill.

2. The Rowe Model, utilizes the total area of the landfill, as described in "*Rowe, 1995, Leachate characteristics for MSW landfills, R.K. Rowe, Geotechnical Research Centre Report, GEOT 8 95*".

3. The proportion of total waste mass that is chloride was determined for Brooks Road Landfill, based on analytical studies.

4. First order decay rate obtained from *Lu et al., 1981, Leachate Production and Management from Municipal Landfill: Summary and Assessment, Land Disposal: Municipal Solid Waste – Proceedings of the Seventh Annual Research Symposium, EPA 600/9 81, pp. 1 17, 1981.*

Appendix G

Copper - 1st Order
British Columbia CSR Contaminating Life Span of Copper

Drinking Water Land Use
Maximum Anticipated Concentration

C_t	1	mg/L	
C_B	0.05	mg/L	
λ	0.2	y^{-1}	
t	-14.98	y	Time to reduce below Criteria
t	-15	y	Time, rounded up
C_o	1.00	mg/L	Check at t (rounded up)

From Column AI

C_t	0.5	mg/L	
C_B	0.05	mg/L	
λ	0.2	y^{-1}	
t	-11.51	y	Time to reduce below Criteria
t	-12	y	Time, rounded up
C_o	0.55	mg/L	Check at t (rounded up)

Note: This calculation uses the average concentration from the investigated Sites listed in the Leachate Profile tab.

Note: First order decay rate obtained from Lu et al., 1981, Leachate Production and Management from Municipal Landfill: Summary and Assessment, Land Disposal: Municipal Solid Waste – Proceedings of the Seventh Annual Research Symposium, EPA 600/9 81, pp. 1 17, 1981.

Appendix G

Sulphate 1st Order
British Columbia CSR Contaminating Life Span of Sulphate

Drinking Water Land Use
Maximum Anticipated Concentration

C_t	500	mg/L	
C_B	1000	mg/L	
λ	0.079	y^{-1}	
t	8.77	y	Time to reduce below Criteria
t	9	y	Time, rounded up
C_o	491.15	mg/L	Check at t (rounded up)

Note: This calculation uses the average concentration from the investigated Sites listed in the Leachate Profile tab.

Note: First order decay rate obtained from Lu et al., 1981, Leachate Production and Management from Municipal Landfill: Summary and Assessment, Land Disposal: Municipal Solid Waste – Proceedings of the Seventh Annual Research Symposium, EPA 600/9 81, pp. 1 17, 1981.

Appendix H
Liner Leakage HELP Model Results

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******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\88877PD.D4
TEMPERATURE DATA FILE:      C:\HELP3\88877TD.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877SRD.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\88877ETD.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877DF6.D10
OUTPUT DATA FILE:           C:\HELP3\88877DF6.OUT


TIME:  17:16     DATE:   3/20/2018


******************************************************************************

     TITLE:  Upland Landfill - Daily Cover HDPE Failure, Secondary Liner

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   2
           THICKNESS                 =     10.00   CM
           POROSITY                  =      0.4370 VOL/VOL
           FIELD CAPACITY            =      0.0620 VOL/VOL
           WILTING POINT             =      0.0240 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.1434 VOL/VOL
```

```
EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC


                        LAYER  2
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   2
THICKNESS                   =     5.00   CM
POROSITY                    =     0.4370 VOL/VOL
FIELD CAPACITY              =     0.0620 VOL/VOL
WILTING POINT               =     0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.4370 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC


                        LAYER  3
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  18
THICKNESS                   =  2400.00   CM
POROSITY                    =     0.6710 VOL/VOL
FIELD CAPACITY              =     0.2920 VOL/VOL
WILTING POINT               =     0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.3171 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC


                        LAYER  4
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  20
THICKNESS                   =     0.50   CM
POROSITY                    =     0.0000 VOL/VOL
FIELD CAPACITY              =     0.0000 VOL/VOL
WILTING POINT               =     0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =   10.0000000000     CM/SEC
FML PINHOLE DENSITY         =     2.00   HOLES/HECTARE
FML INSTALLATION DEFECTS    =     6.00   HOLES/HECTARE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  5
```

```
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER  21
THICKNESS                    =     30.00   CM
POROSITY                     =      0.3970 VOL/VOL
FIELD CAPACITY               =      0.0320 VOL/VOL
WILTING POINT                =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0389 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.300000012000     CM/SEC
SLOPE                        =      1.00   PERCENT
DRAINAGE LENGTH              =     80.0    METERS


                        LAYER  6
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  17
THICKNESS                    =      0.60   CM
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.300000003000E-08 CM/SEC


                        LAYER  7
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   2
THICKNESS                    =     30.00   CM
POROSITY                     =      0.4370 VOL/VOL
FIELD CAPACITY               =      0.0620 VOL/VOL
WILTING POINT                =      0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0700 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.579999993000E-02 CM/SEC
SLOPE                        =      2.00   PERCENT
DRAINAGE LENGTH              =    150.0    METERS


                        LAYER  8
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.15   CM
```

```
   POROSITY                      =      0.0000 VOL/VOL
   FIELD CAPACITY                =      0.0000 VOL/VOL
   WILTING POINT                 =      0.0000 VOL/VOL
   INITIAL SOIL WATER CONTENT    =      0.0000 VOL/VOL
   EFFECTIVE SAT. HYD. COND.     =  0.199999996000E-12 CM/SEC
   FML PINHOLE DENSITY           =      2.00   HOLES/HECTARE
   FML INSTALLATION DEFECTS      =      6.00   HOLES/HECTARE
   FML PLACEMENT QUALITY         =  3 - GOOD


                            LAYER  9
                            --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER  17
   THICKNESS                     =      0.60   CM
   POROSITY                      =      0.7500 VOL/VOL
   FIELD CAPACITY                =      0.7470 VOL/VOL
   WILTING POINT                 =      0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT    =      0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.     =  0.300000003000E-08 CM/SEC


           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 2 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF 10.% AND
          A SLOPE LENGTH OF   35. METERS.

SCS RUNOFF CURVE NUMBER              =     81.70
FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =      1.0000 HECTARES
EVAPORATIVE ZONE DEPTH               =     10.0    CM
INITIAL WATER IN EVAPORATIVE ZONE    =      1.434  CM
UPPER LIMIT OF EVAPORATIVE STORAGE   =      4.370  CM
LOWER LIMIT OF EVAPORATIVE STORAGE   =      0.240  CM
INITIAL SNOW WATER                   =      0.000  CM
INITIAL WATER IN LAYER MATERIALS     =    768.778  CM
TOTAL INITIAL WATER                  =    768.778  CM
TOTAL SUBSURFACE INFLOW              =      0.00   MM/YR


            EVAPOTRANSPIRATION AND WEATHER DATA
            -----------------------------------
```

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Campbell River British Columbia

STATION LATITUDE	=	49.95 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	91
END OF GROWING SEASON (JULIAN DATE)	=	305
EVAPORATIVE ZONE DEPTH	=	10.0 CM
AVERAGE ANNUAL WIND SPEED	=	8.00 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	84.10 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.47 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.95 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	87.08 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

-

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53
	28.36	30.28	30.04	68.74	74.24	69.47
RUNOFF						
TOTALS	34.035	26.786	5.216	0.550	0.336	0.253
	0.335	0.489	0.129	6.234	11.463	20.108
STD. DEVIATIONS	67.175	67.695	13.713	1.344	1.127	0.629
	1.002	2.820	0.565	7.952	13.010	40.118
EVAPOTRANSPIRATION						
TOTALS	7.270	10.909	32.661	50.909	38.585	34.688
	19.103	18.345	23.951	19.526	8.926	6.344
STD. DEVIATIONS	2.877	4.501	6.050	12.277	16.674	16.545
	13.384	13.132	11.467	4.334	1.619	2.045
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	184.9617	124.8822	110.9308	54.5503	29.5131	27.0398
	20.0543	19.7217	28.2646	134.8827	186.5648	187.1910
STD. DEVIATIONS	82.3606	64.2705	45.3760	29.2116	20.9264	19.1694
	18.4242	18.2704	20.5887	61.0835	63.2804	71.2859
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	69.2439	87.4646	106.1008	128.8358	138.5320	121.7064
	116.7813	105.4236	84.6364	53.9413	43.1807	54.1387
STD. DEVIATIONS	25.0072	31.9981	33.4254	32.8829	29.1002	22.3601
	18.7912	16.9541	17.0074	16.5754	15.7972	19.9535
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	65.1089	84.2772	102.4533	123.0865	138.0491	123.4093
	117.0968	106.9451	86.7352	60.5727	43.3287	50.4224
STD. DEVIATIONS	24.4978	28.8200	30.3134	31.9586	29.0905	23.2966
	18.4311	17.3214	15.8749	16.8588	14.9788	17.0222

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.5145	0.6352	0.7635	0.8985	1.0008	0.9006
	0.8611	0.7934	0.6561	0.4842	0.3667	0.4165
STD. DEVIATIONS	0.1633	0.1923	0.2021	0.2131	0.1940	0.1553
	0.1229	0.1155	0.1058	0.1124	0.0999	0.1135

LATERAL DRAINAGE COLLECTED FROM LAYER 7

TOTALS	0.6456	0.5848	0.6505	0.6482	0.7019	0.7062
	0.7462	0.7551	0.7290	0.7374	0.6806	0.6708
STD. DEVIATIONS	0.0759	0.0686	0.0741	0.0698	0.0734	0.0730
	0.0750	0.0748	0.0717	0.0725	0.0683	0.0676

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

-

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

-

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.1754	0.1345	0.1128	0.0588	0.0295	0.0299
	0.0207	0.0206	0.0312	0.1313	0.1855	0.1773
STD. DEVIATIONS	0.0790	0.0695	0.0476	0.0312	0.0224	0.0239
	0.0196	0.0180	0.0240	0.0619	0.0683	0.0707

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0748	0.1027	0.1130	0.1417	0.1474	0.1339
	0.1243	0.1123	0.0931	0.0583	0.0487	0.0588
STD. DEVIATIONS	0.0262	0.0367	0.0354	0.0362	0.0310	0.0245
	0.0201	0.0180	0.0187	0.0175	0.0170	0.0209

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	3.2417	4.6031	5.1011	6.3327	6.8734	6.3493
	5.8302	5.3247	4.4624	3.0159	2.2292	2.5105
STD. DEVIATIONS	1.2197	1.5665	1.5093	1.6442	1.4484	1.1986
	0.9177	0.8624	0.8167	0.8394	0.7706	0.8475

DAILY AVERAGE HEAD ON TOP OF LAYER 8

AVERAGES	1.5592	1.5497	1.5711	1.6177	1.6952	1.7623
	1.8021	1.8236	1.8193	1.7809	1.6984	1.6200
STD. DEVIATIONS	0.1833	0.1783	0.1788	0.1742	0.1774	0.1822
	0.1812	0.1807	0.1789	0.1751	0.1705	0.1632

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	105.931	(128.5090)	1059.31	7.129
EVAPOTRANSPIRATION	271.217	(37.8267)	2712.17	18.252
PERCOLATION/LEAKAGE THROUGH LAYER 2	1108.55688	(180.96466)	11085.568	74.60322
AVERAGE HEAD ON TOP OF LAYER 2	0.923	(0.156)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	1109.98572	(153.82428)	11099.857	74.69937
AVERAGE HEAD ON TOP OF LAYER 4	1.007	(0.139)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	1101.48511	(150.58197)	11014.852	74.12730
PERCOLATION/LEAKAGE THROUGH LAYER 6	8.29104	(1.00393)	82.910	0.55797
AVERAGE HEAD ON TOP OF LAYER 6	46.562	(6.368)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	8.25641	(0.77981)	82.564	0.55564
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00175	(0.00017)	0.017	0.00012

AVERAGE HEAD ON TOP OF LAYER 8	16.916 (1.597)		
CHANGE IN WATER STORAGE	-0.955 (7.3122)	-9.55	-0.064

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(MM)	(CU. METERS)
PRECIPITATION	128.90	1289.000
RUNOFF	87.653	876.5259
PERCOLATION/LEAKAGE THROUGH LAYER 2	60.615021	606.15021
AVERAGE HEAD ON TOP OF LAYER 2	25.039	
PERCOLATION/LEAKAGE THROUGH LAYER 4	8.922950	89.22950
AVERAGE HEAD ON TOP OF LAYER 4	2.946	
DRAINAGE COLLECTED FROM LAYER 5	7.72807	77.28065
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.054120	0.54120
AVERAGE HEAD ON TOP OF LAYER 6	119.280	
MAXIMUM HEAD ON TOP OF LAYER 6	170.266	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	22.9 METERS	
DRAINAGE COLLECTED FROM LAYER 7	0.02983	0.29826
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000006	0.00006
AVERAGE HEAD ON TOP OF LAYER 8	22.330	
MAXIMUM HEAD ON TOP OF LAYER 8	42.487	
LOCATION OF MAXIMUM HEAD IN LAYER 7 (DISTANCE FROM DRAIN)	7.2 METERS	
SNOW WATER	341.73	3417.2583

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4370
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0240

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

****

FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	3.7450	0.3745
2	2.1850	0.4370
3	746.7070	0.3111
4	0.0000	0.0000
5	3.2624	0.1087
6	0.4500	0.7500
7	2.4275	0.0809
8	0.0000	0.0000
9	0.4500	0.7500
SNOW WATER	0.000	

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\88877PD.D4
TEMPERATURE DATA FILE:      C:\HELP3\88877TD.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877SRD.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\88877ETD.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877DF5.D10
OUTPUT DATA FILE:           C:\HELP3\88877DF5.OUT


TIME:  17: 0     DATE:   3/20/2018


******************************************************************************

     TITLE:  Upland Landfill - Daily Cover HDPE Failure

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   2
           THICKNESS                 =     10.00   CM
           POROSITY                  =      0.4370 VOL/VOL
           FIELD CAPACITY            =      0.0620 VOL/VOL
           WILTING POINT             =      0.0240 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.1434 VOL/VOL
```

```
EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC


                        LAYER  2
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   2
THICKNESS                   =      5.00   CM
POROSITY                    =      0.4370 VOL/VOL
FIELD CAPACITY              =      0.0620 VOL/VOL
WILTING POINT               =      0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4370 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC


                        LAYER  3
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  18
THICKNESS                   =   2400.00   CM
POROSITY                    =      0.6710 VOL/VOL
FIELD CAPACITY              =      0.2920 VOL/VOL
WILTING POINT               =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3171 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC


                        LAYER  4
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  20
THICKNESS                   =      0.50   CM
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =   10.0000000000     CM/SEC
FML PINHOLE DENSITY         =      2.00   HOLES/HECTARE
FML INSTALLATION DEFECTS    =      6.00   HOLES/HECTARE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  5
```

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

THICKNESS	=	30.00	CM
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0389	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000012000	CM/SEC
SLOPE	=	1.00	PERCENT
DRAINAGE LENGTH	=	80.0	METERS

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.60	CM
POROSITY	=	0.7500	VOL/VOL
FIELD CAPACITY	=	0.7470	VOL/VOL
WILTING POINT	=	0.4000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 2 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 10.% AND A SLOPE LENGTH OF 35. METERS.

SCS RUNOFF CURVE NUMBER	=	81.70	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.0000	HECTARES
EVAPORATIVE ZONE DEPTH	=	10.0	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	1.434	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	4.370	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.240	CM
INITIAL SNOW WATER	=	0.000	CM
INITIAL WATER IN LAYER MATERIALS	=	766.230	CM
TOTAL INITIAL WATER	=	766.230	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Campbell River British Columbia

STATION LATITUDE	=	49.95 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	91
END OF GROWING SEASON (JULIAN DATE)	=	305
EVAPORATIVE ZONE DEPTH	=	10.0 CM
AVERAGE ANNUAL WIND SPEED	=	8.00 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	84.10 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.47 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.95 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	87.08 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

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AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53
	28.36	30.28	30.04	68.74	74.24	69.47
RUNOFF						
TOTALS	34.035	26.786	5.216	0.550	0.336	0.253
	0.335	0.489	0.129	6.234	11.463	20.108
STD. DEVIATIONS	67.175	67.695	13.713	1.344	1.127	0.629
	1.002	2.820	0.565	7.952	13.010	40.118
EVAPOTRANSPIRATION						
TOTALS	7.270	10.909	32.661	50.909	38.585	34.688
	19.103	18.345	23.951	19.526	8.926	6.344
STD. DEVIATIONS	2.877	4.501	6.050	12.277	16.674	16.545
	13.384	13.132	11.467	4.334	1.619	2.045
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	184.9617	124.8822	110.9308	54.5503	29.5131	27.0398
	20.0543	19.7217	28.2646	134.8827	186.5648	187.1910
STD. DEVIATIONS	82.3606	64.2705	45.3760	29.2116	20.9264	19.1694
	18.4242	18.2704	20.5887	61.0835	63.2804	71.2859
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	69.2439	87.4646	106.1008	128.8358	138.5320	121.7064
	116.7813	105.4236	84.6364	53.9413	43.1807	54.1387
STD. DEVIATIONS	25.0072	31.9981	33.4254	32.8829	29.1002	22.3601
	18.7912	16.9541	17.0074	16.5754	15.7972	19.9535
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	65.1089	84.2772	102.4533	123.0865	138.0491	123.4093
	117.0968	106.9451	86.7352	60.5727	43.3287	50.4224

STD. DEVIATIONS	24.4978	28.8200	30.3134	31.9586	29.0905	23.2966
	18.4311	17.3214	15.8749	16.8588	14.9788	17.0222

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.5145	0.6352	0.7635	0.8985	1.0008	0.9006
	0.8611	0.7934	0.6561	0.4842	0.3667	0.4165
STD. DEVIATIONS	0.1633	0.1923	0.2021	0.2131	0.1940	0.1553
	0.1229	0.1155	0.1058	0.1124	0.0999	0.1135

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.1754	0.1345	0.1128	0.0588	0.0295	0.0299
	0.0207	0.0206	0.0312	0.1313	0.1855	0.1773
STD. DEVIATIONS	0.0790	0.0695	0.0476	0.0312	0.0224	0.0239
	0.0196	0.0180	0.0240	0.0619	0.0683	0.0707

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0748	0.1027	0.1130	0.1417	0.1474	0.1339
	0.1243	0.1123	0.0931	0.0583	0.0487	0.0588
STD. DEVIATIONS	0.0262	0.0367	0.0354	0.0362	0.0310	0.0245
	0.0201	0.0180	0.0187	0.0175	0.0170	0.0209

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	3.2417	4.6031	5.1011	6.3327	6.8734	6.3493
	5.8302	5.3247	4.4624	3.0159	2.2292	2.5105
STD. DEVIATIONS	1.2197	1.5665	1.5093	1.6442	1.4484	1.1986
	0.9177	0.8624	0.8167	0.8394	0.7706	0.8475

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	105.931	(128.5090)	1059.31	7.129
EVAPOTRANSPIRATION	271.217	(37.8267)	2712.17	18.252
PERCOLATION/LEAKAGE THROUGH LAYER 2	1108.55688	(180.96466)	11085.568	74.60322
AVERAGE HEAD ON TOP OF LAYER 2	0.923	(0.156)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	1109.98572	(153.82428)	11099.857	74.69937
AVERAGE HEAD ON TOP OF LAYER 4	1.007	(0.139)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	1101.48511	(150.58197)	11014.852	74.12730
PERCOLATION/LEAKAGE THROUGH LAYER 6	8.29104	(1.00393)	82.910	0.55797
AVERAGE HEAD ON TOP OF LAYER 6	46.562	(6.368)		
CHANGE IN WATER STORAGE	-0.988	(7.3143)	-9.88	-0.066

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(MM)	(CU. METERS)
PRECIPITATION	128.90	1289.000
RUNOFF	87.653	876.5259
PERCOLATION/LEAKAGE THROUGH LAYER 2	60.615021	606.15021
AVERAGE HEAD ON TOP OF LAYER 2	25.039	
PERCOLATION/LEAKAGE THROUGH LAYER 4	8.922950	89.22950
AVERAGE HEAD ON TOP OF LAYER 4	2.946	
DRAINAGE COLLECTED FROM LAYER 5	7.72807	77.28065
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.054120	0.54120
AVERAGE HEAD ON TOP OF LAYER 6	119.280	
MAXIMUM HEAD ON TOP OF LAYER 6	170.266	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	22.9 METERS	
SNOW WATER	341.73	3417.2583
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4370	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0240	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	3.7450	0.3745
2	2.1850	0.4370
3	746.7070	0.3111
4	0.0000	0.0000
5	3.2624	0.1087
6	0.4500	0.7500
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE              **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                  **
**                    USAE WATERWAYS EXPERIMENT STATION                    **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
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PRECIPITATION DATA FILE:    C:\HELP3\88877PD.D4
TEMPERATURE DATA FILE:      C:\HELP3\88877TD.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877SRD.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\88877ETD.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877DO3.D10
OUTPUT DATA FILE:           C:\HELP3\88877DO3.OUT


TIME:  16:43     DATE:   3/20/2018


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     TITLE:  Upland Landfill - Daily Cover DOCP - Poor Liner Install

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
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                          TYPE 1 - VERTICAL PERCOLATION LAYER
                              MATERIAL TEXTURE NUMBER   2
           THICKNESS                  =     10.00   CM
           POROSITY                   =      0.4370 VOL/VOL
           FIELD CAPACITY             =      0.0620 VOL/VOL
           WILTING POINT              =      0.0240 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1434 VOL/VOL
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            EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC


                            LAYER  2
                            --------

                 TYPE 3 - BARRIER SOIL LINER
                 MATERIAL TEXTURE NUMBER   2
            THICKNESS                   =      5.00   CM
            POROSITY                    =      0.4370 VOL/VOL
            FIELD CAPACITY              =      0.0620 VOL/VOL
            WILTING POINT               =      0.0240 VOL/VOL
            INITIAL SOIL WATER CONTENT  =      0.4370 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC


                            LAYER  3
                            --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER  18
            THICKNESS                   =   2400.00   CM
            POROSITY                    =      0.6710 VOL/VOL
            FIELD CAPACITY              =      0.2920 VOL/VOL
            WILTING POINT               =      0.0770 VOL/VOL
            INITIAL SOIL WATER CONTENT  =      0.3171 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC


                            LAYER  4
                            --------

               TYPE 4 - FLEXIBLE MEMBRANE LINER
                 MATERIAL TEXTURE NUMBER  20
            THICKNESS                   =      0.50   CM
            POROSITY                    =      0.0000 VOL/VOL
            FIELD CAPACITY              =      0.0000 VOL/VOL
            WILTING POINT               =      0.0000 VOL/VOL
            INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
            EFFECTIVE SAT. HYD. COND.   =   10.0000000000     CM/SEC
            FML PINHOLE DENSITY         =      2.00   HOLES/HECTARE
            FML INSTALLATION DEFECTS    =     12.00   HOLES/HECTARE
            FML PLACEMENT QUALITY       =  4 - POOR


                            LAYER  5
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TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

```
THICKNESS                    =     30.00   CM
POROSITY                     =      0.3970 VOL/VOL
FIELD CAPACITY               =      0.0320 VOL/VOL
WILTING POINT                =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0390 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.300000012000     CM/SEC
SLOPE                        =      1.00   PERCENT
DRAINAGE LENGTH              =     80.0    METERS
```

LAYER 6

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

```
THICKNESS                    =      0.15   CM
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      2.00   HOLES/HECTARE
FML INSTALLATION DEFECTS     =     12.00   HOLES/HECTARE
FML PLACEMENT QUALITY        =  4 - POOR
```

LAYER 7

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

```
THICKNESS                    =      0.60   CM
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.300000003000E-08 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT

SOIL DATA BASE USING SOIL TEXTURE # 2 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 10.% AND A SLOPE LENGTH OF 35. METERS.

SCS RUNOFF CURVE NUMBER	=	81.70	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.0000	HECTARES
EVAPORATIVE ZONE DEPTH	=	10.0	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	1.434	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	4.370	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.240	CM
INITIAL SNOW WATER	=	0.000	CM
INITIAL WATER IN LAYER MATERIALS	=	766.234	CM
TOTAL INITIAL WATER	=	766.234	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Campbell River British Columbia

STATION LATITUDE	=	49.95	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	91	
END OF GROWING SEASON (JULIAN DATE)	=	305	
EVAPORATIVE ZONE DEPTH	=	10.0	CM
AVERAGE ANNUAL WIND SPEED	=	8.00	KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	84.10	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.47	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.95	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	87.08	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

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AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53
	28.36	30.28	30.04	68.74	74.24	69.47
RUNOFF						
TOTALS	34.035	26.786	5.216	0.550	0.336	0.253
	0.335	0.489	0.129	6.234	11.463	20.108
STD. DEVIATIONS	67.175	67.695	13.713	1.344	1.127	0.629
	1.002	2.820	0.565	7.952	13.010	40.118
EVAPOTRANSPIRATION						
TOTALS	7.270	10.909	32.661	50.909	38.585	34.688
	19.103	18.345	23.951	19.526	8.926	6.344
STD. DEVIATIONS	2.877	4.501	6.050	12.277	16.674	16.545
	13.384	13.132	11.467	4.334	1.619	2.045
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	184.9617	124.8822	110.9308	54.5503	29.5131	27.0398
	20.0543	19.7217	28.2646	134.8827	186.5648	187.1910

STD. DEVIATIONS	82.3606	64.2705	45.3760	29.2116	20.9264	19.1694
	18.4242	18.2704	20.5887	61.0835	63.2804	71.2859

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	69.2439	87.4646	106.1008	128.8358	138.5320	121.7064
	116.7813	105.4236	84.6364	53.9413	43.1807	54.1387
STD. DEVIATIONS	25.0072	31.9981	33.4254	32.8829	29.1002	22.3601
	18.7912	16.9541	17.0074	16.5754	15.7972	19.9535

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	65.5990	84.8830	103.1995	123.9468	139.0431	124.3204
	117.9639	107.7494	87.4097	61.1019	43.6985	50.8228
STD. DEVIATIONS	24.6491	28.9861	30.4956	32.1618	29.2816	23.4550
	18.5503	17.4347	15.9752	16.9680	15.0715	17.1150

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.0020	0.0028	0.0035	0.0044	0.0050	0.0043
	0.0040	0.0036	0.0028	0.0018	0.0013	0.0015
STD. DEVIATIONS	0.0009	0.0012	0.0013	0.0015	0.0014	0.0010
	0.0008	0.0007	0.0006	0.0006	0.0005	0.0006

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.1754	0.1345	0.1128	0.0588	0.0295	0.0299
	0.0207	0.0206	0.0312	0.1313	0.1855	0.1773
STD. DEVIATIONS	0.0790	0.0695	0.0476	0.0312	0.0224	0.0239
	0.0196	0.0180	0.0240	0.0619	0.0683	0.0707

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0748	0.1027	0.1130	0.1417	0.1474	0.1339
	0.1243	0.1123	0.0931	0.0583	0.0487	0.0588
STD. DEVIATIONS	0.0262	0.0367	0.0354	0.0362	0.0310	0.0245
	0.0201	0.0180	0.0187	0.0175	0.0170	0.0209

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	3.2661	4.6362	5.1382	6.3769	6.9228	6.3961
	5.8733	5.3648	4.4971	3.0422	2.2482	2.5304
STD. DEVIATIONS	1.2273	1.5755	1.5183	1.6547	1.4579	1.2067
	0.9236	0.8681	0.8219	0.8448	0.7754	0.8521

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	105.931	(128.5090)	1059.31	7.129
EVAPOTRANSPIRATION	271.217	(37.8267)	2712.17	18.252
PERCOLATION/LEAKAGE THROUGH LAYER 2	1108.55688	(180.96466)	11085.568	74.60322
AVERAGE HEAD ON TOP OF LAYER 2	0.923 (	0.156)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	1109.98572	(153.82428)	11099.857	74.69937
AVERAGE HEAD ON TOP OF LAYER 4	1.007 (	0.139)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	1109.73792	(151.56952)	11097.379	74.68269
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.03697	(0.00634)	0.370	0.00249
AVERAGE HEAD ON TOP OF LAYER 6	46.910 (	6.410)		
CHANGE IN WATER STORAGE	-0.987	(7.3146)	-9.87	-0.066

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(MM)	(CU. METERS)
PRECIPITATION	128.90	1289.000
RUNOFF	87.653	876.5259
PERCOLATION/LEAKAGE THROUGH LAYER 2	60.615021	606.15021
AVERAGE HEAD ON TOP OF LAYER 2	25.039	
PERCOLATION/LEAKAGE THROUGH LAYER 4	8.922950	89.22950
AVERAGE HEAD ON TOP OF LAYER 4	2.946	
DRAINAGE COLLECTED FROM LAYER 5	7.77760	77.77605
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000338	0.00338
AVERAGE HEAD ON TOP OF LAYER 6	120.045	
MAXIMUM HEAD ON TOP OF LAYER 6	171.162	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	23.0 METERS	
SNOW WATER	341.73	3417.2583

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4370
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0240

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	3.7450	0.3745
2	2.1850	0.4370
3	746.7070	0.3111
4	0.0000	0.0000
5	3.2790	0.1093
6	0.0000	0.0000
7	0.4500	0.7500
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     C:\HELP3\88877PF.D4
TEMPERATURE DATA FILE:       C:\HELP3\88877TF.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877SRF.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\88877ETF.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877FF4.D10
OUTPUT DATA FILE:            C:\HELP3\88877FF4.OUT


TIME:  19:10     DATE:   3/20/2018


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     TITLE:  Upland Landfill - Final Cover HDPE Failure, Secondary Liner

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER   4
           THICKNESS                  =     15.00   CM
           POROSITY                   =      0.4370 VOL/VOL
           FIELD CAPACITY             =      0.1050 VOL/VOL
           WILTING POINT              =      0.0470 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.1785 VOL/VOL
```

```
  EFFECTIVE SAT. HYD. COND.   =  0.170000002000E-02 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
        FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                        LAYER  2
                        --------

              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   2
  THICKNESS                   =     60.00   CM
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.0620 VOL/VOL
  WILTING POINT               =      0.0240 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.3227 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC
  SLOPE                       =     10.00   PERCENT
  DRAINAGE LENGTH             =     35.0    METERS


                        LAYER  3
                        --------

                TYPE 3 - BARRIER SOIL LINER
                MATERIAL TEXTURE NUMBER  17
  THICKNESS                   =      0.60   CM
  POROSITY                    =      0.7500 VOL/VOL
  FIELD CAPACITY              =      0.7470 VOL/VOL
  WILTING POINT               =      0.4000 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.300000003000E-08 CM/SEC


                        LAYER  4
                        --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   2
  THICKNESS                   =     15.00   CM
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.0620 VOL/VOL
  WILTING POINT               =      0.0240 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.1250 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC
```

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

```
THICKNESS                    =   2400.00   CM
POROSITY                     =      0.6710 VOL/VOL
FIELD CAPACITY               =      0.2920 VOL/VOL
WILTING POINT                =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC
```

LAYER 6

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 20

```
THICKNESS                    =      0.50   CM
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   10.0000000000     CM/SEC
FML PINHOLE DENSITY          =      2.00   HOLES/HECTARE
FML INSTALLATION DEFECTS     =      6.00   HOLES/HECTARE
FML PLACEMENT QUALITY        =  3 - GOOD
```

LAYER 7

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

```
THICKNESS                    =     30.00   CM
POROSITY                     =      0.3970 VOL/VOL
FIELD CAPACITY               =      0.0320 VOL/VOL
WILTING POINT                =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0337 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.300000012000     CM/SEC
SLOPE                        =      1.00   PERCENT
DRAINAGE LENGTH              =     80.0    METERS
```

LAYER 8

TYPE 3 - BARRIER SOIL LINER

```
                MATERIAL TEXTURE NUMBER  17
THICKNESS                   =      0.60   CM
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.300000003000E-08 CM/SEC


                        LAYER  9
                        --------

              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   2
THICKNESS                   =     30.00   CM
POROSITY                    =      0.4370 VOL/VOL
FIELD CAPACITY              =      0.0620 VOL/VOL
WILTING POINT               =      0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0632 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC
SLOPE                       =      2.00   PERCENT
DRAINAGE LENGTH             =    150.0    METERS


                        LAYER 10
                        --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.15   CM
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      2.00   HOLES/HECTARE
FML INSTALLATION DEFECTS    =      6.00   HOLES/HECTARE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER 11
                        --------

                TYPE 3 - BARRIER SOIL LINER
                MATERIAL TEXTURE NUMBER  17
THICKNESS                   =      0.60   CM
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
```

```
   WILTING POINT                  =      0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  0.300000003000E-08 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

```
 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 4 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF 10.%
          AND A SLOPE LENGTH OF   35. METERS.

SCS RUNOFF CURVE NUMBER            =     56.00
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.0000 HECTARES
EVAPORATIVE ZONE DEPTH             =     30.0    CM
INITIAL WATER IN EVAPORATIVE ZONE  =      5.060  CM
UPPER LIMIT OF EVAPORATIVE STORAGE  =     13.110  CM
LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.065  CM
INITIAL SNOW WATER                 =      0.000  CM
INITIAL WATER IN LAYER MATERIALS   =    728.972  CM
TOTAL INITIAL WATER                =    728.972  CM
TOTAL SUBSURFACE INFLOW            =      0.00   MM/YR
```

EVAPOTRANSPIRATION AND WEATHER DATA

```
 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          Campbell River         British Columbia

     STATION LATITUDE                         =  49.95 DEGREES
     MAXIMUM LEAF AREA INDEX                  =   3.50
     START OF GROWING SEASON (JULIAN DATE)    =     91
     END OF GROWING SEASON (JULIAN DATE)      =    305
     EVAPORATIVE ZONE DEPTH                   =  30.0  CM
     AVERAGE ANNUAL WIND SPEED                =   8.00 KPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY    =  84.10 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY    =  72.47 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY    =  71.95 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY    =  87.08 %

 NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    OLYMPIA             WASHINGTON
```

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53
	28.36	30.28	30.04	68.74	74.24	69.47
RUNOFF						
TOTALS	21.382	20.117	3.223	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.140	8.023
STD. DEVIATIONS	61.417	62.057	12.268	0.000	0.000	0.000
	0.000	0.000	0.000	0.003	0.842	33.796

EVAPOTRANSPIRATION

TOTALS	6.991	10.459	35.089	66.199	66.348	57.095
	36.757	32.885	36.444	17.871	7.401	5.790
STD. DEVIATIONS	2.382	4.007	5.824	10.244	20.874	24.694
	24.988	20.829	18.091	3.718	1.437	1.722

LATERAL DRAINAGE COLLECTED FROM LAYER 2

TOTALS	198.2982	143.5541	130.1599	73.7398	27.9560	10.4772
	5.3721	4.0402	6.3776	70.6105	170.1666	196.9461
STD. DEVIATIONS	73.5734	59.6388	42.8260	29.5571	15.4583	11.1173
	7.3795	9.0126	10.6322	41.1663	57.6571	56.0787

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS	3.1005	2.2607	2.0637	1.2014	0.5063	0.2374
	0.1622	0.1412	0.1732	1.1557	2.6706	3.0813
STD. DEVIATIONS	1.1182	0.9087	0.6526	0.4504	0.2356	0.1694
	0.1124	0.1378	0.1632	0.6281	0.8784	0.8543

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	3.1055	2.6911	2.4135	1.9825	1.4584	0.9163
	0.6560	0.4896	0.3444	0.1259	0.3696	2.2274
STD. DEVIATIONS	0.9502	0.8980	0.8627	0.5128	0.3316	0.1868
	0.1274	0.1012	0.1021	0.1036	0.4582	1.0603

LATERAL DRAINAGE COLLECTED FROM LAYER 7

TOTALS	2.9168	2.6859	2.3986	1.9599	1.4829	0.9079
	0.6186	0.4310	0.2893	0.1173	0.1984	1.8080
STD. DEVIATIONS	0.8955	0.8772	0.8500	0.5565	0.3525	0.2060
	0.1340	0.1000	0.0949	0.0888	0.2906	1.0078

PERCOLATION/LEAKAGE THROUGH LAYER 8

TOTALS	0.0998	0.0911	0.0958	0.0908	0.0902	0.0838
	0.0845	0.0828	0.0782	0.0490	0.0329	0.0870
STD. DEVIATIONS	0.0060	0.0060	0.0077	0.0037	0.0024	0.0014
	0.0009	0.0030	0.0067	0.0205	0.0223	0.0174

LATERAL DRAINAGE COLLECTED FROM LAYER 9

TOTALS	0.0776	0.0728	0.0817	0.0804	0.0840	0.0817
	0.0845	0.0844	0.0815	0.0828	0.0749	0.0760
STD. DEVIATIONS	0.0046	0.0040	0.0039	0.0035	0.0033	0.0029

	0.0027	0.0024	0.0021	0.0024	0.0029	0.0031

PERCOLATION/LEAKAGE THROUGH LAYER 11

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	22.5526	17.9315	14.8102	8.6702	3.1810	1.2319
	0.6113	0.4597	0.7499	8.0344	20.0066	22.4089
STD. DEVIATIONS	8.3496	7.4634	4.8729	3.4753	1.7589	1.3071
	0.8397	1.0255	1.2501	4.6841	6.7776	6.3795

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.0030	0.0029	0.0024	0.0020	0.0014	0.0009
	0.0006	0.0005	0.0003	0.0001	0.0004	0.0022
STD. DEVIATIONS	0.0009	0.0010	0.0008	0.0005	0.0003	0.0002
	0.0001	0.0001	0.0001	0.0001	0.0005	0.0010

DAILY AVERAGE HEAD ON TOP OF LAYER 8

AVERAGES	0.1452	0.1468	0.1194	0.1008	0.0738	0.0467
	0.0308	0.0215	0.0149	0.0058	0.0102	0.0900
STD. DEVIATIONS	0.0446	0.0481	0.0423	0.0286	0.0176	0.0106
	0.0067	0.0050	0.0049	0.0044	0.0150	0.0502

DAILY AVERAGE HEAD ON TOP OF LAYER 10

AVERAGES	0.1875	0.1930	0.1973	0.2006	0.2029	0.2039
	0.2042	0.2039	0.2033	0.2001	0.1868	0.1834
STD. DEVIATIONS	0.0111	0.0100	0.0094	0.0088	0.0080	0.0073
	0.0066	0.0059	0.0053	0.0058	0.0072	0.0075

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	52.886	(114.1105)	528.86	3.559
EVAPOTRANSPIRATION	379.329	(55.0845)	3793.29	25.528
LATERAL DRAINAGE COLLECTED FROM LAYER 2	1037.69824	(180.34677)	10376.982	69.83460
PERCOLATION/LEAKAGE THROUGH LAYER 3	16.75417	(2.74737)	167.542	1.12752
AVERAGE HEAD ON TOP OF LAYER 3	100.540	(17.590)		
PERCOLATION/LEAKAGE THROUGH LAYER 6	16.78025	(2.82458)	167.803	1.12927
AVERAGE HEAD ON TOP OF LAYER 6	0.014	(0.002)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	15.81461	(2.77709)	158.146	1.06429
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.96615	(0.03470)	9.662	0.06502
AVERAGE HEAD ON TOP OF LAYER 8	0.672	(0.119)		
LATERAL DRAINAGE COLLECTED FROM LAYER 9	0.96240	(0.03525)	9.624	0.06477
PERCOLATION/LEAKAGE THROUGH LAYER 11	0.00020	(0.00001)	0.002	0.00001
AVERAGE HEAD ON TOP OF LAYER 10	1.973	(0.072)		
CHANGE IN WATER STORAGE	-0.753	(2.5401)	-7.53	-0.051

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(MM)	(CU. METERS)
PRECIPITATION	128.90	1289.000
RUNOFF	84.875	848.7458
DRAINAGE COLLECTED FROM LAYER 2	22.22717	222.27165
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.320248	3.20248
AVERAGE HEAD ON TOP OF LAYER 3	735.327	
MAXIMUM HEAD ON TOP OF LAYER 3	985.790	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	11.3 METERS	
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.317653	3.17653
AVERAGE HEAD ON TOP OF LAYER 6	0.084	
DRAINAGE COLLECTED FROM LAYER 7	0.21372	2.13717
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.004017	0.04017
AVERAGE HEAD ON TOP OF LAYER 8	3.299	
MAXIMUM HEAD ON TOP OF LAYER 8	6.390	
LOCATION OF MAXIMUM HEAD IN LAYER 7 (DISTANCE FROM DRAIN)	2.5 METERS	
DRAINAGE COLLECTED FROM LAYER 9	0.00287	0.02873
PERCOLATION/LEAKAGE THROUGH LAYER 11	0.000001	0.00001
AVERAGE HEAD ON TOP OF LAYER 10	2.151	
MAXIMUM HEAD ON TOP OF LAYER 10	4.253	
LOCATION OF MAXIMUM HEAD IN LAYER 9 (DISTANCE FROM DRAIN)	1.7 METERS	
SNOW WATER	341.73	3417.2583

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4370

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0355

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	6.5550	0.4370
2	8.1823	0.1364
3	0.4500	0.7500
4	1.6144	0.1076
5	700.8000	0.2920
6	0.0000	0.0000
7	1.0047	0.0335
8	0.4500	0.7500
9	1.9316	0.0644
10	0.0000	0.0000
11	0.4500	0.7500
SNOW WATER	0.000	

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******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\88877PF.D4
TEMPERATURE DATA FILE:      C:\HELP3\88877TF.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877SRF.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\88877ETF.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877FF3.D10
OUTPUT DATA FILE:           C:\HELP3\88877FF3.OUT


TIME:  18:51     DATE:   3/20/2018


******************************************************************************

     TITLE:  Upland Landfill - Final Cover HDPE Failure

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   4
           THICKNESS                  =     15.00   CM
           POROSITY                   =      0.4370 VOL/VOL
           FIELD CAPACITY             =      0.1050 VOL/VOL
           WILTING POINT              =      0.0470 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1785 VOL/VOL
```

```
  EFFECTIVE SAT. HYD. COND.   =  0.170000002000E-02 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
        FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                        LAYER  2
                        --------

              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   2
  THICKNESS                   =     60.00   CM
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.0620 VOL/VOL
  WILTING POINT               =      0.0240 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.3227 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC
  SLOPE                       =     10.00   PERCENT
  DRAINAGE LENGTH             =     35.0    METERS


                        LAYER  3
                        --------

                TYPE 3 - BARRIER SOIL LINER
                MATERIAL TEXTURE NUMBER  17
  THICKNESS                   =      0.60   CM
  POROSITY                    =      0.7500 VOL/VOL
  FIELD CAPACITY              =      0.7470 VOL/VOL
  WILTING POINT               =      0.4000 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.300000003000E-08 CM/SEC


                        LAYER  4
                        --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   2
  THICKNESS                   =     15.00   CM
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.0620 VOL/VOL
  WILTING POINT               =      0.0240 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.1250 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC
```

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

```
THICKNESS                  =   2400.00   CM
POROSITY                   =      0.6710 VOL/VOL
FIELD CAPACITY             =      0.2920 VOL/VOL
WILTING POINT              =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC
```

LAYER 6

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 20

```
THICKNESS                  =      0.50   CM
POROSITY                   =      0.0000 VOL/VOL
FIELD CAPACITY             =      0.0000 VOL/VOL
WILTING POINT              =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =   10.0000000000     CM/SEC
FML PINHOLE DENSITY        =      2.00   HOLES/HECTARE
FML INSTALLATION DEFECTS   =      6.00   HOLES/HECTARE
FML PLACEMENT QUALITY      =  3 - GOOD
```

LAYER 7

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

```
THICKNESS                  =     30.00   CM
POROSITY                   =      0.3970 VOL/VOL
FIELD CAPACITY             =      0.0320 VOL/VOL
WILTING POINT              =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0337 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.300000012000     CM/SEC
SLOPE                      =      1.00   PERCENT
DRAINAGE LENGTH            =     80.0    METERS
```

LAYER 8

TYPE 3 - BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.60 CM
POROSITY	=	0.7500 VOL/VOL
FIELD CAPACITY	=	0.7470 VOL/VOL
WILTING POINT	=	0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 4 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 10.% AND A SLOPE LENGTH OF 35. METERS.

SCS RUNOFF CURVE NUMBER	=	56.00
FRACTION OF AREA ALLOWING RUNOFF	=	100.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.0000 HECTARES
EVAPORATIVE ZONE DEPTH	=	30.0 CM
INITIAL WATER IN EVAPORATIVE ZONE	=	5.060 CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13.110 CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.065 CM
INITIAL SNOW WATER	=	0.000 CM
INITIAL WATER IN LAYER MATERIALS	=	726.626 CM
TOTAL INITIAL WATER	=	726.626 CM
TOTAL SUBSURFACE INFLOW	=	0.00 MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Campbell River British Columbia

STATION LATITUDE	=	49.95 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	91
END OF GROWING SEASON (JULIAN DATE)	=	305
EVAPORATIVE ZONE DEPTH	=	30.0 CM
AVERAGE ANNUAL WIND SPEED	=	8.00 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	84.10 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.47 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.95 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	87.08 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53
	28.36	30.28	30.04	68.74	74.24	69.47
RUNOFF						
TOTALS	21.382	20.117	3.223	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.140	8.023

```
  STD. DEVIATIONS       61.417   62.057   12.268    0.000    0.000    0.000
                         0.000    0.000    0.000    0.003    0.842   33.796

EVAPOTRANSPIRATION
------------------
  TOTALS                 6.991   10.459   35.089   66.199   66.348   57.095
                        36.757   32.885   36.444   17.871    7.401    5.790

  STD. DEVIATIONS        2.382    4.007    5.824   10.244   20.874   24.694
                        24.988   20.829   18.091    3.718    1.437    1.722

LATERAL DRAINAGE COLLECTED FROM LAYER  2
----------------------------------------
  TOTALS               198.2982 143.5541 130.1599  73.7398  27.9560  10.4772
                         5.3721   4.0402   6.3776  70.6105 170.1666 196.9461

  STD. DEVIATIONS       73.5734  59.6388  42.8260  29.5571  15.4583  11.1173
                         7.3795   9.0126  10.6322  41.1663  57.6571  56.0787

PERCOLATION/LEAKAGE THROUGH LAYER  3
------------------------------------
  TOTALS                 3.1005   2.2607   2.0637   1.2014   0.5063   0.2374
                         0.1622   0.1412   0.1732   1.1557   2.6706   3.0813

  STD. DEVIATIONS        1.1182   0.9087   0.6526   0.4504   0.2356   0.1694
                         0.1124   0.1378   0.1632   0.6281   0.8784   0.8543

PERCOLATION/LEAKAGE THROUGH LAYER  6
------------------------------------
  TOTALS                 3.1055   2.6911   2.4135   1.9825   1.4584   0.9163
                         0.6560   0.4896   0.3444   0.1259   0.3696   2.2274

  STD. DEVIATIONS        0.9502   0.8980   0.8627   0.5128   0.3316   0.1868
                         0.1274   0.1012   0.1021   0.1036   0.4582   1.0603

LATERAL DRAINAGE COLLECTED FROM LAYER  7
----------------------------------------
  TOTALS                 2.9168   2.6859   2.3986   1.9599   1.4829   0.9079
                         0.6186   0.4310   0.2893   0.1173   0.1984   1.8080

  STD. DEVIATIONS        0.8955   0.8772   0.8500   0.5565   0.3525   0.2060
                         0.1340   0.1000   0.0949   0.0888   0.2906   1.0078

PERCOLATION/LEAKAGE THROUGH LAYER  8
------------------------------------
  TOTALS                 0.0998   0.0911   0.0958   0.0908   0.0902   0.0838
                         0.0845   0.0828   0.0782   0.0490   0.0329   0.0870

  STD. DEVIATIONS        0.0060   0.0060   0.0077   0.0037   0.0024   0.0014
                         0.0009   0.0030   0.0067   0.0205   0.0223   0.0174
```

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AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

-

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	22.5526	17.9315	14.8102	8.6702	3.1810	1.2319
	0.6113	0.4597	0.7499	8.0344	20.0066	22.4089
STD. DEVIATIONS	8.3496	7.4634	4.8729	3.4753	1.7589	1.3071
	0.8397	1.0255	1.2501	4.6841	6.7776	6.3795

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.0030	0.0029	0.0024	0.0020	0.0014	0.0009
	0.0006	0.0005	0.0003	0.0001	0.0004	0.0022
STD. DEVIATIONS	0.0009	0.0010	0.0008	0.0005	0.0003	0.0002
	0.0001	0.0001	0.0001	0.0001	0.0005	0.0010

DAILY AVERAGE HEAD ON TOP OF LAYER 8

AVERAGES	0.1452	0.1468	0.1194	0.1008	0.0738	0.0467
	0.0308	0.0215	0.0149	0.0058	0.0102	0.0900
STD. DEVIATIONS	0.0446	0.0481	0.0423	0.0286	0.0176	0.0106
	0.0067	0.0050	0.0049	0.0044	0.0150	0.0502

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

-

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	52.886	(114.1105)	528.86	3.559
EVAPOTRANSPIRATION	379.329	(55.0845)	3793.29	25.528
LATERAL DRAINAGE COLLECTED FROM LAYER 2	1037.69824	(180.34677)	10376.982	69.83460
PERCOLATION/LEAKAGE THROUGH	16.75417	(2.74737)	167.542	1.12752

LAYER 3				
AVERAGE HEAD ON TOP OF LAYER 3	100.540 (	17.590)		
PERCOLATION/LEAKAGE THROUGH LAYER 6	16.78025 (	2.82458)	167.803	1.12927
AVERAGE HEAD ON TOP OF LAYER 6	0.014 (	0.002)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	15.81461 (	2.77709)	158.146	1.06429
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.96615 (	0.03470)	9.662	0.06502
AVERAGE HEAD ON TOP OF LAYER 8	0.672 (	0.119)		
CHANGE IN WATER STORAGE	-0.757 (	2.5401)	-7.57	-0.051

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(MM)	(CU. METERS)
PRECIPITATION	128.90	1289.000
RUNOFF	84.875	848.7458
DRAINAGE COLLECTED FROM LAYER 2	22.22717	222.27165
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.320248	3.20248
AVERAGE HEAD ON TOP OF LAYER 3	735.327	
MAXIMUM HEAD ON TOP OF LAYER 3	985.790	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	11.3 METERS	
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.317653	3.17653
AVERAGE HEAD ON TOP OF LAYER 6	0.084	
DRAINAGE COLLECTED FROM LAYER 7	0.21372	2.13717
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.004017	0.04017
AVERAGE HEAD ON TOP OF LAYER 8	3.299	
MAXIMUM HEAD ON TOP OF LAYER 8	6.390	
LOCATION OF MAXIMUM HEAD IN LAYER 7 (DISTANCE FROM DRAIN)	2.5 METERS	
SNOW WATER	341.73	3417.2583
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4370	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0355	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	6.5550	0.4370
2	8.1823	0.1364
3	0.4500	0.7500
4	1.6144	0.1076
5	700.8000	0.2920
6	0.0000	0.0000
7	1.0047	0.0335
8	0.4500	0.7500
SNOW WATER	0.000	

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\88877PF.D4
TEMPERATURE DATA FILE:      C:\HELP3\88877TF.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877SRF.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\88877ETF.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877FO3.D10
OUTPUT DATA FILE:           C:\HELP3\88877FO3.OUT


TIME:  18:31     DATE:   3/20/2018


******************************************************************************

     TITLE:  Upland Landfill - Final Cover DOCP, Poor Liner

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   4
           THICKNESS                 =     15.00   CM
           POROSITY                  =      0.4370 VOL/VOL
           FIELD CAPACITY            =      0.1050 VOL/VOL
           WILTING POINT             =      0.0470 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.1785 VOL/VOL
```

```
  EFFECTIVE SAT. HYD. COND.   =  0.170000002000E-02 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
        FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                         LAYER  2
                         --------

             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   2
  THICKNESS                   =     60.00   CM
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.0620 VOL/VOL
  WILTING POINT               =      0.0240 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.3227 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC
  SLOPE                       =     10.00   PERCENT
  DRAINAGE LENGTH             =     35.0    METERS


                         LAYER  3
                         --------

               TYPE 3 - BARRIER SOIL LINER
               MATERIAL TEXTURE NUMBER  17
  THICKNESS                   =      0.60   CM
  POROSITY                    =      0.7500 VOL/VOL
  FIELD CAPACITY              =      0.7470 VOL/VOL
  WILTING POINT               =      0.4000 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.300000003000E-08 CM/SEC


                         LAYER  4
                         --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER   2
  THICKNESS                   =     15.00   CM
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.0620 VOL/VOL
  WILTING POINT               =      0.0240 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.1250 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC
```

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

```
THICKNESS                    =   2400.00   CM
POROSITY                     =      0.6710 VOL/VOL
FIELD CAPACITY               =      0.2920 VOL/VOL
WILTING POINT                =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC
```

LAYER 6

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 20

```
THICKNESS                    =      0.50   CM
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   10.0000000000     CM/SEC
FML PINHOLE DENSITY          =      2.00   HOLES/HECTARE
FML INSTALLATION DEFECTS     =     12.00   HOLES/HECTARE
FML PLACEMENT QUALITY        =  4 - POOR
```

LAYER 7

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

```
THICKNESS                    =     30.00   CM
POROSITY                     =      0.3970 VOL/VOL
FIELD CAPACITY               =      0.0320 VOL/VOL
WILTING POINT                =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0337 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.300000012000     CM/SEC
SLOPE                        =      1.00   PERCENT
DRAINAGE LENGTH              =     80.0    METERS
```

LAYER 8

TYPE 4 - FLEXIBLE MEMBRANE LINER

```
              MATERIAL TEXTURE NUMBER  35
THICKNESS                  =      0.15   CM
POROSITY                   =      0.0000 VOL/VOL
FIELD CAPACITY             =      0.0000 VOL/VOL
WILTING POINT              =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY        =      2.00   HOLES/HECTARE
FML INSTALLATION DEFECTS   =     12.00   HOLES/HECTARE
FML PLACEMENT QUALITY      =  4 - POOR


                        LAYER  9
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  17
THICKNESS                  =      0.60   CM
POROSITY                   =      0.7500 VOL/VOL
FIELD CAPACITY             =      0.7470 VOL/VOL
WILTING POINT              =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.300000003000E-08 CM/SEC


          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE # 4 WITH A
         GOOD STAND OF GRASS, A SURFACE SLOPE OF 10.%
         AND A SLOPE LENGTH OF   35. METERS.

SCS RUNOFF CURVE NUMBER            =     56.00
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =      1.0000 HECTARES
EVAPORATIVE ZONE DEPTH             =     30.0    CM
INITIAL WATER IN EVAPORATIVE ZONE  =      5.060  CM
UPPER LIMIT OF EVAPORATIVE STORAGE =     13.110  CM
LOWER LIMIT OF EVAPORATIVE STORAGE =      1.065  CM
INITIAL SNOW WATER                 =      0.000  CM
INITIAL WATER IN LAYER MATERIALS   =    726.627  CM
TOTAL INITIAL WATER                =    726.627  CM
TOTAL SUBSURFACE INFLOW            =      0.00   MM/YR


           EVAPOTRANSPIRATION AND WEATHER DATA
```

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Campbell River British Columbia

STATION LATITUDE	=	49.95 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	91
END OF GROWING SEASON (JULIAN DATE)	=	305
EVAPORATIVE ZONE DEPTH	=	30.0 CM
AVERAGE ANNUAL WIND SPEED	=	8.00 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	84.10 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.47 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.95 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	87.08 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53
	28.36	30.28	30.04	68.74	74.24	69.47
RUNOFF						
TOTALS	21.382	20.117	3.223	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.140	8.023
STD. DEVIATIONS	61.417	62.057	12.268	0.000	0.000	0.000
	0.000	0.000	0.000	0.003	0.842	33.796
EVAPOTRANSPIRATION						
TOTALS	6.991	10.459	35.089	66.199	66.348	57.095
	36.757	32.885	36.444	17.871	7.401	5.790
STD. DEVIATIONS	2.382	4.007	5.824	10.244	20.874	24.694
	24.988	20.829	18.091	3.718	1.437	1.722
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	198.2982	143.5541	130.1599	73.7398	27.9560	10.4772
	5.3721	4.0402	6.3776	70.6105	170.1666	196.9461
STD. DEVIATIONS	73.5734	59.6388	42.8260	29.5571	15.4583	11.1173
	7.3795	9.0126	10.6322	41.1663	57.6571	56.0787
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	3.1005	2.2607	2.0637	1.2014	0.5063	0.2374
	0.1622	0.1412	0.1732	1.1557	2.6706	3.0813
STD. DEVIATIONS	1.1182	0.9087	0.6526	0.4504	0.2356	0.1694
	0.1124	0.1378	0.1632	0.6281	0.8784	0.8543
PERCOLATION/LEAKAGE THROUGH LAYER 6						
TOTALS	3.1055	2.6911	2.4135	1.9825	1.4584	0.9163
	0.6560	0.4896	0.3444	0.1259	0.3696	2.2274
STD. DEVIATIONS	0.9502	0.8980	0.8627	0.5128	0.3316	0.1868
	0.1274	0.1012	0.1021	0.1036	0.4582	1.0603

LATERAL DRAINAGE COLLECTED FROM LAYER 7

TOTALS	3.0155	2.7773	2.4950	2.0511	1.5738	0.9922
	0.7034	0.5141	0.3679	0.1767	0.2255	1.8878
STD. DEVIATIONS	0.9012	0.8827	0.8567	0.5604	0.3550	0.2075
	0.1349	0.1015	0.0983	0.1032	0.3019	1.0230

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	22.5526	17.9315	14.8102	8.6702	3.1810	1.2319
	0.6113	0.4597	0.7499	8.0344	20.0066	22.4089
STD. DEVIATIONS	8.3496	7.4634	4.8729	3.4753	1.7589	1.3071
	0.8397	1.0255	1.2501	4.6841	6.7776	6.3795

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.0030	0.0029	0.0024	0.0020	0.0014	0.0009
	0.0006	0.0005	0.0003	0.0001	0.0004	0.0022
STD. DEVIATIONS	0.0009	0.0010	0.0008	0.0005	0.0003	0.0002
	0.0001	0.0001	0.0001	0.0001	0.0005	0.0010

DAILY AVERAGE HEAD ON TOP OF LAYER 8

AVERAGES	0.1501	0.1518	0.1242	0.1055	0.0784	0.0510
	0.0350	0.0256	0.0189	0.0088	0.0116	0.0940
STD. DEVIATIONS	0.0449	0.0484	0.0427	0.0288	0.0177	0.0107
	0.0067	0.0051	0.0051	0.0051	0.0155	0.0509

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	52.886	(114.1105)	528.86	3.559
EVAPOTRANSPIRATION	379.329	(55.0845)	3793.29	25.528
LATERAL DRAINAGE COLLECTED FROM LAYER 2	1037.69824	(180.34677)	10376.982	69.83460
PERCOLATION/LEAKAGE THROUGH LAYER 3	16.75417	(2.74737)	167.542	1.12752
AVERAGE HEAD ON TOP OF LAYER 3	100.540	(17.590)		
PERCOLATION/LEAKAGE THROUGH LAYER 6	16.78025	(2.82458)	167.803	1.12927
AVERAGE HEAD ON TOP OF LAYER 6	0.014	(0.002)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	16.78024	(2.80397)	167.802	1.12927
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00052	(0.00007)	0.005	0.00004
AVERAGE HEAD ON TOP OF LAYER 8	0.712	(0.120)		
CHANGE IN WATER STORAGE	-0.757	(2.5401)	-7.57	-0.051

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(MM)	(CU. METERS)
PRECIPITATION	128.90	1289.000
RUNOFF	84.875	848.7458
DRAINAGE COLLECTED FROM LAYER 2	22.22717	222.27165
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.320248	3.20248
AVERAGE HEAD ON TOP OF LAYER 3	735.327	
MAXIMUM HEAD ON TOP OF LAYER 3	985.790	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	11.3 METERS	
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.317653	3.17653
AVERAGE HEAD ON TOP OF LAYER 6	0.084	
DRAINAGE COLLECTED FROM LAYER 7	0.21737	2.17370
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000006	0.00006
AVERAGE HEAD ON TOP OF LAYER 8	3.355	
MAXIMUM HEAD ON TOP OF LAYER 8	6.496	
LOCATION OF MAXIMUM HEAD IN LAYER 7 (DISTANCE FROM DRAIN)	2.5 METERS	
SNOW WATER	341.73	3417.2583

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4370
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0355

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	6.5550	0.4370
2	8.1823	0.1364
3	0.4500	0.7500
4	1.6144	0.1076
5	700.8000	0.2920
6	0.0000	0.0000
7	1.0066	0.0336
8	0.0000	0.0000
9	0.4500	0.7500
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
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PRECIPITATION DATA FILE:     C:\HELP3\88877PI.D4
TEMPERATURE DATA FILE:       C:\HELP3\88877TI.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\88877SRI.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\88877ETI.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\88877IF4.D10
OUTPUT DATA FILE:            C:\HELP3\88877IF4.OUT


TIME:  18:12     DATE:   3/20/2018


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     TITLE:  Upland Landfill - Intermediate Cover HDPE Failure, 2nd Liner

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   2
           THICKNESS                  =     25.00   CM
           POROSITY                   =      0.4370 VOL/VOL
           FIELD CAPACITY             =      0.0620 VOL/VOL
           WILTING POINT              =      0.0240 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1416 VOL/VOL
```

EFFECTIVE SAT. HYD. COND.   = 0.579999993000E-02 CM/SEC

LAYER 2

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER   2

THICKNESS	=	5.00 CM
POROSITY	=	0.4370 VOL/VOL
FIELD CAPACITY	=	0.0620 VOL/VOL
WILTING POINT	=	0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4370 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.579999993000E-02 CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS	=	2400.00 CM
POROSITY	=	0.6710 VOL/VOL
FIELD CAPACITY	=	0.2920 VOL/VOL
WILTING POINT	=	0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3168 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.50 CM
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000 CM/SEC
FML PINHOLE DENSITY	=	2.00 HOLES/HECTARE
FML INSTALLATION DEFECTS	=	6.00 HOLES/HECTARE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 5

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             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER  21
THICKNESS                    =     30.00   CM
POROSITY                     =      0.3970 VOL/VOL
FIELD CAPACITY               =      0.0320 VOL/VOL
WILTING POINT                =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0376 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.300000012000     CM/SEC
SLOPE                        =      1.00   PERCENT
DRAINAGE LENGTH              =     80.0    METERS


                         LAYER  6
                         --------

               TYPE 3 - BARRIER SOIL LINER
               MATERIAL TEXTURE NUMBER  17
THICKNESS                    =      0.60   CM
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.300000003000E-08 CM/SEC


                         LAYER  7
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             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   2
THICKNESS                    =     30.00   CM
POROSITY                     =      0.4370 VOL/VOL
FIELD CAPACITY               =      0.0620 VOL/VOL
WILTING POINT                =      0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0686 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.579999993000E-02 CM/SEC
SLOPE                        =      2.00   PERCENT
DRAINAGE LENGTH              =    150.0    METERS


                         LAYER  8
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             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.15   CM
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   POROSITY                        =      0.0000 VOL/VOL
   FIELD CAPACITY                  =      0.0000 VOL/VOL
   WILTING POINT                   =      0.0000 VOL/VOL
   INITIAL SOIL WATER CONTENT      =      0.0000 VOL/VOL
   EFFECTIVE SAT. HYD. COND.       =  0.199999996000E-12 CM/SEC
   FML PINHOLE DENSITY             =      2.00   HOLES/HECTARE
   FML INSTALLATION DEFECTS        =      6.00   HOLES/HECTARE
   FML PLACEMENT QUALITY           =  3 - GOOD


                            LAYER  9
                            --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER  17
   THICKNESS                       =      0.60   CM
   POROSITY                        =      0.7500 VOL/VOL
   FIELD CAPACITY                  =      0.7470 VOL/VOL
   WILTING POINT                   =      0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT      =      0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.       =  0.300000003000E-08 CM/SEC


           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 2 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF 10.% AND
          A SLOPE LENGTH OF   35. METERS.

SCS RUNOFF CURVE NUMBER               =     81.70
FRACTION OF AREA ALLOWING RUNOFF      =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE    =      1.0000 HECTARES
EVAPORATIVE ZONE DEPTH                =     25.0    CM
INITIAL WATER IN EVAPORATIVE ZONE     =      3.540  CM
UPPER LIMIT OF EVAPORATIVE STORAGE    =     10.925  CM
LOWER LIMIT OF EVAPORATIVE STORAGE    =      0.600  CM
INITIAL SNOW WATER                    =      0.000  CM
INITIAL WATER IN LAYER MATERIALS      =    770.119  CM
TOTAL INITIAL WATER                   =    770.119  CM
TOTAL SUBSURFACE INFLOW               =      0.00   MM/YR


            EVAPOTRANSPIRATION AND WEATHER DATA
            -----------------------------------
```

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Campbell River British Columbia

STATION LATITUDE	=	49.95 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	91
END OF GROWING SEASON (JULIAN DATE)	=	305
EVAPORATIVE ZONE DEPTH	=	25.0 CM
AVERAGE ANNUAL WIND SPEED	=	8.00 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	84.10 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.47 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.95 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	87.08 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

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AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

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	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53
	28.36	30.28	30.04	68.74	74.24	69.47
RUNOFF						
TOTALS	31.887	24.870	4.887	0.496	0.262	0.200
	0.222	0.399	0.102	6.164	11.299	18.928
STD. DEVIATIONS	62.872	63.609	12.642	1.150	0.918	0.540
	0.761	2.229	0.500	8.004	12.912	37.191
EVAPOTRANSPIRATION						
TOTALS	7.259	10.995	36.327	65.831	57.276	48.516
	31.708	27.282	34.370	21.141	8.928	6.318
STD. DEVIATIONS	2.842	4.575	6.141	11.974	20.883	21.160
	20.687	19.099	17.596	4.743	1.608	2.028
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	186.6601	125.6402	111.8985	45.9513	15.3922	12.4864
	10.1460	8.7020	15.9593	123.3714	185.9916	187.6318
STD. DEVIATIONS	81.1768	64.1526	46.8856	29.5841	15.6416	14.4724
	13.5229	12.9562	16.5228	60.4221	63.0770	70.4321
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	58.0651	76.8939	96.6407	124.7807	140.4466	120.9064
	111.2840	99.9794	80.1117	47.1365	32.8381	42.9325
STD. DEVIATIONS	23.8355	30.0348	33.1503	32.2252	27.5298	22.7987
	21.2783	21.2336	20.0711	16.7919	13.2887	17.5842
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	54.2613	73.3592	92.7060	117.4078	139.5856	122.9260
	112.8487	101.0570	82.7143	54.8109	32.8243	39.5423
STD. DEVIATIONS	23.4180	26.8001	29.4715	31.4007	28.0702	23.4989
	20.3881	21.6544	19.3005	17.9345	12.5164	14.7287

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.4421	0.5624	0.6985	0.8606	1.0111	0.8974
	0.8328	0.7542	0.6293	0.4457	0.2966	0.3440
STD. DEVIATIONS	0.1561	0.1788	0.1965	0.2094	0.1872	0.1567
	0.1359	0.1444	0.1287	0.1198	0.0835	0.0982

LATERAL DRAINAGE COLLECTED FROM LAYER 7

TOTALS	0.5994	0.5398	0.5987	0.5978	0.6542	0.6655
	0.7071	0.7160	0.6919	0.6997	0.6420	0.6276
STD. DEVIATIONS	0.0760	0.0674	0.0717	0.0664	0.0689	0.0680
	0.0710	0.0728	0.0723	0.0757	0.0709	0.0690

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.1967	0.1453	0.1275	0.0505	0.0167	0.0135
	0.0106	0.0087	0.0175	0.1250	0.1970	0.1944
STD. DEVIATIONS	0.0803	0.0779	0.0588	0.0325	0.0168	0.0157
	0.0140	0.0149	0.0184	0.0620	0.0702	0.0736

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0628	0.0903	0.1030	0.1373	0.1495	0.1331
	0.1185	0.1064	0.0881	0.0510	0.0373	0.0469
STD. DEVIATIONS	0.0248	0.0346	0.0350	0.0355	0.0293	0.0250
	0.0226	0.0227	0.0221	0.0177	0.0143	0.0182

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	2.7016	4.0066	4.6158	6.0405	6.9498	6.3244
	5.6186	5.0315	4.2556	2.7290	1.6888	1.9688
STD. DEVIATIONS	1.1660	1.4561	1.4674	1.6155	1.3976	1.2090
	1.0151	1.0781	0.9930	0.8929	0.6440	0.7333

DAILY AVERAGE HEAD ON TOP OF LAYER 8

AVERAGES	1.4475	1.4303	1.4460	1.4918	1.5798	1.6609
	1.7076	1.7292	1.7267	1.6899	1.6022	1.5156
STD. DEVIATIONS	0.1835	0.1756	0.1732	0.1657	0.1663	0.1698
	0.1715	0.1758	0.1805	0.1829	0.1770	0.1666

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	99.716	(120.3010)	997.16	6.711
EVAPOTRANSPIRATION	355.950	(51.2605)	3559.50	23.955
PERCOLATION/LEAKAGE THROUGH LAYER 2	1029.83081	(173.63248)	10298.309	69.30514
AVERAGE HEAD ON TOP OF LAYER 2	0.919 (	0.145)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	1032.01562	(152.68977)	10320.156	69.45217
AVERAGE HEAD ON TOP OF LAYER 4	0.937 (	0.138)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	1024.04333	(149.77515)	10240.434	68.91566
PERCOLATION/LEAKAGE THROUGH LAYER 6	7.77460	(0.99879)	77.746	0.52321
AVERAGE HEAD ON TOP OF LAYER 6	43.276 (	6.318)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	7.73966	(0.75371)	77.397	0.52086
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00163	(0.00017)	0.016	0.00011

AVERAGE HEAD ON TOP OF LAYER 8	15.856 (	1.544)		
CHANGE IN WATER STORAGE	-1.514 (	7.2416)	-15.14	-0.102

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(MM)	(CU. METERS)
PRECIPITATION	128.90	1289.000
RUNOFF	86.028	860.2754
PERCOLATION/LEAKAGE THROUGH LAYER 2	69.487221	694.87219
AVERAGE HEAD ON TOP OF LAYER 2	53.465	
PERCOLATION/LEAKAGE THROUGH LAYER 4	8.388575	83.88574
AVERAGE HEAD ON TOP OF LAYER 4	2.770	
DRAINAGE COLLECTED FROM LAYER 5	7.34898	73.48981
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.051592	0.51592
AVERAGE HEAD ON TOP OF LAYER 6	113.429	
MAXIMUM HEAD ON TOP OF LAYER 6	163.361	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	22.4 METERS	
DRAINAGE COLLECTED FROM LAYER 7	0.02808	0.28082
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000006	0.00006
AVERAGE HEAD ON TOP OF LAYER 8	21.024	
MAXIMUM HEAD ON TOP OF LAYER 8	40.090	
LOCATION OF MAXIMUM HEAD IN LAYER 7 (DISTANCE FROM DRAIN)	6.9 METERS	
SNOW WATER	341.73	3417.2583

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3710

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0240

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	7.9385	0.3175
2	2.1850	0.4370
3	738.4622	0.3077
4	0.0000	0.0000
5	3.1061	0.1035
6	0.4500	0.7500
7	2.3897	0.0797
8	0.0000	0.0000
9	0.4500	0.7500
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:    C:\HELP3\88877PI.D4
TEMPERATURE DATA FILE:      C:\HELP3\88877TI.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877SRI.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\88877ETI.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877IF3.D10
OUTPUT DATA FILE:           C:\HELP3\88877IF3.OUT


TIME:  17:54     DATE:   3/20/2018


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     TITLE:  Upland Landfill - Intermediate Cover HDPE Failure

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                         TYPE 1 - VERTICAL PERCOLATION LAYER
                             MATERIAL TEXTURE NUMBER   2
          THICKNESS                   =     25.00   CM
          POROSITY                    =      0.4370 VOL/VOL
          FIELD CAPACITY              =      0.0620 VOL/VOL
          WILTING POINT               =      0.0240 VOL/VOL
          INITIAL SOIL WATER CONTENT  =      0.1416 VOL/VOL
```

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EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC


                       LAYER  2
                       --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   2
THICKNESS                   =      5.00   CM
POROSITY                    =      0.4370 VOL/VOL
FIELD CAPACITY              =      0.0620 VOL/VOL
WILTING POINT               =      0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4370 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC


                       LAYER  3
                       --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  18
THICKNESS                   =   2400.00   CM
POROSITY                    =      0.6710 VOL/VOL
FIELD CAPACITY              =      0.2920 VOL/VOL
WILTING POINT               =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3168 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC


                       LAYER  4
                       --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  20
THICKNESS                   =      0.50   CM
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =   10.0000000000     CM/SEC
FML PINHOLE DENSITY         =      2.00   HOLES/HECTARE
FML INSTALLATION DEFECTS    =      6.00   HOLES/HECTARE
FML PLACEMENT QUALITY       =  3 - GOOD


                       LAYER  5
```

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

THICKNESS	=	30.00	CM
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0376	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000012000	CM/SEC
SLOPE	=	1.00	PERCENT
DRAINAGE LENGTH	=	80.0	METERS

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.60	CM
POROSITY	=	0.7500	VOL/VOL
FIELD CAPACITY	=	0.7470	VOL/VOL
WILTING POINT	=	0.4000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 2 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 10.% AND A SLOPE LENGTH OF 35. METERS.

SCS RUNOFF CURVE NUMBER	=	81.70	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.0000	HECTARES
EVAPORATIVE ZONE DEPTH	=	25.0	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	3.540	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	10.925	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.600	CM
INITIAL SNOW WATER	=	0.000	CM
INITIAL WATER IN LAYER MATERIALS	=	767.613	CM
TOTAL INITIAL WATER	=	767.613	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Campbell River British Columbia

STATION LATITUDE	=	49.95 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	91
END OF GROWING SEASON (JULIAN DATE)	=	305
EVAPORATIVE ZONE DEPTH	=	25.0 CM
AVERAGE ANNUAL WIND SPEED	=	8.00 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	84.10 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.47 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.95 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	87.08 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

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AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53
	28.36	30.28	30.04	68.74	74.24	69.47
RUNOFF						
TOTALS	31.887	24.870	4.887	0.496	0.262	0.200
	0.222	0.399	0.102	6.164	11.299	18.928
STD. DEVIATIONS	62.872	63.609	12.642	1.150	0.918	0.540
	0.761	2.229	0.500	8.004	12.912	37.191
EVAPOTRANSPIRATION						
TOTALS	7.259	10.995	36.327	65.831	57.276	48.516
	31.708	27.282	34.370	21.141	8.928	6.318
STD. DEVIATIONS	2.842	4.575	6.141	11.974	20.883	21.160
	20.687	19.099	17.596	4.743	1.608	2.028
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	186.6601	125.6402	111.8985	45.9513	15.3922	12.4864
	10.1460	8.7020	15.9593	123.3714	185.9916	187.6318
STD. DEVIATIONS	81.1768	64.1526	46.8856	29.5841	15.6416	14.4724
	13.5229	12.9562	16.5228	60.4221	63.0770	70.4321
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	58.0651	76.8939	96.6407	124.7807	140.4466	120.9064
	111.2840	99.9794	80.1117	47.1365	32.8381	42.9325
STD. DEVIATIONS	23.8355	30.0348	33.1503	32.2252	27.5298	22.7987
	21.2783	21.2336	20.0711	16.7919	13.2887	17.5842
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	54.2613	73.3592	92.7060	117.4078	139.5856	122.9260
	112.8487	101.0570	82.7143	54.8109	32.8243	39.5423

STD. DEVIATIONS	23.4180	26.8001	29.4715	31.4007	28.0702	23.4989
	20.3881	21.6544	19.3005	17.9345	12.5164	14.7287

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.4421	0.5624	0.6985	0.8606	1.0111	0.8974
	0.8328	0.7542	0.6293	0.4457	0.2966	0.3440
STD. DEVIATIONS	0.1561	0.1788	0.1965	0.2094	0.1872	0.1567
	0.1359	0.1444	0.1287	0.1198	0.0835	0.0982

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.1967	0.1453	0.1275	0.0505	0.0167	0.0135
	0.0106	0.0087	0.0175	0.1250	0.1970	0.1944
STD. DEVIATIONS	0.0803	0.0779	0.0588	0.0325	0.0168	0.0157
	0.0140	0.0149	0.0184	0.0620	0.0702	0.0736

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0628	0.0903	0.1030	0.1373	0.1495	0.1331
	0.1185	0.1064	0.0881	0.0510	0.0373	0.0469
STD. DEVIATIONS	0.0248	0.0346	0.0350	0.0355	0.0293	0.0250
	0.0226	0.0227	0.0221	0.0177	0.0143	0.0182

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	2.7016	4.0066	4.6158	6.0405	6.9498	6.3244
	5.6186	5.0315	4.2556	2.7290	1.6888	1.9688
STD. DEVIATIONS	1.1660	1.4561	1.4674	1.6155	1.3976	1.2090
	1.0151	1.0781	0.9930	0.8929	0.6440	0.7333

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	99.716	(120.3010)	997.16	6.711
EVAPOTRANSPIRATION	355.950	(51.2605)	3559.50	23.955
PERCOLATION/LEAKAGE THROUGH LAYER 2	1029.83081	(173.63248)	10298.309	69.30514
AVERAGE HEAD ON TOP OF LAYER 2	0.919	(0.145)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	1032.01562	(152.68977)	10320.156	69.45217
AVERAGE HEAD ON TOP OF LAYER 4	0.937	(0.138)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	1024.04333	(149.77515)	10240.434	68.91566
PERCOLATION/LEAKAGE THROUGH LAYER 6	7.77460	(0.99879)	77.746	0.52321
AVERAGE HEAD ON TOP OF LAYER 6	43.276	(6.318)		
CHANGE IN WATER STORAGE	-1.547	(7.2462)	-15.47	-0.104

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(MM)	(CU. METERS)
PRECIPITATION	128.90	1289.000
RUNOFF	86.028	860.2754
PERCOLATION/LEAKAGE THROUGH LAYER 2	69.487221	694.87219
AVERAGE HEAD ON TOP OF LAYER 2	53.465	
PERCOLATION/LEAKAGE THROUGH LAYER 4	8.388575	83.88574
AVERAGE HEAD ON TOP OF LAYER 4	2.770	
DRAINAGE COLLECTED FROM LAYER 5	7.34898	73.48981
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.051592	0.51592
AVERAGE HEAD ON TOP OF LAYER 6	113.429	
MAXIMUM HEAD ON TOP OF LAYER 6	163.361	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	22.4 METERS	
SNOW WATER	341.73	3417.2583

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3710
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0240

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	7.9385	0.3175
2	2.1850	0.4370
3	738.4622	0.3077
4	0.0000	0.0000
5	3.1061	0.1035
6	0.4500	0.7500
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:    C:\HELP3\88877PI.D4
TEMPERATURE DATA FILE:      C:\HELP3\88877TI.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877SRI.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\88877ETI.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877IO3.D10
OUTPUT DATA FILE:           C:\HELP3\88877IO3.OUT


TIME:  17:35     DATE:   3/20/2018


******************************************************************************

     TITLE:  Upland Landfill - Intermediate Cover DOCP, Poor Liner

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   2
           THICKNESS                  =     25.00   CM
           POROSITY                   =      0.4370 VOL/VOL
           FIELD CAPACITY             =      0.0620 VOL/VOL
           WILTING POINT              =      0.0240 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1416 VOL/VOL
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EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC



                        LAYER  2
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   2
THICKNESS                   =      5.00   CM
POROSITY                    =      0.4370 VOL/VOL
FIELD CAPACITY              =      0.0620 VOL/VOL
WILTING POINT               =      0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4370 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC



                        LAYER  3
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  18
THICKNESS                   =   2400.00   CM
POROSITY                    =      0.6710 VOL/VOL
FIELD CAPACITY              =      0.2920 VOL/VOL
WILTING POINT               =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3168 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC



                        LAYER  4
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            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  20
THICKNESS                   =      0.50   CM
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =   10.0000000000     CM/SEC
FML PINHOLE DENSITY         =      2.00   HOLES/HECTARE
FML INSTALLATION DEFECTS    =     12.00   HOLES/HECTARE
FML PLACEMENT QUALITY       =  4 - POOR



                        LAYER  5
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             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER  21
  THICKNESS                  =      30.00    CM
  POROSITY                   =       0.3970 VOL/VOL
  FIELD CAPACITY             =       0.0320 VOL/VOL
  WILTING POINT              =       0.0130 VOL/VOL
  INITIAL SOIL WATER CONTENT =       0.0377 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.300000012000     CM/SEC
  SLOPE                      =       1.00   PERCENT
  DRAINAGE LENGTH            =      80.0    METERS


                        LAYER  6
                        --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  35
  THICKNESS                  =       0.15    CM
  POROSITY                   =       0.0000 VOL/VOL
  FIELD CAPACITY             =       0.0000 VOL/VOL
  WILTING POINT              =       0.0000 VOL/VOL
  INITIAL SOIL WATER CONTENT =       0.0000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
  FML PINHOLE DENSITY        =       2.00    HOLES/HECTARE
  FML INSTALLATION DEFECTS   =      12.00    HOLES/HECTARE
  FML PLACEMENT QUALITY      =  4 - POOR


                        LAYER  7
                        --------

               TYPE 3 - BARRIER SOIL LINER
               MATERIAL TEXTURE NUMBER  17
  THICKNESS                  =       0.60    CM
  POROSITY                   =       0.7500 VOL/VOL
  FIELD CAPACITY             =       0.7470 VOL/VOL
  WILTING POINT              =       0.4000 VOL/VOL
  INITIAL SOIL WATER CONTENT =       0.7500 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.300000003000E-08 CM/SEC


           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
```

SOIL DATA BASE USING SOIL TEXTURE # 2 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 10.% AND A SLOPE LENGTH OF 35. METERS.

SCS RUNOFF CURVE NUMBER	=	81.70	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.0000	HECTARES
EVAPORATIVE ZONE DEPTH	=	25.0	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	3.540	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	10.925	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.600	CM
INITIAL SNOW WATER	=	0.000	CM
INITIAL WATER IN LAYER MATERIALS	=	767.617	CM
TOTAL INITIAL WATER	=	767.617	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Campbell River British Columbia

STATION LATITUDE	=	49.95	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	91	
END OF GROWING SEASON (JULIAN DATE)	=	305	
EVAPORATIVE ZONE DEPTH	=	25.0	CM
AVERAGE ANNUAL WIND SPEED	=	8.00	KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	84.10	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.47	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.95	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	87.08	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

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AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53
	28.36	30.28	30.04	68.74	74.24	69.47
RUNOFF						
TOTALS	31.887	24.870	4.887	0.496	0.262	0.200
	0.222	0.399	0.102	6.164	11.299	18.928
STD. DEVIATIONS	62.872	63.609	12.642	1.150	0.918	0.540
	0.761	2.229	0.500	8.004	12.912	37.191
EVAPOTRANSPIRATION						
TOTALS	7.259	10.995	36.327	65.831	57.276	48.516
	31.708	27.282	34.370	21.141	8.928	6.318
STD. DEVIATIONS	2.842	4.575	6.141	11.974	20.883	21.160
	20.687	19.099	17.596	4.743	1.608	2.028
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	186.6601	125.6402	111.8985	45.9513	15.3922	12.4864
	10.1460	8.7020	15.9593	123.3714	185.9916	187.6318

STD. DEVIATIONS	81.1768	64.1526	46.8856	29.5841	15.6416	14.4724
	13.5229	12.9562	16.5228	60.4221	63.0770	70.4321

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	58.0651	76.8939	96.6407	124.7807	140.4466	120.9064
	111.2840	99.9794	80.1117	47.1365	32.8381	42.9325
STD. DEVIATIONS	23.8355	30.0348	33.1503	32.2252	27.5298	22.7987
	21.2783	21.2336	20.0711	16.7919	13.2887	17.5842

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	54.6802	73.8920	93.3843	118.2234	140.5836	123.8392
	113.6935	101.8211	83.3620	55.3058	33.1269	39.8708
STD. DEVIATIONS	23.5611	26.9538	29.6455	31.6005	28.2545	23.6575
	20.5187	21.7955	19.4253	18.0545	12.5936	14.8075

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.0016	0.0024	0.0031	0.0041	0.0051	0.0043
	0.0038	0.0033	0.0026	0.0016	0.0009	0.0011
STD. DEVIATIONS	0.0008	0.0010	0.0012	0.0014	0.0013	0.0010
	0.0008	0.0008	0.0007	0.0006	0.0004	0.0005

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.1967	0.1453	0.1275	0.0505	0.0167	0.0135
	0.0106	0.0087	0.0175	0.1250	0.1970	0.1944
STD. DEVIATIONS	0.0803	0.0779	0.0588	0.0325	0.0168	0.0157
	0.0140	0.0149	0.0184	0.0620	0.0702	0.0736

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0628	0.0903	0.1030	0.1373	0.1495	0.1331
	0.1185	0.1064	0.0881	0.0510	0.0373	0.0469
STD. DEVIATIONS	0.0248	0.0346	0.0350	0.0355	0.0293	0.0250
	0.0226	0.0227	0.0221	0.0177	0.0143	0.0182

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	2.7225	4.0357	4.6495	6.0825	6.9995	6.3714
	5.6607	5.0696	4.2889	2.7536	1.7043	1.9851
STD. DEVIATIONS	1.1731	1.4644	1.4760	1.6258	1.4068	1.2172
	1.0216	1.0852	0.9994	0.8989	0.6479	0.7373

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	99.716	(120.3010)	997.16	6.711
EVAPOTRANSPIRATION	355.950	(51.2605)	3559.50	23.955
PERCOLATION/LEAKAGE THROUGH LAYER 2	1029.83081	(173.63248)	10298.309	69.30514
AVERAGE HEAD ON TOP OF LAYER 2	0.919 (	0.145)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	1032.01562	(152.68977)	10320.156	69.45217
AVERAGE HEAD ON TOP OF LAYER 4	0.937 (	0.138)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	1031.78259	(150.75797)	10317.826	69.43649
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.03408 (	0.00607)	0.341	0.00229
AVERAGE HEAD ON TOP OF LAYER 6	43.603 (	6.360)		
CHANGE IN WATER STORAGE	-1.546	(7.2464)	-15.46	-0.104

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(MM)	(CU. METERS)
PRECIPITATION	128.90	1289.000
RUNOFF	86.028	860.2754
PERCOLATION/LEAKAGE THROUGH LAYER 2	69.487221	694.87219
AVERAGE HEAD ON TOP OF LAYER 2	53.465	
PERCOLATION/LEAKAGE THROUGH LAYER 4	8.388575	83.88574
AVERAGE HEAD ON TOP OF LAYER 4	2.770	
DRAINAGE COLLECTED FROM LAYER 5	7.39569	73.95686
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000315	0.00315
AVERAGE HEAD ON TOP OF LAYER 6	114.150	
MAXIMUM HEAD ON TOP OF LAYER 6	164.216	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	22.5 METERS	
SNOW WATER	341.73	3417.2583
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.3710
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0240

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	7.9385	0.3175
2	2.1850	0.4370
3	738.4622	0.3077
4	0.0000	0.0000
5	3.1216	0.1041
6	0.0000	0.0000
7	0.4500	0.7500
SNOW WATER	0.000	

****
****

Appendix I
Downgradient HELP Model Results

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\88877\PPT1.D4
TEMPERATURE DATA FILE:      C:\HELP3\88877\TEMP.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877\SRAD.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\88877\EVAP.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877\DWNGR.D10
OUTPUT DATA FILE:           C:\HELP3\88877\DWNGRO.OUT


TIME:  16:36     DATE:   5/30/2017


******************************************************************************

     TITLE:  Upland Landfill - DOWNGRADIENT

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   1
           THICKNESS                   =   3500.00   CM
           POROSITY                    =      0.4170 VOL/VOL
           FIELD CAPACITY              =      0.0450 VOL/VOL
           WILTING POINT               =      0.0180 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.0757 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.999999978000E-02 CM/SEC
```

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 1.80
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 1 WITH BARE
GROUND CONDITIONS, A SURFACE SLOPE OF 3.% AND
A SLOPE LENGTH OF 200. METERS.

SCS RUNOFF CURVE NUMBER	=	71.90	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.0000	HECTARES
EVAPORATIVE ZONE DEPTH	=	30.0	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	3.597	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12.510	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.540	CM
INITIAL SNOW WATER	=	0.000	CM
INITIAL WATER IN LAYER MATERIALS	=	264.820	CM
TOTAL INITIAL WATER	=	264.820	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Campbell River British Columbia

STATION LATITUDE	=	49.95	DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00	
START OF GROWING SEASON (JULIAN DATE)	=	91	
END OF GROWING SEASON (JULIAN DATE)	=	305	
EVAPORATIVE ZONE DEPTH	=	30.0	CM
AVERAGE ANNUAL WIND SPEED	=	8.00	KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	84.10	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.47	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.95	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	87.08	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53
	28.36	30.28	30.04	68.74	74.24	69.47
RUNOFF						
TOTALS	3.934	14.270	1.151	0.004	0.004	0.000
	0.001	0.065	0.001	0.883	1.951	1.639
STD. DEVIATIONS	13.587	54.972	8.056	0.036	0.032	0.000
	0.014	0.626	0.008	1.913	4.537	2.905
EVAPOTRANSPIRATION						
TOTALS	7.840	13.199	40.143	67.513	56.813	50.345

	32.543	28.117	33.634	22.952	9.510	7.228
STD. DEVIATIONS	2.334	3.971	4.979	12.991	21.388	22.293
	21.697	19.702	17.191	5.052	1.334	1.686

PERCOLATION/LEAKAGE THROUGH LAYER 1

TOTALS	71.9297	98.2503	122.8276	137.1311	137.3340	113.6443
	100.3723	88.5671	71.0573	46.5177	33.3858	47.1655
STD. DEVIATIONS	26.3691	35.3745	38.3219	35.3850	29.2549	22.0743
	17.4402	14.6448	13.3432	13.2981	12.2372	15.9583

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	23.902	(65.8864)	239.02	1.609
EVAPOTRANSPIRATION	369.840	(52.3562)	3698.40	24.889
PERCOLATION/LEAKAGE THROUGH LAYER 1	1068.18250	(190.94087)	10681.825	71.88612
CHANGE IN WATER STORAGE	24.012	(9.0187)	240.12	1.616

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(MM)	(CU. METERS)
PRECIPITATION	128.90	1289.000
RUNOFF	76.924	769.2419
PERCOLATION/LEAKAGE THROUGH LAYER 1	10.355275	103.55275
SNOW WATER	304.80	3048.0220
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.3769
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0180

****

****

FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	504.9421	0.1443

SNOW WATER 0.000

****
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Appendix J
Fire Safety and Emergency Contingency Plan

FIRE SAFETY AND EMERGENCY CONTINGENCY PLAN

NORTHWIN LANDFILL
CAMPBELL RIVER, BRITISH COLUMBIA

Prepared For: **Upland Excavating Ltd.**
Northwin Landfill
7295 and 7311 Gold River Highway
Campbell River, British Columbia

JULY 13, 2020
REF. NO. 088877 (14) APPK

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<u>LIST OF FIGURES</u>

REVISIONS

DATE	REVISION NO.	AUTHOR/COMPANY	

1.0 INTRODUCTION

The operators of the Northwin Landfill, in compliance with British Columbia Occupational Health and Safety (B.C. OH&S) Regulation 296/97 Part 4, s.4.13-4.18 (Emergency Preparedness and Response) and Part 5, s.5.97-5.102 (Emergency Procedures) and Section 2.8 of the British Columbia Fire Code, have developed the following Fire Safety and Emergency Contingency Plan based on an assessment of the risks identified on-site. This plan documents the potential hazards and sets out the safety measures, roles, responsibilities, procedures, and parties to be contacted in the event of a medical or environmental emergency, or the occurrence of any of the identified hazardous situations.

The Northwin Landfill is located on an approximately 10 hectare parcel of land located in the City of Campbell River, British Columbia, within Lot A, District Lot 85, Plan 30709, Sayward District, approximately 10 km west of the city centre of Campbell River. The Site fronts onto Gold River Highway and is situated west of the Island Highway and south of McIvor Lake. The Northwin Landfill is owned by Upland Excavating Ltd. and operated by Northwin Environmental.

The Northwin Landfill is being developed and operated under Operational Certificate 107689.
The 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, sludge from Landfill leachate or water management works, asbestos containing materials (in accordance with Section 40 of the HWR), and other wastes as authorized in writing by the director.

The following sections detail the Fire Safety and Emergency Contingency Plan for waste disposal operations at the Northwin Landfill. It is essential that site personnel be prepared in the event of an emergency. Emergencies can take many forms. The potential health and safety concerns identified in this plan include illnesses or injuries, chemical exposure, fires, explosions, spills, leaks, releases of harmful contaminants, or sudden changes in the weather. The following sections outline the general procedures for dealing with emergency situations that may potentially be experienced at the Northwin Landfill

This Plan will be reviewed by all on-Site personnel and kept at the Northwin Landfill. Emergency information presented herein, will be posted at the Site in locations where it can readily be seen. This Plan will be reviewed at least once annually by the owner/operator of the landfill, in consultation with the employee health and safety representative, to ensure that it remains effective and accurate as a Fire Safety and Emergency Contingency Plan.

2.0 EMERGENCY CONTACTS

This page is to be posted with the hospital road map in conspicuous workplace locations.

Fire:	911
Police:	911
Ambulance:	911
Poison Control Center:	1-800-567-8911
Hospital:	250-850-2141 Campbell River Hospital 375 2nd Ave. Campbell River, BC V9W 3V1

Directions to Campbell River Hospital (see Figure 2.1):

- Head northeast on Gold River Hwy/BC-28 E toward Argonaut Rd
- Turn right onto Inland Island Hwy/BC-19 S (signs for Nanaimo)
- Turn left onto 14 Ave
- Continue onto Homewood Road
- Continue onto 9 Ave
- Slight right onto Alder St
- Turn right onto 2 Ave, Destination will be on the left

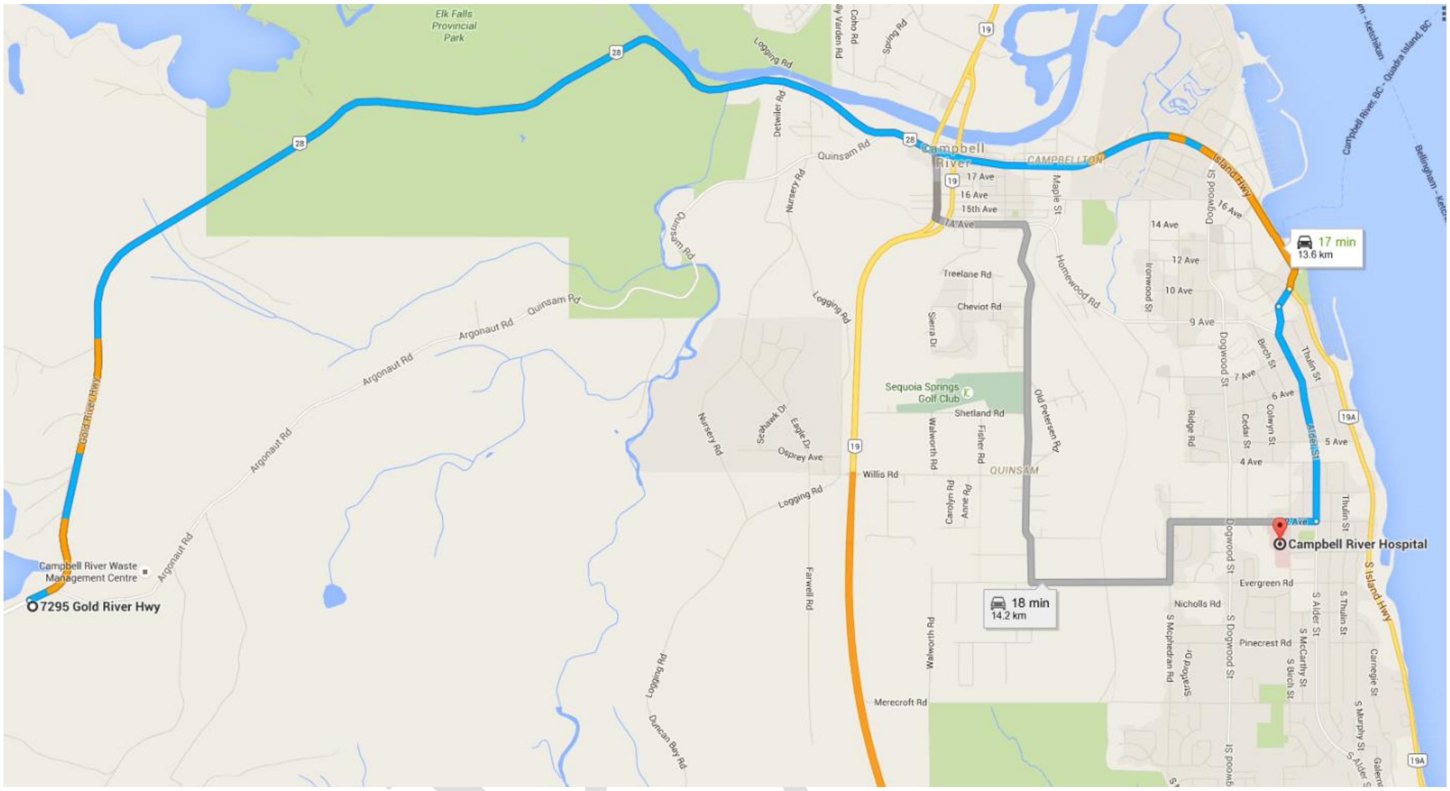
Provincial Emergency Program (PEP), 24 hour Spill Reporting:	1-800-663-3456
ENV Regional Waste Manager (Allan Leuschen)	250-751-3199
Ministry of Forest, Lands and Natural Resources	250-286-9300
Fire Department	250-286-6266
Forest Fire Reporting	1-800-633-5555 *5555 Cellular

Upland Excavating Ltd. (Northwin Landfill Operator)

- Site Manager (Brian Fagan) 250-202-8644 (Cell)
- Site Manager (Terry Stuart) 250-287-5910 (Cell)

FIGURE 2.1
EMERGENCY HOSPITAL ROUTE

TO BE POSTED IN CONSPICUOUS AREAS OF THE WORKPLACE



Map Data/Image Source: Google Maps, 2016

Hospital: 250-850-2141
Campbell River Hospital
375 2nd Ave.
Campbell River, BC
V9W 3V1

Directions to Campbell River Hospital (see Figure 2.1):

- Head northeast on Gold River Hwy/BC-28 E toward Argonaut Rd
- Turn right onto Inland Island Hwy/BC-19 S (signs for Nanaimo)
- Turn left onto 14 Ave
- Continue onto Homewood Road
- Continue onto 9 Ave
- Slight right onto Alder St
- Turn right onto 2 Ave, Destination will be on the left

3.0 EMERGENCY EQUIPMENT AVAILABLE ON SITE

The following emergency equipment is available at the Front Desk of the Site Office:

- First aid kit (Level 1 Kit)
- 20 pound Class A, B, and C dry chemical fire extinguisher
- Petroleum spill containment kit
- Telephone
- Portable air horn alarm

All Site vehicles and equipment, including excavators, loaders, rock-trucks, and pick-up trucks, are all equipped with Class A, B, and C dry chemical fire extinguishers.

A suitable pump with appropriate length of hose will be kept available on-site at all times to pump water from the wash plant pond for emergency use.

4.0 EMERGENCY ROUTES AND ASSEMBLY POINTS

The Northwin Landfill Operator will ensure that emergency exit routes and assembly points are marked on Site by clear signage and in accordance with municipal and provincial requirements.

5.0 MEDICAL EMERGENCIES

The Northwin Landfill Operator will employ, and assign to the Site, a competent and authorized representative, herein referred to as the HSO. A Site Health & Safety Representative will also be selected. The Site Supervisor will be present at the Northwin Landfill during normal operating hours.

The Northwin Landfill Operator will ensure that all on-Site personnel, as a minimum, are equipped with the appropriate first aid materials and supplies and personnel protective equipment (PPE), and clothing required by municipal and provincial regulations. Safety and emergency equipment and PPE and clothing will be stored in a readily accessible location when not in use and kept clean and well maintained. The location of the equipment will be marked by clear signage.

Emergency and first-aid equipment will be placed at or near the active work area of the Northwin Landfill during normal operating hours. A list of the emergency and first aid equipment available at the Site and where this equipment is located is provided in Section 3.0 of this Plan.

As a minimum, the Northwin Landfill Operator will designate at least one person who is trained in basic first aid and CPR as the First Aid Attendant, to be on-Site at all times. This person may perform other duties, but will be immediately available to render first aid when required.

In the event of injury requiring immediate first-aid / medical attention to on-Site personnel, the following procedures will be implemented:

- Notify the First Aid Attendant and administer initial first aid services
- Notify the HSO/Site Supervisor
- Phone the hospital and/or medical service provider closest to the Northwin Landfill (see Section 2.0) and describe the nature of the injury or event
- As directed by the hospital, administer additional on-going first aid or CPR
- As directed by the hospital, either wait for an ambulance to arrive or transport personnel to the specified hospital along the most direct route
- If the injured person will be transported by ambulance and it is safe to leave them (when only two workers are on Site) meet the ambulance at the gate and direct them to the injured person, otherwise, give the ambulance/hospital complete and accurate directions to your exact location at the Site

Note: Any person transporting an injured/exposed person to the designated hospital for treatment, should take directions to the hospital with them (Figure 2.1). Details of the injury and a list of the compounds of concern, animal or insect bites, or other injurious circumstances to which the worker may have been exposed should also accompany the injured person.

6.0 FIRE OR EXPLOSION

All fire fighting equipment present at the Site shall be regularly inspected (monthly minimum) and maintained in accordance with manufacturer's recommendation and a record of these inspections will be kept on Site.

In the event of an uncontrolled fire, explosion, release of hazardous material, or the need for emergency evacuation, the following procedures will be followed:

- Notify all workers on Site by sounding the air horn alarm
- Site personnel will report immediately to the upwind safe assembly area and the Site Supervisor will confirm the safe evacuation of all workers from the hazardous area
- Notify the Fire Department / emergency services immediately
- Notify the HSO
- Notify any adjacent workplaces or residences which may be affected by exposure (**Note:** notification of the public must be in conformity with the requirements of municipal and provincial agencies (BC Reg. 296/97, s.5.100))
- Site personnel will position themselves at the entrance gate and such other safe locations as to effectively direct the Fire Department to the location of the uncontrolled fire or hazardous circumstances
- Site personnel will advise the Fire Commander of the location, nature, and identification of any hazardous materials at the Site as per the Inventory of Hazardous Substances maintained at the Site (see Section 10.0)
- If the Site Supervisor determines that it is safe to do so, before the Fire Department arrives, site personnel may:
    - Use fire equipment available on Site
    - Remove or isolate flammable or other hazardous materials that may contribute to the fire
- If the Fire Commander determines that it is safe to do so, Site personnel may assist the Fire Department

7.0 SPILLS OR LEAKS

The Northwin Landfill operator will ensure that all on-Site personnel have received the appropriate Work Place Hazardous Materials Information System (WHMIS) training as required by provincial regulations. The Northwin Landfill operator will ensure that personnel assigned to spill clean-up and re-entry duties have been trained in the safe procedures and use of personal protective equipment appropriate to the spill conditions. Written procedures for clean up and record of training will be maintained on Site. The Northwin Landfill operator will ensure that PPE and related clean-up equipment is readily available on Site and maintained in good condition.

In the event of a spill or leak, site personnel will follow the following procedures:

- Notify the Site Supervisor and/or HSO of the accidental release
- Report off-Site spills and releases of hydrocarbon contaminated soils or contaminated water to PEP and the B.C. Ministry of Environment and Climate Change Strategy in accordance with the B.C. Spill Reporting Regulation
    - **B.C. Emergency Management: 800-663-3456**
- Locate the source of the spillage, determine the degree of hazard associated with the clean-up activities, and if it can be done safely, stop the flow or release of the contaminant
- Contain and recover the spilled materials, in a safe manner as appropriate

Where volumes of spilled or leaked material exceed those specified in the BC Spill Reporting Regulation (B.C. Reg. 187/2017) (Attached as Table 1) a report shall be made to PEP including the following information. Reportable limits should be confirmed at least annually during the revision of the report.

1) The reporting person's name and telephone number

2) The name and telephone number of the person who caused the spill

3) The location and time of the spill,

4) The type and quantity of the substance spilled,

5) The cause and effect of the spill,

6) Details of action taken or proposed to comply with section 3,

7) a description of the spill location and of the area surrounding the spill,

8) The details of further action contemplated or required,

9) The names of agencies on the scene, and

10) The names of other persons or agencies advised concerning the spill.

If the spill is not reportable, under the B.C. Spill Reporting Regulation a Notification of Independent Remediation Initiation form, Site Risk Classification Report Form, and Exposure Pathway Questionnaire is required and the independent remediation may be initiated.

If the spill is reportable, under the B.C. Spill Reporting Regulation, a B.C. Ministry of Environment case manager will be appointed to guide remediation requirements.

8.0 INCLEMENT WEATHER

The following special procedures will be implemented during periods of severe weather, such as high winds, rain, electrical storms, thermal inversions, and winter conditions.

High Winds

If winds become excessive, the following control measures will be implemented at the Northwin Landfill to ensure that dust and litter does not become problematic or hazardous:

- Low speed limits will be enforced
- All vehicle traffic transporting waste to and around the Northwin Landfill will be appropriately loaded to prevent debris from blowing out of the vehicle
- Landfilling activities will be reduced
- Soil handling operations will be suspended
- If dry conditions warrant, water (dust suppressant) will be applied to roadways and borrow areas, and if required, to the active disposal area
- Personnel will wear appropriate respiratory protection if total dust particulates exceed provincial exposure limits

Rain and Electrical Storms

Rain: is not expected to adversely affect operations; therefore the Northwin Landfill will be operated during all but extremely excessive rain periods. If access roads become impassable due to heavy rain, they will be graded and granular material will be added as necessary to maintain and improve operating conditions.

Electrical Storms: In the event of an electrical storm, all operations will be suspended until the storm subsides and personnel will take safe shelter in the Site Office. All electrical powered equipment will be immediately shut down in a manner that will not endanger personnel.

Winter Conditions

During winter operations, the Northwin Landfill Operator will undertake advanced planning for site preparation/access, snow removal, and the stockpiling and storage of waste cover material.

The following procedures will be taken during winter weather conditions:

- The Northwin Landfill operator will ensure that all on-Site personnel are suitably clothed for working in winter conditions and monitor ongoing conditions to minimize the potential for cold related stress/hypothermia
- During severe winter conditions the HSO will provide appropriate direction to on-site personnel, regarding the continuance or curtailing of Northwin Landfill operations
- Site equipment will be cleaned and maintained on a daily basis to ensure safe operation during periods of cold or extreme weather
- Snow accumulation will be removed from the access roads and working areas prior to and during each day's landfilling activities, as required to maintain safe working conditions
- Frozen fill materials will not be placed in the landfill
- All runoff from snow, which has contacted waste or soil in the Landfill will be managed as leachate and controlled accordingly

9.0 EMERGENCY PROCEDURES TRAINING & DRILLS

The following training requirements will be followed as written in the B.C. OH&S Reg. 296/97 Part 4, s.4.16:

- All workers must be given adequate instruction in fire prevention and emergency evacuation procedures applicable to their workplace
- Workers assigned firefighting duties must be given adequate training by a qualified instructor in suppression methods, fire prevention, emergency procedures, company organization and chain of command, and firefighting crew safety and communications applicable to their workplace
- Retraining must occur once per year
- A worker not covered by B.C. OH&S Reg. 296/97 Part 31 (Firefighting), who is assigned firefighting duties, must be physically capable of performing the duties assigned safely and effectively, before being permitted to do them
- At least once per year, emergency drills must be conducted to ensure worker awareness and effectiveness of the exit routes and procedures
- A record of the drills is to be kept at the Site Office

10.0 HAZARDOUS SUBSTANCE INVENTORY & NOTIFICATION OF FIRE DEPARTMENT

The Northwin Landfill Operator will maintain a Hazardous Substance Inventory (Inventory) at the Site. The Inventory will include safe handling methods for all hazardous substances that are stored at the Site in quantities that may endanger workers in an emergency. The Inventory will include such materials as WHMIS controlled products, explosives, pesticides, radioactive materials, hazardous wastes, and will provide the nature, location, quantity and Material Safety Data Sheets (SDS) for the material.

As part of Site operations, the Northwin Landfill Operator performs visual inspections of all waste loads received at the Site and any material that is not authorized for discharge at the Site, including hazardous substances, is rejected by the operator and sent off Site for disposal. As such, the Inventory is limited to materials that are stored on Site for use by the Northwin Landfill only and not for landfilled materials.

The Inventory is to be kept up to date and located in an area readily accessible by personnel during an emergency. The Fire Department shall be notified of any significant changes to the Inventory.

Table 1

Reportable Limits for Spills and Releases
Fire and Emergency Contingency Plan
New Landfill (Northwin Landfill)
Upland Excavating Ltd.
Campbell River, British Columbia

Substance spilled[(1)]	**Specified amount[(1)]**
Explosives Class 1 as defined in section 2.9 of the Federal Regulations	50 kg, or less if the substance poses a danger to public safety
Flammable Gases Class 2.1 other than natural gas, as defined in section 2.14 (a) of the Federal Regulations	10 kg
Non-Flammable and Non-Toxic Gases Class 2.2 as defined in section 2.14 (b) of the Federal Regulations	10 kg
Toxic Gases Class 2.3 as defined in section 2.14 (c) of the Federal Regulations	5 kg
Flammable Liquids Class 3 as defined in section 2.18 of the Federal Regulations	100 L
Flammable Solids Class 4 as defined in section 2.20 of the Federal Regulations	25 kg
Oxidizing Substances Class 5.1 as defined in section 2.24 (a) of the Federal Regulations	50 kg or 50 L
Organic Peroxides Class 5.2 as defined in section 2.24 (b) of the Federal Regulations	1 kg or 1 L
Toxic Substances Class 6.1 as defined in section 2.27 (a) of the Federal Regulations	5 kg or 5 L
Infectious Substances Class 6.2 as defined in section 2.27 (b) of the Federal Regulations	1 kg or 1 L, or less if the waste poses a danger to public safety or the environment
Radioactive Materials Class 7 as defined in section 2.37 of the Federal Regulations	Any quantity that could pose a danger to public safety and an emission level greater than the emission level established in section 20 of the Packaging and Transport of Nuclear Substances Regulations, 2015 (Canada)
Corrosives Class 8 as defined in section 2.40 of the Federal Regulations	5 kg or 5 L
Miscellaneous Products, Class 9 Substances or Organisms as defined in section 2.43 of the Federal Regulations	25 kg or 25 L
Waste containing dioxin as defined in section 1 of the Hazardous Waste Regulation	1 kg or 1 L, or less if the waste poses a danger to public safety or the environment
Leachable toxic waste as defined in section 1 of the Hazardous Waste Regulation	25 kg or 25 L
Waste containing polycyclic aromatic hydrocarbons as defined in section 1 of the hazardous Waste Regulation	5 kg or 5 L
Waste asbestos as defined in section 1 of the Hazardous Waste Regulation	50 kg
Waste oil as defined in section 1 of the Hazardous Waste Regulation	100 L
Waste containing a pest control product as defined in section 1 of the Hazardous Waste Regulation	5 kg or 5 L
PCB Wastes as defined in section 1 of the Hazardous Waste Regulation	25 kg or 25 L
Waste containing tetrachloroethylene as defined in section 1 of the Hazardous Waste Regulation	50 kg or 50 L
Biomedical waste as defined in section 1 of the Hazardous Waste Regulation	1 kg or 1 L, or less if the waste poses a danger to public safety or the environment
A hazardous waste as defined in section 1 of the Hazardous Waste Regulation and not covered under items 1 to 22	25 kg or 25 L
A substance, not covered by items 1 to 23, that can cause pollution	200 kg or 200 L
Natural gas	10 kg

NOTES:
(1) Substance definitions and reportable spill amounts from BC Spill Reporting Regulation (B.C. Reg. 187/2017 including amendments upto B.C. Reg 221/2017, December 5,2017) current to July 7, 2020

Federal Regulations: The Transportation of Dangerous Goods Regulations made under the *Transportation of Dangerous Goods Act* (Canada)
Hazardous Waste Regulation: B.C. Reg. 63/88.

Appendix K
Trigger Level Assessment Program

Appendix K Trigger Level Assessment Program

The following Site-specific tiered Trigger Level Assessment Program (TLAP) has been developed for the Upland Landfill. The TLAP follows a three-tiered approach to monitor and assess primary liner leakage rates and potential groundwater quality impacts associated with Landfill activities. The TLAP will trigger the timely implementation of contingency measures related to liner leakage or water quality alterations, if needed.

The trigger level monitoring locations include:

- Landfill leak detection system
- Aeration pond leak detection system
- Aeration pond point of discharge
- Future monitoring well MW13 located adjacent to and downgradient of the aeration pond
- Future monitoring well MW12 located downgradient of the landfill and adjacent to the south property boundary
- Existing monitoring well MW10-17 located at the downgradient south property boundary
- Future monitoring well MW11 located at the downgradient east property boundary

1. Trigger: Primary Liner Leakage Rate

1.1 Tier I – Routine Leakage Rate Monitoring

The Tier I TLAP includes quarterly monitoring of the Landfill and aeration pond leak detection systems. Lysimeters will be installed within the leak detection system(s) drainage layer to monitor for the presence of leakage from the primary liner of the landfill and/or aeration pond at various locations within the system. Leakage rate monitoring will be completed as part of the Environmental Monitoring Program (EMP) prepared for the Site. The EMP is described in Section 14 of the DOCP.

Leakage rate monitoring results will be assessed for the following triggers:

- Leakage rates at the landfill and/or aeration pond leak detection systems show an increasing trend toward 10.1 m^3 in one quarter. Trends will be assessed using statistical analysis such as Mann-Kendall and/or t-test.
- Leakage rate is at or above 10.1 m^3 per quarter during a single monitoring event.

The leakage rate of 10.1 m^3 per quarter represents 25 percent of the leakage associated with the complete geomembrane liner failure scenario. GHD modelled a leakage rate of 40 m^3 per quarter indicative of a complete failure or breach of the geomembrane (Scenario 3), as described in Section 13.3 of the DOCP.

If either trigger occurs, Tier II increased monitoring and primary liner performance investigation will be initiated.

1.2 Tier II – Increased Monitoring and Investigation

The Tier II TLAP includes two parts. The first part of Tier II includes monthly monitoring of the leak detection system(s) to confirm leakage monitoring results. If monitoring results confirm that leakage is occurring, a Tier II investigation will be initiated. The second part of Tier II is an investigation using dedicated lysimeters to determine where the leakage is occurring within the detection system(s). The Tier II investigation includes an assessment of the primary liner(s) to determine where leakage is occurring and the ability to expose the liner for repair.

The completion of the Tier II investigation triggers the Tier III contingency measures and confirmatory monitoring.

1.3 Tier III – Contingency Measures and Confirmatory Monitoring

The Tier III TLAP includes either:

- Repairing the primary liner or
- If the primary liner cannot be repaired due to the practicality in accessing the location, the leachate collection system will be operated under dry conditions to reduce leakage through the primary liner system and an intermediate/final cover deployment plan will be prepared.

The design of the cover deployment plan will be dependent on the stage of the Landfill's development and the location of the primary liner system leakage. The objective of the plan is to proceed with early deployment of intermediate and/or final cover. Confirmatory leakage rate monitoring will continue on a monthly basis until steady state conditions are again achieved.

2. Trigger: Water Quality

2.1 Tier I – Routine Water Quality Monitoring

The Tier I TLAP includes quarterly groundwater quality monitoring at existing monitoring well MW10-17 and future monitoring wells MW11, MW12, and MW13. Water quality monitoring will be completed as part of the EMP prepared for the Site. The EMP is described in Section 14 of the DOCP. Groundwater samples will be analyzed for field parameters, general chemistry, nutrients, LEPH/HEPH, and CSR metals.

The water quality monitoring results for MW10-17, MW11, MW12, and MW13 will be assessed for the following triggers:

- At two or more TLAP monitoring locations, leachate indicator concentrations show an increasing trend toward half of the applicable CSR DW Standard. Increasing trends will be assessed using statistical analysis such as Mann-Kendall and/or t-test; or
- During a single monitoring event, concentrations of two or more leachate indicator parameters at a single TLAP monitoring location meet or exceed half of the applicable CSR DW Standard.

If either trigger occurs, Tier II confirmatory sampling will be initiated.

2.2 Tier II – Confirmatory Sampling and Investigation

The Tier II confirmatory sampling will consist of resampling the triggered monitoring location(s) under increased frequency (e.g. monthly). If confirmatory sampling results confirm that Landfill water quality impairments are present, as defined under Tier I trigger levels, an investigation will be triggered. The investigation will assess the degree, nature, and potential source(s) of the trigger level exceedance. Increased sampling frequency will continue at the appropriate location(s) during the investigation.

The results of the Tier II investigation will assist in determining the most suitable water quality contingency measure as outlined in the Contingency Plan developed for the Landfill. The implementation of the contingency measure should stabilize or reduce the Landfill-derived water quality impairments at the appropriate location(s). Should the Tier II investigation confirm increasing concentrations above the trigger levels, Tier III contingency measures and compliance monitoring will be initiated.

2.3 Tier III – Implementation of Contingency Measure(s) and Compliance Monitoring

The Tier III TLAP includes the development of an implementation plan for the water quality contingency measures identified under Tier II, the deployment of the water quality contingency measures, and compliance monitoring. Following approval of the plan and implementation of the contingency measures, compliance monitoring will begin at monitoring wells MW10-17, MW11, MW12, and MW13. The purpose of the compliance monitoring will be to assess and evaluate the effectiveness of the contingency measure(s) implemented. A specific compliance monitoring program cannot be detailed in the TLAP as the extent and type of future groundwater quality impacts, if any, are unknown.

Appendix L
Financial Security Plan

Financial Security Plan

Upland Landfill
Campbell River, British Columbia

Upland Excavating Ltd.

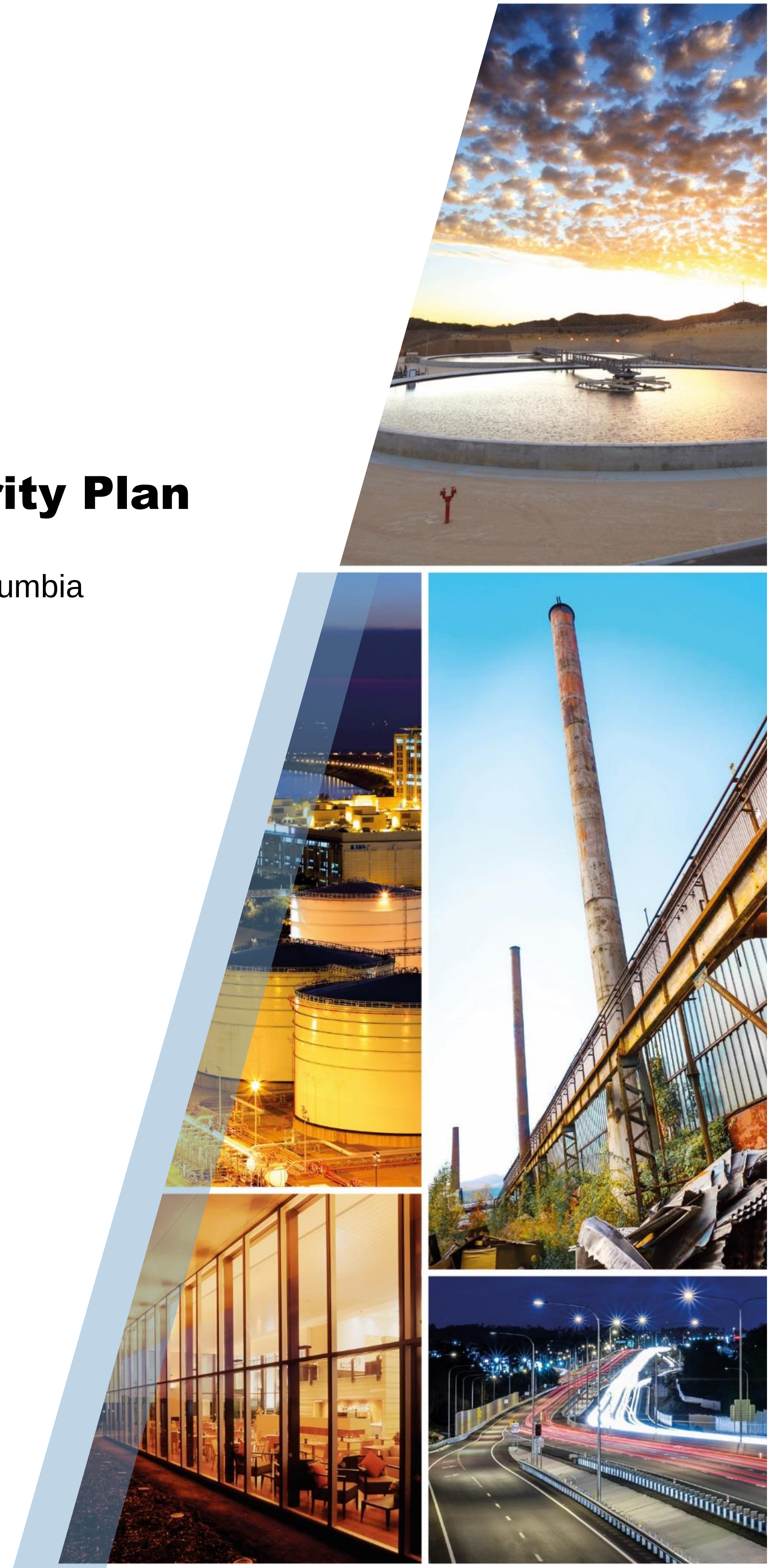


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Table Index

Table Index (Following Text)

1. Introduction

This Financial Security (FS) Plan was prepared by GHD for the New Landfill, known as Northwin Landfill located on the Upland Pit Property (Site) in Campbell River, British Columbia. The FS Plan forms part of the 2021 Design, Operations and Closure Plan (DOCP), and was prepared based on the *"British Columbia Landfill Criteria for Municipal Solid Waste, Second Edition"* (BCMOE, June 2016), herein referred to as the *Landfill Criteria*.

FS 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.

Section 2.10 of the Operational Certificate Number: 107689 (OC) provides additional instruction for calculating the Financial Security. This FS satisfies Section 2.10(b), which states:

> *(b) The DOCP submitted pursuant to section 2.5 of this operational certificate must include a financial security plan that includes:*
>
> *(i) the tasks, estimated costs, contingency costs, calculations of the amounts of financial security and time periods, to carry out and complete the plan referred to in section 2.9(a) of this operational certificate (plan to remove all waste from the Original Landfill),*
>
> *(ii) the calculations of the amounts of financial security and time periods for each phase of development for the New Landfill in accordance with the Landfill Criteria Section 8.0 Financial Security, and,*
>
> *(iii) the amounts of financial security for the corresponding time periods.*

2. Closure, Post-Closure and Contingency Activities Considered for the Security Funds Evaluation

2.1 Closure Costs

The closure costs consist of the estimated capital and engineering cost to install final cover on the Landfill in accordance with DOCP. The final cover design consists of a low permeability ($<1x10^{-7}$ cm/s), barrier layer including a geosynthetic clay liner, 0.6 metre (m) sand cover and a 0.15 m vegetated topsoil layer.

The activities considered in the closure costs to estimate the security fund are:

- Compaction and grading of the landfill surface
- Final cover placement and hydroseeding
- Installation of fences and surface water control works
- Installation of landfill gas collection (LFG) vents

2.2 Post-Closure Costs

The post-closure costs consist of the Site monitoring, operation, and maintenance cost during the post-closure stage in accordance with the DOCP. Activities considered in the post-closure cost estimation include:

- Administration
- Site maintenance including road maintenance/repair, vegetation management, erosion/surface water repairs
- Leachate treatment (on-Site or off-Site)
- Water quality monitoring
- Consultation and reporting

2.3 Costs of Contingency Measure Implementation

Section 16 – Contingency Plan of the DOCP outlines the possible contingency measures or actions that will be taken to address potential failure or non-compliance of the Landfill performance criteria. The activities considered in the financial security contingency cost estimation are those not encompassed in the post-closure costs described in Section 2.2 above, and include:

- Modifications/upgrades to the leachate treatment system
- Replacement/repair of the aeration pond base liner

2.4 Financial Contingency

In accordance with *Section 8.2 – Calculating Financial Security* of the Landfill Criteria, the amount of financial security shall include a contingency of 20 percent of the sum of the closure costs, post-closure costs and the contingency measures cost.

3. Site Operating Parameters

The following Site operating parameters were taken into consideration to establish the closure and post-closure cost estimates:

- Projected rate of fill and landfill lifespan
- Leachate generation rates, landfill gas generation rates, and contaminating lifespan of the landfill with respect to groundwater, surface water, and landfill gas

3.1 Site Capacity and Estimated Site Life

As discussed in the DOCP, the total Site capacity is estimated to be 532,365 cubic metres. The Site life has been estimated based on the maximum annual fill rate of 45,000 tonnes per year. Waste from the Original Landfill to the New Landfill does not contribute to the maximum allowable fill rate. Using a waste density of 1.3 tonnes per cubic metre, the annual airspace consumption is approximately 34,615 cubic metres (except in the year when approximately 71,722 cubic metres of waste will be relocated from the Original Landfill). The Site life is a function of refuse density and refuse quantities received, and will also be influenced by market conditions in British Columbia. The estimated Site life is 13.3 years, based on the forecasted fill rate.

A summary of the landfill and financial inputs is presented in Table 3.1.

3.2 Contaminating Lifespan

The contaminating lifespan of a landfill is the time required for the leachate concentrations to decrease by a combination of biological decomposition of the organics, physiochemical processes which reduce the solubility of inorganics, dissolution, adsorption, or complexation and dilution by infiltration, to regulatory defined surface water quality objectives (i.e., Contaminated Sites Regulation Water Quality Standards). Post-closure care funding have been estimated for the duration of the contaminating lifespan of the Site, following closure of the Site, to ensure that adequate funds are available to mitigate any potential environmental impacts.

As discussed in the DOCP, it is anticipated that leachate generated from the Site will reduce to concentrations below regulatory levels or Site-specific trigger levels in approximately 28 years from time of closure. This is less than the minimum 30-years specified in *Section 8.3 – Post-Closure Period* of the Landfill Criteria. As such, the post-closure period for the purposes of estimating the amount of financial security required is 30 years.

4. Discount and Inflation Rates

All cost estimates for the financial security are presented in net present values (2021) and adjusted for inflation and discount rates. The discount and inflation rates used for the cost projection were selected based on *Section 8.4 – Cost To Be Presented In Current Dollars* of the Landfill Criteria, which states the following:

All cost estimates should be presented in net present values and adjusted for inflation and discount rates. Inflation rates shall be based on the British Columbia Consumer Price Index averaged over the preceding 10-year period or as recommended by a qualified professional. Discount rates shall be based on the current Government of Canada Long Term Bond Yield or as recommended by a qualified professional.

4.1 Discount Rate

Due to fluctuations in Canadian bond yields in recent years, the discount rate was selected to be the 10-year average Government of Canada benchmark bond yields: long term, as published in the Bank of Canada website: http://www.bankofcanada.ca/rates/interest-rates/lookup-bond-yields/. The Government of Canada 10-year average benchmark bond yields: long term, for the period between 2012 and 2021 is 3.15 percent as presented in Table 3.1.

4.2 Inflation Rate

The inflation rate applied to forecast construction costs, is calculated based on 10-year average monthly % change in Consumer Price Index (CPI) for British Columbia. Statistics Canada, 18-10-0004-01, Data Visualization: 71-607-X2018016, last accessed June 26, 2021. The 10-year average inflation rate for the period between 2011 and 2021 is 1.53 percent as presented in Table 3.1.

5. Cost Estimation Results

Closure, post-closure and contingency costs have been developed based on present day estimates of the cost to complete the activities discussed in Section 2. The present day (year of this report) cost estimates are provided in Table 5.1.

5.1 Closure Costs

As discussed in the DOCP, the Landfill will be developed in three phases and progressively closed throughout the lifespan of the Landfill. The planned closure costs are estimated based on the closure schedule presented in the DOCP Fill Plan, whereas emergency closure costs are based on the cost to close the remaining open landfill footprint area in a given year.

In Phase 1 a total of 27,440 m^2 of lined landfill footprint will be constructed over the four year period. During year one of Phase 1 East only 13,763 m^2 is filled, therefore, the area that could potentially require final cover in that year is 13,763 m^2. In Phase 1 West, 3,720 m^2 of side slopes will be closed. In Phase 2A, the landfill footprint is expanded to 33,471 $m^{2,}$ however, 9,050 m^2 of area is closed with final cover. In this Phase, 24,421 m^2 could potentially require final cover under an emergency closure scenario.

In Phase 3A, the total footprint is expanded to the maximum size of 36,683 m^2 with 27,633 m^2 remaining open. In Phase 3B, an area of 7,185 m^2 is closed. In both Phase 3B and 3C, the area potentially requiring emergency closure is 16,235 m^2.

Progressive planned closure is scheduled for 2024, 2029 and 2033, and final closure is planned for 2035.

Table 5.2 presents the financial security calculations, including the planned and emergency closure costs based on the area requiring to be closed. The cost of emergency closure is higher than planned closure in each year, except in the year of final landfill closure.

5.2 Post-Closure Costs

Post-closure cost estimates are based on information supplied by Upland Excavating Ltd. and engineer's estimates. During Landfill operations leachate management will consist of on-Site treatment with discharge an infiltration pond, and this method was planned to continue 3 years of post-closure. After 3 years of post-closure, it is anticipated that the volume of leachate generated will be very low (less 2 m^3 per day on average or 573 m^3 per year), as such, the on-Site leachate treatment infrastructure will be decommissioned, and residual leachate will be managed by trucking for disposal off-Site. The calculation of leachate generation rates are presented in the DOCP.

As shown in Table 5.1, the estimated annual cost associated with post-closure activities will decrease over time as the Landfill nears the end of its contaminating lifespan (30 years). Post-closure costs will be highest in the first three years of post-closure. The monitoring and reporting effort are expected to be reduced three years after closure and further reduced after 7-years post-closure. General operations and maintenance requirements are also expected to reduce following a similar schedule.

The annual cost for the first 3 years is estimated to be $161,400 ($2021). The annual for the next three years after closure (years 4, 5 and 6) is estimated as $72,600 per year ($2021), and the annual cost between seven and 30 years after closure is estimated as $42,600 ($2021).

As presented in Table 5.2, the maximum present value sum of post-closure costs, associated with an emergency closure in 2022 is $1,414,695.

5.3 Contingency Costs

The estimated contingency costs for upgrading or modifying the leachate treatment system and repairing or replacing the aeration pond base liner are provided in Table 5.1. A total of $350,000 of contingency costs have been considered in the financial security calculation shown in Table 5.2.

5.4 Financial Contingency

A financial contingency of 20 percent has been applied to the closure and post-closure cost estimation, as introduced in Section 2.4. These costs are included on Table 5.1. Contingency measure costs (Section 5.3) are estimated conservatively and include a 20 percent contingency in the nominal value.

6. Cost to Carry-Out the Plan to Remove All Waste from the Original Landfill

The Plan to Remove All Waste from the Original Landfill is outlined in Section 6.3.3 of the DOCP. The Original Landfill is a historical landfill located in the southeastern corner of the Site. Authorization to discharge a maximum of 45,000 tonnes per year of waste to the Original Landfill is provided under the OC. Authorization to discharge waste to the Original Lined Cell ceases on the earlier of: (i) the date the Original Lined Cell is filled to capacity with grades not steeper than 3H:1V (33 percent), (ii) the date of commencement of waste discharge to the New Landfill.

The fill plan provided in the 2020 Annual Report estimates that the Original Landfill has 2.8 years of remaining capacity. The total capacity of the Landfill, including the lined and unlined portions is 74,746 m^3.

The estimated cost of carrying out the Plan to Remove All Waste from the Original Landfill is $4.63 per cubic metre of waste. The cost was calculated based on the Island Equipment Owners Association's suggested equipment rates for two Class 11 excavators, a Class 3 dozer and a 30 ton rock truck (a combined hourly rate of $925). Based on previous work carried out at the Site, this combination of equipment can move approximately 200 cubic metres of material per hour. A 20 percent contingency was carried, as presented in Table 5.1.

The financial security for the Original Landfill is required until the Plan to Remove All Waste is carried out and a report certified by a Qualified Professional confirming such is submitted to the director, satisfying OC Section 2.9(d):

> *If the plan referred to in section 2.9(a) of this operational certificate is carried out, the operational certificate holder must cause a Qualified Professional to certify and submit a report to the director that confirms that the plan has been carried out and completed in accordance with the director's requirements, describes the plan implementation, describes and provides the waste categorization, describes and provides the sampling and results, describes the decommissioning of the Original Landfill and the Original Leachate Management Works, provides photos documenting the implementation of the plan referred to in section 2.9(a) of this operational certificate, and lists the tonnages or volumes, and categories of waste removed and discharged to the New Landfill and to other identified and authorized waste management facility(ies), on or before 60-days after the plan referred to in section 2.9(a) of this operational certificate has been carried out and completed.*

7. Financial Security Plan Summary

Table 7.1 below presents the amount of financial security required each year of the first five years of operating life of the New Landfill. The maximum amount of security will be required during year four of operations, which corresponds to the maximum open landfill area that would require closure. The financial security amount is calculated in accordance with *Section 8* of the Landfill Criteria and is presented in 2021 Canadian dollars.

In addition, the financial security required for the Original Landfill for each year of the same first five-year period is also presented in Table 7.1.

The total financial security for the Site is calculated to satisfy Section 2.10(d) of the OC:

> *The amount of financial security at any time must be equal to or greater than:*
>
> *(i) Before the report referred to in section 2.9(d) (report that confirms that the plan referred to in section 2.9(a) of this operational certificate has been carried out and completed) of this operational certificate is submitted to the director, the greater amount specified for the corresponding time period in:*
>
> - *the financial security plan in the most recent OCP,*
> - *the financial security plan in the most recent DOCP.*
>
> *(ii) On and after the report referred to in section 2.9(d) (report that confirms that the plan referred to in section 2.9(a) of this operational certificate has been carried out and completed) of this operational certificate is submitted to the director, the amount specified for the corresponding time period in the financial security plan in the most recent DOCP.*

On or after the report referred to in Section 2.9(d) is submitted the financial security associated with the Original Landfill will be zero, and only the New Landfill financial security will be required.

Table 7.1 Financial Security – 5 Years

Year (Operating year)	New Landfill Financial Security Required	Original Landfill Financial Security Required
2022 (Year 1)	$2,049,079.57	$408,757.68
2023 (Year 2)	$2,111,347.94	$402,324.82
2024 (Year 3)	$2,095,240.57	$395,993.19
2025 (Year 4)	$2,274,959.57	$389,761.21
2026 (Year 5)	$2,239,157.17	$383,627.31

All of Which is Respectfully Submitted,

GHD

Roxanne Hasior, P.Eng.

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Tables

Table 3.1

Financial and Landfill Input Data
Financial Security Plan
Northwin Landfill
Campbell River, British Columbia

Financial

Inflation rate (1)	1.53%
Discount rate (2)	3.15%

Northwin Landfill

Year	Forecasted Average Annual Waste Disposal Rate (Tonne)	Forecasted Cumulative Waste Disposed (tonnes)	Forecasted Average Annual Airspace Consumption (m^3) (3)	Forecasted Cumulative Airspace Consumption (m^3)
2022	138,238	138,238	106,337	106,337
2023	45,000	183,238	34,615	140,952
2024	45,000	228,238	34,615	175,568
2025	45,000	273,238	34,615	210,183
2026	45,000	318,238	34,615	244,799
2027	45,000	363,238	34,615	279,414
2028	45,000	408,238	34,615	314,029
2029	45,000	453,238	34,615	348,645
2030	45,000	498,238	34,615	383,260
2031	45,000	543,238	34,615	417,875
2032	45,000	588,238	34,615	452,491
2033	45,000	633,238	34,615	487,106
2034	45,000	678,238	34,615	521,722
2035	13,836	692,075	10,643	532,365
Total	**678,238**		**521,722**	

Original Landfill

Capacity of Unlined Portion of Original Landfill (m3)	35,000
Waste-In-Place Unlined Portion of Original Landfill (m3)	35,000
Capacity of Lined Cell of Original Landfill (m3)	39,746
Waste-In-Place in Lined Cell of Original Landfill (as of Dec 31, 2020) (m3)	17,703
Total Capacity of Original Landfill (m3)	74,746
Total Waste-In-Place in Original Landfill (as of Dec 31, 2019) (m3)	52,703

Notes:

(1) 'The inflation rate applied to forecast construction costs, calculated based on 10-year average monthly % change in Consumer Price Index (CPI) for British Columbia. Statistics Canada, 18-10-0004-01, Data Visualization: 71-607-X2018016, last accessed June 26, 2021

(2) Discount rate calculated based on 10 year average Government of Canada Benchmark Bond Yields - Long Term. Bank of Canada, http://www.bankofcanada.ca/rates/interest-rates/lookup-bond-yields/, last accessed June 23, 2021

(3) Apparent Density of the waste = 1.3 tonnes per cubic metre

Table 5.1

Closure, Post-Closure and Contingency Cost Estimates
Financial Security Plan
Northwin Landfill
Campbell River, British Columbia

Closure Cost Estimate			
Description	**Unit**	**Price per Unit**	**Price per m^2**
Sand (Available on-site)	m^3	$ 3.00	$ 2.25
GCL	m^2	$ 12.00	$ 12.00
Topsoil	m^3	$ 4.00	$ 0.60
Hydroseeding	m^2	$ 1.00	$ 1.00
LFG Vents	L.S.	$ 25,000.00	$ 0.69
Swales and Erosion Control	lin. m	$ 80.00	$ 1.29
Contingency (20%)			$ 3.57
Total			**$21.40**

Post-Closure Costs			
Description	**Annual Cost in the Years Post-Closure**		
	1 to 3	**4 to 6**	**7 to 30**
Administration	$ 2,500.00	$ 2,500.00	$ 2,500.00
Access Road Maintenance/Repair	$ 2,000.00	$ 2,000.00	$ 2,000.00
Vegetation Maintenance	$ 5,000.00	$ 3,000.00	$ 3,000.00
Erosion/Surface Water Repair	$ 5,000.00	$ 3,000.00	$ 3,000.00
Leachate Management System O&M	$ 60,000.00	$ -	$ -
Allowance for Off-Site Disposal of Residual Leachate	$ -	$ 10,000.00	$ 5,000.00
Groundwater/Leachate Monitoring	$ 48,000.00	$ 30,000.00	$ 15,000.00
Consultants (Reporting)	$ 12,000.00	$ 10,000.00	$ 5,000.00
Contingency (20%)	$ 26,900.00	$ 12,100.00	$ 7,100.00
Total	**$ 161,400.00**	**$ 72,600.00**	**$ 42,600.00**

Cost of Implementing Contingency Measures	
Contingencies	**Estimated Cost**
Leachate treatment system modifications	$ 300,000.00
Allowance for aerated equalization pond liner repairs	$ 50,000.00
Total	**$ 350,000.00**

Cost of Removal of All Waste from Original Landfill		
Description	**Unit**	**Price**
Equipment Cost	m^3	$ 4.63
Cost of Removal of All Waste from Original Landfill	-	$ 346,073.98
Contingency (20%)	-	$ 69,214.80
Total		$ 415,293.41

Table 5.2

Financial Security Calculation
Financial Security Plan
Northwin Landfill
Campbell River, British Columbia

Year	Year of Operation	Stage	Lined Area m^2	Open Area m^2	Scheduled Closure m^2	Closed Area m2	A Cost of Planned Closure Cash Flow	A Cost of Planned Closure with inflation	A Cost of Planned Closure (PV)	B Cost of Emergency Closure Cash Flow	B Cost of Emergency Closure with inflation	B Cost of Emergency Closure (PV)	C Sum of 30 Years Post-Closure O&M Costs (PV)	D Cost of Implementing Contingency Measures (PV)	Amount of FS Required for New Landfill (PV) = (MAX A or B) + C + D	Amount FS Required to Carry out Plan to Remove All Waste from Original Landfill* (PV)	Total FS* (PV)
2021																	
2022	1	1 East	13,763	13,763	0	0	$ -	$ -	$ -	$ 294,528.20	$ 299,024.66	$ 289,893.03	$ 1,414,694.69	$ 344,491.84	**$ 2,049,079.57**	**$ 408,757.68**	**$ 2,457,837.25**
2023	2	1 West	18,322	18,322	0	0	$ -	$ -	$ -	$ 392,090.80	$ 404,154.02	$ 379,846.77	$ 1,392,430.80	$ 339,070.37	**$ 2,111,347.94**	**$ 402,324.82**	**$ 2,513,672.76**
2024	3	1 West	22,881	19,161	3,720	3,720	$ 79,608.00	$ 83,309.99	$ 75,908.32	$ 410,045.40	$ 429,113.65	$ 390,989.08	$ 1,370,517.28	$ 333,734.21	**$ 2,095,240.57**	**$ 395,993.19**	**$ 2,491,233.77**
2025	4	1 West/ 2 A	33,471	29,751	0	3,720	$ -	$ -	$ -	$ 636,671.40	$ 676,450.23	$ 597,528.91	$ 1,348,948.63	$ 328,482.04	**$ 2,274,959.57**	**$ 389,761.21**	**$ 2,664,720.79**
2026	5	2 A	33,471	29,751		3,720	$ -	$ -	$ -	$ 636,671.40	$ 686,777.37	$ 588,125.24	$ 1,327,719.41	$ 323,312.52	**$ 2,239,157.17**	**$ 383,627.31**	**$ 2,622,784.48**
2027	6	2 A	33,471	29,751	0	3,720	$ -	$ -	$ -	$ 636,671.40	$ 697,262.18	$ 578,869.56	$ 1,306,824.30	$ 318,224.36	**$ 2,203,918.22**	**$ 377,589.93**	**$ 2,581,508.15**
2028	7	2 A	33,471	29,751	0	3,720	$ -	$ -	$ -	$ 636,671.40	$ 707,907.05	$ 569,759.54	$ 1,286,258.02	$ 313,216.27	**$ 2,169,233.83**	**$ 371,647.57**	**$ 2,540,881.41**
2029	8	2 A/ 2 B	33,471	24,421	5,330	9,050	$ 114,062.00	$ 128,760.31	$ 100,468.09	$ 522,609.40	$ 589,954.12	$ 460,324.81	$ 1,266,015.41	$ 308,287.00	**$ 2,034,627.21**	**$ 365,798.73**	**$ 2,400,425.95**
2030	9	2 B/ 2 C	33,471	24,421	0	9,050	$ -	$ -	$ -	$ 522,609.40	$ 598,960.75	$ 453,080.40	$ 1,246,091.37	$ 303,435.30	**$ 2,002,607.07**	**$ 360,041.94**	**$ 2,362,649.01**
2031	10	3 A	36,683	27,633	0	9,050	$ -	$ -	$ -	$ 591,346.20	$ 688,086.58	$ 504,604.09	$ 1,226,480.88	$ 298,659.96	**$ 2,029,744.92**	**$ 354,375.74**	**$ 2,384,120.67**
2032	11	3 A	36,683	27,633	0	9,050	$ -	$ -	$ -	$ 591,346.20	$ 698,591.37	$ 496,662.83	$ 1,207,179.02	$ 293,959.77	**$ 1,997,801.61**	**$ 348,798.72**	**$ 2,346,600.33**
2033	12	3 A / 3 B	36,683	20,448	7,185	16,235	$ 153,759.00	$ 184,417.48	$ 127,107.53	$ 437,587.20	$ 524,839.05	$ 361,739.02	$ 1,188,180.92	$ 289,333.54	**$ 1,839,253.48**	**$ 343,309.47**	**$ 2,182,562.94**
2034	13	3 B / 3C	36,683	20,448	0	16,235	$ -	$ -	$ -	$ 437,587.20	$ 532,851.59	$ 356,046.11	$ 1,169,481.80	$ 284,780.13	**$ 1,810,308.04**	**$ 337,906.60**	**$ 2,148,214.64**
2035	14	3 C/ Closure	36,683	0	20,448	36,683	$ 437,587.20	$ 540,986.46	$ 350,442.80	$ -	$ -	$ -	$ 1,151,076.97	$ 280,298.37	**$ 1,781,818.14**	**$ 332,588.76**	**$ 2,114,406.90**
2035	N/A	Post-Closure	36,683	0	0	36,683	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,132,961.78	$ -	**$ 1,132,961.78**	**$ 332,588.76**	**$ 1,465,550.54**

Notes:

Costs in columns A, B, C and D are based on the cost estimates provided in Table 5.1 and discounted using the rates shown in Table 3.1.

All values are presented in 2021 Canadian dollars, unless otherwise specified.

*Amount FS Required for the Original Landfill will no longer be required once the Plan to Remove All Waste from Original Landfill is carried out (Section 2.9(a) of OC) and completion report is submitted by a Qualified Professional (Section 2.9(d)).

about

GHD

GHD is one of the world's leading professional services companies operating in the global markets of water, energy and resources, environment, property and buildings, and transportation. We provide engineering, environmental, and construction services to private and public sector clients.

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