

# 2016 Design, Operations, and Closure Plan

Upland Landfill

Campbell River, British Columbia

Upland Excavating Ltd.



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# Symbols and Abbreviations

%	Percent
AMSL	Above Mean Sea Level
BC	British Columbia
BTU	British thermal unit
BOD	Biological Oxygen Demand
C&D waste	Construction and Demolition Waste
Ca	Calcium
CCA	Copper Chromium Arsenate
cfm	Cubic Feet Per Minute
CH <sub>4</sub>	Methane
City	City of Campbell River
cm/sec	centimetre per second
CO <sub>2</sub>	Carbon Dioxide
COD	Chemical Oxygen Demand
CSR	Contaminated Sites Regulation
DOCP	Design, Operations, and Closure Plan
EFW	Energy from Waste
EMA	Environmental Management Act
EMP	Environmental Monitoring Program
Fe	Iron
FOS	Factor of Safety
GCL	Geosynthetic Clay Liner
H <sub>2</sub> S	Hydrogen Sulfide
Ha	Hectare
HDPE	High Density Polyethylene
HEC-HMS	Hydrologic Engineering Centre-Hydrologic Modelling System
HELP	Hydrologic Evaluation of Landfill Performance
Hp	horsepower
HWR	Hazardous Waste Regulation
km	kilometre
Landfill	Upland Landfill
Landfill Criteria	Revised Second Edition Landfill Criteria for Municipal Solid Waste, dated November 2015
LCP	Leachate Collection Pipe
LFG	Landfill Gas
LTF	Leachate Treatment Facility
m	Metre
m <sup>2</sup>	Square Metre

m <sup>3</sup>	Cubic Metre
mm	Millimetre
mm <sup>2</sup>	Square millimetre
MDL	Method Detection Limit
Mg	Magnesium
MOE	British Columbia Ministry of Environment
MOLO	Manager of Landfill Operations
MSW	Municipal Solid Waste
N <sub>2</sub>	Nitrogen
O <sub>2</sub>	Oxygen
OC	Operational Certificate
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
Permit	Permit PR-10807
Pit	Upland Sand and Gravel Pit
Ppm	Parts Per Million
Property	Upland Excavating Ltd. - 7295 Gold River Highway
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance and Quality Control
scfm	standard cubic feet per minute
Site	Upland Excavating Ltd. – 7295 Gold River Highway
SRD	Strathcona Regional District
SWANA	Solid Waste Association of North America
SWMP	Solid Waste Management Plan
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
WDA	Waste Discharge Application
WQG	Water Quality Guidelines
Zn	Zinc

# 1. Introduction

GHD Limited (GHD) was retained by Upland Excavating Ltd. (Upland) to prepare a Design, Operations, and Closure Plan (DOCP), for the Upland Landfill (Landfill). The DOCP will form part of the Waste Discharge Application submitted to the British Columbia Ministry of Environment (MOE) to obtain an Operational Certificate (OC) for the Landfill. The DOCP has been prepared in general accordance with the MOE's "Draft Second Edition Landfill Criteria for Municipal Solid Waste", dated September 2015.

## 1.1 Site Location

The Landfill is located at 7295 Gold River Highway (Site or Property) within the city limits of the City of Campbell River (City), British Columbia. The Site is located approximately 7 kilometres (km) west of city centre. The Site's southern property coincides with the boundary between the City and the Strathcona Regional District (SRD). The Gold River Highway and Mclvor Lake are located to the north and west of the Site. The legal description is Lot A, District Lot 85, Plan 30709, Sayward District. The total area of the Site is approximately 48.2 hectares (ha). A Site location map is presented in Figure 1.1.

## 1.2 Site Zoning and Adjacent Land Use

The Site is currently an active sand and gravel pit (Pit) owned and operated by Upland. The Upland Pit has been in operation since 1969. 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 current land uses in proximity to the Site include residential, industrial and forest logging activities. The area surrounding the Site is not serviced by a municipal sanitary sewer system or water distribution system. Gold River Highway, also referred to as Highway 28, is located to the north of the Site.

Specific current adjacent land use is presented in Figure 1.2. To the north and west, on the opposite side of the Gold River Highway, lakeshore residential properties line the Mclvor Lake shore. To the immediate west surrounding Rico Lake are industrial properties including contractor storage yards and a lakeshore residential property. To the northeast of the Site on the opposite side of Argonaut Road, there are a number of industrial activities including gravel extraction pit, concrete redi-mix manufacturer, wood recycling and processing facility and the municipal waste management facility. 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. To the south the Site, there is undeveloped forested land with some areas used for logging activities.

## 1.3 Legal Survey

Upland provided the topographic and legal land surveys for the Site. A copy of the original legal survey plan is provided in Appendix A.



## 1.4 Definitions

In this report the term “Landfill” refers to the Upland Landfill as designed and described within this DOCP the terms “Site” and “Property” refer to the property located at 7295 Gold River Highway.

## 1.5 Regulatory Setting

### 1.5.1 Existing Permit

The Site is currently authorized to accept and discharge inert municipal refuse under existing Permit PR-10807, dated June 01, 1992 (Permit). The Permit allows open burning of wood waste. A copy of the Permit is provided in Appendix B. The inert municipal solid waste (refuse) permitted for discharge includes:

- Tree stumps
- Trees
- Land clearing waste
- Selected building demolition debris
- Residue from combustion of open burning of wood waste

The sand and gravel extraction operations are conducted under Mines Act Permit G-8-114 issued December 1989, last amended in February 2014.

### 1.5.2 Provincial Regulations

The following provincial regulations are applicable to the design, operations, and monitoring of non-hazardous, solid waste landfill in BC and have been considered in the preparation of the DOCP:

- Environmental Management Act
- Comox Strathcona Waste Management - 2012 Solid Waste Management Plan, December 2012
- Landfill Criteria For Municipal Solid Waste, June 1993
- Draft Second Edition Landfill Criteria For Municipal Solid Waste, September 2015 (hereinafter referred to as “Landfill Criteria”)
- Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills, January 1996 (hereinafter called the “Environmental Monitoring Guidelines”)
- A Compendium of Working Water Quality Guidelines for British Columbia
- Hazardous Waste Regulation

## 1.6 Objectives and Scope

The objectives of the DOCP are as follows:

- Present the conceptual design of the Landfill including base liner system, surface water management systems, leachate collection and treatment systems, and final cover.
- Present the operational procedures for waste acceptance and landfilling.

- Present the environmental monitoring and Landfill monitoring plans
- Present the closure and post-closure requirements for the Landfill.
- Demonstrate that the Landfill design, operations, and closure will meet the requirements of the Ministry of Environment.
- Support the Waste Discharge Application.

## 1.7 Report Organization

The DOCP is organized into the following sections:

- Section 1.0 - General introduction including Site location, the current regulatory setting applicable to the Site, the objectives and scope, and the general organization of the DOCP.
- Section 2.0 - Site characteristics including Site topography, geology, hydrogeology, and hydrology.
- Section 3.0 - Landfill design including base contours, final waste contours, Site life, available airspace, final cover, and existing and Site layout.
- Section 4.0 - Site development and materials requirements.
- Section 5.0 – Lifespan Analysis include Landfill layout, total Landfill volume, waste acceptance, and airspace consumption.
- Section 6.0 - Site operation including hours, Site security, authorized waste, traffic volumes, operation personnel, equipment requirements, cover requirements, nuisance controls, record keeping requirements, health and safety.
- Section 7.0 –Summary of geotechnical conditions, settlement analysis, seismic evaluation, and slope stability analysis for the Landfill.
- Section 8.0 - Surface water management including objectives and design criteria, surface water controls, hydrological analysis, sediment and erosion control, and surface water infiltration requirements.
- Section 9.0 - Leachate management including objectives and design criteria, leachate quality and quantity forecasts, leachate handling treatment and disposal requirements, leachate management systems and leachate monitoring.
- Section 10.0 – Landfill gas (LFG) management including LFG production, LFG generation assessment, and LFG monitoring and safety.
- Section 11.0 - A Closure Plan, including final cover design, progressive closure strategy, end use options, and post closure requirements.
- Section 12.0 – Contaminating lifespan assessment.
- Section 13.0 – Groundwater and surface water impact assessment including compliance requirements, on-site groundwater flow characterization, leachate leakage into aquifer, treated leachate infiltration into aquifer, aquifer modelling.
- Section 14.0 - Environmental Monitoring Plan including surface water monitoring, groundwater monitoring, leachate monitoring, air monitoring, inspection and reporting requirements.
- Section 15.0 – Fire safety and emergency response plan.

## 2. Site Characteristics

The Site characteristics are detailed in GHD's report entitled Hydrogeology and Hydrology Characterization Report, February 2016. A summary of the Site characteristics are provided below.

### 2.1 Site Topography and Drainage

#### 2.1.1 Topography

The Site is located on a terrace that gradually slopes toward the Quinsam River located 4 km to the east of the east boundary of the Landfill. The Quinsam River channel occurs at elevations greater than 100 meters below the Site. Prominent topographic features near the Site include bedrock outcrops at the base of a small mountain near the southwestern Site boundary. The mountain is located off-Site and stands approximately 80 m above the terrace elevation, locally. To the west and northwest of the Site are two lakes (Rico Lake and Mclvor Lake).

Near the central portion of the western Site boundary, above the Pit, a localized area of surface topography dips towards Rico Lake. At the centre of the Site is the Pit that has been excavated to an approximate depth of 20 m below surrounding land surface.

#### 2.1.2 Drainage & Watercourses

The area in the vicinity of the Site is divided between the Campbell River and Quinsam River watersheds. Campbell River watershed covers an area of 182,000 ha and is intersected by three manmade dams which form Upper Campbell Lake, Campbell Lake and John Hart Lake. The Quinsam River watershed covers an area of 20,900 ha and is bound to the north and west by a mountainous divide that isolates it from the Campbell River watershed (Blackmun, Lukyn, McLean & Ewart, 1985). The last segment of the Quinsam River (approximately 25 km long) flows east and then north toward the confluence with Campbell River. The Site is located approximately 4 km west of this portion of the Quinsam River.

No permanent surface water features are located on Site. Two lakes in close proximity to the Site include Mclvor and Rico Lakes. Mclvor Lake is contiguous with Campbell Lake and is located approximately 50 to 150 m north of the northern Site boundary. Rico Lake is located approximately 10 m west of the western Site boundary and approximately 280 m west of the Landfill.

To the east and southeast of the Site, there are several ephemeral creeks that provide drainage locally. These creeks drain into the Quinsam River, which is located approximately 4 km to the east of the Landfill footprint.

Lost Lake (also known as Hidden Lake) is located 2 km to the northeast of the Site. Lost Lake drains through Cold Creek which feeds the Quinsam Hatchery before discharging into the Quinsam River to the northeast of the Site. The Cold Creek watershed is located northeast of the Site.

### 2.2 Geology

#### 2.2.1 Regional Geology

The Site is located on the eastern portion of central Vancouver Island approximately 7 km southwest of Campbell River, BC. 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 (Guthrie, 2005) (Greene, Scoates & Weis, 2005). The outcrop of rock on the southwestern portion of the Site and the bedrock encountered in boreholes advanced below the overburden is Karmutsen basalt.

At several time periods during the Pleistocene Epoch, Vancouver Island was glaciated with ice thicknesses to 2,000 metres. 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, which is deposited directly by glacial activity and consist of larger clasts supported in a matrix of fine grained sediment, and of glacial outwash, which consists primarily of poorly sorted, coarse grained (sand and gravel) sediments deposited by glacial melt water (Greene, Scoates & Weis, 2005). The overburden at the site consists of glacio-fluvial and outwash deposits of sand and gravel.

## 2.2.2 Site Geology

The understanding of the Site geology presented in the following sections is based on subsurface investigations and documents reviewed by GHD (2015 and 2016). Documents reviewed included regional mapping, previous reports, and well completion logs from private wells.

### 2.2.2.1 Overburden Geology

The geologic conditions within the Site have been ascertained through examination of the Pit sidewalls and soil samples collected during borehole advancement overseen by GHD.

The details of the field work, sample collection and analysis are detailed GHD's Hydrogeology and Hydrology Characterization Report (HHCR) (2016).

In general, Site stratigraphy can be characterized as follows (in order from shallowest to deepest):

1. A native interbedded sand and gravel unit is present across most of the Site. The thickness of this unit is variable and ranges from non-existent at the south-western portion of the Site, where bedrock outcrops are present, to greater than 24 m at the south eastern portion of the Site.
  - A sand unit greater than 33 m in thickness underlies the native sand and gravel in the east portion of the Site. Water well records from the north and northeast of the Site indicate the presence of additional layers of sand and gravel, likely underlying this sand unit.
2. The fractured bedrock is composed of igneous rock (basalt).

The structure of the overburden unit is consistent with glacio-fluvial and outwash depositional sources.

The stratigraphy in the southwestern area of the Site, where a topographic high exists, differs from the rest of the Site and can be characterized as follows (in order from shallowest to deepest):

1. Granular fill consisting primarily of sand and gravel. The cover thickness is approximately 3 m. The fill unit is not present within the investigation locations in the Pit.
2. An interbedded silt unit consisting of layers of silty sand or silt with clay was observed underlying the sand and gravel fill unit. The silt layer is not continuous.
3. Bedrock composed of igneous rock.

#### **2.2.2.2 Bedrock Geology**

Bedrock at the Site consists of fine textured massive igneous rock of the Karmutsen Formation which varies in colour from blueish black to dark grey and green to dark brown (Golder 2014). Fractures of various sizes, densities and orientations (vertical, horizontal and oblique) were observed in bedrock from samples collected at borings and in exposures in the southwest area of the Site. More significant fracturing was noted in the boring in the Pit. Evidence of weathering (i.e. iron staining) and secondary mineralization were observed in some fractures. According to laboratory tests completed by Golder in 2014, calcite is present in fractures and amygdules.

Bedrock outcrops in the south western portion of the Site. A near-surface bedrock ridge runs west and north of the Site.

### **2.3 Hydrogeology**

#### **2.3.1 Site Hydrogeology**

In general, the geologic units identified in the previous sections may be grouped into the following hydrogeologic units:

1. An overburden sand and gravel aquifer
2. A shallow fractured bedrock unit
3. Perched overburden and bedrock aquifers (located in the south-western undisturbed area of the Site)

The hydrogeologic properties of these units are discussed in the following sections.

##### **2.3.1.1 Overburden Sand and Gravel Aquifer**

An unconfined, shallow sand and gravel aquifer was identified within the overburden unit in boreholes advanced across the Site. Based on the consistency and spatial distribution of borehole locations, this aquifer is interpreted to be continuous across much of the Site (with the exception of the southwest undisturbed area of the Site).

The sand and gravel aquifer unit identified at the Site is a major aquifer in the region, and is identified in the BC Water Resource Atlas as aquifer 975 IIA (10)). This aquifer is interpreted to be the principal groundwater flow zone on-Site. In the context of the Landfill, this aquifer represents the main receptor to potential landfill-related groundwater quality impairments. As such, this aquifer is of particular importance to this hydrogeologic characterization.

The sand and gravel aquifer unit does not exist in the southwestern portion of the Site. As previously discussed, significant topographic increases and bedrock outcropping is observed in the southwest corner of the Site and adjoining property. Significant hydraulic (water level) differences also exist when comparing the southwestern corner to water levels measured across the remainder of the Site. Based on the stratigraphic elevation differences and hydraulic water level differences it is interpreted that the sand and gravel aquifer does not extend to the southwest corner of the Site.

The details of the stratigraphic elevations and hydraulic water levels are further discussed in the 2016 HHCR.

The groundwater flow at the Site within the sand and gravel aquifer is directed from the northwest to the southeast.

The static water elevations within Rico and McIvor lakes are much higher (greater than 11 m higher) than the static groundwater elevations within the principal groundwater flow system on-Site (overburden sand and gravel aquifer). The substantial difference between the static elevations in these surface water bodies and the groundwater elevations presented supports the following interpretations:

- Based on the elevation differences between the lakes and the overburden sand and gravel flow zone and the large difference in static water elevations between these two water bearing zones, it is likely that any hydraulic connection between the lakes and the overburden sand and gravel aquifer is a muted connection (weak connection) likely as a result of a bedrock ridge between the Site and the lakes.
- If there is a vertical hydraulic connection between these water bearing units, the vertical gradient would be downward, from the lakes to the overburden sand and gravel aquifer.
- If there is a horizontal hydraulic connection between these water bearing units, then the direction of flow between these units would be from the lakes to the overburden sand and gravel aquifer and not vice versa (i.e. flow will occur from high elevation to low).

These interpretations are of particular significance to the Site's hydrogeology due to the sensitivity of Rico and McIvor lakes as potential receptors to landfill-related water quality impairments. Based on the hydraulic relationship described above, it is not possible for Rico or McIvor to be potential receptors of landfill-related water quality impacts under the scenario of landfill development at the Site.

#### **2.3.1.2 Bedrock Aquifer Unit**

The bedrock aquifer is monitored at one location (MW4A-15), located in the central portion of the Site. The groundwater elevations at this bedrock monitoring well are on average 0.2 m higher than in the nested well MW4B-15, which is installed within the overburden sand and gravel aquifer. This indicates the presence of an upwards vertical hydraulic gradient between the shallow bedrock aquifer and the overlying sand and gravel aquifer. Therefore, groundwater from the bedrock aquifer unit is recharging the overburden sand and gravel aquifer. In the scenario of Landfill development, the gradient in the sand and gravel aquifer beneath the base of the Pit is upward. As a result, any potential Landfill derived impacts to the bedrock aquifer will be limited.

There are insufficient monitoring points to accurately map the groundwater flow direction within the fractured bedrock aquifer unit; however, it is expected that flow direction will be similar to regional flow which is expected to be to the southeast towards the Quinsam River.

### 2.3.1.3 Perched Aquifer

Two aquifer units were identified above the Pit in the southwest portion of the Site. These aquifers are interpreted to be disconnected from the primary flow zone within the sand and gravel and bedrock aquifer units described above.

A perched overburden aquifer and separate bedrock aquifer were identified at monitoring well MW5A/B-15. Groundwater was found perched within the silty sand overlying interbedded sandy silt and silt with clay layers. The interbedded sandy silt and silt with clay unit is approximately 2 m in thickness (noted between approximately 6.5 and 8.2 mBGS) and overlies water bearing bedrock. MW5A-15 was completed within the bedrock in this area while MW5B-15 was completed in the perched overburden water bearing zone.

Groundwater was encountered within the perched overburden aquifer at an average elevation of 185.4 mAMSLL in MW5B-15 and at an elevation of 183.5 mAMSLL in the bedrock aquifer well, MW5A-15.

As discussed above, groundwater elevations across the rest of the Site were not found at comparable elevations. As such, it is expected that the aquifer units noted at MW5A/B-15 are not connected with the remaining groundwater units at the Site.

## 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.

Data associated with climatic conditions for the Site were based upon 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. The average annual precipitation is reported to be 1,489 millimetres 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 millimetres, respectively. On average 84 millimetres worth of snowfall is recorded per year.

The Pacific Climate Impacts Consortium Plan2Adapt tool 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.

### Plan2Adapt tool estimated change in precipitation (2050)

		Projected Change from 1961-1990 Baseline to 2050s (2040-2069) Study Period	
	Season	Ensemble Median	Range (10 <sup>th</sup> to 90 <sup>th</sup> Percentile)
Precipitation (%)	Annual	+6%	-1% to +10%



	Summer	-14%	-23% to +1%
	Winter	+6%	-4% to +13%

## 3. Landfill Design

### 3.1 Design and Siting Criteria

The Landfill design is based on the design requirements outlined in the Draft Updated Landfill Criteria. The following design criteria were utilized in developing this DOCP:

- 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 meters 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 kilometer (km) buffer zone between the limit of refuse and an airport.
  - The 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 base shall be a minimum 1.5 m above groundwater.
- Primary liner: 1.5 millimetre (mm) thick HDPE geomembrane liner.
- Secondary liner: Geosynthetic Clay Liner (GCL) or 0.75 m thick compacted clay liner with a minimum hydraulic conductivity of  $1 \times 10^{-7}$  cm/sec.
- Minimum base slope of 2 percent.
- 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.
- Final cover comprising of 0.6 m, measured perpendicular to the slope, of low permeability (less than  $1 \times 10^{-7}$  cm/s) compacted soil or equivalent.
- Placement and vegetation of a minimum 150 mm of topsoil.
- Minimum top slope of 10H:1V (10 percent).
- Maximum side slope of 3H:1V (33 percent).

## 3.2 General Requirements

The Landfill shall be developed and operated in accordance with this 2016 DOCP. Any changes to the 2016 DOCP must be reviewed and accepted by the Director prior to being implemented.

## 3.3 Use of Soil

### 3.3.1 Final Cover Soil

Soil utilized for the Landfill final cover will meet the industrial level soil quality standards as defined in the Contaminated Sites Regulation. The final cover must meet the criteria discussed in Section 6.3.

### 3.3.2 Waste Soil disposed of in the Landfill

Soil disposed of in the Landfill must meet the requirements for authorized waste as discussed in Section 13.1.

### 3.3.3 Daily/Intermediate Cover Soil

Soil with contaminant concentrations above the industrial level, as defined in the Contaminated Sites Regulation, but that is not classified as Hazardous Waste, as defined in the Hazardous Waste Regulation, may be utilized for daily cover, temporary access roads within the limit of waste, and temporary berms within the limit of waste. The daily cover soils must meet the criteria discussed in Section 6.3.

### 3.3.4 Other Soil Uses

Soil utilized for Site development such as road construction, berm construction, fire breaks, and other applications outside of the limit of waste, and soil used for intermediate cover will be virgin material sourced from the on-site gravel production operations and will meet the industrial land use soil quality standards as defined in the Contaminated Sites Regulation (CSR).

## 3.4 Site Layout

The Site consists of an active sand and gravel extraction Pit, as such that the Site layout is designed to facilitate both the Landfill operations and gravel extraction operations.

The 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 Pit is not intended to be further excavated beyond the

current bottom elevation for the purposes of gravel extraction. Near the centre of the Pit an aggregate wash plant has been installed. The current gravel excavation activities are taking place in the southwest portion of the Site, as shown on Drawing C-02, labelled as 'production area'. The existing conditions are presented on Drawing C-01.

The Landfill footprint location is shown on Drawing C-02. The footprint is in the centre east-west on the property, and located 50 metres north of the southern boundary to provide a buffer zone in accordance with the Landfill Criteria.

The leachate treatment pond and infiltration pond will be located immediately east of the Landfill footprint.

### 3.5 Base Contours

The base contours will have a grade of two percent north to south along the leachate collection pipes, which will act as the primary drainage path. The base contours will have a grade of one percent along the secondary drainage path, or perpendicular to the leachate collection pipes. The southern portion of the Landfill will be constructed on the slope of the Pit. The slope will be excavated to two horizontal to one vertical (2H:1V). The leachate collection system will extend up this slope.

The maximum drainage path leachate will travel will be less than 50 m towards the nearest leachate collection pipe. The maximum grade along this drainage path is approximately 2.2 percent.

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 7.0 of this report.

The base contours extend to a maximum depth of approximately three metres below the existing ground surface at the base of the Pit, with the exception of the leachate sump which extends deeper than the surrounding base contours, as discussed in Section 3.7. The maximum depth is located along the northern edge of the Landfill footprint. The base contours extend to an existing grade toward the south of the Landfill footprint, just north of the interface with the 2H:1V slope. The excavation required as part of the construction of the Landfill cells is shown in Drawings C-06 through to C-09. The base contours are a minimum of 1.5 m above the groundwater table as required by the Landfill Criteria. The base contours ranges from 2 to over 10 metres above the high groundwater level.

### 3.6 Base Liner

The Landfill base liner will be comprised of a primary HDPE geomembrane liner and a secondary liner consisting of a geosynthetic clay liner. 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

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  $1 \times 10^{-7}$  cm/sec
- Minimum organic carbon content of 0.1 percent

The secondary clay liner may be comprised of compacted clay liner with the same specifications. A QA/QC program conducted by a qualified professional will be implemented during the construction of the base liner system to minimize the occurrence of defects. The QA/QC program will include non-destructive testing of each seam.

### 3.7 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 150 mm wrapped in protective geotextile layers within the stone drainage blanket
- 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 a LCPs
- Minimum 2 percent slope along primary flow path of the LCPs
- Minimum 1 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 north end of the Landfill running towards a central leachate collection sump at a minimum slope of 1 percent
- A sump with bottom dimension of 3,900 mm<sup>2</sup>
- Two leachate sump riser pipes with minimum diameters of 450 mm

### 3.8 Perimeter Containment Berms

A perimeter containment berm will be constructed on all sides of the Landfill. The perimeter containment berm will enhance the natural control of the leachate within the Landfill. The perimeter containment berm also serves as an embankment to facilitate construction of perimeter ditching, the Site perimeter maintenance road, and the final cover tie-in.

The perimeter berm to the south will also prevent surface water run-on to the Landfill from the upper portion of the Site. The southern surface water berm will extend beyond the limit of waste in the east and west direction, as shown in Drawing C-05, to ensure surface water from outside the Landfill footprint to the south is completely diverted away from the Landfill.

Details of the berms are presented on Drawing C-13 and C-14 as part of the perimeter tie-in details.

### 3.9 Final Contours

The final contours (top of waste) are presented in Drawing C-05. 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 m AMSL, and a peak elevation of 195 m AMSL.

The final cover ties into the top of the perimeter berm to minimize the potential for leachate seepage from 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 at the Site during waste placement activities.

### 3.10 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 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 1:100-year, 24-hour storm event

The surface water management works are described in Section 8.0.

### 3.11 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 WorkSafe BC 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 LFG generation assessment and forecasted management works are described in Section 10.

### 3.12 Final Cover

Final Cover will be applied to the Landfill to achieve the following objectives:

- Prevent exposure of humans and wildlife to the waste
- 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 is designed to minimize the post-closure leachate generation rate and maximize the evapo-transpirative potential.

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 6.3.3.

### 3.13 Site Security and Fencing

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

### 3.14 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.

### 3.15 Vector and Wildlife Management and Nuisance Controls

Vector, wildlife, and nuisance management strategies will be employed at the Landfill as discussed in Section 6.7.

## 4. Life Span Analysis

### 4.1 Landfill Layout Criteria

The Landfill has been designed for an approximate lifespan of 20 years. The area of the limit of waste is approximately 180 m by 200 m (Landfill footprint).

A 50 m buffer zone separates the southern limit of waste and the south property boundary. There is sufficient room to the east and west to expand the Landfill footprint on either side while maintaining a 50 m buffer zone on all sides. An expansion of the Landfill footprint is not planned at this time and has not included in the 2016 Application and associate reports

### 4.2 Total Site Volume and Airspace Consumption

The Landfill has a total airspace volume of approximately 506,000 m<sup>3</sup> for waste and cover material. The Landfill is expected to have a lifespan of 20 years as shown in Table 4.1. The average annual airspace consumption is expected to be approximately 25,300 m<sup>3</sup>. The assumed apparent density, as discussed in Section 4.4, is 1.3 tonnes per m<sup>3</sup>, which results to a forecasted annual average of 32,890 tonnes of waste disposed in the Landfill.

### 4.3 Waste Acceptance

The accepted waste will be comprised of select municipal solid waste, as defined by the Environmental Management Act, and will include the following:

- Construction and demolition waste
- Land clearing debris
- Non-hazardous contaminated soil, as defined by the Hazardous Waste Regulations (HWR)

### 4.4 Apparent Density

The apparent waste density, which is utilized airspace consumption, is not a true density but a relationship that represents the mass of waste discharged into each  $\text{m}^3$  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 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  $\text{m}^3$ . The apparent density observed at construction and demolition landfills is generally in the range of 0.6 to 1.0 tonne per  $\text{m}^3$ . As it is anticipated at this time 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 per  $\text{m}^3$  is forecasted for the Site.

## 5. Development 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 the continued gravel extraction in the southern Landfill footprint while landfilling commences in the north. The base liner 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-07 through to C-09. The conceptual Landfill development plan includes a three phase approach. Each phase will 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 three stages, 1A, 1B, 1C as presented on Drawings C-07. The total estimated airspace is 201,600 m<sup>3</sup>. The major construction activities during this Phase are as follows:

- Construction of the northern most lined cell including perimeter berm to north, west, and east, and required excavation
- Construction of temporary divider berm to south of first cell
- Construction of leachate collection pipes, leachate header pipes and sump
- Construction of associated leachate management systems, including pump station, leachate treatment facility and infiltration pond
- Filling in Stage 1A
- Construction of the second cell to the south including required excavation and perimeter berms
- Filling in Stage 1B and application of intermediate cover over Stage 1A
- Removal of intermediate cover over Stage 1A and filling in Stage 1C
- Intermediate cover over southern portion of Stage 1B
- Construction of the third lined cell to the south including excavation and grading of southern slope

## 5.2 Phase 2

Phase 2 contains three stages, 2A, 2B, 2C as presented on Drawings C-08. The total estimated airspace is 165,700 m<sup>3</sup>. The major construction activities during this Phase are as follows:

- Filling in Stage 2A
- Final cover over northern most side slopes
- Intermediate cover over a portion of Stage 1C
- 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

## 5.3 Phase 3

Phase 3 contains three stages, 3A, 3B, 3C as presented on Drawings C-09. The total estimated airspace is 138,700 m<sup>3</sup>. The major construction activities during this Phase are as follows:

- Extension of liner up the southern slope
- 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 Wastes

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

- Construction and demolition waste, excluding clean wood and other separated recyclables
- Land clearing debris
- Non-hazardous contaminated soil, as defined by the HWR
- Waste asbestos containing materials (ACM) managed according to Section 40 of the HWR
- Burn ash (from previous operations) and future burning if authorized

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

- Hazardous waste according to HWR, except waste asbestos
- Domestic Solid Waste
- Sludge and Liquid Waste
- Controlled Wastes as defined by the Landfill Criteria
- Gypsum drywall, unless asbestos containing
- Organic waste

### 6.2 Material Recovery

Materials recovered from the incoming waste streams for recycling include:

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

### 6.3 Waste Acceptance Policy

#### 6.3.1 Soil

Prior to the acceptance of soil at the Site, Upland will require the completion of the Waste Profile Sheet (WPS) and representative soil quality data, in accordance with CSR and HWR. Waste Profile Sheets require signature of a Qualified Professional (QP) confirming the samples collected and analysed are representative of the soil in question. The submitted data will be compared by Upland to the Site acceptance criteria to ensure compliance with the OC.

#### 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 houses or renovations must be

accompanied with record 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 MOE Technical Guidance. The submitted data will be compared by Upland to the Site acceptance criteria to ensure compliance with the OC. Construction debris from new construction will not require a hazard assessment.

## 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 metres.
- The waste will be compacted to achieve the most efficient compaction density.

### 6.4.1 Landfilling of Waste Asbestos Containing Materials

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

Cover is required to control vectors, wildlife, fire, litter, odour, infiltration, landfill gas, scavenging, etc.

### 6.5.1 Daily Cover

Daily cover will be placed on the active face at the end of each operating day. Daily cover will consist of either 150 mm of non-hazardous level soil, as defined by the HWR or approved alternative cover. Soil used for daily cover may be removed from the active face immediately prior to landfilling in the same area.

Surface water contact with the daily cover will be contained and treated as leachate and will be 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 virgin soil sourced from the on-site gravel production operations and will meet 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 and the daily cover meets the Industrial soil quality standards. 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 180 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 millimeters of topsoil with suitable vegetation
- 600 millimeters of sand as a protective cover
- Geosynthetic clay liner
- 150 millimeters sand cushion layer over the waste

The final cover system is shown in Drawing C-10. A water balance model, as discussed in Section 6.9.1, 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 standards.

## 6.6 Hours of Operation

The hours of operations of the overall site are Monday to Friday 7:30 am to 4:00 pm. The Landfill hours will be 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 recognizes 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 resolution will be documented. The records must be kept in accordance with the record keeping procedures described in Section 6.15 and 14.7, and included in the next annual operations report, as discussed in Section 14.8.

## 6.8 Nuisance Controls

The Landfill will comply with all local government nuisance bylaws.

### 6.8.1 Dust Control

Dust generation is common at most 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 measure will be employed at the Site on an as-needed basis and may include the following:

- Reduction of allowable vehicular speeds
- Use of water to control dust
- Seeding programs
- Proper placement of stockpiles and covers to minimize dispersion

Soil stockpiles that will not be used for more than one year will 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 the blowing of 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 windblown litter:

- All loads must be tarped to prevent litter from blowing out of the vehicle. Upland 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 discharge 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 from all activities having the potential to cause nuisance odours. The following measures will be used at the Site to control and minimize nuisance odours:

- Daily and intermediate cover will be applied as outlined in Section 13.3
- Leachate management systems will include adequate odour controls such as aeration to prevent unpleasant odours
- Odour control systems must be in place when odourous 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 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 include vegetative cover as soon as reasonably possible

### 6.9 Vector and Wildlife Management

The Landfill is not expected to attract large amounts of vectors or wildlife due to the lack of municipal solid waste, such as curbside garbage, or other organic matter to be disposed of in the Landfill. Furthermore, the Landfill will comply with the daily, intermediate, and final cover requirements stated in Section 6.3. 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 management system is also not expected to attract wildlife or waterfowl, due to the aerators that will operate intermittently and will prohibit 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 Burning

The Permit allows open burning of non-treated wood material including stumps, trees and similar material. The proposed operations will continue burning in a manner consistent with the existing Permit or the Landfill Criteria, whichever is more stringent, including the following criteria:

- Maximum quantity of waste to be treated is 750 m<sup>3</sup> per burn. (Permit)
- Maximum burn frequency is four burns per year. (Permit)

- The maximum duration of each open burn event shall be limited to the period of dawn to dusk of a single day, after which time the fire shall be extinguished. (Landfill Criteria)
- The wood residue to be burned shall be stacked in piles of a size that may be consumed by the fire in the dawn to dusk time frame and will promote rapid and hot combustion. (Landfill Criteria)
- Relevant requirements of the Open Burning Smoke Control Regulation area applicable. (Landfill Criteria)
- Notification of the regional MOE office is required, at least 24 hours prior to the open burn event. (Landfill Criteria)
- The open burn process shall satisfy all fire safety and general safety requirements of WorkSafe BC and other agencies as required.
- Open burning shall not be initiated unless the MOE's ventilation index is forecasted as 'good' for on the day of the burn. (Landfill Criteria) The ventilation index can be found at <http://www.env.gov.bc.ca/epd/epdpa/venting/venting.html>.
- Only clean wood shall be burned, this does not include the following :
  - Composite wood products (plywood, particle board, fibre board, hardboard, orientated strand board, laminated lumber, laminated wood, veneer, laminated flooring, or engineering wood products (Landfill Criteria)
  - Treated, coated or contaminated wood with antisapstain, preservative, fire retardant, glue, adhesive, laminate, bonding agents, resin, paint, stain, varnish, or other substances harmful to humans, animals, plants or the environment. (Landfill Criteria)
  - Other non-wood related materials such as rubber, plastics, tars, insulations, demolition debris, etc. (Permit)
- Burning will only take place with an attendant on duty and available to supervise the burn. (Permit and Landfill Criteria)
- Suitable approved devices shall be available for extinguishing fires to prevent them from spreading to surrounding areas, such as pressurized water supply, chemical type fire extinguishers, or an earth stockpile. (Permit)
- A fireguard shall be cleared and maintained free of combustible materials. (Landfill Criteria and Permit)
- No burning shall take place during periods of fire hazard or when burning is prohibited by other government agencies. (Permit)
- The fire shall be started and maintained in a manner that reduces smoke generation. An excavator with a thumb is recommended for active management of the burn pile.
- If smoke is excessive, or for any other reason, the fire may be extinguished if requested by the Director. (Landfill Criteria)
- Additional requirements will be met if imposed by the Director based on site specific circumstances and/or on the performance of the open burn events. (Landfill Criteria)
- The operator shall within 30 days of the completion of the open burn event submit a report to the Director including the following information:
  - Weather conditions



- Time of ignition
- Time of completion
- Quantity of material open burned
- A photo log including:
  - Photo pre-burn
  - Photos during the burn at a frequency of one photo per hour
  - Photo at completion of burn
- Any complaints regarding the burn and how they were addressed
- Fire safety measures in place in accordance with the fire safety plan discussed in Section 15.
- Burning will be conducted in accordance with the City of Campbell River Fire Department permit requirements.

### 6.11 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 6.3 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.

### 6.12 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 will be 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.

### 6.13 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 WorkSafe BC.

### 6.14 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 has a gate which 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 and contact information
- Hours of operation
- Emergency contact information
- Accepted and restricted wastes

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

### 6.15 Weigh Scale

A weigh scale is currently located at the Site entrance. This weigh scale will continue to be used for the Landfill operations.

The weigh scale will be maintained in proper working order and meet the requirements of the federal Weights and Measures Act.

### 6.16 Traffic Volumes

Traffic volumes will be dependent on the amount of waste and non-hazardous soils destined for the Site during any given time period. The waste may be received at specific times of the year and be distributed unequally throughout the year. In general, the traffic flow volume is expected to see a marginal increase from the existing traffic volumes to the Site.

### 6.17 Records

The Site owner will keep and maintain all relevant records for a minimum of seven years. The records must be available on-site for inspection and shall be submitted to the director within 14 days of a request from the MOE. Records will include the following:

- The Permit or the Operations Certificate
- All plans and reports prepared in support of the development for the Site
- Inspection records conducted by regulatory agencies
- A complaint log system providing 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

### 6.18 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 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 utilized at the Site as the work load demands to meet environmental control requirements including dust, litter, and odour control measures.

### 6.19 Operator Training

At least one supervisor shall successfully complete the Solid Waste Association of North America's (SWANA) Manager of Landfill Operations (MOLO) course. At least one of the operations staff 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.

### 6.20 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

### 6.21 Winter and Wet Weather Operation

Winter operations require advanced planning for Site preparation, snow removal, and the stockpiling and storage of cover material.

Many operational problems 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 should be prepared in advance of the onset of winter. In addition, stockpiles of cover material, areas for stockpiling snow, and snow fences to minimize and control drifting on an as needed basis, should be provided and placed prior to 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 stop receiving waste material.

Snow maintenance and wet weather operation will be conducted in such a manner as to minimize infiltration and operate the Landfill in a dewatered condition.

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. Secondary haul roads to the active Landfill area will be located so as to ensure continuous access to the active face 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

The Site consists of deep layers of sand and gravel, sandy, and gravelly sand deposits turning into fine sand layers at increasing depths overlying bedrock. 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. Bed rock is confirmed to have a west to east slope. The bedrock outcrops in the western portions of the Site, and dips steeply to the east. A bedrock ridge is present northwest of the Site. Bedrock was encountered at depths ranging from 16 to 24 metres below ground surface in the central portion of the Pit, and was found to be deeper than 45 metres below ground surface in the eastern portion of the Pit.

### 7.2 Landfill Settlement

The Landfill area was analysed 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 evaluations. 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 2475 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 Site 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

- Minimize potential for on-site erosion and sediment loading in the base of the Pit (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.

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

- The storm water channels shall be designed to convey the discharge of a 1:100-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).
- The channels must be armored (rip rap, erosion control matting, or vegetative cover) to prevent erosion of ditch bottom and side slopes.
- Make allowances for additional water that may result from snowmelt.

### 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 Prepared for Greater Vancouver Sewerage and Drainage District (Gibb, Kelly & Schueler, 1999), the infiltration pond should meet the following criteria:
  - The maximum draining time is 48 hours
  - Recommended maximum water ponding depth is 0.3 m
  - Minimum infiltration capacity is 13 mm/hr
  - Maximum infiltration capacity is 61 mm/hr
  - Minimum 600 mm free board
3. 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:

- Sedimentation forebay should provide 10% volume of permanent pool storage for wet pond
  - Sedimentation forebay should provide 10% volume of total design storage volume for dry pond
4. In accordance with the Storm water Management Planning and Design Manual (MOE 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
5. In addition, the storm water management system will be designed to meet the following criteria:
- The storm water management system will be designed using the 24-hour, 25-year and 100-year synthetic design storm with a Type 1A distribution
  - The storm water infiltration basin will have the capacity to accommodate the runoff volume generated from the 100 year storm event with 0.6 metres (m) of freeboard
  - To account for frozen 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
  - Make allowances for additional precipitation and greater storm events due to the possibility of climate change in the region

### 8.3 SWMP Overview

The SWMP will include the following elements:

- Mid-slope swales approximately half way up the side slopes of the final closure to shorten the drainage path and help prevent erosion
- Drop-down channels where the southern edge of the Landfill 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 to 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 forebays located at the ditch outlets north of the Landfill will also act as a sediment trap to minimize larger sediment migration into the infiltration areas.
- Infiltration area in the base of the Pit

## 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, which are used to develop the synthetic design storms. They are Strathcona Dam (ID 1027775), Campbell River Airport weather station (Station No. 1021261), and Campbell River STP (ID 1021265). The location of these three weather stations is 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 C.

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 increased the synthetic design storm rainfall depths by 6%, which represents a total increase of 16% over the IDF reported values.

Synthetic design storms were created for the 5-year, 10-year, and 100 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



#### 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 top soil over 600 mm sand over a GCL, as discussed in Section 6.3.3. 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. 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

Two infiltration areas proposed for the stormwater runoff from the Landfill. 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-meters 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 2,682 m<sup>2</sup>, while the top surface area of both of the infiltration areas will be 4,320 m<sup>2</sup> excluding sediment forebay area. The total available storage volume from each of the infiltration areas is approximately 3,500 m<sup>3</sup>.

A stage-area table for pond configuration is included in Appendix C.

#### 8.4.5 Infiltration Rate

The area to the adjacent north of the Landfill is proposed as an infiltration area. Stratigraphic and instrumentation test were completed for this area.

A copy of test results is included in GHD's 2016 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 main 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. Actual infiltration rates should be confirmed in the field as part of the detailed design stage.

#### 8.4.6 Infiltration Discharge Estimation

Using the stage area table provided in Appendix C, the infiltration area at an elevation of 167.3 m was interpolated as 2,682 m<sup>2</sup>. 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 forebay 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 sediment forebay is provided in Appendix C.

An energy dissipation structure at the outlet of the steep channels is required to prevent erosion of natural channel bed and banks. A basin approximately 0.5m deep that is 5m wide and 10m in length will be required 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 and 100-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 100-year design storm that in excess of 90% of the rainfall results in runoff.

Hydrologic model outputs files are provided in Appendix C.

The model also calculates the peak discharge within the channels. The channels were designed to convey the peak discharge from the 100-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 100-year design storm event and have a sufficient surface area to drain in less than the maximum limit for all storms (48-hours).

## 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 can 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 water as it 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 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). Unlike MSW, DLC waste consists largely of inorganic components and organic

matter with a low degree of biodegradability. Preliminary investigation results of DLC lysimeter 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 (Townsend, 2000). 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 a likely 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.

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 is could increase the concentrations of PAHs, VOCs, and PHCs in leachate but these compounds are readily biodegradable with in the leachate. It should be noted that contaminated soil must be considered non-hazardous for acceptance 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 distinguished hazardous chemicals, identified in the HWR.

### 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 could be 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.

In general, 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<sub>2</sub>) 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.

It should be noted that 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 oxidize 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.

Based on the above, typical C&D landfills will likely not reach methanogenic anaerobic degradation due to the ability of sulphate-reducing bacteria to out compete methanogenic bacteria for fermentable substrates in the presence of sulphate, which is plentiful in C&D leachate (Eun, 2004). Conditions in typical C&D landfills favour sulphate-reducing bacteria, therefore unlike in municipal solid waste landfills, little methane gas is produced and hydrogen sulphide gas is generated instead.

Anaerobic conditions can occur within the refuse during landfilling, but are generally more ideal after closure. 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 could potentially be utilized 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 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. .

## 9.5 Site Specific Leachate Quality Estimation

This Section presents the conceptual leachate quality estimation. It is recommended that a leachate treatment design basis report be completed as part of the detailed design of the leachate treatment facility. As the nature of the waste may vary throughout the Landfill lifespan, it is anticipated that the contaminants of concern may require modifications or additions. The leachate chemistry will be re-characterized and updated annually, and documented as part of the annual operations and monitoring report discussed in Section 14.

For the purpose of this DOCP, a forecasted leachate profile has been developed using leachate quality data from other similar landfills in BC, and compared with similar landfills in other parts of Canada for verification purposes. It should be noted that the specific waste streams accepted at each landfill can alter the leachate quality and the presence or absence of specific parameters. The forecasted leachate profile contained in this report serves as an estimated 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.

Table 9.1 provides a range of leachate concentrations from four similar landfills that are used to forecast the leachate quality profile for the Site. As shown in Table 9.1, parameters that are forecasted to exceed the CSR Standards within the untreated leachate include:

- |            |             |
|------------|-------------|
| • Ammonia  | • Boron     |
| • Chloride | • Copper    |
| • Phenols  | • Iron      |
| • Sulphate | • Magnesium |
| • Sulphide | • Manganese |
| • LEPH     | • Sodium    |
| • Arsenic  | • Zinc      |

As noted in Section 9.4, typical C&D waste leachate chloride concentrations are reported to range from 5 to 62 mg/L (Townsend, 2000). However the observed leachate chloride concentrations from C&D landfills evaluated herein vary significantly. Sodium concentrations are also likely linked to the concentration of chloride in the leachate. As shown in Table 9.1, the maximum concentrations of chloride and sodium observed in leachate from the Mayer Waste Disposal Site were 98.9 mg/L and 256 mg/L, respectively. When compared to the maximum concentrations of chloride and sodium observed in leachate from the Highwest Waste Management Facility (4,300 mg/L, each), it is clear that chloride and sodium concentrations in leachate at C&D landfills is highly site specific and

dependent on the waste accepted at the Site. The actual sodium and chloride concentrations in the leachate should be evaluated during the preparation of a leachate treatment design basis to ensure the treatment process is capable of reducing these concentrations appropriately.

Similarly, sulphate concentrations in leachate are highly variable from one landfill to the next as shown in Table 9.1. The variation in sulphate concentrations is likely related to the relative proportion of gypsum waste present at the Site. Therefore, the sulphate concentrations forecasted for the Site assume that gypsum drywall will be disposed of on Site and therefore the sulphate concentrations will be elevated. If gypsum is not disposed of on Site in significant quantities, the actual sulphate concentrations may be lower.

## 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 a number of possible sources (McBean et al., 1995):

- Water present in waste mass when landfilled
- Percolation of water through the landfill surface
- Horizontal flow through sides
- Upgradient flow from the bottom

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 principle 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 channelling 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 north, west, and east sides of the Landfill, as well as 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 side slopes 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

It is generally assumed that all precipitation, which infiltrates through the Landfill cover will eventually become leachate once the Site has reached field capacity. A tool commonly used to estimate the amount of water in a landfill is the Water Balance Method (WBM). This method is based on the principle of conservation of mass and accounts for the total amount of precipitation falling onto a landfill. It utilizes the following equation to estimate the total amount of water infiltrating the landfill (McBean et al., 1995):

$$\text{Infiltrate} = \text{Precipitation} - \text{Surface Runoff} - \text{Soil Moisture Storage} - \text{Evapotranspiration}.$$

In addition to the WBM, The Hydrologic Evaluation of Landfill Performance (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.

For the purpose of this report, the HELP Model will be used to estimate leachate generation. The WBM will be used to verify HELP Model results. HELP Model outputs are presented in Appendix D.

### 9.6.2 Conceptual Leachate Generation Model

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

The cover systems are discussed in Section 6.3. A summary of the HELP results, or the annual leachate generation for each cover system is provided in Table 9.2.

The Landfill development is described in Section 4.0. During each of the nine stages, the estimated area that will be covered with daily, intermediate and final cover varies. The estimated area of each type of cover during each stage is presented in Table 9.3.

### 9.6.3 Leachate Generation Results

Leachate generation is dependent on precipitation rates at the Site. Precipitation data for the Campbell River Airport (Station 1021262) from 1981 to 2010 is summarized in Table 2.1. 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 6 percent during the life of the Landfill. The leachate generation rates have been developed with historical data; however leachate management systems discussed in subsequent sections will include adequate factor of safety to manage leachate and precipitation rate increases expected from climate change.

The development plan includes a Landfill footprint of 34,147 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 discussed in Section 9.6.2.2. Annual leachate volumes were calculated by multiplying the corresponding leachate generation rate of each cover system, discussed in Section 9.6.2.1, by the respective areas during each stage of development. The approximate annual collected leachate volumes will range from 13,508 m<sup>3</sup> (37 m<sup>3</sup>/day) in Stage 1A to 23,643 m<sup>3</sup> (65 m<sup>3</sup>/day) in Stage 1C to 580 m<sup>3</sup> (less than 2 m<sup>3</sup>/day) post-closure, as shown in Table 9.4.



## 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-03. The collection pipes will discharge to a sump to be constructed at the low point of the Landfill in the center (east-west) of the northern most end of the Landfill, as shown on Drawing C-03 and C-11. The leachate will be pumped from the sump on an as-needed basis via a manually operated leachate 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 infiltration pond. The location of the treatment ponds is shown on Drawing 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 6 DW) prior to discharge to the Infiltration Pond. The CSR standards are published by the BC MOE 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 shallow aquifer downgradient of the Site.

As noted in Section 13.1.1 the groundwater flux in the shallow aquifer beneath the Pit is 854 m<sup>3</sup>/day one order of magnitude above the average annual daily leachate generation rate. As such the available on-Site attenuation capacity within the shallow 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 saturation and Landfill base liner leakage are negligible. This HELP model is further discussed in Section 13.

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 1C. During Stage 1C, the annual leachate generation rate is estimated to be 23,643 cubic metres (65 m<sup>3</sup>/day).

The leachate treatment pond 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 1C. Table 9.5 provides a summary of the monthly average forecasted Stage 1C leachate generation rates. As shown in Table 9.5 the maximum forecasted monthly average leachate generation is 123 m<sup>3</sup>/day during November. The maximum monthly average leachate generation with a potential six percent increase due to climate change will not exceed the design treatment capacity, as shown in Table 9.5.

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 metres. Therefore, the storage capacity of the Landfill is limited to 0.3 metres over

the base area available during Stage 1C. Accounting for an assumed leachate collection system porosity of 0.3, this results in a maximum storage capacity of 1,910 cubic metres.

### 9.8.3 Conceptual Treatment Process

#### 9.8.3.1 Process Components

##### *Lined Cells*

All Phases of the Landfill will be lined with a geomembrane and GCL base liner system to collect leachate, as described in Section 3.6. The lined Landfill allows for the temporary storage of leachate prior to treatment and also mitigates the need to design the system for peak daily precipitation. 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-10.

##### *Leachate Collection*

All Phases of the Landfill will include the installation of leachate collection pipes (Drawing C-03) 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-10 and C-11. 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-11 and C-12. A single manually operated pump will be installed in one of the sump risers. The second sump riser provides redundancy in the event of a blockage or the need for a second pump.

##### *Aeration Pond*

The conceptual design features of the aeration pond include:

- 2.5H:1V side walls lined with 60-mil HDPE liner overlying a GCL
- Side slopes protected with poorly graded round drainage stone
- A submerged coarse bubble aeration system
- Positive displacement blowers, including variable frequency drives, sized to provide the required air demand
- Floating decant pump
- Decant outlet pipes located at the bottom of the pond and at a height of approximately 1.2 metres from the bottom of the pond
- Approximate bottom dimensions of the aeration pond will be 25 metres by 30 metres. The approximate top dimensions of the aeration pond will be 39 metres by 46 metres.

Treated leachate will be allowed to settle prior to decantation to the infiltration pond. The settling period will facilitate the removal of suspended solids. Periodic removal of sludge accumulated in the aeration lagoon will be required. Sludge can be removed by vacuum truck and conveyed to an excavated infiltration area in the Landfill's active face.

### ***Infiltration Pond***

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 Hydrogeology and Hydrology Characterization Report prepared by GHD in conjunction with this report as part of the Application.

The location of the infiltration pond has been selected to maximize the natural attenuation capacity and increase the distance to the property line, while allowing for continued site operations. The Site is underlain by a vadose zone of varying thickness, and will be used to attenuate the treated leachate to further reduce the concentrations of the leachate derived constituents prior to reaching the aquifer and the downgradient property line.

#### **9.8.3.2 General Operation**

Leachate will be stored temporarily in the Landfill. When leachate levels in the Landfill warrant removal and the previous leachate treatment cycle is complete, the pump system will be activated to pump leachate collected in the sump into the adjacent aeration pond. The aeration pond will operate as a batch reactor in three distinct cycles: fill/aeration, settle, and decant, controlled by process times and the aeration pond water level.

An aeration pond will provide the necessary biological and physical-chemical treatment processes when operated. The batch treatment will be completed in a 7 day cycle as follows:

- Fill – 1 day
- Aerate – 2 days
- Settle – 1 day
- Decant – 1 day
- Idle – 2 days (for operator weekends)

The aeration pond will be designed to ensure a minimum freeboard of one metre under maximum leachate generation scenarios. This freeboard will ensure that even under the peak seven day rainfall event and peak leachate generation scenarios that suitable freeboard will remain. The leachate volume within the aeration pond will be divided into three categories:

- Residual Volume (1090 m<sup>3</sup>) – This volume of leachate will remain in the aeration pond at all times to ensure the treatment bacteria and chemical processes remain active
- Maximum Annual Average 7 day leachate flow volume (465 m<sup>3</sup>) – This is the anticipated average volume that will be treated in each cycle.
- Maximum leachate flow volume (465 m<sup>3</sup>) – This is the anticipated redundant volume available for treatment during higher leachate generating months without utilizing the freeboard volume.

A schematic illustrating the aeration pond operating levels is provided as Figure 9.1.

#### **9.8.3.3 Treatment Process**

Aeration oxidizes dissolved metals such as iron and manganese to less soluble forms and produces flocs that settle into a sludge for periodic removal. 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 settle out into the sludge.

Hydrocarbons and volatile organic compounds will be readily volatilized in an aeration lagoon thereby reducing the concentration.

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.

An aeration lagoon will also biologically treat ammonia by converting it to nitrite and subsequently nitrate in a process called nitrification. Nitrification also reduces BOD should it be a concern for the leachate. It should be noted that the biological process requires a balance of nitrogen (in the form of ammonia), carbon (naturally present in leachate in the form of alkalinity) and phosphorus. The forecasted leachate quality estimates low concentrations of phosphorus which may be limiting to the biological process. Should process modeling indicate that biological processes will be phosphorus limited, manual addition of phosphoric acid will provide the required nutrient balance. Similarly, if in the future the process becomes carbon limited due to a reduction in alkalinity, an alternate carbon source such as sodium bicarbonate can be added manually to maintain the nutrient balance. It is also noted that biological processes are impeded at lower temperatures. Process modeling during the preparation of a leachate treatment design basis will indicate whether additional steps are required to ensure adequate temperature is maintained during the colder months of the year. Note that sulphate, chloride, and sodium treatment are dependent on the form that each is present in the leachate and the forecasted concentration of each is highly dependent on the composition of incoming waste. Also note that arsenic, boron, magnesium, and zinc treatment is dependent on the form that each is present in the leachate.

The forecasted treated leachate quality is presented in Table 9.1. Further studies will be performed on the actual leachate during the preparation of the leachate treatment detailed design basis to ensure adequate level treatment is attained.

#### 9.8.4 Treatment Sampling Program

During the commissioning of the aeration pond and during the operation in Stage 1A, the leachate treatment system will not be at maximum capacity, a program will be implemented to determine the leachate treatment sampling program. The untreated leachate and treated leachate 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 held while the commission 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.

- BOD
- COD
- Alkalinity
- Phosphorus
- TKN
- Ammonia
- pH
- Iron
- Manganese
- 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 (CO<sub>2</sub>) 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<sub>4</sub>) and CO<sub>2</sub>, and in some cases hydrogen sulphide gas (H<sub>2</sub>S). 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.

Conditions in typical C&D landfills favour sulphate-reducing bacteria, therefore unlike in municipal solid waste landfills, little CH<sub>4</sub> is produced and H<sub>2</sub>S is generated instead.

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.

Collected LFG may contain varying amounts of nitrogen (N<sub>2</sub>) and oxygen (O<sub>2</sub>) 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<sub>4</sub> and 50% CO<sub>2</sub>, 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 BCMOE 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 generations 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 MOE
- If the landfill is currently generating over 1,000 tonnes of methane per year, according to the LFG generation assessment, then a LFG design plan must be submitted to the MOE within one year
- Once the LFG design plan is accepted, an active landfill gas collection system is required to be installed within four years of the LFG design plan acceptance

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

### 10.3 LFG Generation Model

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

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

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

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

Where:

$Q_T$  = total LFG emissions (50 % CH<sub>4</sub> and 50 % CO<sub>2</sub> by volume)

k = LFG generation constant (year<sup>-1</sup>)

$L_0$  = methane generation potential (m<sup>3</sup> CH<sub>4</sub>/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. The Regulation applies to landfills that accept MSW on or after January 1, 2009. 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 MOE 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 will be 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 2.6 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 than 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,  $L_0$ , represents the total potential yield of methane from a mass of waste ( $m^3$  of methane per tonne of waste). The  $L_0$  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 anticipated average annual waste tonnages throughout the life of the Landfill (32,890 tonnes per year) were used. When an actual LFG assessment is produced for submission to the MOE, 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 at the 2017 (assumed Landfill start date) to 2066 (end of the 30 post-closure monitoring period).

#### **10.4.2.4 Future Considerations**

The estimated 2036 (Landfill closure year) methane generation for the Site is approximately 544 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, a LFG Management Facility Design Plan will be submitted to the MOE 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<sub>2</sub> and CH<sub>4</sub>. 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<sub>2</sub>S, 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<sub>2</sub>S 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 H<sub>2</sub>S 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 H<sub>2</sub>S 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 H<sub>2</sub>S safety plan and restricts smoking anywhere onsite.

## 10.6 LFG Control

The Landfill expansion will utilize a geosynthetic liner system, which will limit subsurface migration of LFG. As such, sub-surface migration of LFG will likely occur through the final cover, resulting in degradation of the final cover and vegetative stress. The LFG Management Plan shall be limited to 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.

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.

## 10.7 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 leak within the Landfill cells. It is therefore recommended that the potential off-Site LFG migration be monitored at the periphery of the Site, and into the existing buildings currently occupied by the operational personnel. The soil gas concentrations at the Landfill 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 Site office.
2. At the northern property boundary along the Gold River Highway to monitor migration of LFG off-site.

The monitoring requirements are further discussed in Section 12.0.

# 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 estimated total and remaining Site capacity is estimated to be 506,000 m<sup>3</sup>.

## 11.2 Landfill Site Life

The estimated Landfill Site life is approximately 20 years, and is assumed to start in 2017.

## 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 millimetres of sand overlain by a GCL, 0.6 metres of protective sand layer, 150 millimetres of topsoil) constructed over top of the final waste grades presented on

Drawing C-05. 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 3.10. When a Section of the Landfill reaches final contour elevation 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-07 through to C-09 will be closed once sufficient area to warrant closure 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

There is presently no end use plan formulated for the Site. It is anticipated that the Site will remain industrial land use and continue the gravel extraction activities.

In this regard, it is proposed that a detailed End Use Plan be developed for the Site within one to two years prior to closure, which will comply with the requirements of the Contaminated Sites Regulation, and a new declaration may be submitted to the 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 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 will be implemented into the post closure surface water control measures. The mid-slope swales, surface water diversion berm, ditches, 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 or other factors are found, maintenance will be required.

#### 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 gravel pit to manage the surface water in large rainfall events. The conceptual infiltration pond design is discussed in Section 8.4.

#### 11.6.5 Post Closure Maintenance and Monitoring Requirements

The EMP, discussed in Section 14, 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 to ensure conditions do not change.

#### 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 parameters have decayed sufficiently that the leachate constituent concentrations meet the Water Quality Guidelines (WQG) criteria 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 parameters modeled to estimate the CLS include chloride and sulphate. These parameters 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 utilized 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% 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 rate of leakage through the liner system but will increase the rate of decay resulting in a shorter contaminating lifespan.

## 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.

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

For the purpose of this investigation, GHD focused on the time period where  $t$  is greater than or equal to  $t_2$ , representing Landfill closure. When the simulation time is greater than  $t_2$ , the source concentration is assumed to decay exponentially at a rate of  $\mu$ , the first order decay constant. The initial concentration,  $C_B$ , was estimated for each contaminant of concern (COC), based on data from existing 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. GHD compiled data 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 E.

Parameter	Years to Meet WQG DW Criteria	Years to Meet CSR DW Criteria
Chloride	28.0	28.0
Sulphate	9.0	9.0

Note: The WQG DW and CSR DW criteria are equal for these parameters.

## 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 (kg)
$A_0$	=	area ( $m^2$ )
$H_w$	=	maximum waste thickness (m)
$\rho_{dw}$	=	dry density of waste ( $kg/m^3$ )
$p$	=	proportion of the total mass of waste that is contributed by chloride
$C_0$	=	peak or average chloride concentration (mg/L)
$q_0$	=	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<sup>3</sup>.

#### ***Volume of Waste***

The anticipated total volume of waste is 506,000 m<sup>3</sup> within an area of 36,000 m<sup>2</sup>.

#### ***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 are 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 WQG and CSR standards required to achieve compliance in the groundwater. In the case of chloride, the Drinking Water standard for both criteria 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 E.



Scenario	Years to Meet WQG 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 decay to meet WQG DW and CSR DW criteria 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 28 years.

## 13. Groundwater and Surface Water Impact Assessment

In order to estimate 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 in order to quantify and characterize the basic hydrogeologic functioning 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 or flux into the Landfill area from upgradient sources
- Precipitation over the Landfill area which 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, the forecasted rate of change of change for annual precipitation was found to be 6% 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 Landfill (Flux)

Groundwater flow beneath the Landfill footprint, or groundwater flux, was estimated using aquifer properties as measured using on the on-Site monitoring well network. The groundwater flow direction and gradient was calculated using an average of the groundwater elevations measured through 2015 at MW1-14, MW2-14, MW3-14, and MW4B-15. The locations of the monitoring wells are discussed in Section 14. The stratigraphic details from the above monitoring wells were used to estimate the aquifer characteristics. In order to determine the cross sectional area of groundwater flow that is approximately perpendicular to the direction of groundwater flow, the northeast to southwest diagonal of the Landfill footprint, approximately 270 m in length is multiplied by the expected mixing zone within the saturated thickness of the sand and gravel aquifer. It should be noted that upward hydraulic gradients have been calculated between shallow and deep portions of the overburden aquifer and as such it is expected that the mixing zone (where the water balance inputs mix) will be limited to the upper portion of the overburden aquifer. For the purposes of the model a conservative mixing zone thickness of 5.0 m has been assumed.

The groundwater flux, volume of groundwater flowing, across this cross-sectional area can be calculated using Darcy's Law and is expressed with the following equation:

$$Q = K i A$$

Where:

Q = flux or flow across the 2-dimensional boundary perpendicular to the groundwater flow direction

K = hydraulic conductivity

A = area through which groundwater is flowing

i = horizontal hydraulic gradient in the direction of groundwater flow

The results from the single well response tests completed on September 18, 2015 for the sand and gravel overburden unit were used to estimate the overburden aquifer hydraulic conductivity ( $2.0 \times 10^{-2}$  cm/sec). This value, in addition to the estimated average saturated area of the 2-dimensional mixing zone (1,345 m<sup>2</sup> [270 m X 5 m]) and a hydraulic gradient of 0.037 m/m (an average of the gradient calculated between MW1-14 and MW2-14 and MW4B-15 and MW3-14) the groundwater flux beneath the Landfill footprint is estimated to be 312,000 m<sup>3</sup>/year or 854 m<sup>3</sup>/day. This groundwater flux equates to a groundwater velocity of 2.1 m<sup>3</sup>/day and an estimated travel time of 128 days to reach the Site boundary from the treated leachate pond.

### 13.1.2 Potential Leachate Leakage

Leachate generation rates were estimated using the Hydrologic Evaluation Landfill Performance (HELP) model, as discussed in Section 9. Three separate HELP models were created to simulate differing stages of Landfill development. As a conservative estimate, the Landfill development stage with the highest leachate generation rates (Stage 1C) has been used for the purposes of assessing downgradient water quality. An additional HELP model was conducted to determine the maximum potential leachate leakage through the Landfill base liner. The maximum potential occurs when the minimum runoff occurs and when leachate generation is at its highest rate. Applying the results from this 'worst-case' scenario provides the most conservative estimate of the potential impacts to groundwater quality (i.e. the maximum contaminant mass loading with the least un-impacted runoff entering the groundwater mixing zone).

The following HELP model results were used in estimating the annual leachate leakage as well as the runoff rates using daily, intermediate, and final cover conditions (results shown in mm/yr):

- Total precipitation – 1,489 mm
- Runoff
  - Daily Cover – 59 mm
  - Intermediate Cover – 64 mm
  - Final Cover – 19 mm (direct runoff) & 1,057 mm (runoff from the sand drainage layer)
- Leachate Generation
  - Daily Cover – 1,138 mm
  - Intermediate Cover – 1,052 mm
  - Final Cover – 17 mm
- Leakage Through the Landfill
  - Daily Cover – 0.00581 mm
  - Intermediate Cover – 0.00534 mm
  - Final Cover – 0.00011 mm

In the 'worst-case' Landfill development scenario, Stage 1C, the approximate area that will be completed with daily, intermediate, and final cover will be 15,466 m<sup>2</sup>, 5,744 m<sup>2</sup>, and 0 m<sup>2</sup> respectively.

By multiplying the generation rates provided through HELP modeling by the anticipated area of the respective development type (daily, intermediate, or final), volumetric generation rates can be calculated for leachate generation, runoff, and leakage through the Landfill.

The total volume of leachate generation is estimated to be 23,643 m<sup>3</sup>/year (65 m<sup>3</sup>/day). Of the total leachate generated 0.121 m<sup>3</sup>/year (0.00033 m<sup>3</sup>/day) may potentially leak through the Landfill base and enter the mixing zone beneath the Landfill footprint. This leakage rate conservatively assumes no clogging of the pore space within the individual liner system materials will occur. The remaining leachate, which is the vast majority, will be collected and treated and will ultimately infiltrate into the mixing zone as treated effluent.

Of the total precipitation predicted to fall on the Landfill footprint approximately 3 m<sup>3</sup>/day will runoff of the Landfill during Stage 1C development as clean storm water. This runoff will be conveyed via

drainage ditches to the northeastern and northwestern corners of the Landfill footprint where it will infiltrate through the floor of the existing Pit and ultimately enter the mixing zone in the sand and gravel overburden aquifer.

#### 13.1.3 Infiltration from Treated Effluent

Based on the anticipated maximum leachate generation rates, it is expected that the maximum annual average daily leachate collection and treatment rate resulting from 1,489 mm of precipitation per year will be approximately 65 m<sup>3</sup>/day. As discussed earlier this which occurs during Stage 1C which will be active for less than 3 years under the modelled Landfill fill rate of 32,890 m<sup>3</sup>/year. This treated leachate infiltration rate represents a conservative long term estimate of leachate that will be removed from the Landfill and treated on a daily basis based on the 'worst-case' development scenario described above.

#### 13.1.4 Downgradient Precipitation

The final input into the Site's water balance is the infiltration of precipitation downgradient to each of the above sources. Precipitation that falls downgradient of the Landfill footprint and infiltration pond will provide an additional source of un-impacted water entering the mixing zone within upper 5 m of the shallow, sand and gravel, overburden aquifer.

Using the precipitation data from the Campbell River Airport Station (summarized in Table 2.1) it is estimated that 1,489 mm of precipitation will fall annually over the downgradient area. The downgradient area between the Landfill footprint and the southern Site boundary is approximately 78,400 m<sup>2</sup>.

In order to estimate the percentage of precipitation that will infiltrate into the mixing zone, an additional HELP model was created to simulate the undeveloped portion of the Site. This HELP model, included in Appendix F, shows that downgradient of the Landfill footprint, approximately 94 mm will result in runoff, 280 mm will be removed from the water balance through evapotranspiration, and the remaining 1,111 mm, or 74.6%, will infiltrate directly into the shallow overburden.

Thus, at a conservative infiltration rate of 74.6%, an additional 234 m<sup>3</sup>/day will enter the mixing zone.

### 13.2 Contaminant Mass Balance

To assess the future potential groundwater quality and identify any potential compliance issues at the Site boundary, future contaminant concentrations need to be calculated to compare against applicable regulatory standards (BC WQGs). In order to predict future groundwater contaminant concentrations, a generalized mass balance approach has been utilized 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 at various stages of groundwater flow across the Site. These contaminant mass inputs can then be divided over the total water inputs to derive future groundwater concentrations at the downgradient Site boundary.

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

$$\text{Mass of Chloride} = [Cl^-] * \text{groundwater flux}$$

Where:

$[Cl^-]$  = existing average concentration of chloride (from fall 2015 samples)

Similarly, the masses of potential contaminants can be calculated for the surface water runoff from the Landfill footprint and the precipitation that will infiltrate downgradient of the Landfill footprint. In order to estimate the quality of the runoff and precipitation infiltrating into the sand and gravel overburden aquifer, it is assumed that both will be characterized by similar concentrations to existing water quality.

$$\text{Mass of Chloride} = [Cl^-] * \text{total runoff from landfill footprint}$$

$$\text{Mass of Chloride} = [Cl^-] * \text{precipitation over downgradient area}$$

$[Cl^-]$  = existing median concentration of chloride (from the 2015 samples)

Using the forecasted leachate profile, discussed in Section 9, and the leakage rates calculated with the HELP model, forecasted effluent characteristics, and maximum daily flow into the infiltration pond 65 m<sup>3</sup>/day total contaminant mass loading can be calculated for the leachate and treated effluent inputs into the mixing zone. The treated effluent concentration used as inputs were the CSR schedule 6 standards as a conservative input to this assessment.

Table 13.1 provides a summary of the calculated contaminant mass for each input as well as the pre-landfilling groundwater quality, anticipated leachate concentrations, and forecasted treated leachate effluent concentrations.

### 13.3 Compliance Assessment

Adding the mass inputs from each of the 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:

$$\text{Forecasted Groundwater } [Cl^-] = \frac{Cl_{flux} + Cl_r + Cl_l + Cl_{eff} + Cl_{dwnprec}}{GW_{flux} + R + LL + Eff + DwnPrec}$$

Where:

$Cl_{flux}$  = existing mass of chloride from upgradient groundwater flow (calculated from the average pre-landfill concentrations)

$Cl_r$  = mass of chloride within the runoff (assumed to be at a concentration similar to pre-landfill groundwater)

$Cl_l$  = mass of chloride within the leachate (from the forecasted leachate quality)

$Cl_{eff}$  = mass of chloride with the treated leachate effluent (from the forecasted effluent quality)

$Cl_{downprec}$  = mass of chloride infiltrating the mixing zone in the downgradient precipitation

GWflux = volume of groundwater from upgradient flux

R = runoff from the Landfill footprint

LL = leachate leakage from the Landfill

Eff = infiltrating treated leachate effluent

Dwnprec = volume of precipitation infiltrating downgradient of the Landfill and infiltration pond

Table 13.1 provides a summary of the forecasted final contaminant concentrations at the downgradient Site boundary.

As shown in Table 13.1 the predicted concentration of each of the contaminant parameters is below its respective BCMOE Drinking Water Supply Guideline with the exceptions and manganese.

Analysis of the existing, pre-landfill groundwater samples indicates an average sulphide concentration of 0.0044 mg/L. Adding the mass of sulphide from leachate leakage and treated leachate (with concentrations reduced to match the BC CSR) results in a 'worst-case' range of 0.0042 – 0.0069 mg/L in groundwater at the downgradient property boundary. There is no Drinking Water Supply Guideline for sulphide.

Analysis of the existing 2015 pre-landfill groundwater samples indicates an average concentration of manganese in pre-landfilling water quality exceed the Drinking Water Supply Guidelines with an average concentration 0.051 mg/L. 'Worst-case' concentrations are predicted to range from 0.054 to 0.079 mg/L at the downgradient Site boundary. Thus, the potential concentrations of manganese in groundwater may be above the Drinking Water Supply Guidelines of 0.05 mg/L.

## 14. Environmental Monitoring Program (EMP)

The EMP for the Site is developed to ensure performance and compliance criteria are met and to help prevent unacceptable environmental impacts throughout the lifespan of the Landfill through to post-closure. The EMP must be developed in accordance with the following documents:

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

The monitoring program summarized herein includes leachate, groundwater, surface water, soil gas, and refuse/soil volume monitoring. The monitoring program 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 findings during routine inspections, monitoring events and any other information related to the effect of discharge on the receiving environment.

### 14.1 Leachate Monitoring

The objective of the leachate monitoring program is to provide data on the quality and quantity of leachate generated at the Site. Leachate monitoring data is used to assess potential impacts to the receiving environment and ensure the treatment methods are appropriate.

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 quarterly. Once annually, the samples collected will be analysed for a comprehensive set of parameters. At the three remaining monitoring events, the list of parameters may be reduced.

The sample 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.

## 14.2 Groundwater

The objective of the groundwater monitoring program is to detect the extent and magnitude of potential contamination to groundwater associated with landfilling activities, ensure regulatory compliance, and to identify the need to mitigate potential environmental risk.

The groundwater monitoring program will include five wells MW2-14, MW 2A-16, MW4A-15, MW4B-15, future downgradient compliance well, and one residential well (#98020) located on an upgradient property on Gold River Highway. Groundwater monitoring locations are shown on Figure 14.1 and monitoring well completion details are presented on Table 14.1. Groundwater samples will be collected quarterly at the five wells and annually at the residential well.

Water levels were measured during the baseline monitoring events in September 2015, October 2015, January 2016, and February 2016. The recorded water levels are also presented in Table 14.1.

## 14.3 Surface Water

The objective of the surface water monitoring program is to obtain supplementary information to characterize background water quality, in addition to the upgradient residential well. The two surface water lakes in the vicinity of the Landfill, Rico Lake and McIvor Lake, are both upgradient of the Site and recharge to the aquifer underlying the Site, as discussed in Section 2. The location of the lakes and the monitoring locations are shown on Figure 14.1. Additional surface water sampling location may be required within the surface water ditches on the east and west side of the Landfill, when water is present.

## 14.4 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

## 14.5 LFG Monitoring

LFG monitoring is required to ensure the health and safety of the Upland staff, users of the Site and the public. The LFG monitoring will be conducted annually using subsurface 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 10.7

#### 14.6 Refuse/Soil Volume Monitoring

A 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.

#### 14.7 Inspection and Record Keeping

Regular Landfill inspections will be conducted by Landfill personnel to verify that nuisance factors associated with the Landfill are minimized. Regular housekeeping procedures will be inspected to ensure nuisances such as dust, litter, and odour, are under control. 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.

#### 14.8 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 facilities for the year including tonnage received, sorted and processed at the material recovery facility, stored on-Site, and discharged to the selected waste Landfill
- Remaining selected waste Landfill life and capacity
- Leachate management 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 this operational certificate, an action plan and schedule to achieve compliance
- 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 also 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. As such, 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 noted and 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. As such, the followings 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 thermisters

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 greatly 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). It is noted that the use of low permeability cover material in combination with the application of water may 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 should be undertaken with great 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

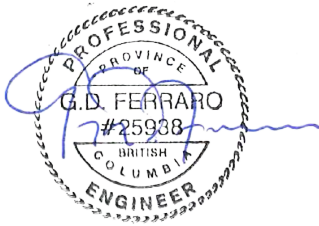
A Fire Safety and Emergency Contingency Plan has been developed for the Site operating in accordance with the BC Occupational Health and Safety Regulation 296/97 Part 4, S.4.13 - 4.18 (Emergency Preparedness and Response) and Part 5, s.5.97 - 5.102 (Emergency Procedures), as well as Section 2.8 of the 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 Fire Safety and Emergency Contingency Plan is provided in Appendix G. This plan will be reviewed and updated at least once annually.

All of which is Respectfully Submitted,  
GHD

A handwritten signature in black ink, appearing to read "Shauna Sturgeon".

Shauna Sturgeon, B.Sc.Eng.



Gregory D. Ferraro, P. Eng.

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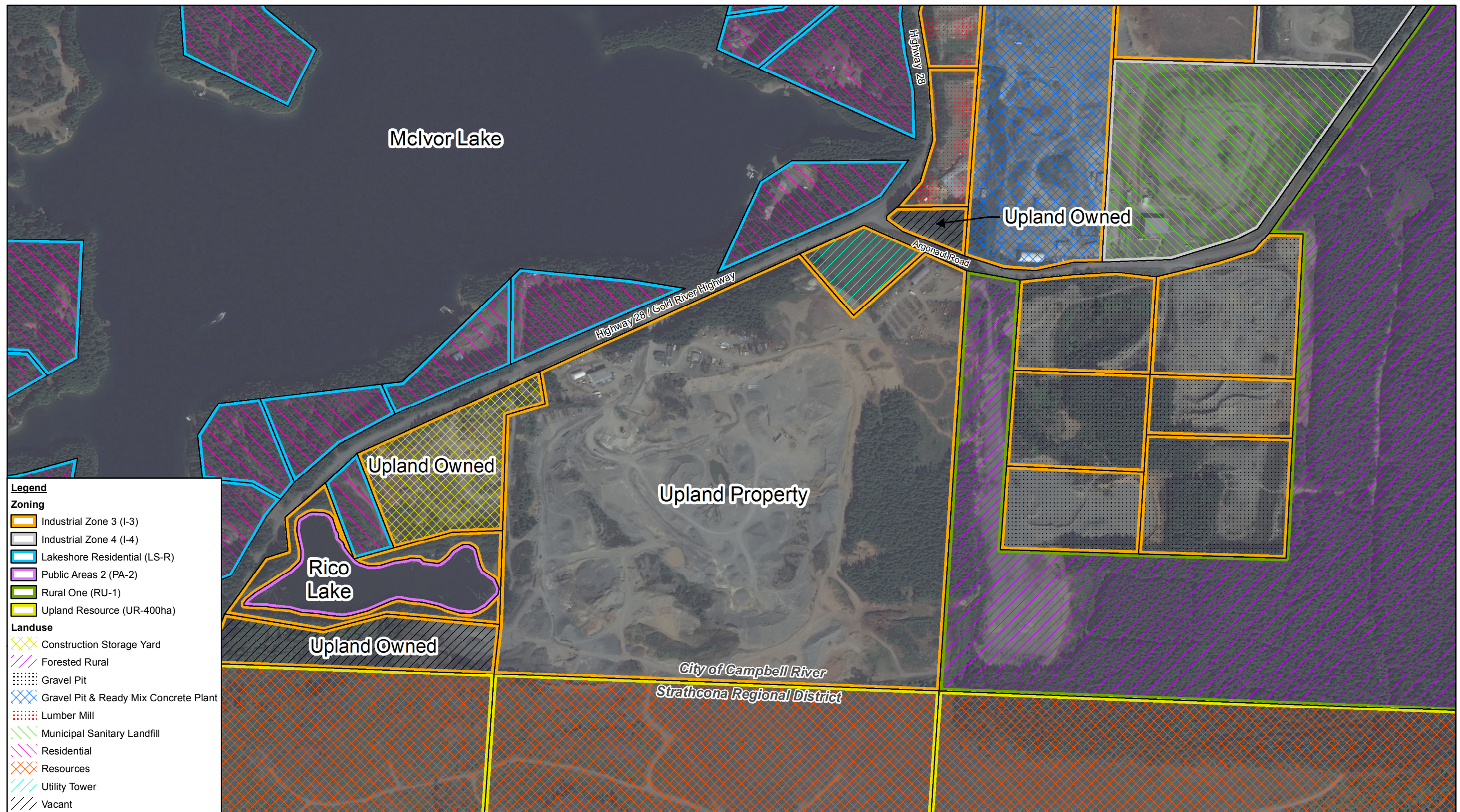
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0 60 120 180  
Meters  
Coordinate System:  
NAD 1983 UTM Zone 10N



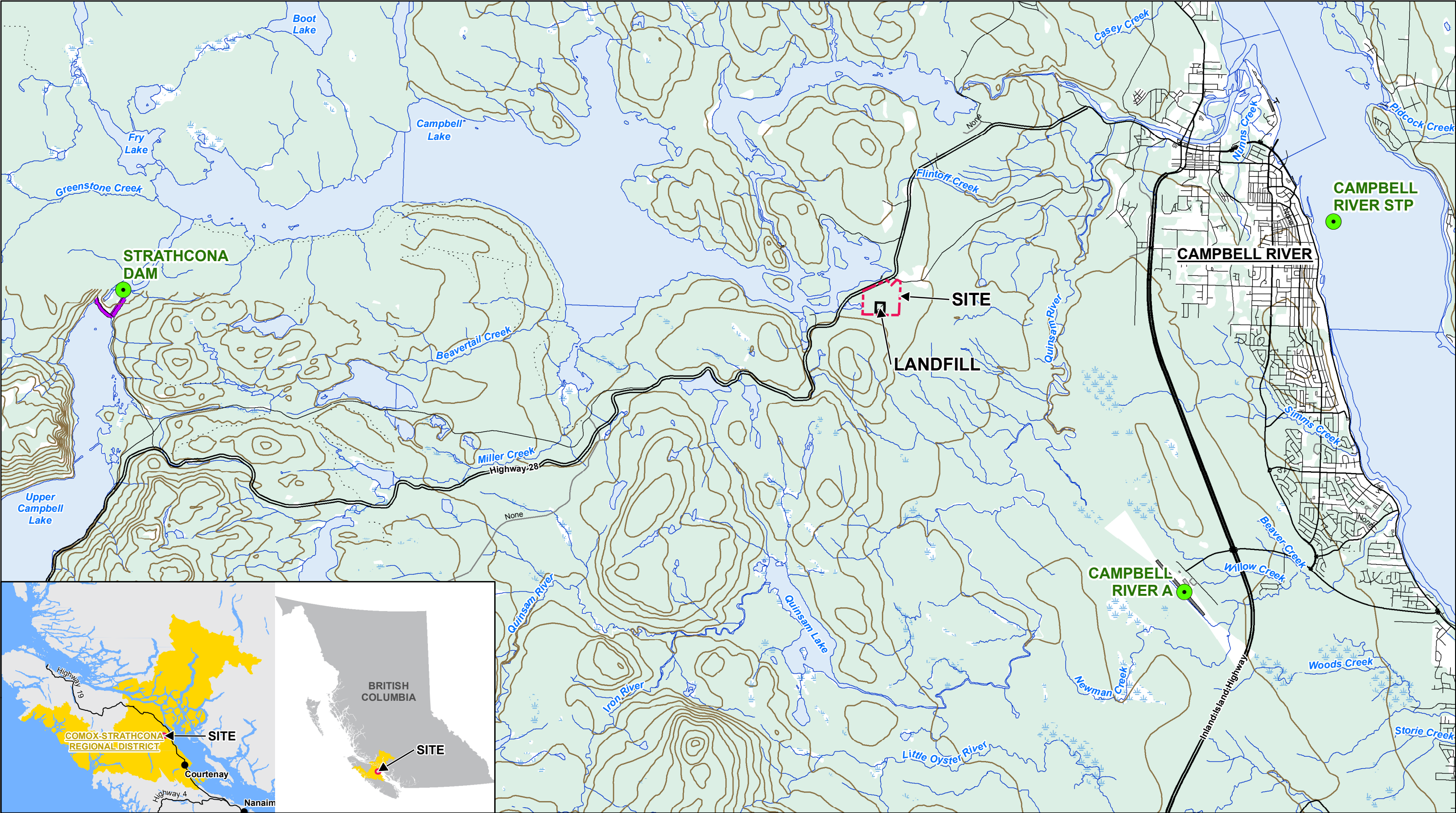
UPLAND EXCAVATING LTD.  
UPLAND LANDFILL, CAMPBELL RIVER, BRITISH COLUMBIA  
DESIGN, OPERATIONS, AND CLOSURE PLAN

ADJACENT LAND USES AND ZONING

088877-02  
May 27, 2016

FIGURE 1.2





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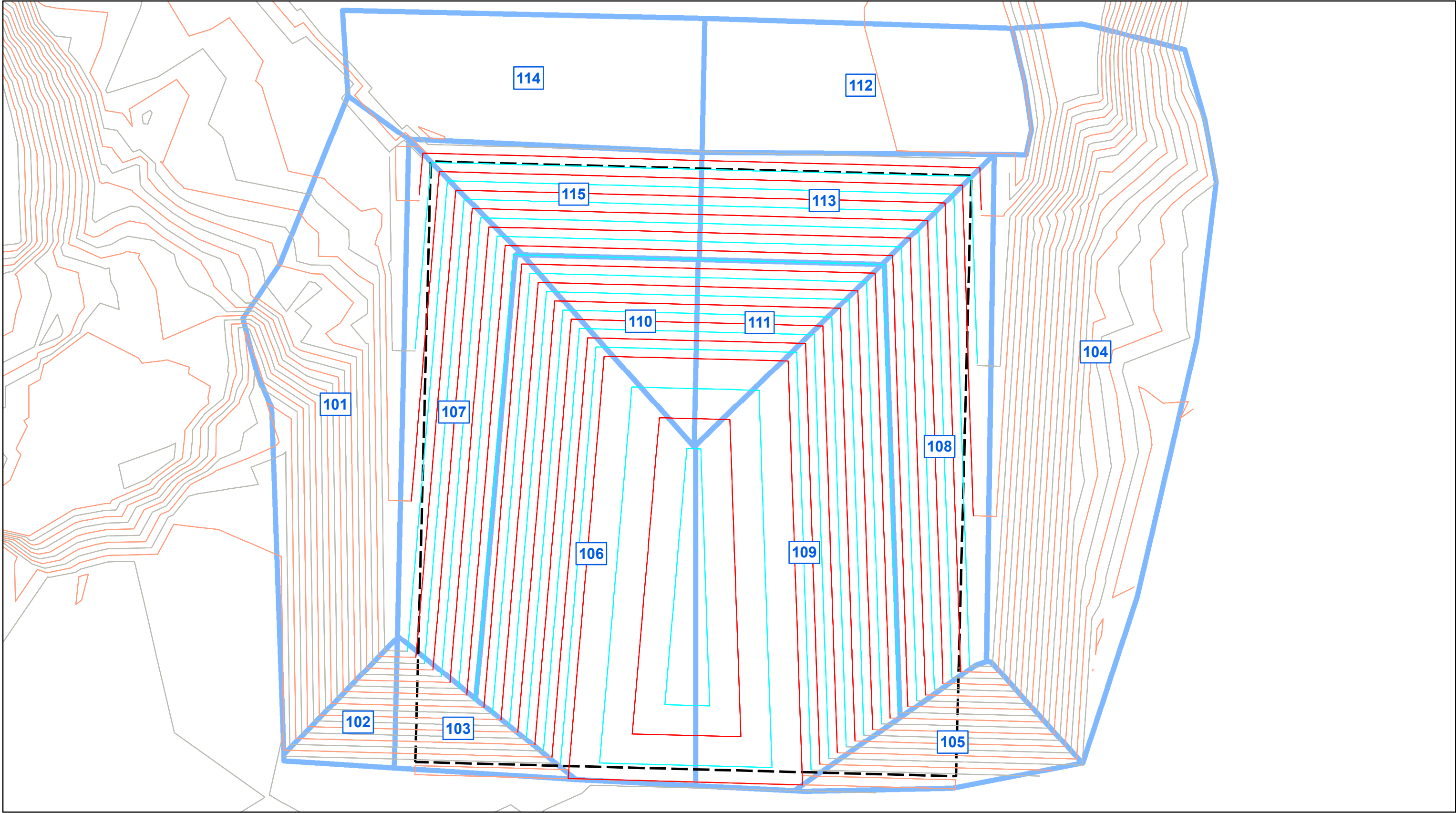


UPLAND EXCAVATING LTD.  
UPLAND LANDFILL, CAMPBELL RIVER, BRITISH COLUMBIA  
DESIGN, OPERATIONS, AND CLOSURE PLAN

SITE LOCATION & IDF STATION LOCATIONS

088877-02  
May 27, 2016

FIGURE 8.1



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0122436

Meters

Coordinate System:  
NAD 1983 UTM Zone 10N

N

**Legend**

--- Limit of Waste

Subcatchment

GHD

UPLAND EXCAVATING LTD.  
UPLAND LANDFILL, CAMPBELL RIVER, BRITISH COLUMBIA  
DESIGN, OPERATIONS, AND CLOSURE PLAN

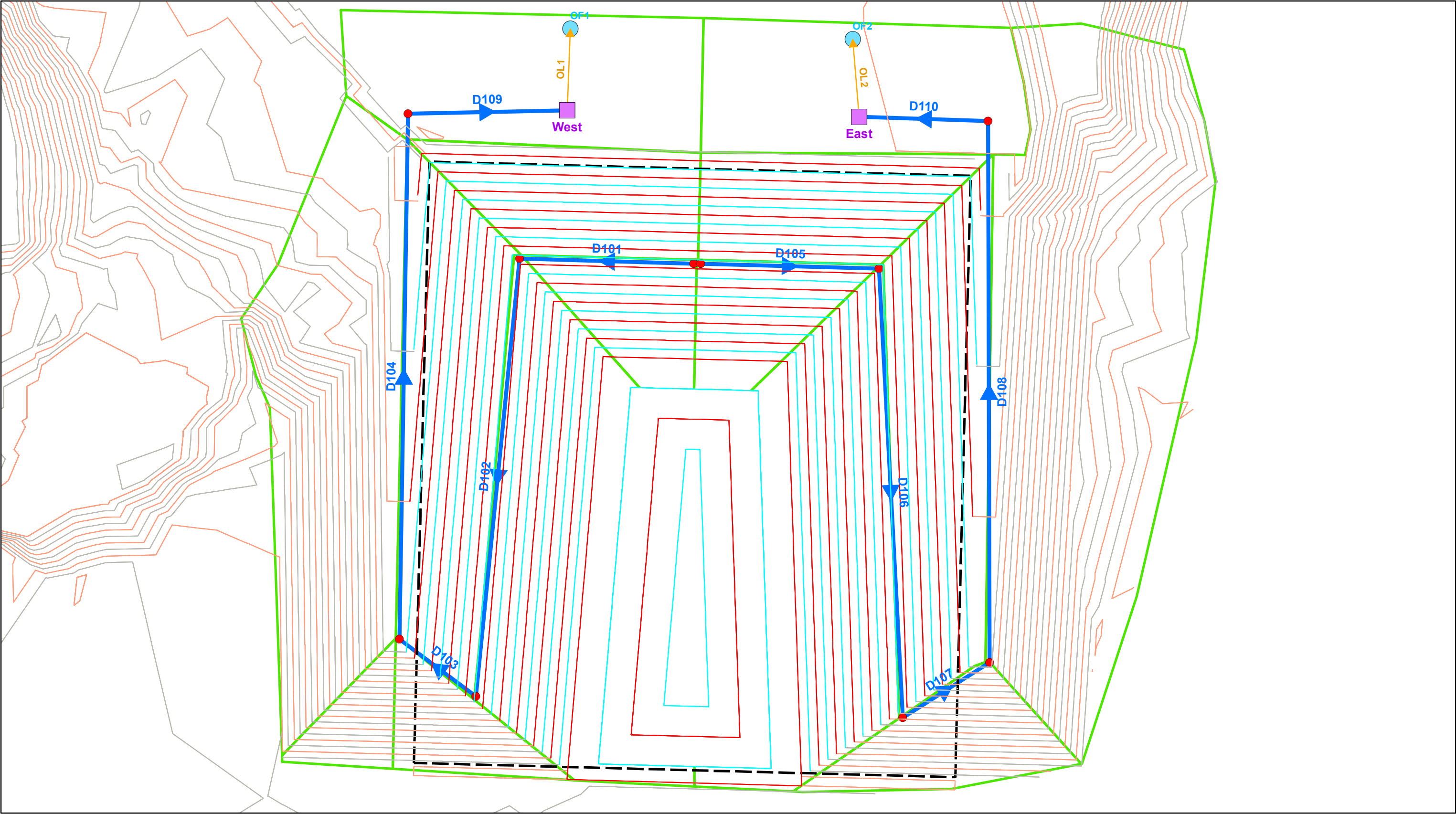
SURFACE WATER CATCHMENT BOUNDARIES

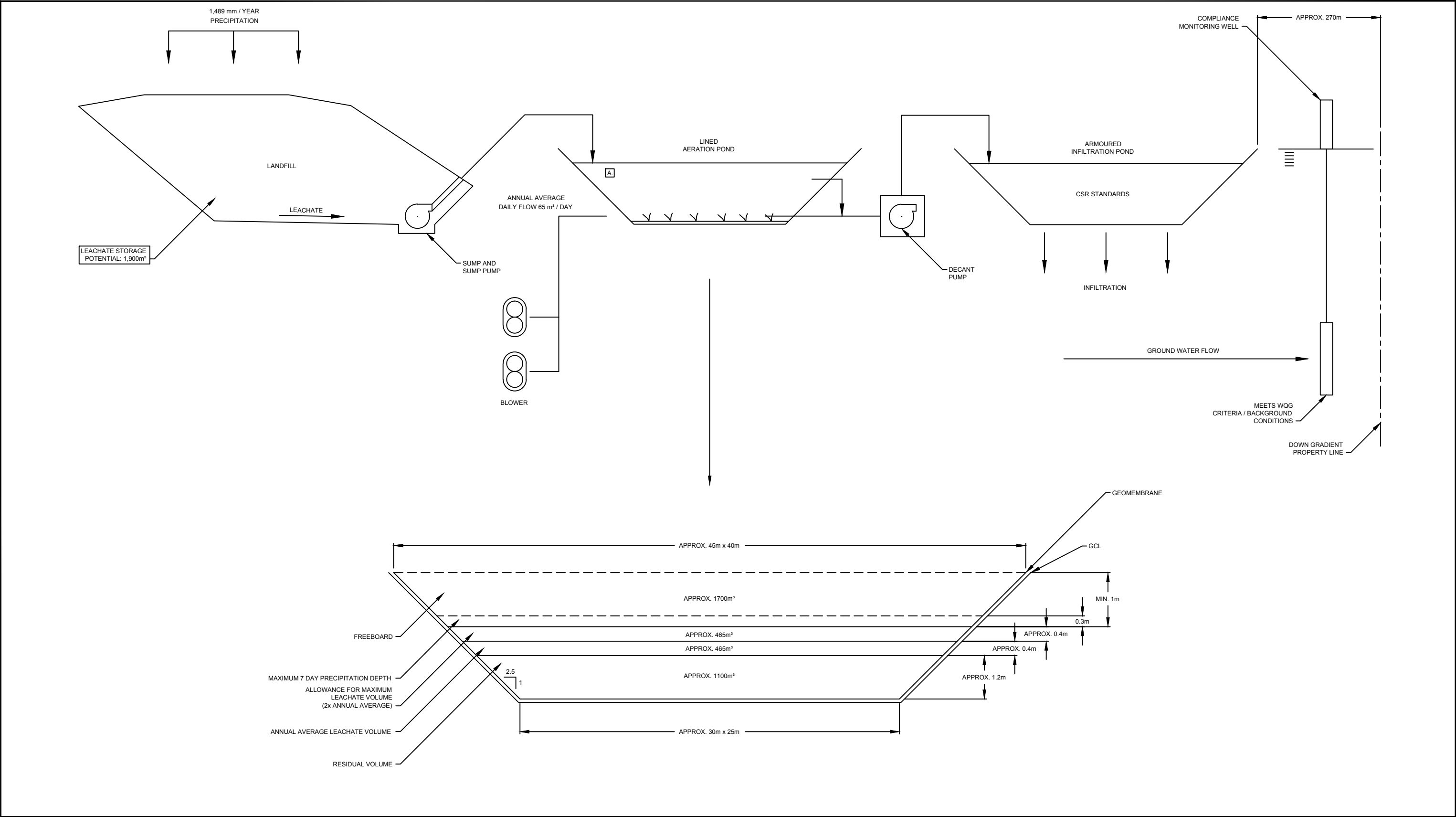
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FIGURE 8.2

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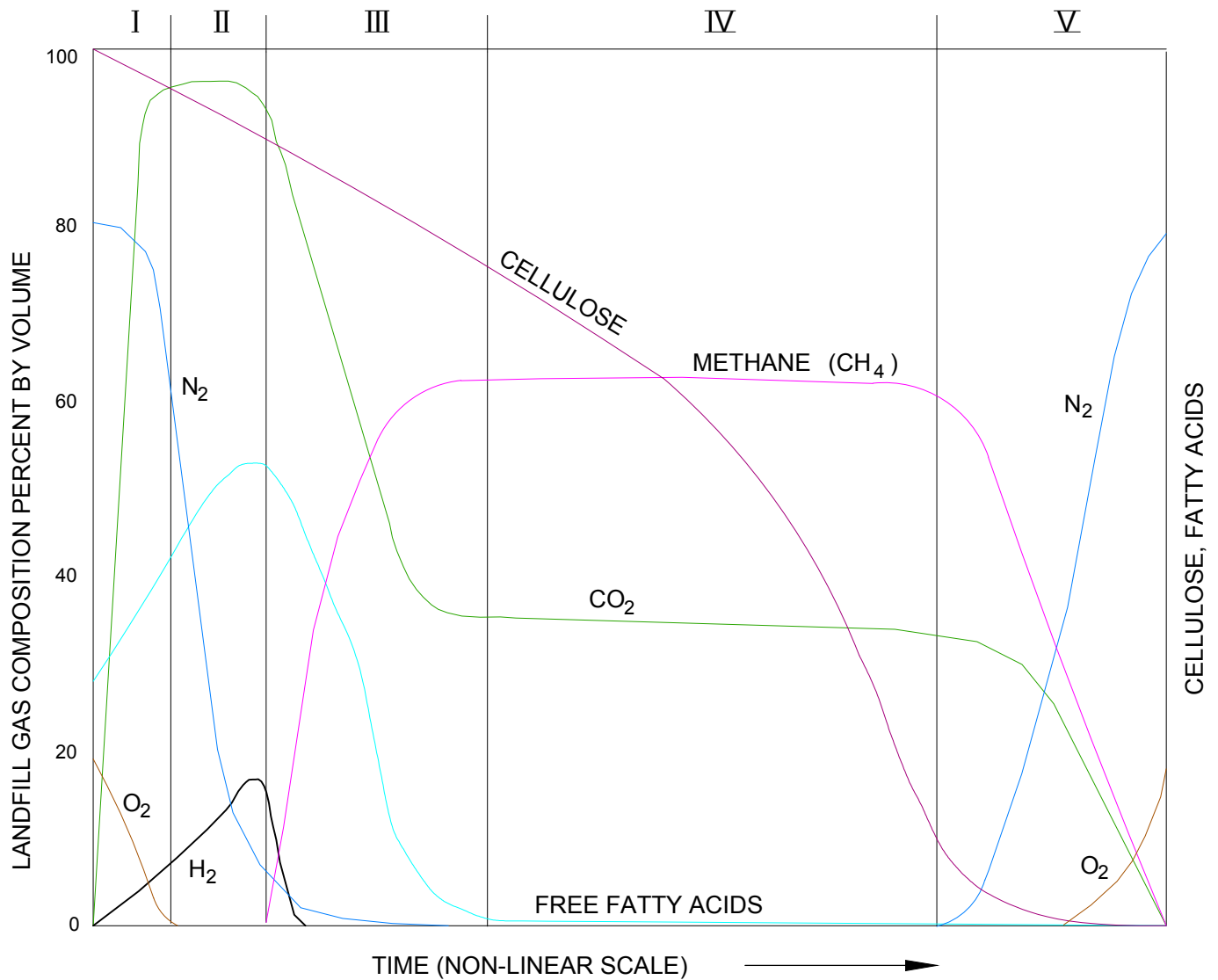


UPLAND EXCAVATING LTD.  
PROPOSED UPLAND LANDFILL  
DESIGN, OPERATION, AND CLOSURE PLAN  
LEACHATE TREATMENT FLOW SCHEMATIC  
CONCEPTUAL LEACHATE TREATMENT FACILITY

PROJECT NO.  
May 17, 2016

FIG. 9.1

# LANDFILL GAS PRODUCTION PATTERN PHASES



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:

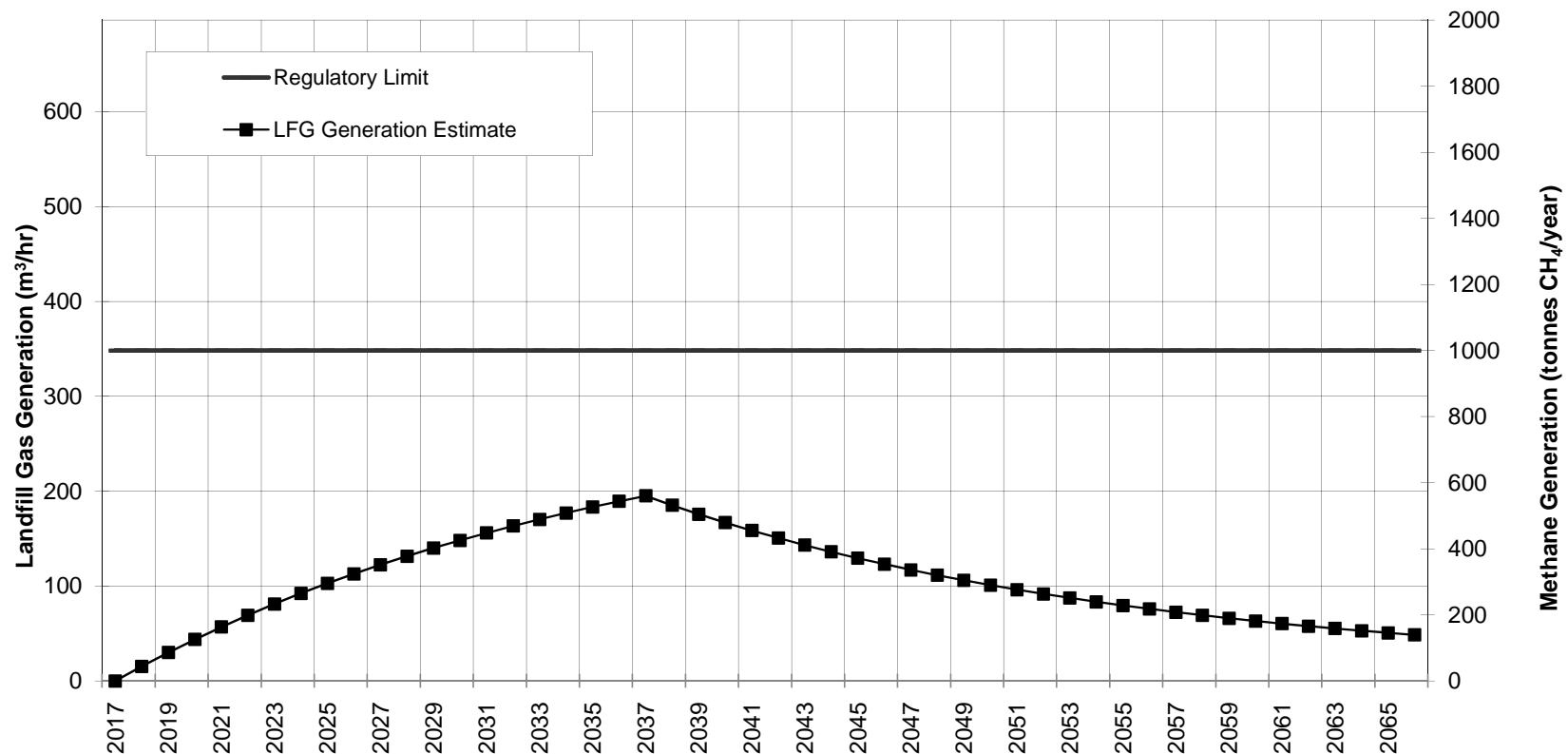
FARQUHAR AND ROVERS, 1973,  
AS MODIFIED BY REES, 1980,  
AND AUGENSTEIN & PACEY, 1991.



UPLAND EXCAVATING LTD.  
PROPOSED UPLAND LANDFILL  
DESIGN, OPERATIONS AND CLOSURE PLAN  
TYPICAL LANDFILL GAS  
PRODUCTION STAGES

88877-01  
Feb 12, 2016

FIG. 10.1



k values (year <sup>-1</sup> )	0.02, 0.06, 0.11	<u>Waste Composition</u>	
L <sub>0</sub> (weighted) (m <sup>3</sup> CH <sub>4</sub> /tonne)	20, 120, 160	Relatively Inert (%)	50.0%
Precipitation (mm/year)	1,489	Moderately Decomposable (%)	50.0%
Volumetric LFG Composition (percent methane)	50%	Decomposable (%)	0.0%



**figure 10.2**  
**LANDFILL GAS GENERATION ESTIMATE**  
**DESIGN, OPERATIONS, AND CLOSURE PLAN**  
**UPLAND LANDFILL**  
*Upland Excavations Ltd.*





Table 2.1

**Climate Data**  
**2016 Design, Operations and Closure Plan**  
**Upland Landfill**  
**Campbell River, British Columbia**

<b>Month</b>	<b>Daily Average Temperature (Celcius)</b>	<b>Daily Maximum Temperature (Celcius)</b>	<b>Daily Minimum Temperature (Celcius)</b>	<b>Rainfall (mm)</b>	<b>Snowfall (cm) <sup>1</sup></b>	<b>Precipitation (mm) <sup>1</sup></b>	<b>Average Relative Humidity (0600LST) (%)</b>	<b>Average Relative Humidity (1500LST) (%)</b>
January	2.4	5.5	-0.8	194.6	23.3	217.5	93	84.9
February	3.2	7.2	-0.7	135.5	14.4	149.5	92.4	75.1
March	5.2	9.7	0.7	128.4	11.7	140	91.4	67.8
April	8	13.2	2.8	91.6	0.5	92.1	90.2	59.6
May	11.6	17	6.2	68.4	0	68.4	86.5	57.2
June	14.7	20.1	9.3	62.9	0	62.9	83.7	57.6
July	17.3	23	11.5	39.4	0	39.4	83.8	54.4
August	17.2	23.3	11.1	44.6	0	44.6	87.8	55.1
September	13.7	19.8	7.6	55.2	0	55.2	91.5	59.1
October	8.6	13.1	4.0	161	1.2	162.2	93.3	74
November	4.4	7.7	1.0	222.1	10.5	231.9	93	83.3
December	2.1	4.9	-0.8	204.2	22.6	225.7	92.6	86.3
<b>Annual</b>	<b>9.0</b>	<b>13.7</b>	<b>4.3</b>	<b>1407.9</b>	<b>84.2</b>	<b>1489.4</b>	<b>89.9</b>	<b>67.9</b>

Notes:

Source: Environment Canada: Climate Normals - Campbell River Airport (Station No. - 1021261), 1981 - 2010 Station Data

<sup>1</sup> 1 cm of snowfall corresponds to 1 mm of precipitation

**Average Annual Tonnes of Waste to be Disposed in Landfill**  
**2016 Design, Operations and Closure Plan**  
**Upland Landfill**  
**Campbell River, British Columbia**

<b>Year</b>	<b>Forecasted Average Annual Waste Disposal Rate (Tonne)</b>	<b>Forecasted Cumulative Waste Disposed (tonnes)</b>	<b>Forecasted Average Annual Airspace Consumption (m³)</b>	<b>Forecasted Cumulative Airspace Consumption (m³)</b>
2017	32890	32890	25,300	25,300
2018	32890	65780	25,300	50,600
2019	32890	98670	25,300	75,900
2020	32890	131560	25,300	101,200
2021	32890	164450	25,300	126,500
2022	32890	197340	25,300	151,800
2023	32890	230230	25,300	177,100
2024	32890	263120	25,300	202,400
2025	32890	296010	25,300	227,700
2026	32890	328900	25,300	253,000
2027	32890	361790	25,300	278,300
2028	32890	394680	25,300	303,600
2029	32890	427570	25,300	328,900
2030	32890	460460	25,300	354,200
2031	32890	493350	25,300	379,500
2032	32890	526240	25,300	404,800
2033	32890	559130	25,300	430,100
2034	32890	592020	25,300	455,400
2035	32890	624910	25,300	480,700
2036	32890	657800	25,300	506,000
<b>Total</b>	<b>657,800</b>		<b>506,000</b>	

Apparent Density <sup>1</sup>

1.3 tonnes/m³

<sup>1</sup>Average Apparent Density of the following waste streams

1) Waste Soil Typical Average Apparent Density - 1.6 tonne/m³

2) Construction and Demolition Waste Typical Average Apparent Density - 1.0 - 1.2 tonne/m³

Table 5.1

**Landfill Stages**  
**2016 Design, Operations and Closure Plan**  
**Upland Landfill**  
**Campbell River, British Columbia**

<b>Phase</b>	<b>Stage</b>	<b>Approximate Cumulative Airspace (m<sup>3</sup>)</b>	<b>Approximate Airspace Per Stage (m<sup>3</sup>)</b>	<b>Tonnes per Stage <sup>1</sup></b>	<b>Cumulative Tonnes</b>
1	1A	69,500	69,500	90,350	90,350
1	1B	141,000	71,500	92,950	183,300
1	1C	201,600	60,600	78,780	262,080
2	2A	276,100	74,500	96,850	358,930
2	2B	336,200	60,100	78,130	437,060
2	2C	367,300	31,100	40,430	477,490
3	3A	431,300	64,000	83,200	560,690
3	3B	469,000	37,700	49,010	609,700
3	3C	506,000	37,000	48,100	657,800
		<b>506,000</b>		<b>657,800</b>	

Apparent Density <sup>1</sup> = 1.3 tonnes/m<sup>3</sup>

Table 5.2

**Material Requirement**  
**2016 Design, Operations and Closure Plan**  
**Upland Landfill**  
**Campbell River, British Columbia**

		Cell Construction			Operations		Final Cover		
		Area	Volume		Volume		Area	Volume	
		Base Liner		Non-Woven Geotextile (m²) Drain Rock (m³)	Intermediate		Final Cover		
		Geomembrane			Daily Cover	Cover Volume	GCL Area	Final Cover	Final Cover
Phase	Stage	Area (m²)			Volume (m³)¹	(m³)	(m²)	Sand (m³)	Topsoil (m³)
1	1A	21,539	24,242	3,636	5,792	0	0	0	0
1	1B	0	18,836	2,825	5,958	3,615	0	0	0
1	1C	0	0	0	5,050	1,784	0	0	0
2	2A	9,684	19,368	2,905	6,208	2,291	10,488	7,866	1,573
2	2B	0	0	0	5,008	2,666	0	0	0
2	2C	0	0	0	2,592	1,785	0	0	0
3	3A	2,349	4,698	705	5,333	0	8,384	6,288	1,258
3	3B	0	0	0	3,142	0	0	0	0
3	3C	0	0	0	3,083	0	15,111	11,333	2,267
Total		33,572	67,144	10,072	42,167	12,140	33,983	25,487	5,097

<sup>1</sup>Waste to Daily Cover Ratio of 12:1

Table 8.1

**Design Storm Parameters**  
**2016 Design, Operations and Closure Plan**  
**Upland Landfill**  
**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	6	81.2	12.75	24
10-year	SCS Type 1A	77.7	10	6	90.1	14.15	24
100-year	SCS Type 1A	101.9	10	6	118.2	18.56	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.

Table 8.2

**Post Development Conditions Catchment Parameters  
2016 Design, Operations and Closure Plan  
Upland Landfill  
Campbell River, British Columbia**

Subcatchment ID	Area (ha)	Flow length (m)	Slope (%)	Imperviousness (%)	Manning' n		Depression Storage		Infiltration	
					Impervious	Pervious	Impervious (mm)	Pervious (mm)	Maximum (mm/hr)	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
112	0.46	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
114	0.50	25	15	100	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
<b>Total</b>	<b>7.38</b>									

**Post Development Conditions Peakflow Summary**  
**2016 Design, Operations and Closure Plan**  
**Upland Landfill**  
**Campbell River, British Columbia**

<b>Subcatchment ID</b>	<b>5-year (m<sup>3</sup>/s)</b>	<b>10-year (m<sup>3</sup>/s)</b>	<b>100-year (m<sup>3</sup>/s)</b>
101	0.03	0.03	0.04
102	0.00	0.00	0.00
103	0.00	0.01	0.01
104	0.05	0.05	0.07
105	0.01	0.01	0.01
106	0.03	0.04	0.05
107	0.02	0.02	0.03
108	0.02	0.02	0.03
109	0.03	0.04	0.05
110	0.01	0.01	0.01
111	0.01	0.01	0.01
112	0.02	0.02	0.02
113	0.01	0.01	0.01
114	0.02	0.02	0.03
115	0.01	0.01	0.01

**Table 8.4**

**Post Development Conditions Runoff Volume Summary  
2016 Design, Operations and Closure Plan  
Upland Landfill  
Campbell River, British Columbia**

<b>Subcatchment ID</b>	<b>5-year (m<sup>3</sup>)</b>	<b>10-year (m<sup>3</sup>)</b>	<b>100-year (m<sup>3</sup>)</b>
101	580	650	870
102	60	70	90
103	100	110	150
104	990	1110	1490
105	150	170	220
106	690	770	1040
107	370	420	560
108	380	430	570
109	660	750	1000
110	130	150	200
111	140	150	210
112	370	410	540
113	210	230	310
114	400	450	590
115	210	230	310



Table 8.5

Channel Performance Summary  
2016 Design, Operations and Closure Plan  
Upland Landfill  
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	100-Year Storm					Recommended Channel Lining
									Max. Flowrate (m³/s)	Max. Velocity (m/s)	Max. Depth (m)	Minimum Freeboard (m)	Max. Shear Stress (Pa)	
D101	58	0.003	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.02	0.02	0.18	0.33	6	Vegetation, Unreinforced
D102	146	0.002	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.07	0.11	0.16	0.34	3	Vegetation, Unreinforced
D103	32	0.261	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.07	0.01	0.11	0.39	281	FLEXMAT
D104	175	0.017	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.14	0.08	0.15	0.36	24	Vegetation, Unreinforced
D105	59	0.003	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.00	0.00	0.13	0.38	4	Vegetation, Unreinforced
D106	150	0.002	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.05	0.07	0.14	0.37	3	Vegetation, Unreinforced
D107	34	0.241	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.06	0.01	0.11	0.39	259	FLEXMAT
D108	180	0.017	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.15	0.08	0.15	0.36	24	Vegetation, Unreinforced

Table 8.6

**Post-Closure Infiltration Pond Performance Summary**  
**2016 Design, Operations and Closure Plan**  
**Upland Landfill**  
**Campbell River, British Columbia**

**West Infiltration Pond**

Design Storm	Peak Inflow (m <sup>3</sup> /s)	Infiltration Discharge (m <sup>3</sup> /s)	Maximum Depth (m)	Maximum Elevation (AMSL m)	Maximum Storage (m <sup>3</sup> )	Minimum Freeboard (m)	Duration Time (Hour)
5-Year	0.13	0.044	0.16	167.46	439	0.84	12
10-Year	0.14	0.044	0.20	167.50	558	0.80	15
100-Year	0.19	0.044	0.36	167.66	1050	0.64	23

**East Infiltration Pond**

Design Storm	Peak Inflow (m <sup>3</sup> /s)	Infiltration Discharge (m <sup>3</sup> /s)	Maximum Depth (m)	Maximum Elevation (AMSL m)	Maximum Storage (m <sup>3</sup> )	Minimum Freeboard (m)	Duration Time (Hour)
5-Year	0.13	0.044	0.17	167.47	475	0.83	12
10-Year	0.15	0.044	0.21	167.51	600	0.79	16
100-Year	0.19	0.044	0.38	167.68	1130	0.62	24

Table 9.1  
Forecasted Leachate Quality Profile  
2016 Design, Operations and Closure Plan  
Upland Landfill  
Campbell River, British Columbia

Parameters	Units	Historical Results from Similar Landfills for Comparison								Forecasted Upland Landfill Leachate Concentrations			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)	HWMF Highest Concentration Observed in Leachate 2012 - 2015(3)	Confiential BC Contaminated Soil Landfill - Average Concentrations Observed in Leachate 2012 <sup>(14)</sup>	Confiential BC Contaminated Soil Landfill - Average Concentration Observed in Leachate 2013 <sup>(16)</sup>	Highest observed - C&D Levis Landfill, Quebec 2003 <sup>(4)</sup>	Highest observed - Mayer Waste Disposal Site 1994-2001 <sup>(5)</sup>	Highest observed - Inter-Recycling Systems Landfill <sup>(6)</sup>				Maximum Percent Reduction From Leachate Treatment	Maximum Concentration Reduction Resulting From Leachate Treatment		
											Minimum	Maximum	Schedule 6 DW			Minimum
GENERAL CHEMISTRY																
Alkalinity (total)	mg/L	327	1152	2670	-	-	--	1550	3050	500	2500	-	90%	2250	50	250
Ammonia-N	mg/L	1.07	20.1	45.6	24.1	25.7	--	27	--	1	30	-	90%	27	0.10	3
BOD	mg/L	8.3	13.5	18.9	9	10	17	69	648	10	50	-	65%	32.5	3.5	17.5
Chloride (Cl) (dissolved)	mg/L	75	1642	4300	710	667	243	98.9	702	100	1500	250	83%	1250	16.7	250
COD	mg/L	52	431	1450	300	390	132	517	--	50	500	-	70%	350	15	150
Conductivity <sup>(4)</sup>	us/cm	1800	7974	25100	4100	3920	--	2730	6900	200	7500	-	-	-	200	7500
Hardness	mg/L	581	1855	4980	980	1050	--	1341	3100	750	2500	-	-	-	750	2500
pH <sup>(4)</sup>	pH units	6.84	7.35	8.06	7.02	6.88	6.2-7.3	6.2-7.1	6.1-8.4	6	8	-	-	-	6	8
Phenols	mg/L	0.005	0.044	0.096	-	-	0.026	0.0075	0.172	0.005	0.1	-	90%	0.09	0.0005	0.01
Sulphate (SO4)	mg/L	36	529	1770	40	40	742	521	356	50	1000	500	50%	500	25	500
Sulphide	mg/L	0.023	1.979	7	-	-	-	-	-	0.1	5	0.05	99%	4.95	0.001	0.05
Total Suspended Solids (TSS)	mg/L	13.7	27.2	39.2	100	237	-	-	-	10	150	-	50%	75	5	75
Total Dissolved Solids (TDS)	mg/L	1180	5742	18400	-	-	-	-	-	2000	10000	-	50%	5000	1000	5000
Total Kjeldahl Nitrogen (TKN)	mg/L	2.89	26.3	61.3	36.1	43.1	-	-	-	3	60	-	65%	39	1.05	21
Phosphorus	mg/L	0.08	0.31	0.83	0.2 <sup>(15)</sup>	-	-	-	-	0.1	0.5	-	-	-	0.1	0.5
HYDROCARBONS																
HEPH	mg/L	0.49	1.10	2.21	-	-	-	-	-	0.5	2	-	-	-	0.5	2
LEPH	mg/L	0.36	1.08	2.54	-	-	-	-	-	0.5	2	-	75%	1.5	0.125	0.5
METALS																
Aluminum (Dissolved)	mg/L	0.022	0.063	0.124	0.100	0.070				0.01	0.1		-	-	0.01	0.1
Arsenic	mg/L	0.001	0.009	0.022	0.008	0.042	-	0.001	0.019 <sup>(10)</sup>	0.001	0.04	0.01	75%	0.03	0.00025	0.01
Arsenic (Dissolved)	mg/L	0.006	0.010	0.020	0.003	0.003				0.001	0.04		75%	0.03	0.00025	0.01
Barium	mg/L	0.060	0.284	0.571	1.000	3.760	-	-	0.97	0.05	0.7	1	-	-	0.05	0.7
Barium (Dissolved)	mg/L	0.059	0.289	0.571	0.550	0.724				0.05	0.7		-	-	0.05	0.7
Boron	mg/L	1.74	7.81	13.6	10.4	10.9	-	-	-	5	10	5	50%	5	2.5	5
Boron (Dissolved)	mg/L	1.71	7.78	13.3	11.4	11.4				5	10		50%	5	2.5	5
Cadmium	mg/L	0.0001	0.0001	0.0001	0.0003	0.0003	<0.001	0.0006	0.005	0.0001	0.0003	0.005	-	-	0.0001	0.0003
Cadmium (Dissolved)	mg/L	0.0001	0.0001	0.0001	0.0005	0.0005				0.0001	0.0003		-	-	0.0001	0.0003
Calcium	mg/L	179	548	1520	262	288	-	376	720	200	700	-	-	-	200	700
Calcium (Dissolved)	mg/L	179	550	1540	243	226				200	700		-	-	200	700
Chromium	mg/L	0.002	0.011	0.022	0.006	0.020	0.11	0.054	0.241	0.005	0.05	0.05	-	-	0.005	0.05
Chromium (Dissolved)	mg/L	0.001	0.009	0.020	0.007	0.007				0.005	0.05		-	-	0.005	0.05
Cobalt	mg/L	0.001	0.002	0.007	0.003	0.005	-	0.02	0.018	0.001	0.01	-	-	-	0.001	0.01
Cobalt (Dissolved)	mg/L	0.001	0.002	0.005	0.003	0.004				0.001	0.01		-	-	0.001	0.01
Copper	mg/L	0.002	0.043	0.165	0.007	0.023	0.32	0.06	0.067	0.005	0.05	1	-	-	0.005	0.05
Copper (Dissolved)	mg/L	0.007	0.031	0.076	0.007	0.007				0.005	0.05		-	-	0.005	0.05
Iron	mg/L	0.418	5.46	25.5	47.6	267	69	65	180	1	70	6.5	91%	63.5	0.09	6.5
Iron (Dissolved)	mg/L	0.032	3.31	26.4	0.130	2.39				0.1	7		7%	0.5	0.09	6.5
Lead	mg/L	0.0015	0.0024	0.003	0.001	0.038	<0.05	0.062	0.053	0.001	0.01	0.01	-	-	0.001	0.01
Lead (Dissolved)	mg/L	--	--	--	0.001	0.001				0.001	0.01		-	-	0.001	0.01
Magnesium	mg/L	30	115	265	77.8	77.7	-	111	365	30	300	100	67%	200	10	100
Magnesium (Dissolved)	mg/L	30	118	274	75.7	71.2				30	300		67%	200	10	100
Manganese	mg/L	0.300	1.93	4.00	1.47	0.846	-	6.01	2.62	1	5	0.55	89%	4.45	0.11	0.55
Manganese (Dissolved)	mg/L	0.297	1.81	4.03	1.31	0.360				1	5		89%	4.45	0.11	0.55
Mercury	mg/L	--	--	--	0.00003	0.00001	<0.0002	<0.00005	<0.00005	0.00001	0.00003	0.001	-	-	0.00001	0.00003
Mercury (Dissolved)	mg/L	--	--	--	0.00001	0.00001				0.00001	0.00001		-	-	0.00001	0.00001
Molybdenum	mg/L	0.0017	0.0018	0.0019	0.001	0.001	-	<0.05	0.006	0.001	0.002	0.25	-	-	0.001	0.002
Molybdenum (Dissolved)	mg/L	0.0012	0.0016	0.0020	0.001	0.001				0.001	0.002		-	-	0.001	0.002
Nickel	mg/L	0.0075	0.0120	0.0199	0.020	0.017	0.13	0.02	0.086	0.0075	0.02	-	-	-	0.0075	0.02
Nickel (Dissolved)	mg/L	0.0052	0.0114	0.0203	0.010	0.016				0.0075	0.02		-	-	0.0075	0.02
Selenium	mg/L	ND	ND	ND	0.005	0.004	-	0.021	0.046	0.001	0.005	0.01	-	-	0.001	0.005
Selenium (Dissolved)	mg/L	-	-	-	0.004	0.004				0.001	0.005		-	-	0.001	0.005
Silver	mg/L	0.0001	0.0001	0.0001	0.0002	0.0002	-	0.0002	<0.0001	0.0001	0.00002	-	-	-	0.0001	0.00002
Silver (Dissolved)	mg/L	--	--	--	0.0002	0.0002				0.0001	0.0002		-	-	0.0001	0.0002
Sodium	mg/L	107	1153	4300	541	516	-	256	889	100	1000	200	80%	800	20	200
Sodium (Dissolved)	mg/L	92.3	1173	4350	577	518				100	1000		80%	800	20	200
Zinc	mg/L	0.027	0.238	1.34	0.050	0.110	0.72	2.12	2.57	0.05	2	5	-	-	0.05	2
Zinc (Dissolved)	mg/L	0.006	0.137	1.01	0.020	0.030				0.025	1		-	-	0.025	1

Notes for Table:

- (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) Chemical analyses results - HWMF cell seepage - Highest concentration - 2004 (Appendix B).  
(4) Highest concentration reported for the C&D Landfill in Levis, Quebec in 2005 (Appendix C).  
(5) Highest concentration reported for the Mayer Industrial Landfill Site between 1994 and 2001 (Appendix C).  
(6) Highest concentration reported for the Inter-Recycling Systems Landfill Site between 1988 and 2001 (Appendix C).  
(7) Based on reported ranges from above mentioned C&D landfills.  
(9) Upland beackground groundwater conditions include average hardness of 70 mg/l  
(10) Only the total concentration will be reduced through settling, the dissolved component will not be removed. The parameter is expected to be present primarily in the dissolved form  
(11) Removal is dependent on the form of the parameter present in the leachate  
(12) Upland background groundwater conditions include average temperature of 12.79 degree celcius  
(13) Upland background groundwater conditions include average ph measure in the field of 7.46  
(14) Confidential Landfill Leachate - Treatment Program 2013 - Tables 5,6,7. Concentrations represent average of 4 samples.  
(15) Concentration represents average of 2 samples.  
(16) Confidential Landfill Leachate - Leachate Treatment Program 2013 - Tables 5,6,7. Concentrations represent average of 3 samples.

**HELP Model Results**  
**2016 Design, Operations and Closure Plan**  
**Upland Landfill**  
**Campbell River, British Columbia**

<b>HELP MODEL</b>	<b>Percolation into Waste (m/year)</b>	<b>Percolation through Base Liner (m/year)</b>
Daily Cover	1.138	0.00000581
Intermediate Cover	1.052	0.00000534
Future Final Cover	0.017	0.00000011

Table 9.3

**Cover Areas**  
**2016 Design, Operations and Closure Plan**  
**Upland Landfill**  
**Campbell River, British Columbia**

<b>Areas (m<sup>2</sup>)</b>				
<b>Stage</b>	<b>Daily Cover</b>	<b>Intermediate Cover</b>	<b>Final Cover</b>	<b>Total Area (m<sup>2</sup>)</b>
<b>1A</b>	11,870	0	0	11,870
<b>1B</b>	9,354	11,870	0	21,224
<b>1C</b>	15,466	5,744	0	21,210
<b>2A</b>	13,002	7,451	9,947	30,400
<b>2B</b>	11,637	8,816	9,947	30,400
<b>2C</b>	14,545	5,907	9,947	30,399
<b>3A</b>	16,280	0	17,865	34,145
<b>3B</b>	16,280	0	17,865	34,145
<b>3C</b>	0	0	34,147	34,147

**Estimated Leachate Generation Per Stage  
2016 Design, Operations and Closure Plan  
Upland Landfill  
Campbell River, British Columbia**

Volume (m <sup>3</sup> )								
Phase	Stage	Daily Cover	Intermediate Cover	Final Cover	Total Annual Leachate Generation (m <sup>3</sup> )	Minimum Daily Leachate Generation (m <sup>3</sup> ) (1)	Maximum Daily Leachate Generation (m <sup>3</sup> ) (2)	Average Daily Leachate Generation (m <sup>3</sup> /day)
1	1A	13,508	0	0	13,508	12	70	37
1	1B	10,645	12,487	0	23,132	20	120	63
1	1C	17,600	6,043	0	23,643	20	123	65
2	2A	14,796	7,838	169	22,804	19	118	62
2	2B	13,243	9,274	169	22,686	19	118	62
2	2C	16,552	6,214	169	22,935	20	119	63
3	3A	18,527	0	304	18,830	16	98	52
3	3B	18,527	0	304	18,830	16	98	52
3	3C	0	0	580	580	0.5	3	2

**Notes**

(1) Minimum daily leachate generation occurs in July based on precipitation data

(2) Maximum daily leachate generation occurs in November based on precipitation data

**Leachate Treatment Capacity Summary  
2016 Design, Operations and Closure Plan  
Upland Landfill  
Campbell River, British Columbia**

Month	Days	Percent of Annual Precipitation <sup>1</sup>	Stage 1C Monthly Leachate Generation (m3)	Monthly Average Daily Leachate Generation (m3)	Leachate Generation Accounting for Potential Precipitation Increases (+6%)(m3) <sup>2</sup>	Annual Average Daily Leachate Generation (m3)	Leachate Treatment Design Capacity (m3)
January	31	14.60%	3453	111	118	65	130
February	28	10.04%	2373	85	90	65	130
March	31	9.40%	2223	72	76	65	130
April	30	6.18%	1462	49	52	65	130
May	31	4.59%	1086	35	37	65	130
June	30	4.22%	999	33	35	65	130
July	31	2.65%	626	20	21	65	130
August	31	2.99%	708	23	24	65	130
September	30	3.71%	876	29	31	65	130
October	31	10.89%	2575	83	88	65	130
November	30	15.57%	3682	123	130	65	130
December	31	15.15%	3583	116	123	65	130

**Notes**

<sup>1</sup>Quantity of precipitation per each month divided by annual precipitation \* 100

<sup>2</sup>Maximum monthly average daily leachate generation plus a six percent increase to illustrate potential leachate generation rates due to climate change

**Waste Characterization**  
**2016 Design, Operations and Closure Plan**  
**Upland Landfill**  
**Campbell River, British Columbia**

<b>Waste Type</b>	<b>Percent of Total Waste Composition</b>	<b>Percent Relatively Inert</b>	<b>Percent Moderately Decomposable</b>	<b>Percent Decomposable</b>
Waste Soil	50%	100%	0%	0%
Construction, Demolition and	50%	50%	50%	0%
<b>Total</b>	<b>100%</b>	<b>75%</b>	<b>25%</b>	<b>0%</b>



Table 10.2

**Landfill Gas Generation Summary  
2016 Design, Operations and Closure Plan  
Upland Landfill  
Campbell River, British Columbia**

<b>Year</b>	<b>Annual Waste Tonnage (tonnes)</b>	<b>Methane Generation (tonnes CH<sub>4</sub>/year)</b>	<b>Total Waste in Place (tonnes)</b>
2017	32,890	0	32,890
2018	32,890	44	65,780
2019	32,890	86	98,670
2020	32,890	126	131,560
2021	32,890	163	164,450
2022	32,890	199	197,340
2023	32,890	233	230,230
2024	32,890	265	263,120
2025	32,890	295	296,010
2026	32,890	324	328,900
2027	32,890	351	361,790
2028	32,890	377	394,680
2029	32,890	402	427,570
2030	32,890	426	460,460
2031	32,890	448	493,350
2032	32,890	469	526,240
2033	32,890	489	559,130
2034	32,890	508	592,020
2035	32,890	526	624,910
2036	32,890	544	657,800
2037	0	560	657,800
2038	0	532	657,800
2039	0	505	657,800
2040	0	479	657,800
2041	0	455	657,800
2042	0	433	657,800
2043	0	411	657,800
2044	0	391	657,800
2045	0	372	657,800
2046	0	353	657,800
2047	0	336	657,800
2048	0	320	657,800
2049	0	305	657,800
2050	0	290	657,800
2051	0	276	657,800
2052	0	263	657,800
2053	0	251	657,800
2054	0	240	657,800
2055	0	228	657,800
2056	0	218	657,800
2057	0	208	657,800
2058	0	199	657,800
2059	0	190	657,800
2060	0	181	657,800
2061	0	173	657,800
2062	0	166	657,800
2063	0	159	657,800
2064	0	152	657,800
2065	0	145	657,800
2066	0	139	657,800

**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  
2016 Design, Operations and Closure Plan  
Upland Landfill  
Campbell River, British Columbia

		Moderately		
	Relatively Inert	Decomposable	Decomposable	
Gas Production potential, Lo =	20	120	160	m <sup>3</sup> CH <sub>4</sub> /tonne
Waste Composition (2006 SWMP)	75.0%	25.0%	0.0%	

lag time before start of gas production, lag =	1 yr
Historical Data Used (years)	30
1st Year of Historical Data Used	2017
Proposed year of closure	2036
methane (by volume)	50%
carbon dioxide (by volume)	50%
methane (density)	0.6557 kg/m <sup>3</sup> (25°C,1ATM)
carbon dioxide (density)	1.7988 kg/m <sup>3</sup> (25°C,1ATM)

Year	Annual Tonnage (tonnes)	Cumulative Waste-in-place (tonnes)	Waste Tonnage			Methane Generation Rate, k			Annual Methane Production (tonnes/yr)	Landfill Gas Production (m <sup>3</sup> /hr)	Greenhouse Gas Emissions (as CO <sub>2</sub> e/year)
			Relatively Inert (tonnes)	Moderately Decomposable (tonnes)	Decomposable (tonnes)	Relatively Inert (year <sup>-1</sup> )	Moderately Decomposable (year <sup>-1</sup> )	Decomposable (year <sup>-1</sup> )			
2017	32,890	32,890	24,668	8,223	0	0.02	0.06	0.11	0.0	0.0	0
2018	32,890	65,780	24,668	8,223	0	0.02	0.06	0.11	44.2	15.4	928
2019	32,890	98,670	24,668	8,223	0	0.02	0.06	0.11	86.1	30.0	1,808
2020	32,890	131,560	24,668	8,223	0	0.02	0.06	0.11	125.8	43.8	2,641
2021	32,890	164,450	24,668	8,223	0	0.02	0.06	0.11	163.4	56.9	3,431
2022	32,890	197,340	24,668	8,223	0	0.02	0.06	0.11	199.0	69.3	4,179
2023	32,890	230,230	24,668	8,223	0	0.02	0.06	0.11	232.8	81.1	4,889
2024	32,890	263,120	24,668	8,223	0	0.02	0.06	0.11	264.9	92.2	5,562
2025	32,890	296,010	24,668	8,223	0	0.02	0.06	0.11	295.3	102.8	6,200
2026	32,890	328,900	24,668	8,223	0	0.02	0.06	0.11	324.1	112.9	6,806
2027	32,890	361,790	24,668	8,223	0	0.02	0.06	0.11	351.5	122.4	7,381
2028	32,890	394,680	24,668	8,223	0	0.02	0.06	0.11	377.5	131.4	7,927
2029	32,890	427,570	24,668	8,223	0	0.02	0.06	0.11	402.2	140.0	8,445
2030	32,890	460,460	24,668	8,223	0	0.02	0.06	0.11	425.6	148.2	8,937
2031	32,890	493,350	24,668	8,223	0	0.02	0.06	0.11	447.9	155.9	9,405
2032	32,890	526,240	24,668	8,223	0	0.02	0.06	0.11	469.0	163.3	9,849
2033	32,890	559,130	24,668	8,223	0	0.02	0.06	0.11	489.1	170.3	10,272
2034	32,890	592,020	24,668	8,223	0	0.02	0.06	0.11	508.3	177.0	10,673
2035	32,890	624,910	24,668	8,223	0	0.02	0.06	0.11	526.4	183.3	11,055
2036	32,890	657,800	24,668	8,223	0	0.02	0.06	0.11	543.8	189.3	11,419
2037	0	657,800	0	0	0	0.02	0.06	0.11	560.2	195.1	11,765
2038	0	657,800	0	0	0	0.02	0.06	0.11	531.7	185.1	11,166
2039	0	657,800	0	0	0	0.02	0.06	0.11	504.8	175.8	10,600
2040	0	657,800	0	0	0	0.02	0.06	0.11	479.3	166.9	10,065
2041	0	657,800	0	0	0	0.02	0.06	0.11	455.3	158.5	9,560
2042	0	657,800	0	0	0	0.02	0.06	0.11	432.5	150.6	9,083
2043	0	657,800	0	0	0	0.02	0.06	0.11	411.1	143.1	8,632
2044	0	657,800	0	0	0	0.02	0.06	0.11	390.8	136.1	8,206
2045	0	657,800	0	0	0	0.02	0.06	0.11	371.6	129.4	7,803
2046	0	657,800	0	0	0	0.02	0.06	0.11	353.4	123.1	7,422
2047	0	657,800	0	0	0	0.02	0.06	0.11	336.3	117.1	7,062
2048	0	657,800	0	0	0	0.02	0.06	0.11	320.0	111.4	6,721
2049	0	657,800	0	0	0	0.02	0.06	0.11	304.7	106.1	6,399
2050	0	657,800	0	0	0	0.02	0.06	0.11	290.2	101.0	6,094
2051	0	657,800	0	0	0	0.02	0.06	0.11	276.5	96.3	5,805
2052	0	657,800	0	0	0	0.02	0.06	0.11	263.5	91.7	5,533
2053	0	657,800	0	0	0	0.02	0.06	0.11	251.2	87.4	5,274
2054	0	657,800	0	0	0	0.02	0.06	0.11	239.5	83.4	5,030
2055	0	657,800	0	0	0	0.02	0.06	0.11	228.5	79.6	4,798
2056	0	657,800	0	0	0	0.02	0.06	0.11	218.0	75.9	4,579
2057	0	657,800	0	0	0	0.02	0.06	0.11	208.1	72.5	4,371
2058	0	657,800	0	0	0	0.02	0.06	0.11	198.8	69.2	4,174
2059	0	657,800	0	0	0	0.02	0.06	0.11	189.9	66.1	3,988
2060	0	657,800	0	0	0	0.02	0.06	0.11	181.5	63.2	3,811
2061	0	657,800	0	0	0	0.02	0.06	0.11	173.5	60.4	3,643
2062	0	657,800	0	0	0	0.02	0.06	0.11	165.9	57.8	3,485
2063	0	657,800	0	0	0	0.02	0.06	0.11	158.8	55.3	3,334
2064	0	657,800	0	0	0	0.02	0.06	0.11	152.0	52.9	3,191
2065	0	657,800	0	0	0	0.02	0.06	0.11	145.5	50.7	3,055
2066	0	657,800	0	0	0	0.02	0.06	0.11	139.4	48.5	2,927

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

Table 13.1  
Groundwater Compliance Forecast  
2016 Design, Operations and Closure Plan  
Upland Landfill  
Campbell River, British Columbia

Parameters	Units	Average Pre-Landfilling Concentrations <sup>(1)</sup>	Forecasted Upland Landfill Leachate Concentrations	Forecasted Upland Landfill Treated Leachate Concentrations	Contaminant Masses & Source Volumes <sup>(2)</sup>								Average Pre-Landfilling Concentrations <sup>(1)</sup>	Final Forecasted Groundwater Concentrations <sup>(3)</sup>		BC WQG		
					Existing	Landfill Leakage	Infiltration Pond	Infiltration of Runoff and Lateral Drainage from Landfill Cap	Infiltration Downgradient of Landfill				Drinking Water Guidelines					
			Minimum	Maximum	Minimum	Maximum	Volume of Source						Minimum	Maximum	Approved			
			mg/L	mg/L	mg/L	mg/L	Units m3/day L/day	854 854,000	0.00033 0.33	65 65,000	3.5 3,500	234 234,000	mg/L	mg/L	mg/L			
GENERAL CHEMISTRY																		
Alkalinity (total)	mg/L	71.9	500	2500	50	250	mg/day	61402600	165	826	3250000	16250000	251650	16824600	71.90	70.67	81.91	-
Ammonia-N	mg/L	0.05	1	30	0.10	3	mg/day	41633	0.33	9.9	6500	195000	171	11408	0.05	0.05	0.21	-
BOD	mg/L	1.75	10	50	3.5	17.5	mg/day	1494500	3.30	16.5	227500	1137500	6125	409500	1.75	1.85	2.64	-
Chloride (Cl) (dissolved)	mg/L	8.11	100	1500	16.7	250	mg/day	6925940	33.0	495	1083333.333	16250000	28385	1897740	8.11	8.59	21.71	250
COD	mg/L	39.6	50	500	15	150	mg/day	33818400	16.5	165	975000	9750000	138600	9266400	39.60	38.22	45.81	-
Conductivity <sup>(4)</sup>	us/cm	200	200	7500	200	7500	us/cm	-	-	-	-	-	-	-	200.00	200.00	7500.00	-
Hardness	mg/L	72	750	2500	750	2500	mg/day	61488000	248	826	48750000	162500000	252000	16848000	72.00	110.11	208.46	-
pH <sup>(4)</sup>	pH units	7.88	6	8	6	8	pH units	-	-	-	-	-	-	-	7.88	6.00	8.00	6.5-8.5
Phenols	mg/L	0.0	0.005	0.1	0.0005	0.01	mg/day	0	0.00165	0.03	32.5	650	0	0	ND	0.00003	0.00056	0.05
Sulphate (S04)	mg/L	14	50	1000	25	500	mg/day	11956000	16.5	330	1625000	32500000	49000	3276000	14.00	14.62	41.32	500
Sulphide	mg/L	0.0044	0.1	5	0.001	0.05	mg/day	3736	0.033	1.65	65	3250	15	1024	0.0044	0.0042	0.0069	-
Total Suspended Solids (TSS)	mg/L	632	10	150	5	75	mg/day	539728000	3.30	49.5	325000	4875000	2212000	147888000	632.00	596.76	600.69	-
Total Dissolved Solids (TDS)	mg/L	108	2000	10000	1000	5000	mg/day	92232000	660	3302	65000000	325000000	378000	25272000	108.00	158.13	382.95	-
Total Kjeldahl Nitrogen (TKN)	mg/L	0.235	3	60	1.05	21	mg/day	200690	0.99	19.81	68250	1365000	823	54990	0.24	0.28	1.40	-
Phosphorus	mg/L	0.5	0.1	0.5	0.1	0.5	mg/day	427000	0.033	0.17	6500	32500	1750	117000	0.50	0.48	0.50	-
HYDROCARBONS																		
HEPH	mg/L	0.0	0.5	2	0.5	2	mg/day	0	0.17	0.66	32500	130000	0	0	ND	0.03	0.11	-
LEPH	mg/L	0.0	0.5	2	0.125	0.5	mg/day	0	0.17	0.66	8125	32500	0	0	ND	0.007	0.028	5
METALS																		
Aluminum	mg/L	-	0.1	1	0.1	1		-	0.033022033	0.330220329	6500	65000			-	-	-	0.2
Aluminum (Dissolved)	mg/L	0.01056	0.01	0.1	0.01	0.1	mg/day	9018	0.0033	0.033	650	6500	37.0	2471	0.011	0.01	0.02	0.2
Arsenic	mg/L	-	0.001	0.04	0.00025	0.01	mg/day	-	0.00033022	0.013	16.25	650			-	-	-	0.025
Arsenic (Dissolved)	mg/L	0.00028	0.001	0.04	0.00025	0.01	mg/day	239	0.00033	0.013	16.25	650	0.98	66	0.0003	0.0003	0.0008	0.025
Barium	mg/L	-	0.05	0.7	0.05	0.7	mg/day	-	0.016511016	0.231	3250	45500			-	-	-	1
Barium (Dissolved)	mg/L	0.005516667	0.05	0.7	0.05	0.7	mg/day	4711	0.017	0.23	3250	45500	19	1291	0.01	0.01	0.04	1
Boron	mg/L	-	5	10	2.5	5	mg/day	-	1.651101644	3.302203288	162500	325000			-	-	-	5
Boron (Dissolved)	mg/L	0.0	5	10	2.5	5	mg/day	0	1.7	3.30	162500	325000	0	0	ND	0.14	0.28	5
Cadmium	mg/L	-	0.0001	0.0003	0.0001	0.0003	mg/day	-	3.3022E-05	9.90661E-05	6.5	19.5			-	-	-	-
Cadmium (Dissolved)	mg/L	1.79167E-05	0.0001	0.0003	0.0001	0.0003	mg/day	15.3	3.3E-05	9.9E-05	6.5	19.5	0.06	4	0.00002	0.00002	0.00003	0.005
Calcium	mg/L	-	200	700	200	700	mg/day	-	66.04406575	231.1542301	13000000	45500000			-	-	-	-
Calcium (Dissolved)	mg/L	22.46916667	200	700	200	700	mg/day	19188668	66.0	231	13000000	45500000	78642	5257785	22.47	32.45	60.55	-
Chromium	mg/L	-	0.005	0.05	0.005	0.05	mg/day	-	0.001651102	0.016511016	325	3250			-	-	-	-
Chromium (Dissolved)	mg/L	0.0	0.005	0.05	0.005	0.05	mg/day	0	0.0017	0.017	325	3250	0	0	ND	0.0003	0.0028	0.05
Cobalt	mg/L	-	0.001	0.01	0.001	0.01	mg/day	-	0.00033022	0.003302203	65	650			-	-	-	-
Cobalt (Dissolved)	mg/L	0.00010	0.001	0.01	0.001	0.01	mg/day	83	0.0003	0.0033	65	650	0.34	23	0.0001	0.0001	0.0007	-
Copper	mg/L	-	0.005	0.05	0.005	0.05	mg/day	-	0.001651102	0.016511016	325	3250			-	-	-	0.5
Copper (Dissolved)	mg/L	0.0009	0.005	0.05	0.005	0.05	mg/day	787	0.0017	0.017	325	3250	3.2	216	0.001	0.0012	0.0037	0.5
Cyanide	mg/L	-	0.057	0.057	0.057	0.057	mg/day	-	0.018822559	0.018822559	3705	3705			-	-	-	0.2 (SAD)
Cyanide (Dissolved)	mg/L	-	-	-	0	0	mg/day	-	0	0	0	0			-	-	-	0.2 (SAD)
Iron	mg/L	-	1	70	0.09	6.5	mg/day	-	0.33	23.1	6036	422500	-	-	-	-	-	6.5
Iron (Dissolved)	mg/L	0.049	0.1	7	0.09	6.5	mg/day	41697	0.033	2.3	6035.714286	422500	171	11425	0.05	0.05	0.41	0.3
Lead	mg/L	-	0.001	0.01	0.001	0.01	mg/day	-	0.00033022	0.003302203	65	650			-	-	-	0.05
Lead (Dissolved)	mg/L	0.0	0.001	0.01	0.001	0.01	mg/day	0	0.00033	0.0033	65	650	0	0	ND	0.000056	0.00056	0.05
Magnesium	mg/L	-	30	300	10	100	mg/day	-	9.906609863	99.06609863	650000	6500000			-	-	-	-
Magnesium (Dissolved)	mg/L	3.9	30	300	10	100	mg/day	3295017	9.9	99.1	650000	6500000	13504	902850	3.86	4.20	9.26	100
Manganese	mg/L	-	1	5	0.11	0.55	mg/day	-	0.330220329	1.651101644	7150	35750			-	-	-	0.05
Manganese (Dissolved)	mg/L	0.05	1	5	0.11	0.55	mg/day	43205	0.33	1.7	7150	35750	177	11838	0.051	0.054	0.079	0.05
Mercury	mg/L	-	0.00001	0.00003	0.00001	0.00003	mg/day	-	3.3022E-06	9.90661E-06	0.65	1.95			-	-	-	0.001
Mercury (Dissolved)	mg/L	0.0	0.00001	0.00001	0.00001	0.00001	mg/day	0	3.3E-06	3.3E-06	0.65	0.65	0.0	0	ND	0.0000006	0.0000006	0.001
Molybdenum	mg/L	-	0.001	0.002	0.001	0.002	mg/day	-	0.00033022	0.000660441	65	130			-	-	-	0.25
Molybdenum (Dissolved)	mg/L	0.0007	0.001	0.002	0.001	0.002	mg/day	626	0.00033	0.0007	65	130	2.6	172	0.0007	0.0007	0.0008	0.25
Nickel	mg/L	-	0.0075	0.02	0.0075	0.02	mg/day	-	0.002476652	0.006604407	487.5	1300			-	-	-	-
Nickel (Dissolved)	mg/L	0.0005	0.0075	0.02	0.0075	0.02	mg/day	455	0.0025	0.007	487.5	1300	1.9	125	0.001	0.0009	0.0016	-
Selenium	mg/L	-	0.001	0.005	0.001	0.005	mg/day	-	0.00033022	0.001651102	65	325			-	-	-	0.01
Selenium (Dissolved)	mg/L	0.0003	0.001	0.005	0.001	0.005	mg/day	243	0.00033	0.002	65	325	0.99	66	0.0003	0.0003	0.0005	0.01
Silver	mg/L	-	0.0001	0.00002	0.0001	0.00002	mg/day	-	3.3022E-05	6.60441E-06	6.5	1.3			-	-	-	-
Silver (Dissolved)	mg/L	0.0	0.0001	0.0002	0.0001	0.0002	mg/day	0	3.3E-05	6.6E-05	6.5	13	0	0	ND	0.0000056	0.0000112	-
Sodium	mg/L	-	100	1000	20	200												

Notes for Table:

(1) Concentrations have been calculated using the average conentration of each sample collected from the overburden, sand and gravel aquifer in 2015.

Groundwater Compliance Forecast  
2016 Design, Operations and Closure Plan  
Upland Landfill  
Campbell River, British Columbia

For the purposes of predicting the mass inputs, concentrations of 0.0 mg/L have been used wherever the 2015 samples were below detection limits (ND or less than the reporting limit).

(2) Contaminant masses are calculated by multiplying the forecasted 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.

pH and conductivity are not expected to fall outside of the min. and max. range in pre-Landfill, leachate, or effluent.

- not analyzed.

ND - not detected above the respective laboratory reporting limit

exceeds the BC Drinking Water Supply Guideline

CSR-Specific Notes:

\* Criterion dependent on hardness and pH values were determined using the uppper maximum of the respective parameter ranges.

\*\* Criteria for total non chlorinated phenols

\*\*\*0.01 (0.09) - Standard for Chromium VI and III, respectively

(SAD) Criteria for Cyanide (strong acid dissociable)

BC WQG Notes:

BC WQG data is not to be included in the leachate treatment objectives of the aeration pond. The BC WQG will be used for compliance monitoring at the site boundary. Where no WQG is published, drinking water guidelines defers to Health Canada or CSR.

Many of the BC WQG limits increase as the water hardness increases. Each such guideline has been tested up to a maximum hardness. It is assumed that the limit continues to increase for hardnesses above the maximum tested hardness.

Water at the site boundary is assumed to have a very high hardness (greater than the maximum hardness that each guideline is tested up to). Therefore, the limit at the maximum tested hardness is taken as a conservative estimate.

Table 14.1

Static Water Levels and Well Completion Details  
Design, Operations, and Closure Plan  
Upland Landfill  
Campbell River, British Columbia

Monitoring ID	Borehole Depth (m BGS)	Easting	Northing	2015 Reference	2015	Stick-up (m)	Screened Interval (m BGS)	Screen Interval (m AMSL)	Screen Length (m)	Well Diameter (mm)	Depth to Water (m BTOR)						Water Level <sup>(3)</sup> (m AMSL)						Hydraulic Conductivity (cm/s)	Screened Unit			
				Elevation Ground Surface (m AMSL) <sup>1</sup>	Reference Elevation TOR (m AMSL) <sup>1</sup>						11-Sep-15	17-Sep-15	5-Oct-15	25-Jan-16	29-Jan-16	15-Feb-16	11-Sep-15	17-Sep-15	5-Oct-15	25-Jan-16	29-Jan-16	15-Feb-16					
Date:												11-Sep-15	17-Sep-15	5-Oct-15	25-Jan-16	29-Jan-16	15-Feb-16	11-Sep-15	17-Sep-15	5-Oct-15	25-Jan-16	29-Jan-16	15-Feb-16			Primary Constituent	
MW1-14	10.97	330788.539	5541791.638	171.8	172.9	1.1	4.9	11.0	166.9	160.8	6.1	50.8	5.6	6.3	6.1	6.0	-	-	167.3	166.6	166.9	166.9	-	-	-	-	Sand/gravel
MW2-14*	21.64	330961.402	5541591.181	173.1	173.8	0.8	15.5	21.6	157.5	151.4	6.1	50.8	14.5	14.7	15.2	14.7	-	14.6	159.4	159.1	158.6	159.1	-	159.3	-	-	Sand/gravel (Shallow Overburden)
MW2A-16**	45.42	330961.699	5541600.583	173.1	173.9	0.8	37.5	40.5	135.6	132.6	6.1	50.8	-	-	-	14.5	-	-	-	-	-	159.3	-	159.3	-	-	Sand (Deep Overburden)
MW3-14	18.59	330885.439	5541429.793	167.6	168.6	1.0	11.3	17.4	156.3	150.2	6.1	50.8	12.8	12.7	12.8	11.3	-	-	155.8	155.9	155.8	157.2	-	-	-	-	Sand/gravel
MW4A-15	21.33	330737.351	5541583.042	168.5	169.3	0.8	19.8	21.4	148.7	147.2	1.52	50.8	3.9	4.3	4.9	4.0	-	-	165.4	165.0	164.4	165.3	-	-	-	-	Bedrock - Igneous Rock
MW4B-15	18.28	330743.926	5541575.024	168.4	169.3	0.9	15.2	18.3	153.2	150.1	3.04	50.8	4.1	4.5	5.1	4.2	-	-	165.2	164.8	164.1	165.0	-	-	-	-	Sand
MW5A-15	10.66	330675.167	5541325.831	191.3	191.9	0.6	9.1	10.7	182.1	180.6	1.52	50.8	9.0	9.0	8.3	7.3	-	-	182.9	182.9	183.6	184.6	-	-	-	-	Bedrock -Basalt (Perched)
MW5B-15	8.22	330685.323	5541325.831	190.4	192.0	1.7	4.9	7.9	185.5	182.4	3.04	50.8	7.1	7.2	7.0	5.4	-	-	184.9	184.9	185.0	186.6	-	-	-	-	Sand/Silt with clay (Perched)
RW-98020	60.96	330012.000	5541724.000	195.6	196.9	1.3	1.8	61.0	193.8	134.7	59.1	152.4	-	-	-	-	-	17.1	-	-	-	-	-	179.9	-	-	Bedrock - Basalt
SW15-01																											
Mclvor Lake**	-	330439.260	5542720.740	-	-	-	-	-	-	-	-	-	-	-	0.81 <sup>2</sup>	-	-	-	-	-	-	-	177.9	-	-	-	-
SW15-02																											
Rico Lake**	-	330449.605	5541459.832	-	-	-	-	-	-	-	-	-	-	-	0.88 <sup>2</sup>	-	-	-	-	-	-	-	181.2	-	-	-	-

Notes:  
1 - Survey completed by Upland Excavating Ltd. on March 8, 2016. Elevations measured with respect to AMSL.  
2 - Reference elevations have not been measured.  
\* - Survey completed by Upland Excavating Ltd. on January 29 2015. Elevations measured with respect to AMSL.  
\*\* - Survey completed by Upland Excavating Ltd. on April 6, 2016. Elevations measured with respect to AMSL.  
m BGS - metres below ground surface  
m AMSL - metres above mean sea level  
TOR - top of riser

# UPLAND LANDFILL UPLAND EXCAVATING LTD. BRITISH COLUMBIA DESIGN, OPERATIONS, AND CLOSURE PLAN



AREA MAP

SOURCE:  
JANUARY 1, 2002. GOVERNMENT OF CANADA; NATURAL RESOURCES  
CANADA; EARTH SCIENCES SECTOR; THE ATLAS OF CANADA



LOCATION MAP

SOURCE:  
SEPTEMBER 12, 2014, © 2016 - TerraServer ®

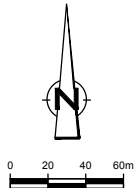
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C-01	0	APRIL 2016	EXISTING CONDITIONS
C-02A	0	MAY 2016	SITE OPERATIONS
C-02B	0	MAY 2016	LANDFILL EXCAVATION PLAN
C-03	0	MAY 2016	BASE / LINER GRADES
C-04	0	MAY 2016	LEACHATE COLLECTION SYSTEM (TOP OF GRANULAR DRAINAGE BLANKET)
C-05	0	MAY 2016	FINAL GRADES (TOP OF FINAL COVER)
C-06	0	MAY 2016	CROSS-SECTIONS
C-07	0	MAY 2016	FILL PLAN PHASE I: STAGE 1A - 1C
C-08	0	MAY 2016	FILL PLAN PHASE II: STAGE 2A - 2C
C-09	0	MAY 2016	FILL PLAN PHASE III: STAGE 3A - 3C
C-10	0	MAY 2016	LINER AND LEACHATE COLLECTION DETAILS
C-11	0	MAY 2016	LEACHATE COLLECTION SYSTEM SUMP AND RISER I
C-12	0	MAY 2016	LEACHATE COLLECTION SYSTEM SUMP AND RISER II
C-13	0	MAY 2016	PERIMETER TIE-IN DETAILS I
C-14	0	MAY 2016	PERIMETER TIE-IN DETAILS II

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Drafting Check **D. BARTON** Design Check **S. STURGEON**

Project Manager **G. FERRARO** Date **DECEMBER 2015**

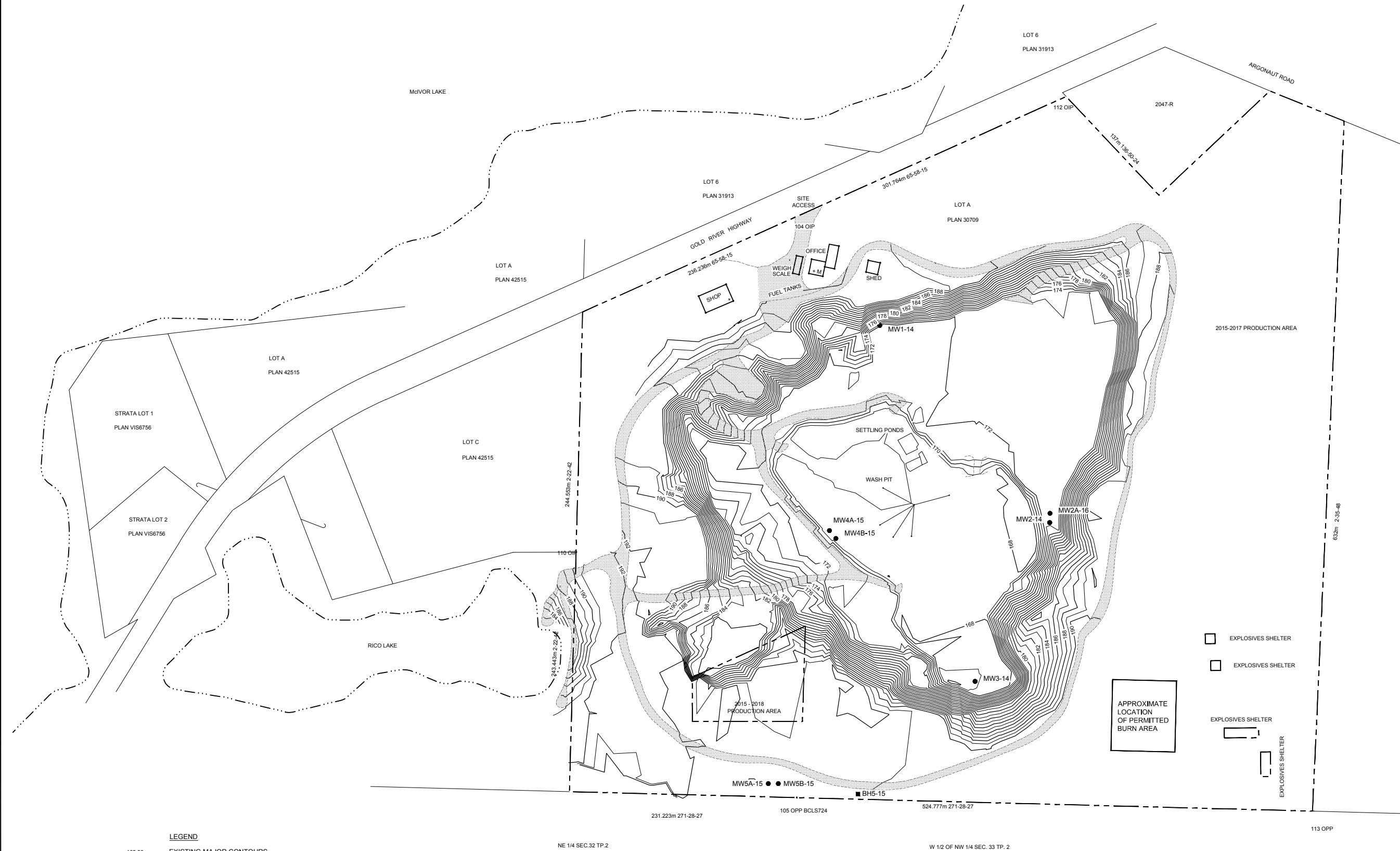
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Title  
**EXISTING CONDITIONS**

Sheet No.  
**C-01**



**LEGEND**  
— 165.00 — EXISTING MAJOR CONTOURS  
— — — EXISTING MINOR CONTOUR  
- - - - - PROPERTY LINE  
- - - - - EXISTING LAKE  
EXISTING ACCESS ROADWAY  
● MW3-14 EXISTING MONITORING WELLS

SOURCE: TOPOGRAPHICAL SURVEY CONDUCTED BY  
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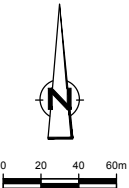
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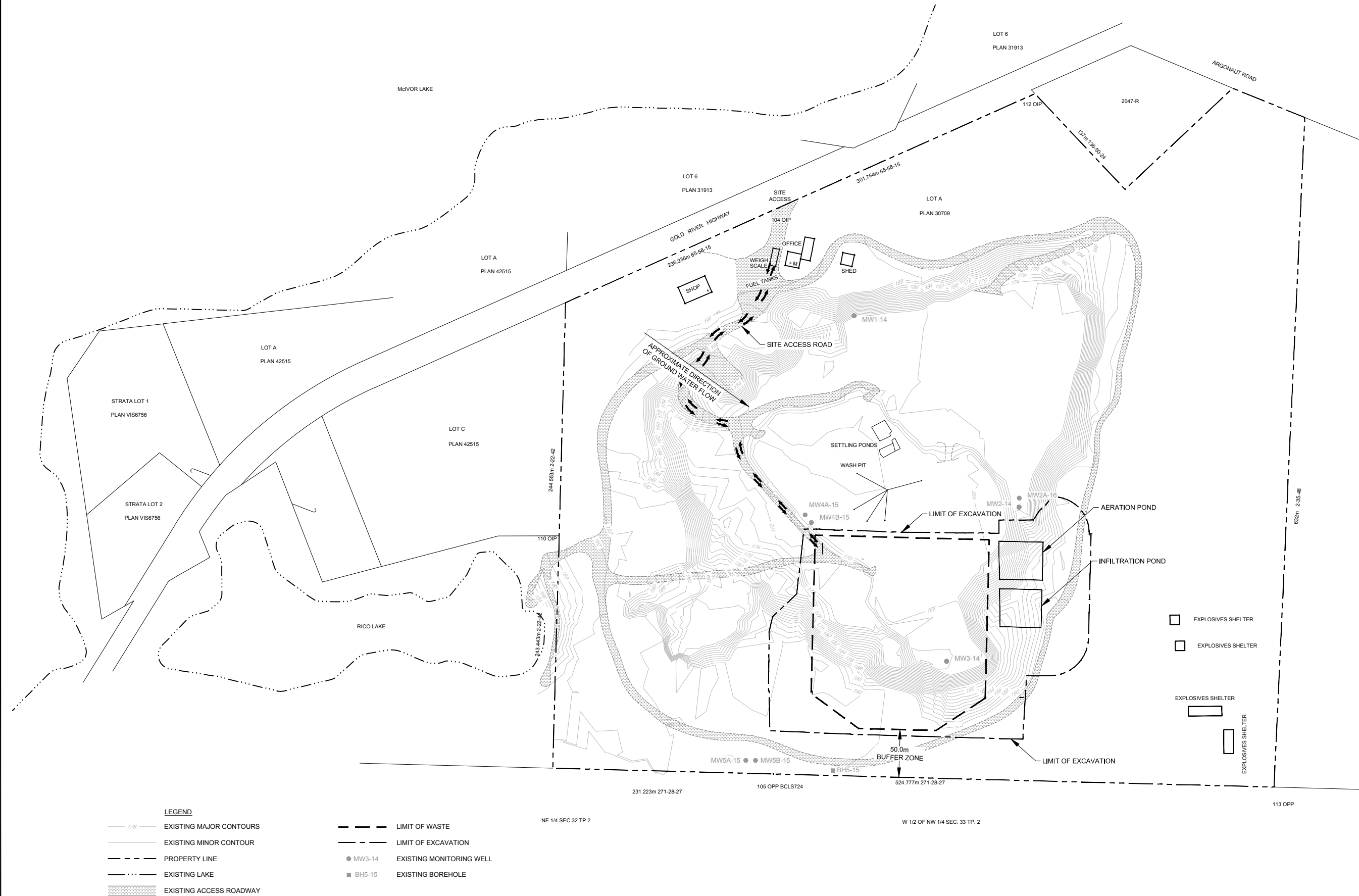
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**SITE OPERATIONS**

Sheet No.

**C-02A**

Sheet 2 of 15



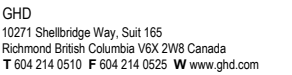
LEGEND

— 1/75 —	EXISTING MAJOR CONTOURS	— — —	LIMIT OF WASTE
— — —	EXISTING MINOR CONTOUR	- - - - -	LIMIT OF EXCAVATION
- - - - -	PROPERTY LINE	● MW3-14	EXISTING MONITORING WELL
· · · · ·	EXISTING LAKE	■ BH5-15	EXISTING BOREHOLE
▨ ▨ ▨	EXISTING ACCESS ROADWAY		

SOURCE: TOPOGRAPHICAL SURVEY CONDUCTED BY  
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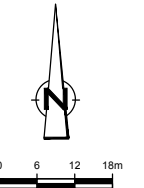
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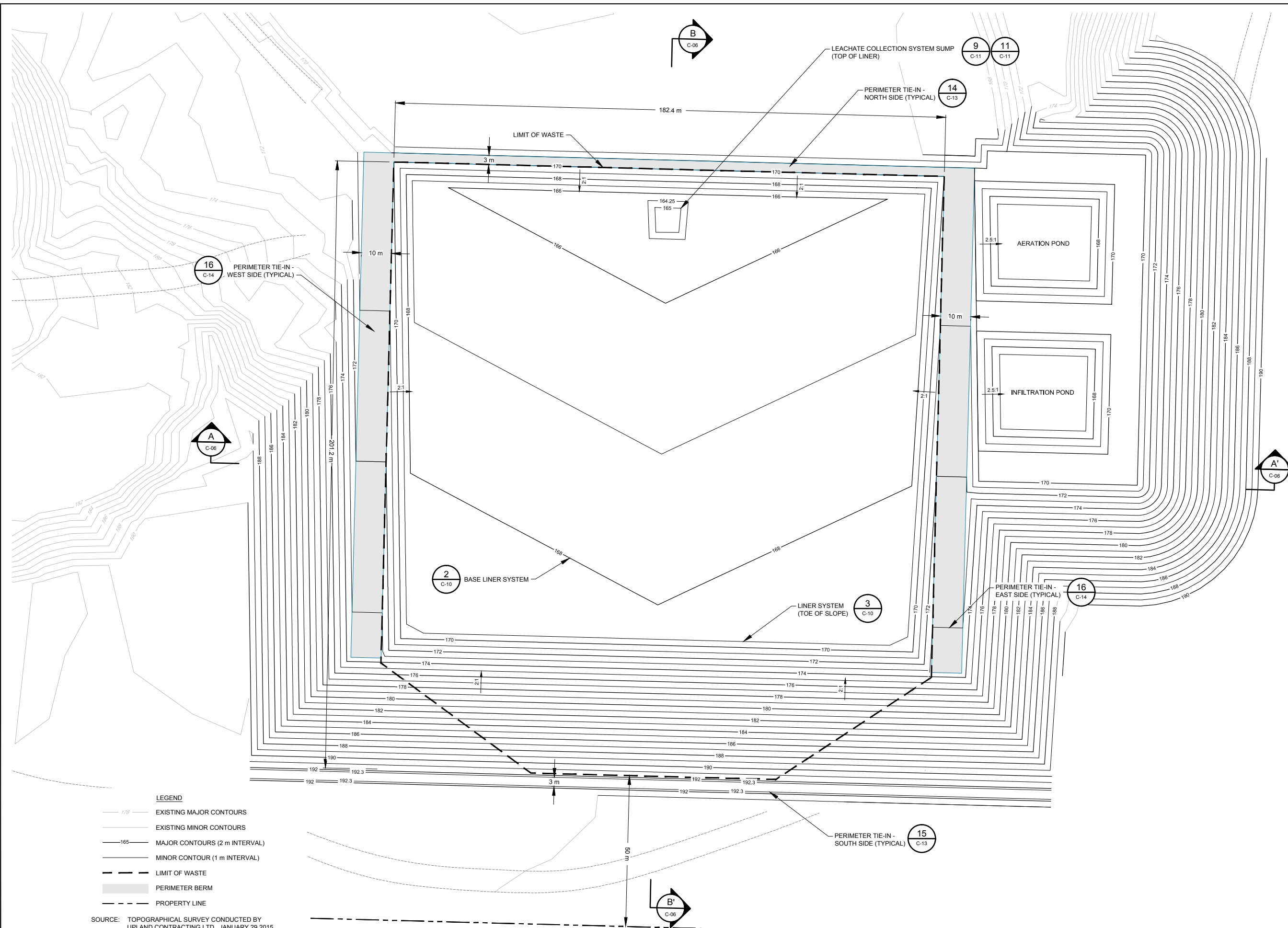
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## LANDFILL EXCAVATION PLAN

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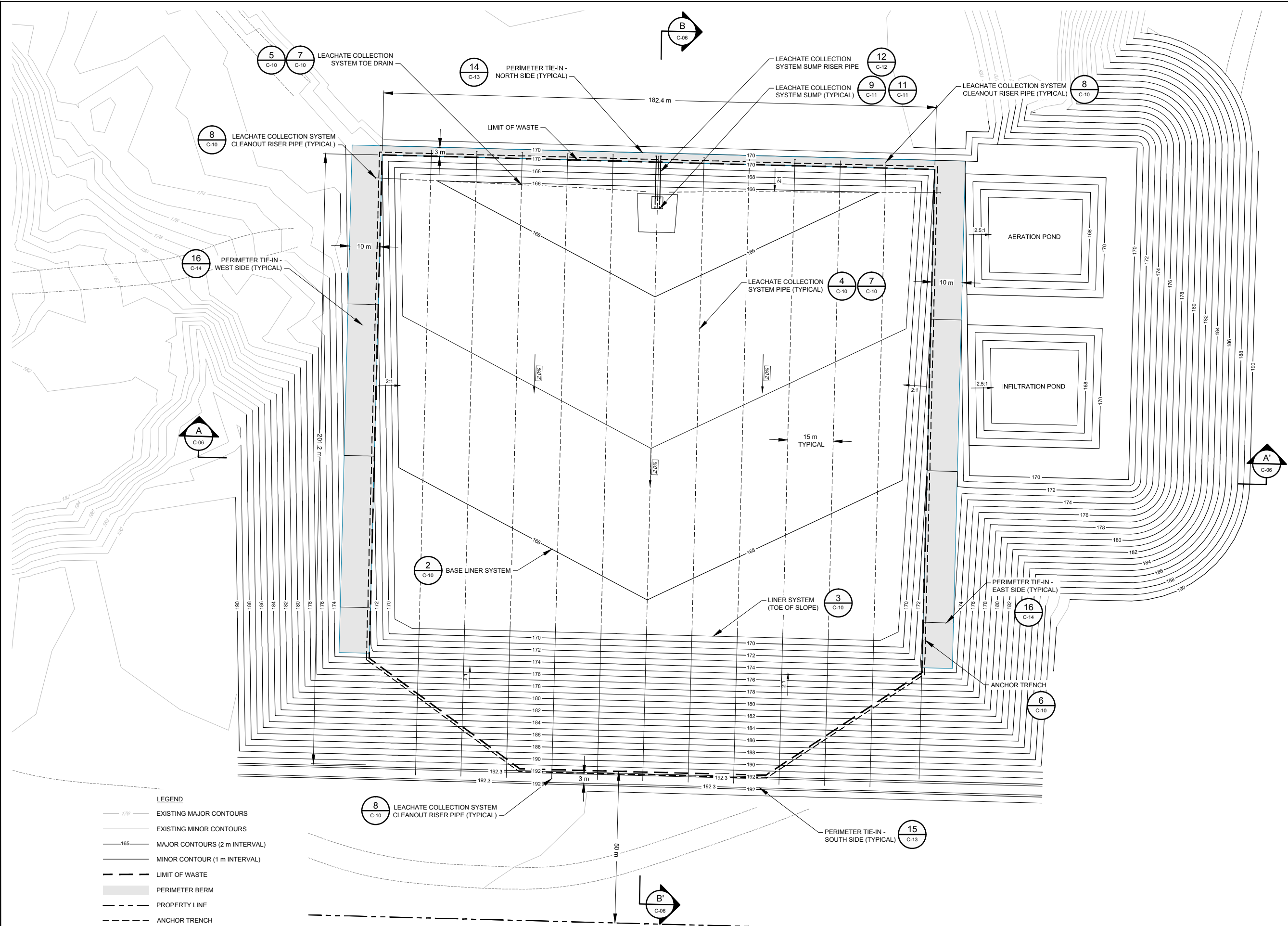
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Sheet 4 of 15



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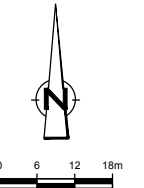
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Drafting D. BARTON	Design S. STURGEON
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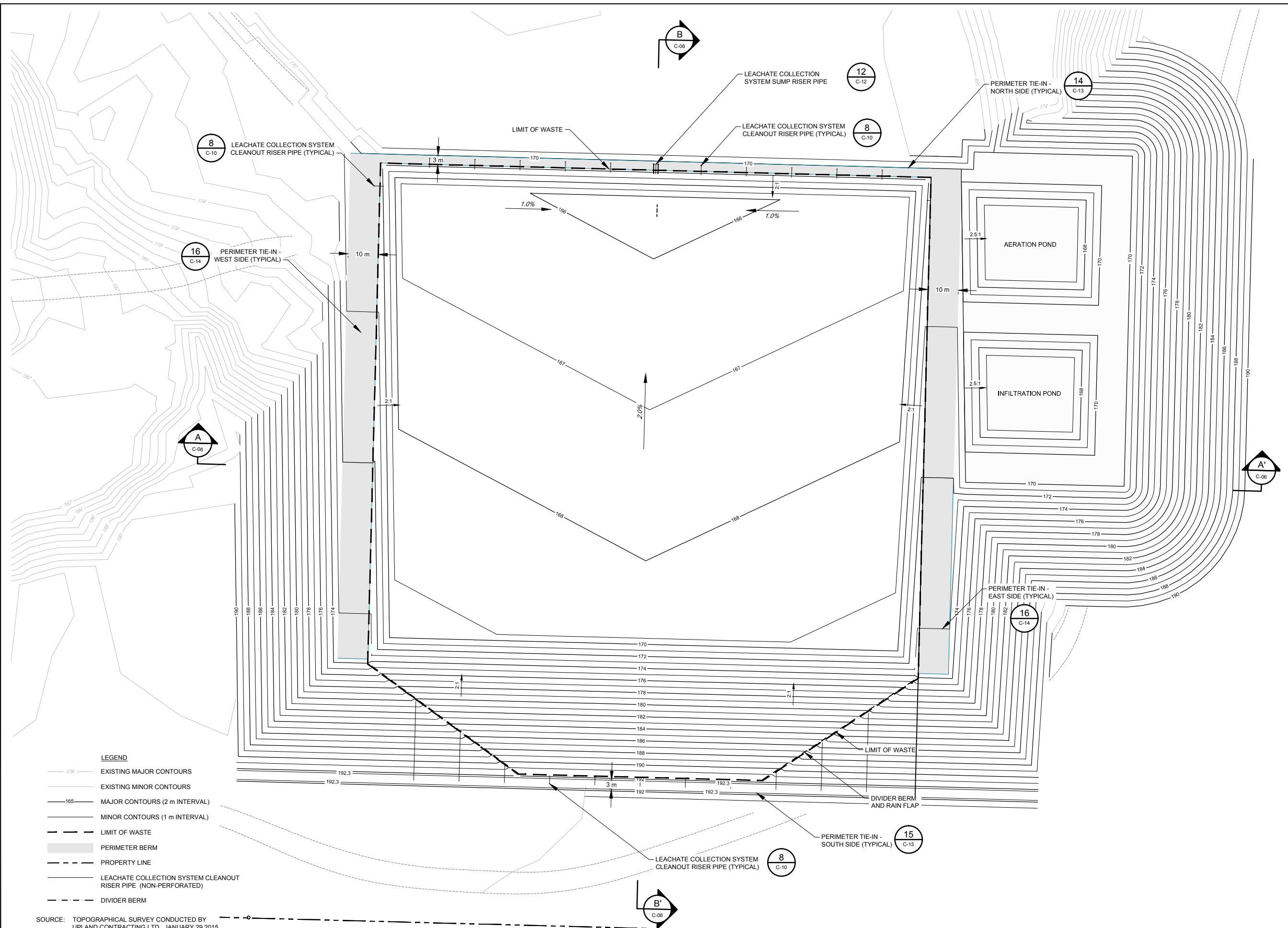
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**LEACHATE COLLECTION SYSTEM  
(TOP OF GRANULAR  
DRAINAGE BLANKET)**

Sheet No.

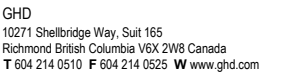
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Sheet 5 of 15

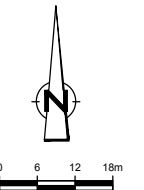


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Project Manager	<b>G. FERRARO</b>	Date	<b>DECEMBER 2015</b>
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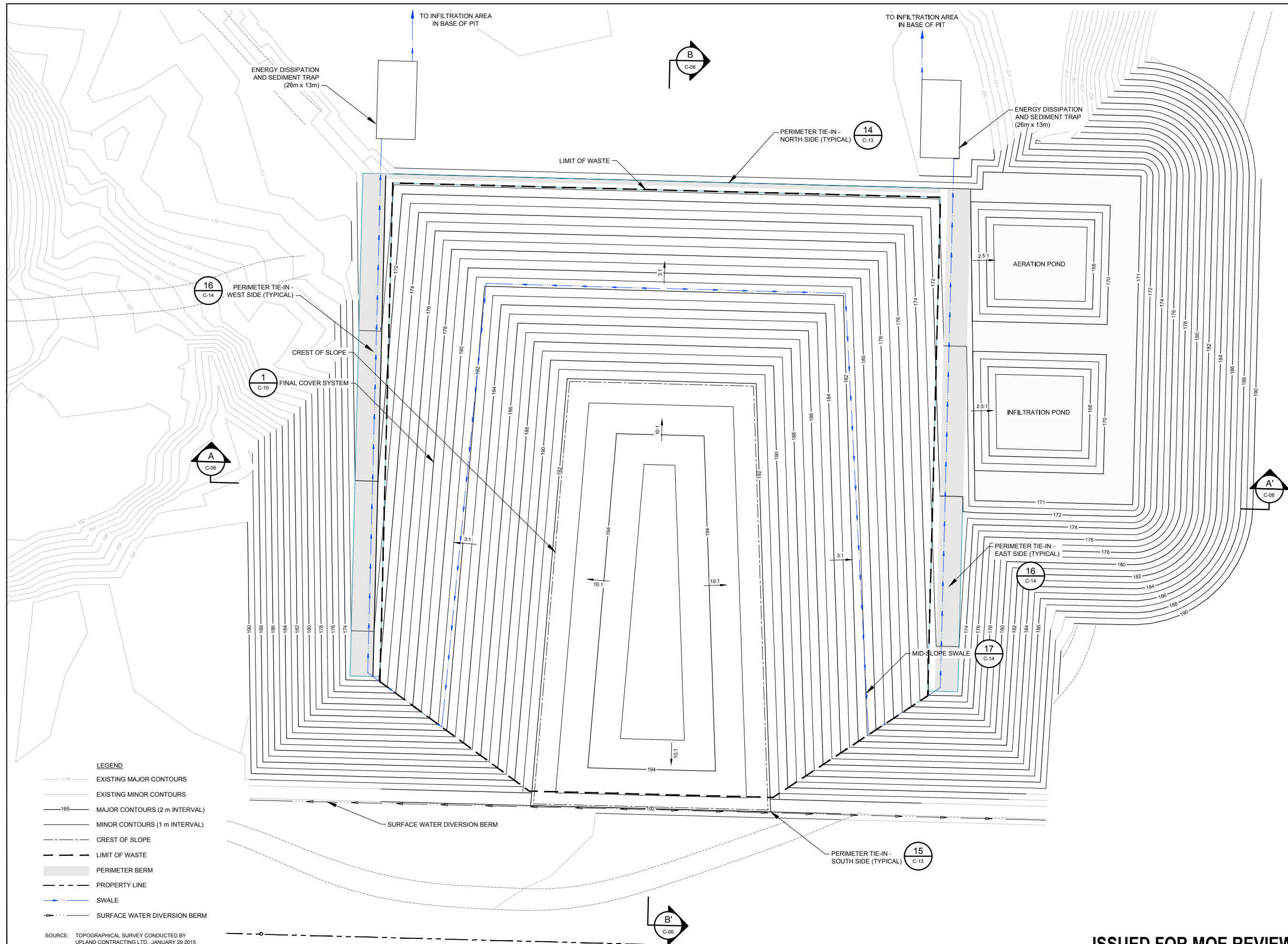
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**FINAL GRADES  
(TOP OF FINAL COVER)**

Sheet No.

**C-05**

Page 6 of 15



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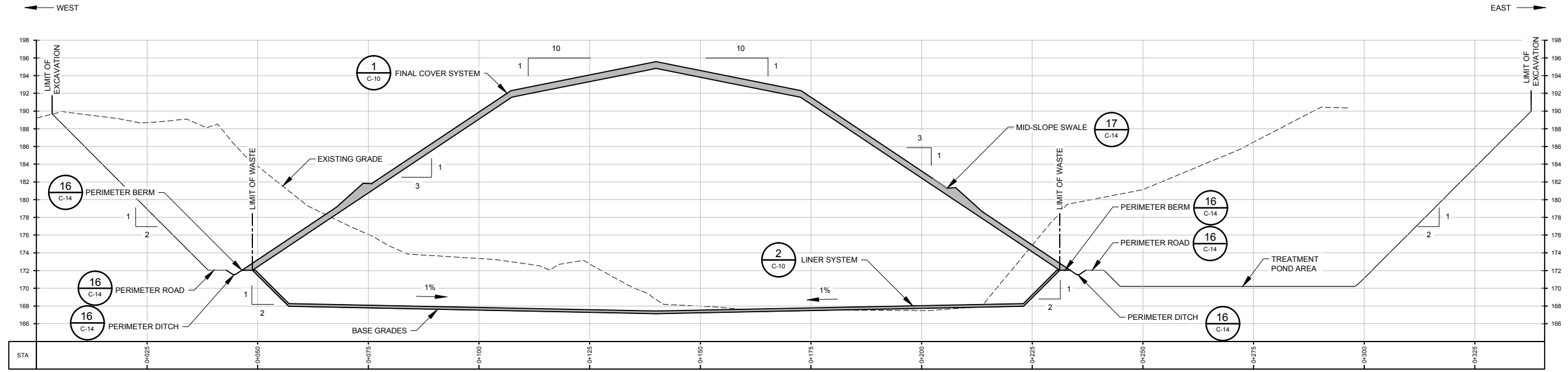
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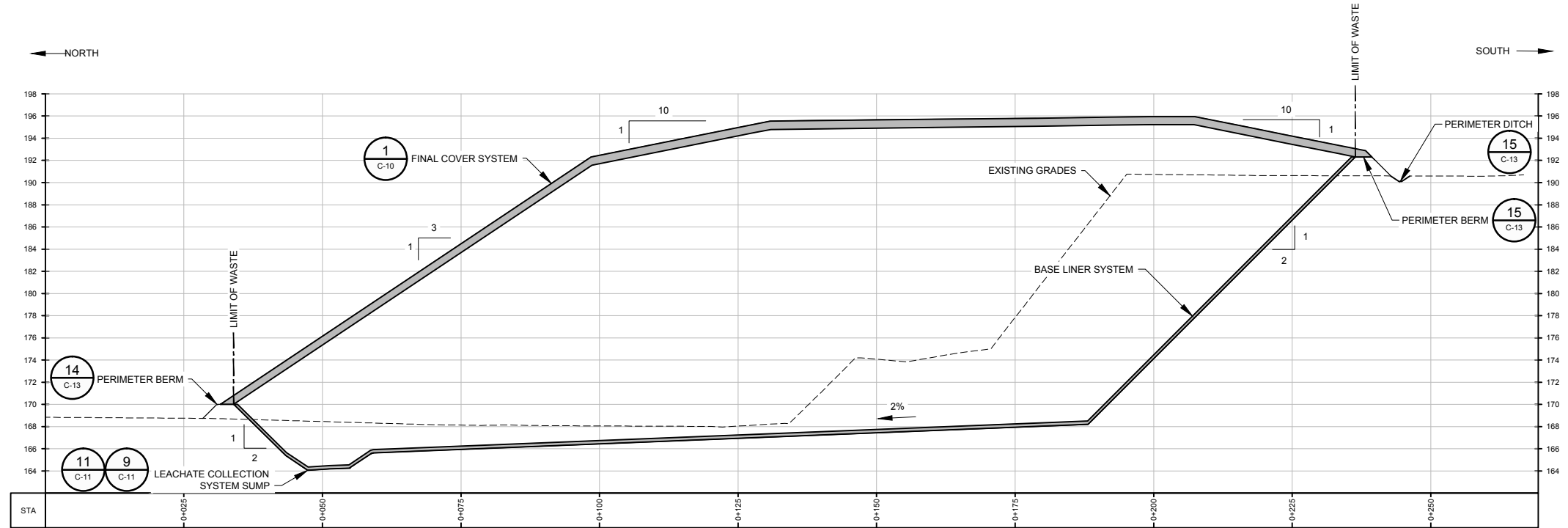
Project No. 88877-02

Title  
**CROSS-SECTIONS**

Sheet No.  
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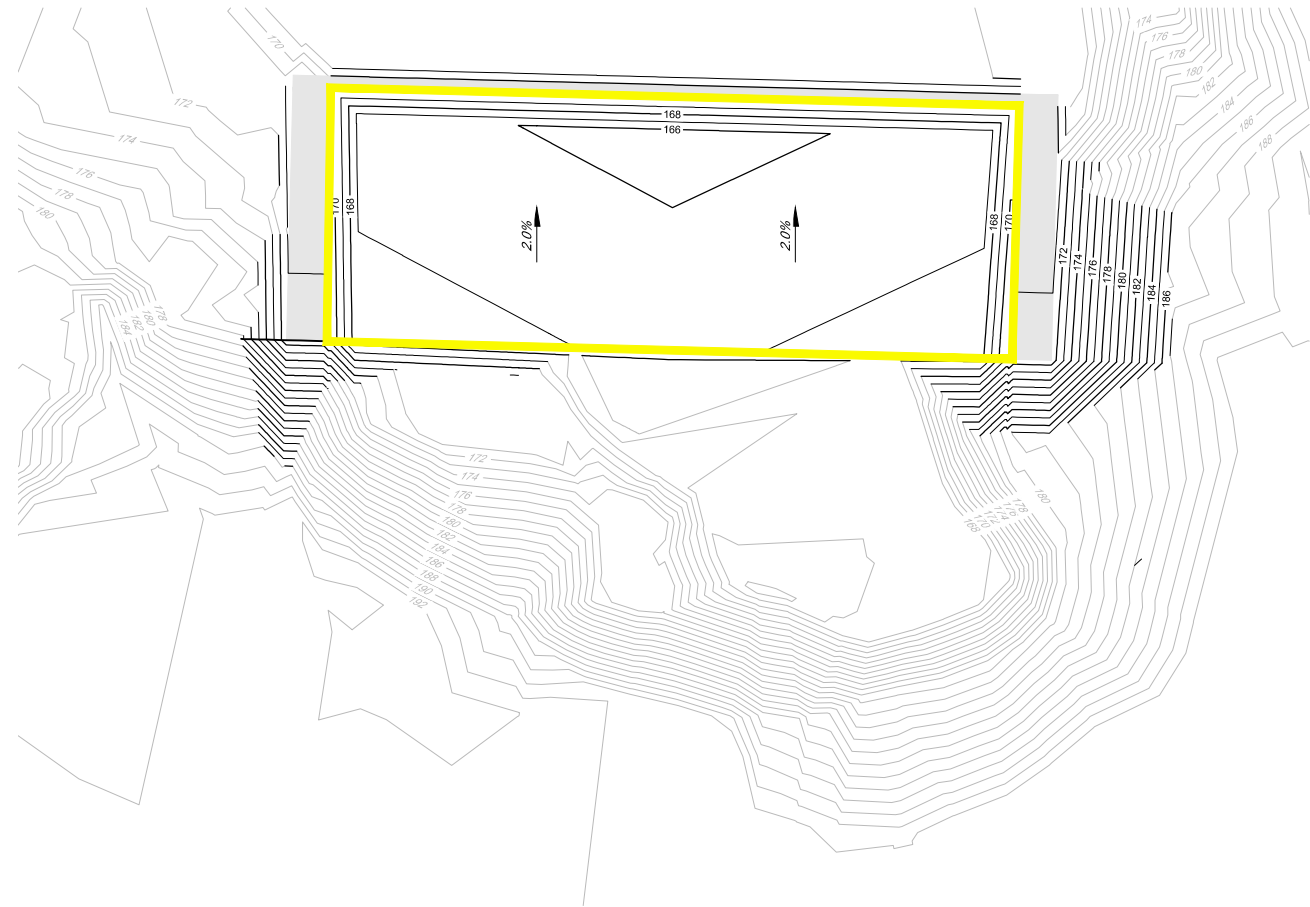


SECTION A-A'  
HORZ: 1:500  
VERT: 1:250  
C-2B

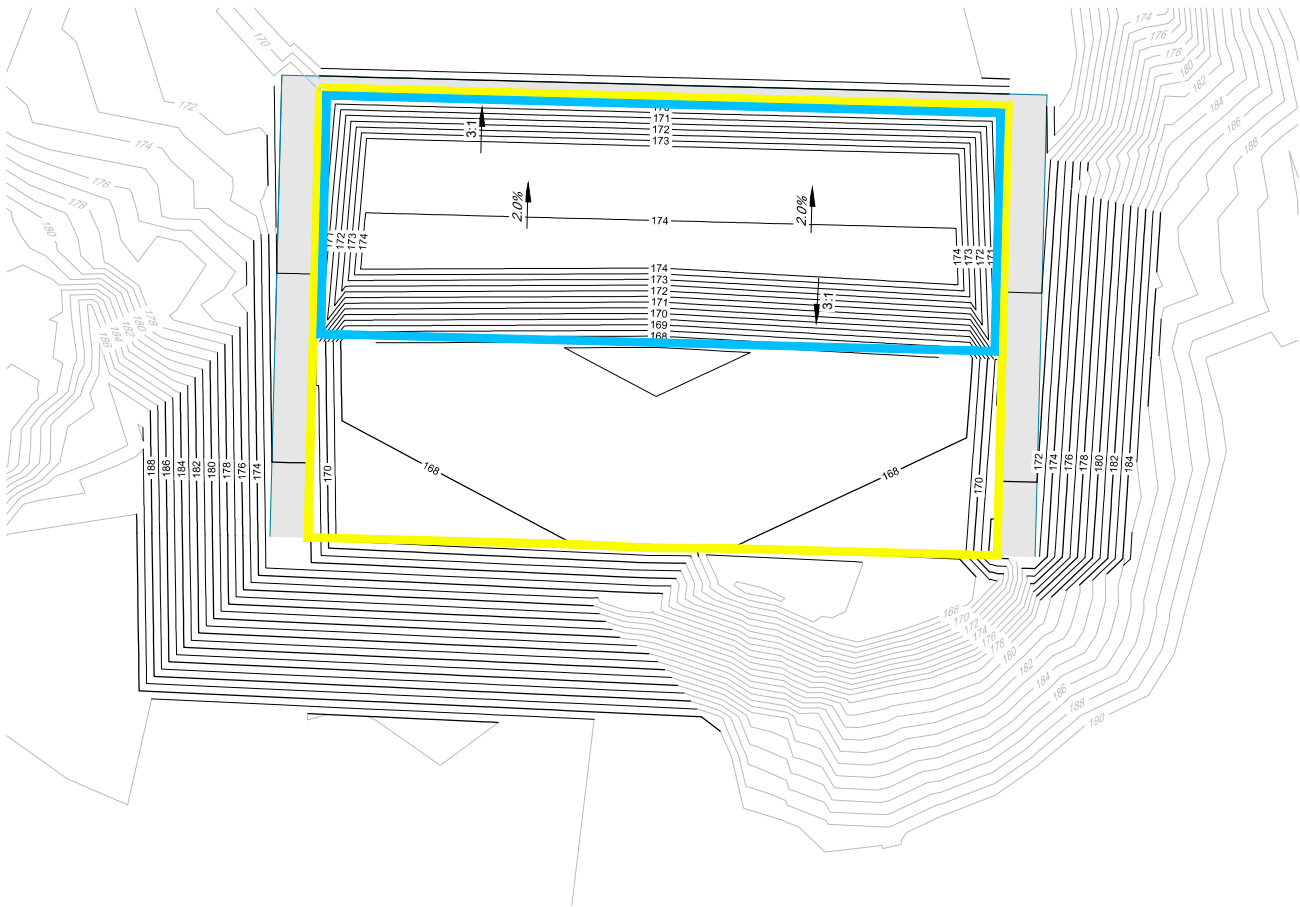


SECTION B-B'  
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VERT: 1:250  
C-2B

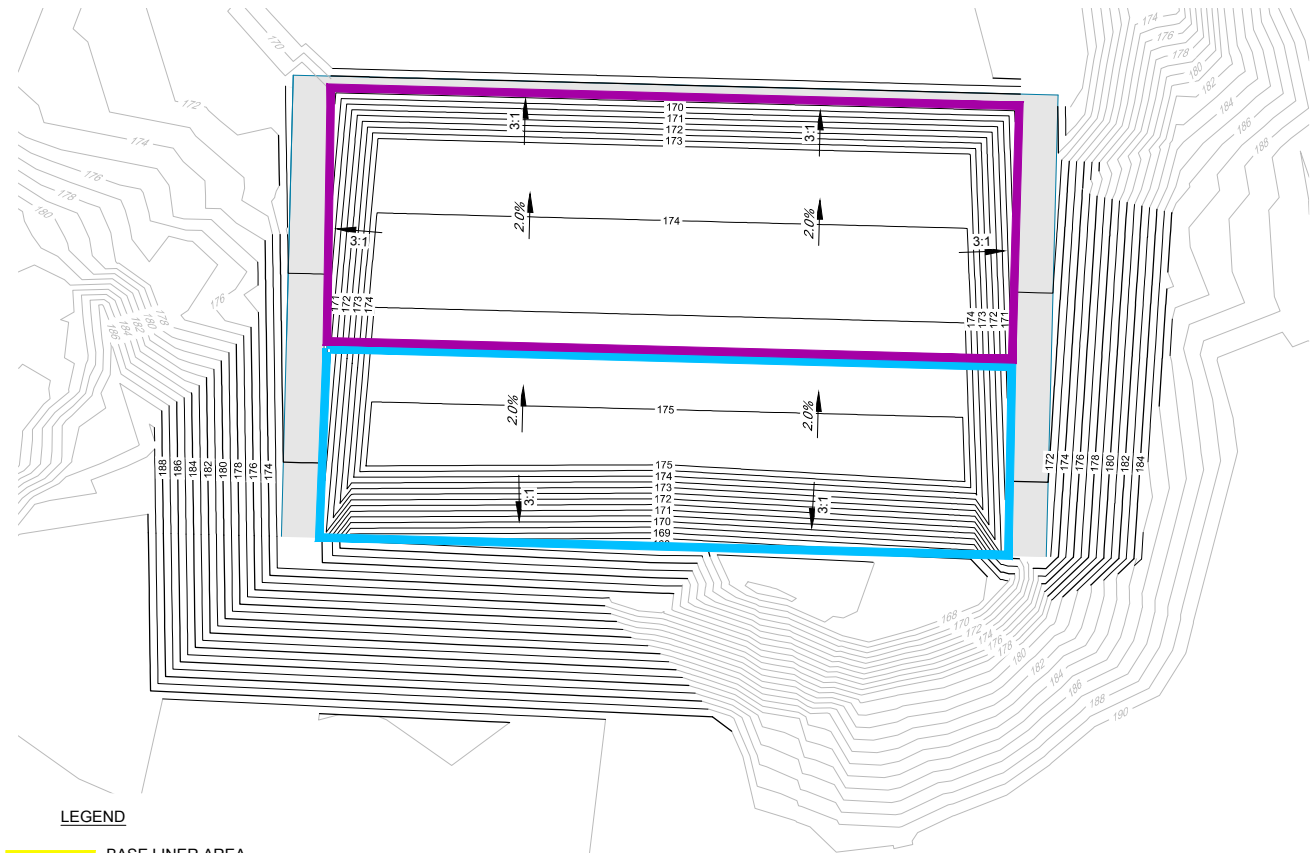
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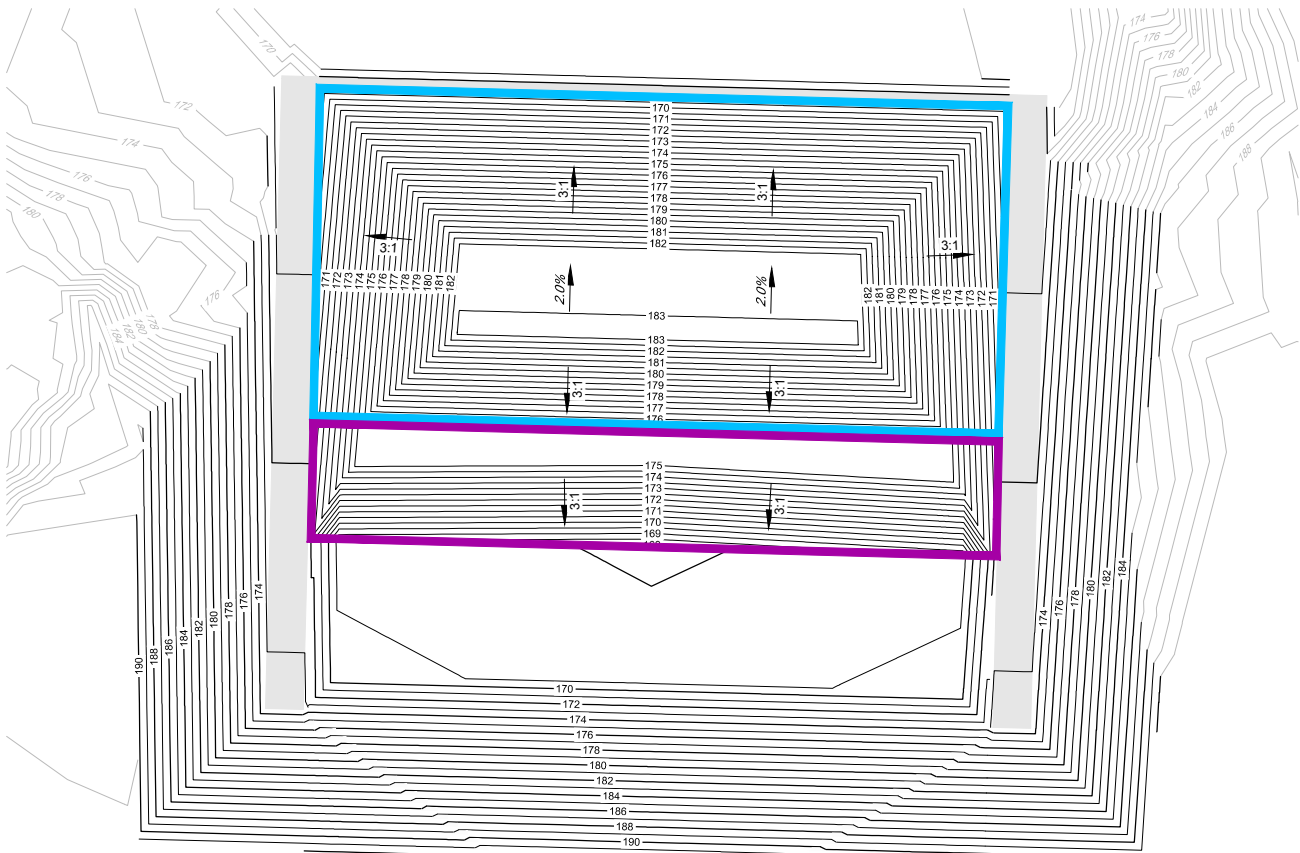
PHASE I



PHASE I: STAGE 1A



PHASE I: STAGE 1B



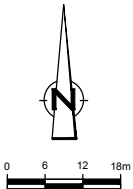
PHASE I: STAGE 1C

- LEGEND
- BASE LINER AREA
  - DAILY COVER AREA
  - INTERMEDIATE COVER AREA
  - FINAL COVER AREA



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Project Manager **G. FERRARO** Date **DECEMBER 2015**

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Title  
**FILL PLAN  
PHASE 1: STAGE 1A - 1C**

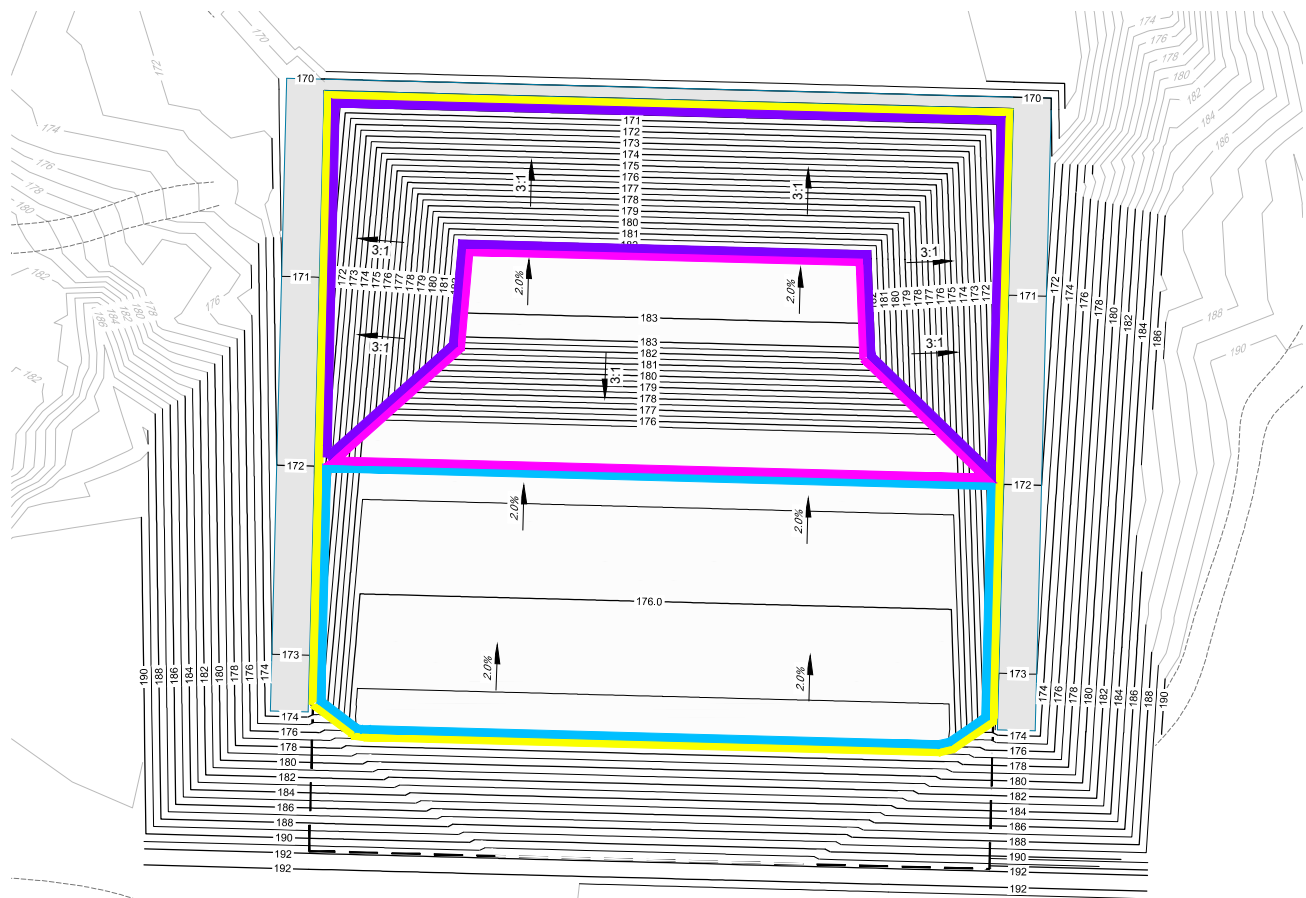
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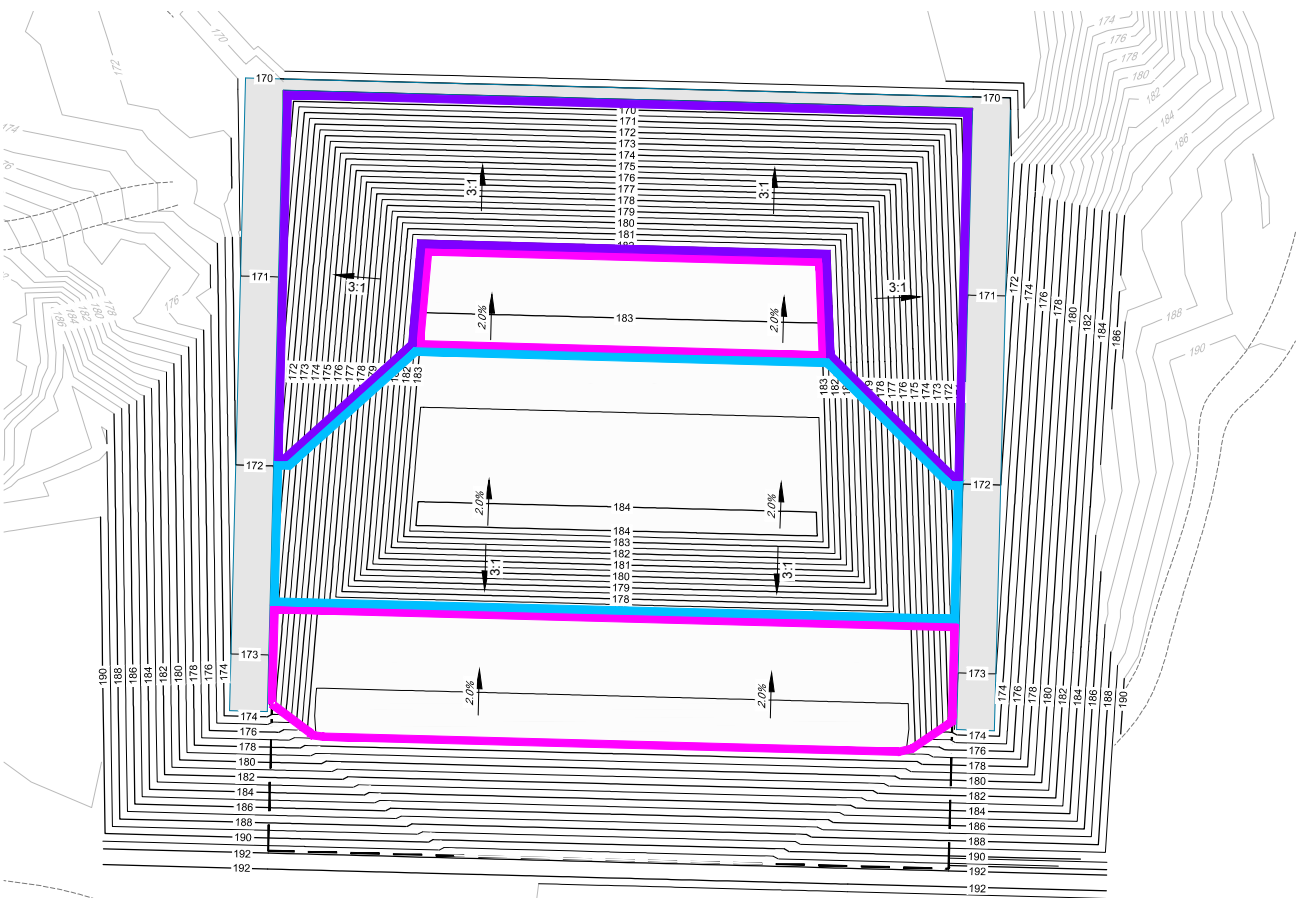
Sheet 8 of 15

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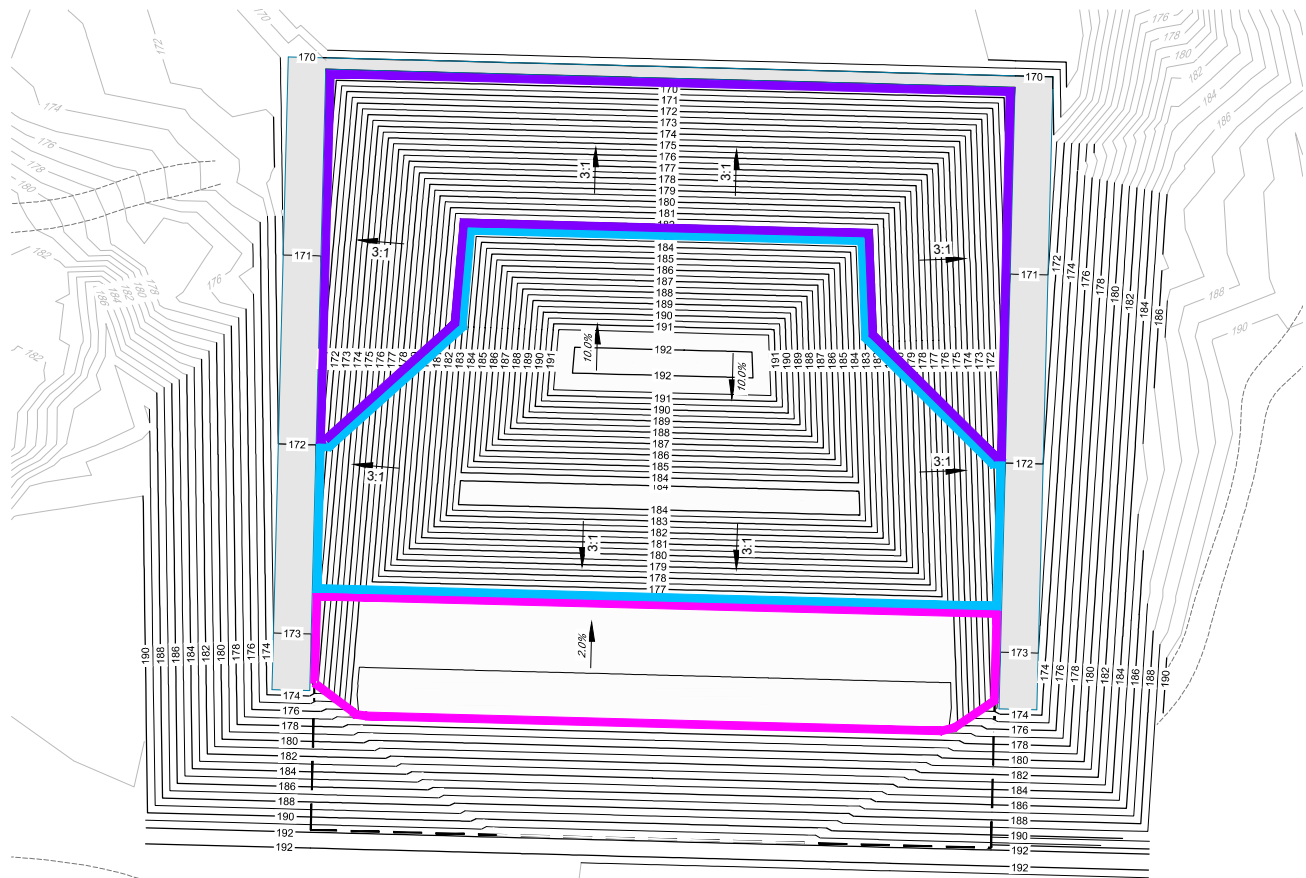




PHASE II: STAGE 2A



PHASE II: STAGE 2B



PHASE II: STAGE 2C

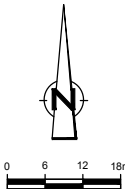
- LEGEND
- BASE LINER AREA
  - DAILY COVER AREA
  - INTERMEDIATE COVER AREA
  - FINAL COVER AREA

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Project  
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	FINAL - CLIENT REVIEW	KD	DB	APR 2016
	DRAFT - STAKEHOLDER CONSULTATION	TW	DB	FEB 2016
	DRAFT - CLIENT REVIEW	TW	DB	DEC 2016

No.	Issue	Drawn	Approved	Date
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Drawn **T.WAGSTAFF** Designer **D. BARTON**

Drafting Check **D. BARTON** Design Check **S. STURGEON**

Project Manager **G. FERRARO** Date **DECEMBER 2015**

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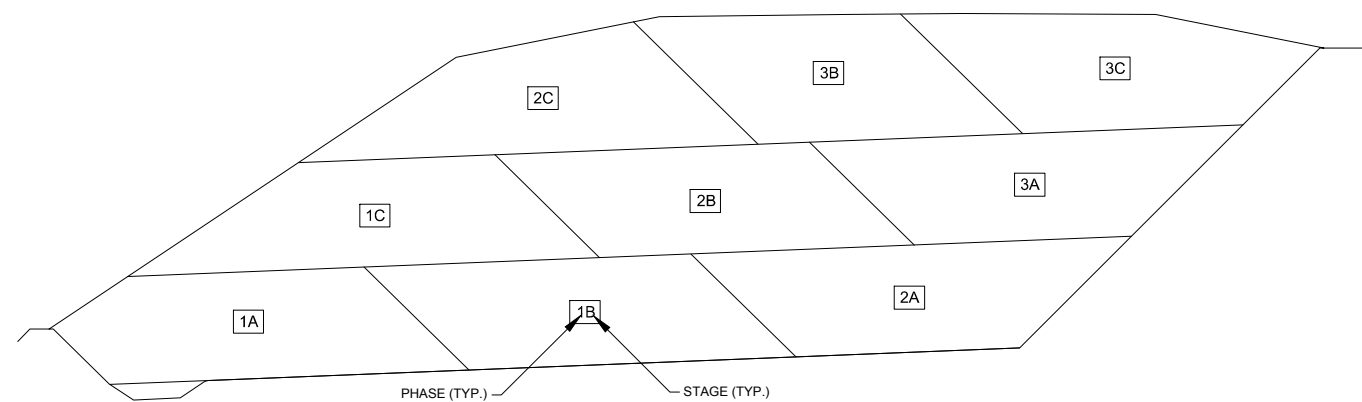
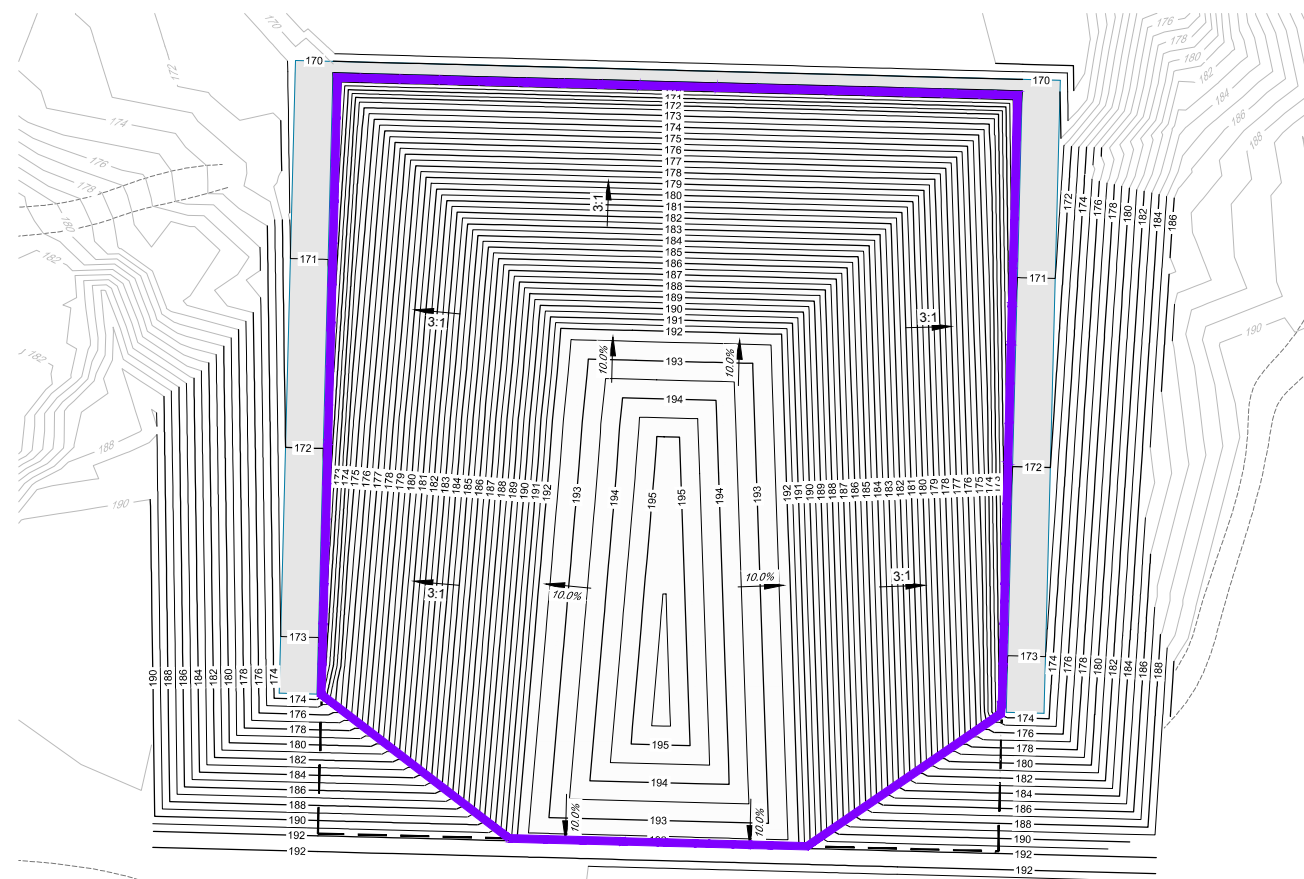
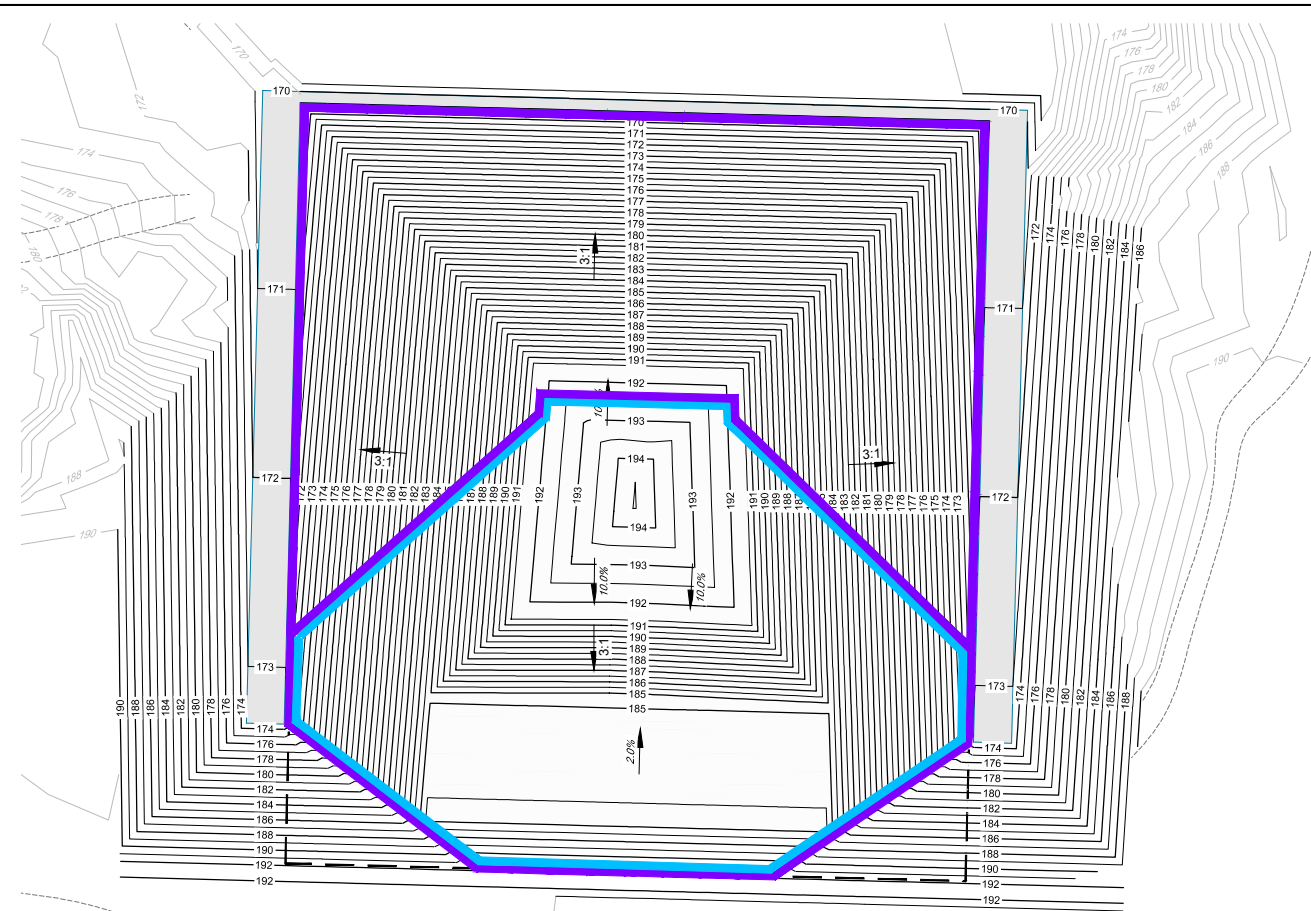
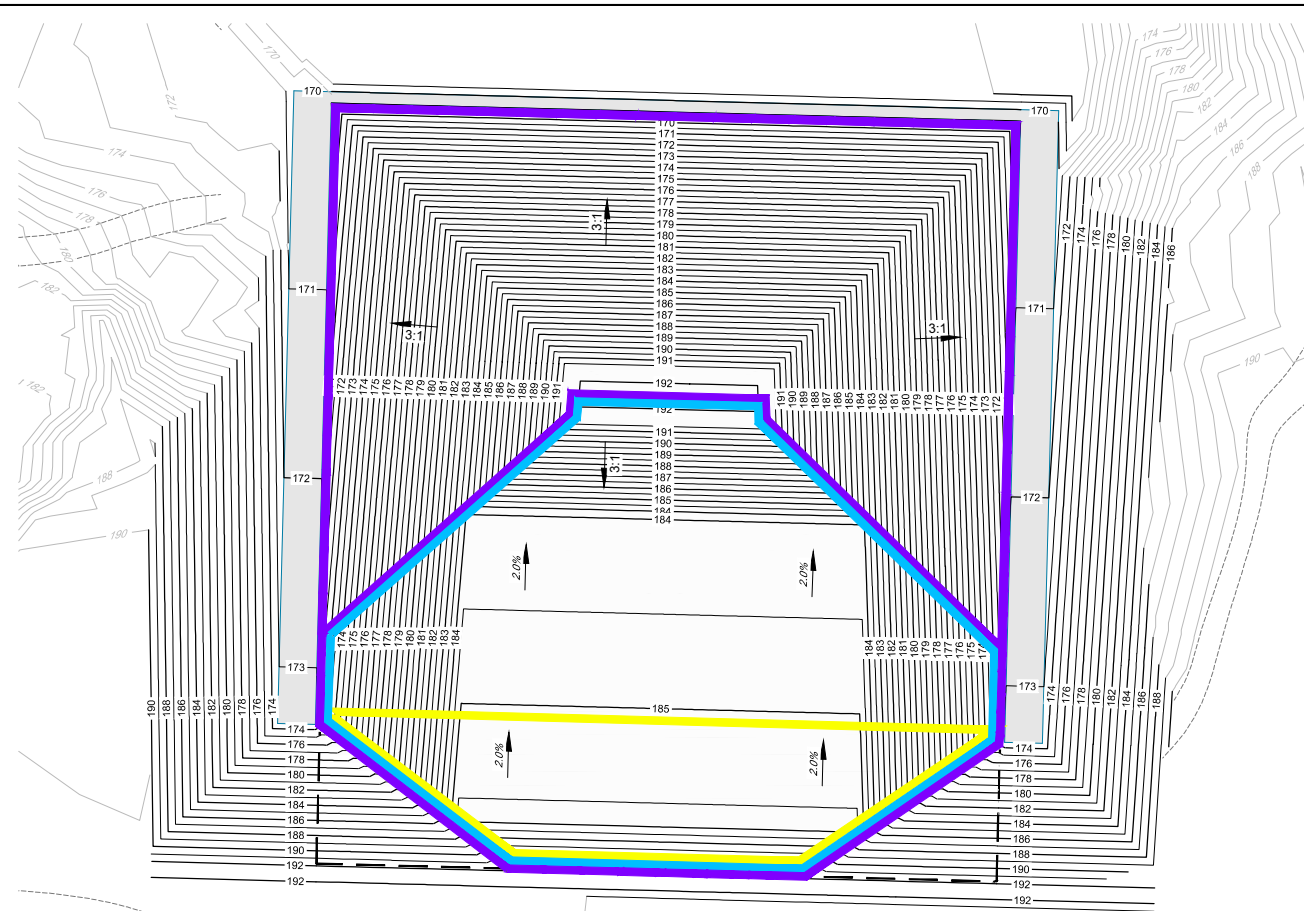
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Project No. **88877-02**

Title  
**FILL PLAN  
PHASE II: STAGE 2A - 2C**

Sheet No.

**C-08**



## FILL SEQUENCE

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

LEGEND

 BASE LINER AREA



 DAILY COVER AREA

INTERMEDIATE COVER AREA

 FINAL COVER AREA

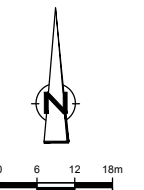
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	DRAFT - CLIENT REVIEW	TW	DB	DEC 2016

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Drafting	D. BARTON	Design	S. STURGEON
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Check	D. BARTON	Check	S. STURGEON
Project			

Project Manager	<b>G. FERRARO</b>	Date	<b>DECEMBER 2015</b>
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**ANSI D** size drawing  
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Project No. 88877-02

Title
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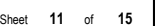
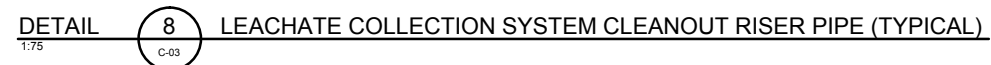
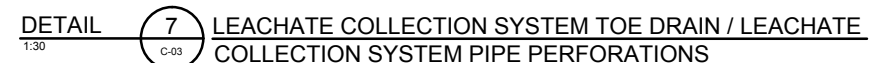
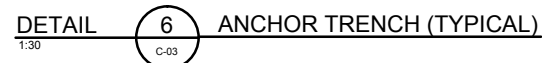
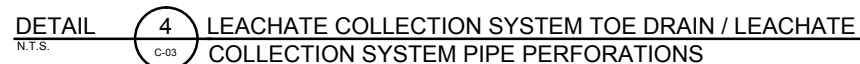
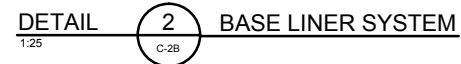
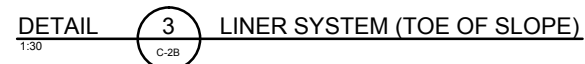
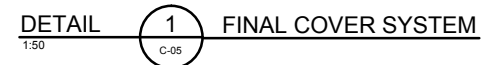
**FILL PLAN**  
**PHASE III: STAGE 3A - 3C**

Sheet No.

**C-09**

Sheet 10 of 15





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Project Manager **G. FERRARO** Date **DECEMBER 2015**

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Original Size  
**ANSI D**  
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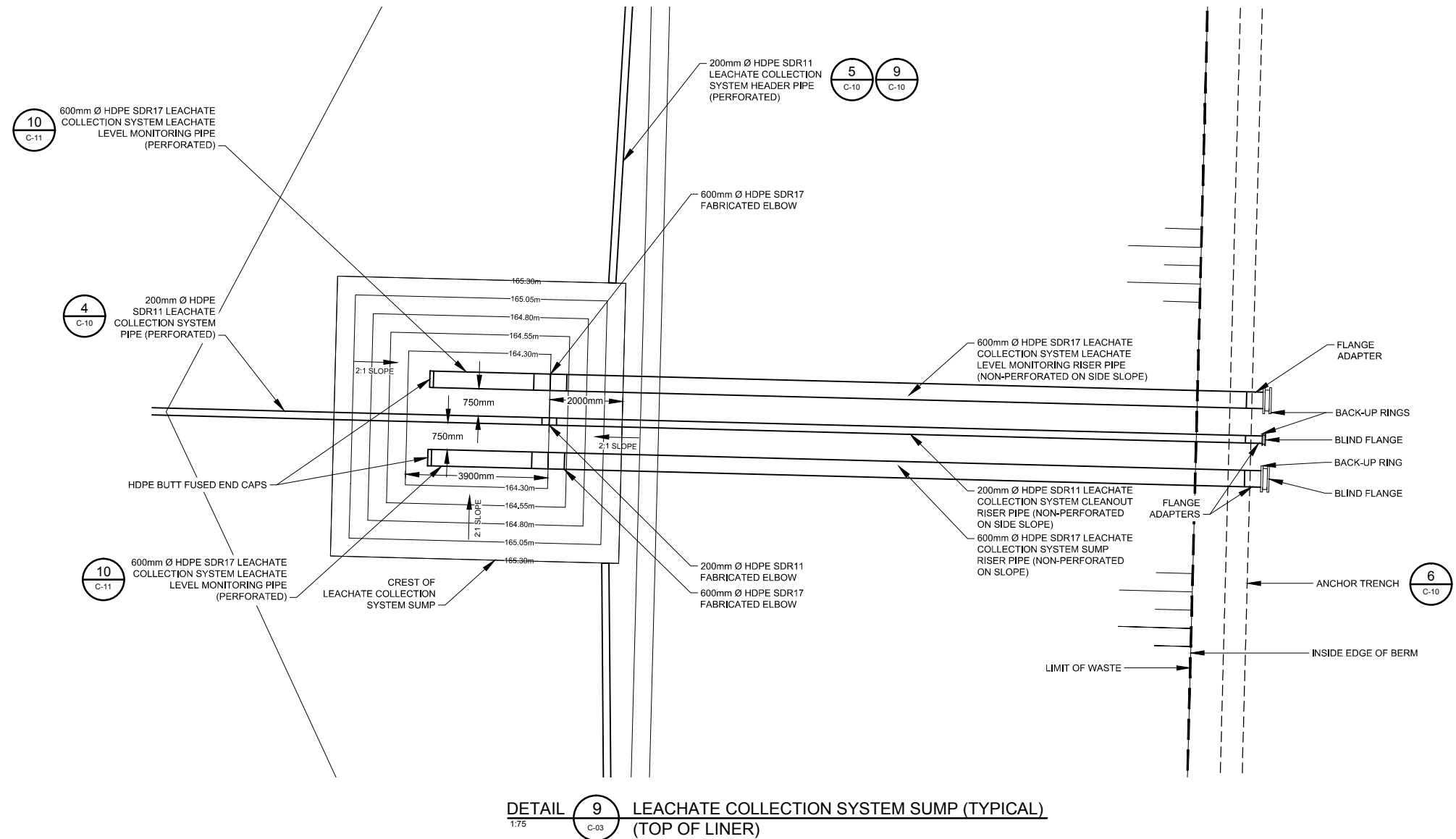
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**LEACHATE COLLECTION SYSTEM SUMP AND RISERS I**

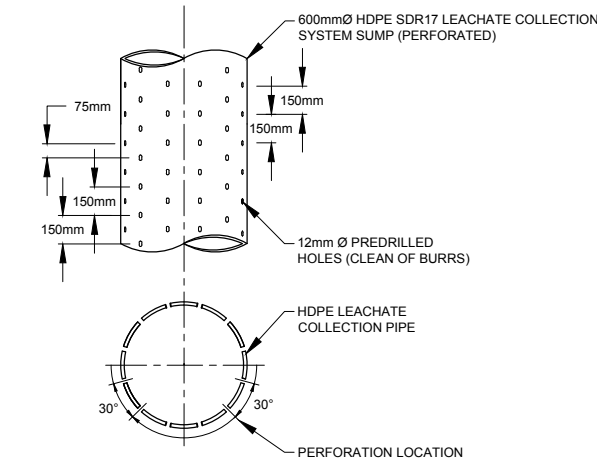
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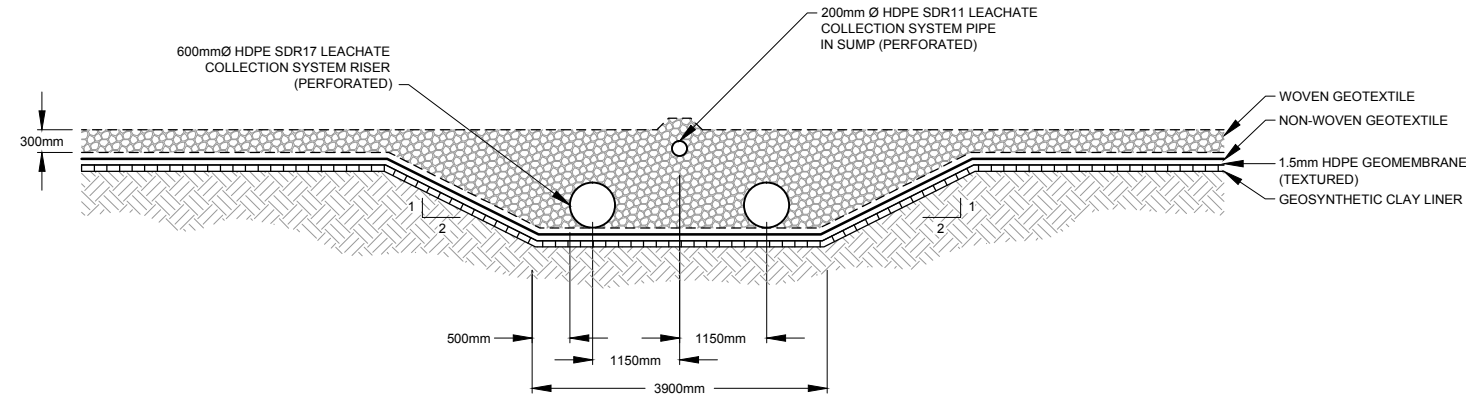
Sheet 12 of 15



DETAIL 9 LEACHATE COLLECTION SYSTEM SUMP (TYPICAL)  
1:75 (TOP OF LINER)



DETAIL 10 600mmØ LEACHATE COLLECTION SYSTEM SUMP PIPE PERFORATIONS  
NTS



DETAIL 11 LEACHATE COLLECTION SYSTEM SUMP  
1:50

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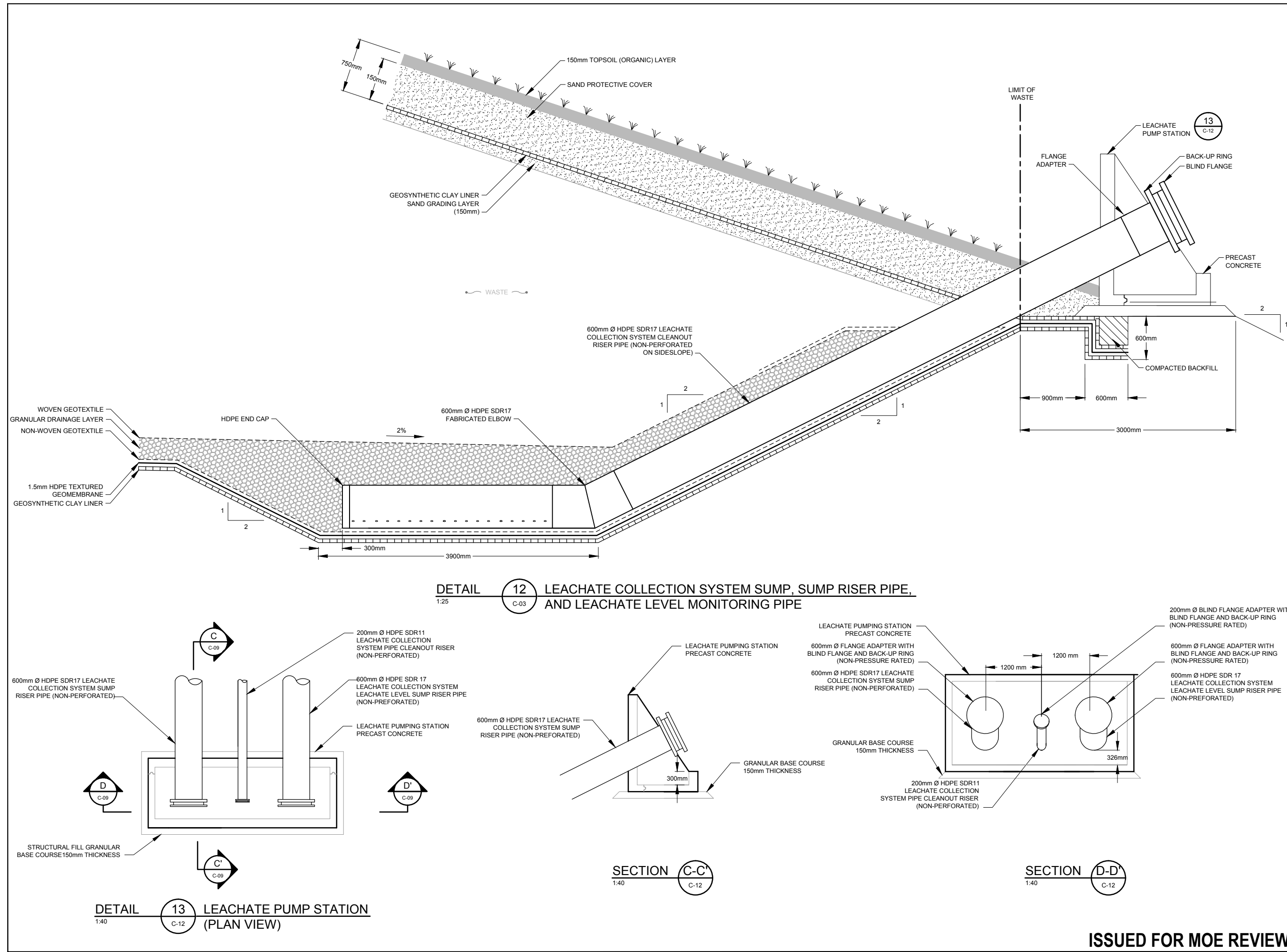
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**LEACHATE COLLECTION SYSTEM SUMP AND RISERS II**

Sheet No.

**C-12**

Sheet **13** of **15**







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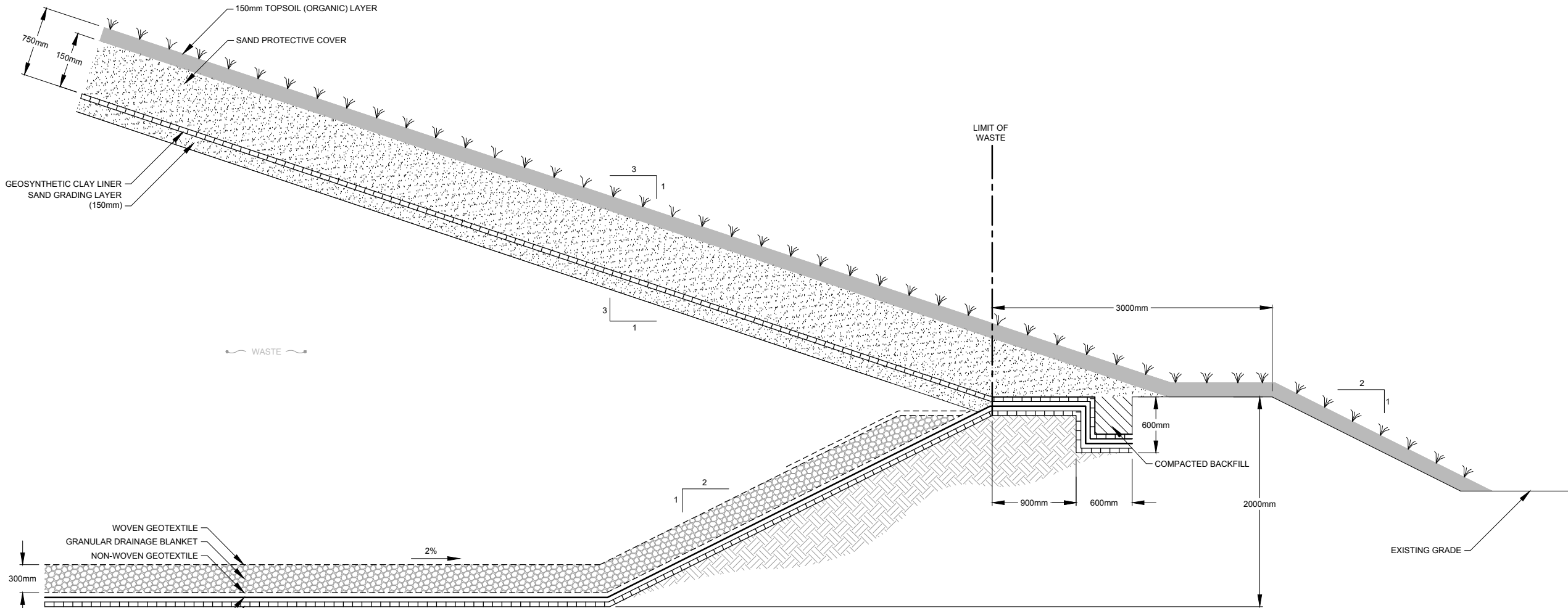
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**PERIMETER TIE-IN DETAILS I**

Sheet No.

**C-13**

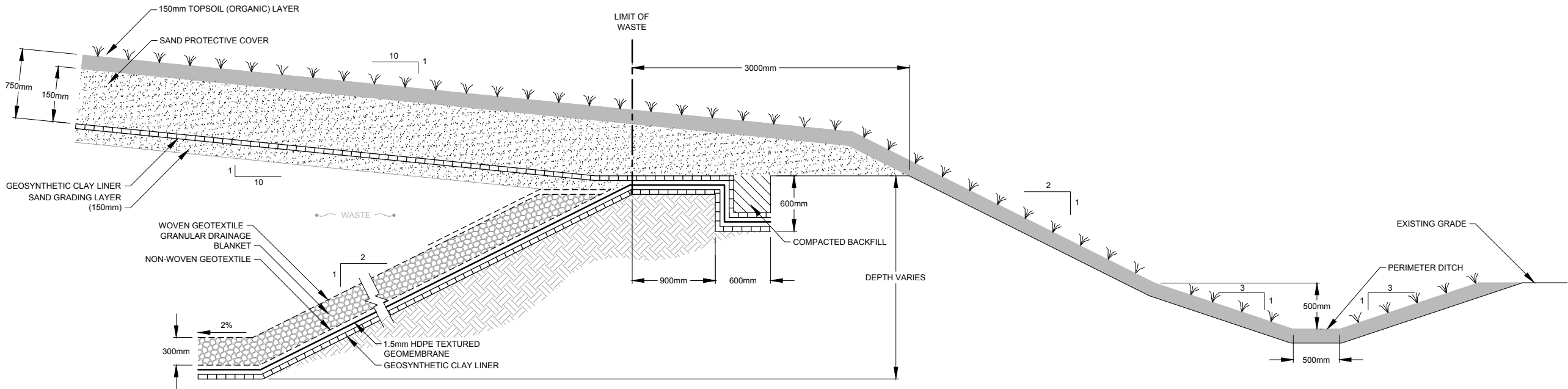
Sheet 14 of 15



**DETAIL 14 PERIMETER TIE-IN DETAIL ON NORTH SIDE (TYPICAL)**

1:25

C-2B



**DETAIL 15 PERIMETER TIE-IN DETAIL ON SOUTH SIDE (TYPICAL)**

1:25

C-2B

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Original Size  
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Scale **1:25**  
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0 20mm

Project No. **88877-02**

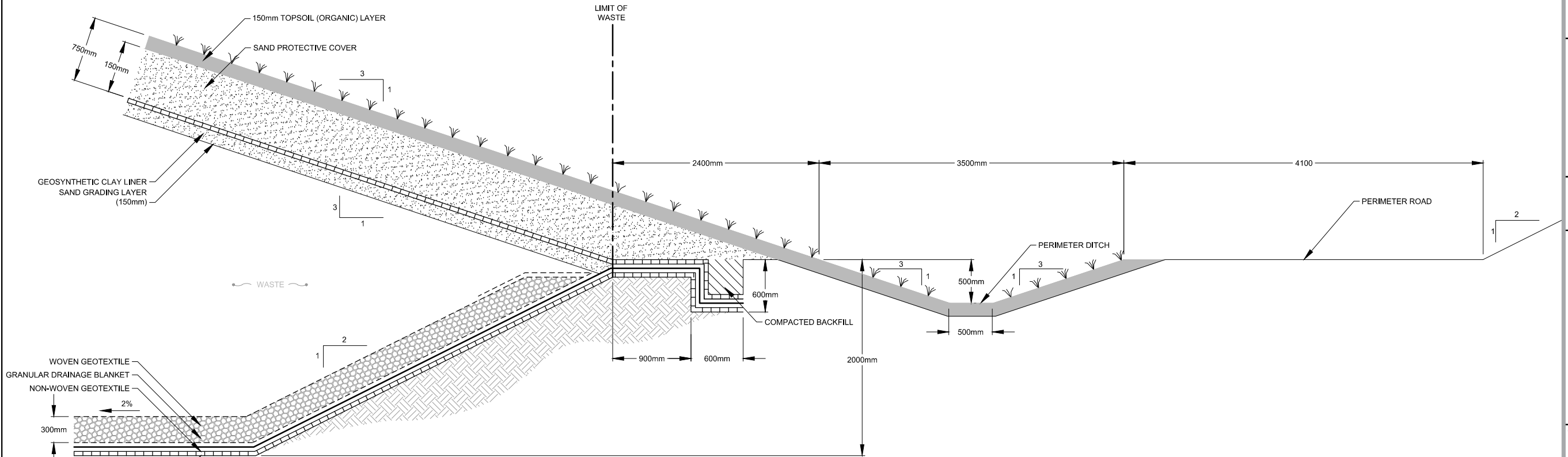
Title

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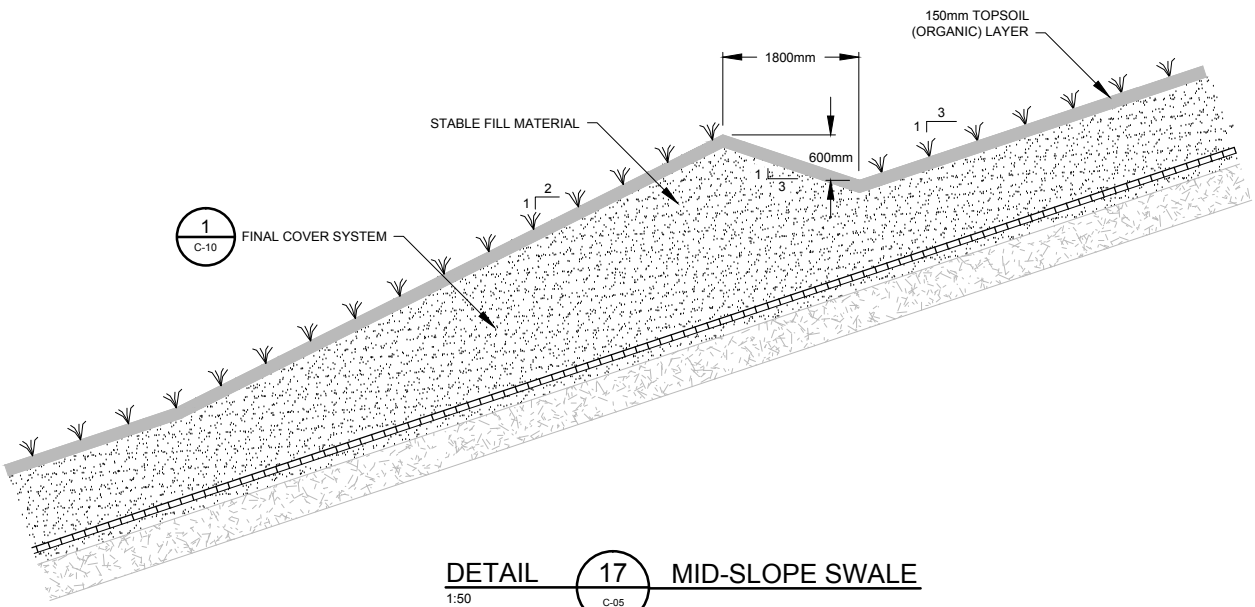
Sheet No.

**C-14**

Sheet 15 of 15



DETAIL **16** PERIMETER TIE-IN DETAIL - EAST/WEST (TYPICAL)  
1:25 C-2B



DETAIL **17** MID-SLOPE SWALE  
1:50 C-05

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# Appendices

# Appendix A

## Legal Survey Plan

# SUBDIVISION PLAN OF PART OF THE WEST PART OF LOT 85 (D.D. 10038) SAYWARD DISTRICT

SCALE: 1 inch = 300 feet

## LEGEND

- ① G.P. Cor. indicates Standard Concrete Monument found
- I.P. indicates Standard Iron Post set
- O.P. indicates Iron survey post found
- I.P. indicates Iron survey post set

Bearings are astronomic and derived from Plan 1443 R

PLAN

10038

Entered in the Land Registry Office at Victoria  
British Columbia this day of 1977

REGISTRAR

706

85

D L

MCIVOR LAKE

BLOCK A

PLAN  
2047-R

A  
121.3 Ac

UPLAND EXCAVATING (1971) LTD.

President

This plan lies within the Regional  
District of Comox-Strathcona

Approved under the Land Registry  
Act this 12th day of MAY, 1977

*C. J. Anderson*  
Deputy Registrar  
District of Comox-Strathcona

Approved under the Land Registry  
Act this 26th day of MAY, 1977

*Don Young*  
Deputy Registrar  
District of Comox-Strathcona

Don Young & Associates  
Surveyors  
Highway 10  
Sayward, B.C.  
287-4865  
77027  
Don Young

LAKEHURST DEVELOPMENTS LTD.

I, D. YOUNG, of Comox-Strathcona, British Columbia, Land Surveyor  
make oath and say that I was present at and did personally  
superintend the survey represented by this plan and that the  
survey and plan are correct. The said survey was completed on  
the 12th day of April, 1977

Sworn before me this 2nd day of April, 1977

A Commissioner for taking oaths in British Columbia



# Appendix B

## Existing Permit PR - 10807



Province of  
British Columbia

Ministry of Environment,  
Lands and Parks

BC  
Environment

Vancouver Island Region 1  
Regional Headquarters  
2569 Kenworth Road  
Nanaimo  
British Columbia  
V9T 4P7  
Telephone: (604) 751-3100

JUN 01 1992

File: PR-10807

REGISTERED MAIL

Upland Excavating Ltd.  
480 - 10th Avenue  
Campbell River, British Columbia  
V9W 4E3

Gentlemen:

Enclosed is a copy of Permit No. PR-10807 issued under the provisions of the Waste Management Act, in the name of Upland Excavating Ltd. Your attention is respectfully directed to the terms and conditions outlined in the Permit.

The administration of this Permit will be carried out by staff from our Regional Office located at 2569 Kenworth Road, Nanaimo, British Columbia, V9T 4P7 (telephone 751-3100). Plans, data and reports pertinent to the Permit are to be submitted to the Regional Waste Manager at this address.

Yours truly,

G.E. Oldham, P. Eng.  
Regional Waste Manager

Enclosure

PROVINCE OF  
BRITISH COLUMBIA



ENVIRONMENTAL PROTECTION  
2569 Kenworth Road  
Nanaimo, British Columbia  
V9T 4P7  
Telephone: (604) 751-3100

MINISTRY OF ENVIRONMENT,  
LANDS AND PARKS

## PERMIT

*Under the Provisions of the Waste Management Act*

Upland Excavating Ltd.

480 - 10th Avenue

Campbell River, British Columbia

V9W 4E3

is authorized to discharge refuse from Campbell River and the surrounding area to the land and air contaminants from a regulated open burning operation.


An annual fee will be determined on the basis of your industrial code and capacity in accordance with the Waste Management Fees Regulation.

This Permit 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 shall rest with the Permittee.

Date issued: JUN 01 1992

Date amended:  
(most recent)

Page: 1 of 6

  
G. E. Oldham, P. Eng.  
Regional Waste Manager

Permit No. PR-10807

1. AUTHORIZED DISCHARGES AND RELATED REQUIREMENTS

1.1 Refuse

1.1.1 The maximum rate at which refuse may be discharged is 3200 m<sup>3</sup>/year.

1.1.2 The type of refuse which may be discharged is inert municipal.

1.1.3 The components of the refuse which may be discharged are stumps, trees, land clearing waste, selected building demolition debris, and residue of combustion from the open burning of woodwaste.

1.1.4 The works authorized are a landfill operation as directed, located approximately as shown on the attached Appendix A-1.

1.1.5 The works authorized must be complete and in operation on and from the date of this permit.

1.2 Emissions

1.2.1 The works authorized are a regulated open burning operation, as directed, located approximately as shown on the attached Appendix A-1.

1.2.2 The works authorized must be complete and in operation on and from the date of this permit.

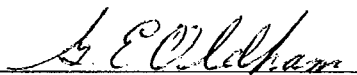
2. LOCATION OF THE FACILITIES

Lot A, District Lot 85, Plan 30709, Sayward District.

Date issued: JUN 01 1992

Date amended:  
(most recent)

Page: 2 of 6

  
G. E. Oldham, P. Eng.  
Regional Waste Manager

Permit No. PR-10807

3. LANDFILL OPERATION

The Permittee shall maintain the landfill as a Level E operation in accordance with the Pollution Control Objectives for Municipal Type Waste Discharges in British Columbia, dated September 1975, which, in normal conditions, requires that cover material be applied once per forty days of operation and at least once every two months. The Regional Waste Manager may vary the frequency of covering when freezing conditions or other circumstances affect normal operation.

4. SITE PREPARATION AND RESTORATION

Provision of fencing, site access, vehicle safety barriers, surface water diversionary works, firebreaks and site restoration as required, shall be carried out to the satisfaction of the Regional Waste Manager.

5. PUTRESCIBLE WASTE

No putrescible wastes shall be discharged at this site.

6. OPERATIONAL REQUIREMENTS FOR REGULATED OPEN BURNING

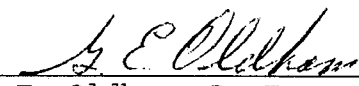
(a) Area

The operation shall be restricted to an area on the site which is satisfactory to the Regional Waste Manager. If required, this area shall be fenced to restrict access to the burn area stockpile.

Date issued: JUN 01 1992

Date amended:  
(most recent)

Page: 3 of 6

  
G. E. Oldham, P. Eng.  
Regional Waste Manager

Permit No. PR-10807

(b) Quantity and Frequency

The maximum quantity of wastes to be treated is 750 m<sup>3</sup> per burn at a frequency not to exceed four burns per year. Each burn shall comprise one continuous period necessary to reduce the stockpiled waste to ashes, and shall not exceed 48 hours.

(c) Nature of Wastes

Generally, no waste shall be burned which is unacceptable to the Regional Waste Manager. Acceptable materials may include stumps, trees and similar items, but exclude nuisance causing combustibles such as rubber, plastics, tars, insulation, etc. Demolition debris, excepting wood products, shall not be burned at this site. Burning of any antisapstain treated wood products is prohibited.

(d) Timing

Burning shall take place only when an attendant is on duty and when conditions promote rapid combustion and dispersion of combustion products with a wind direction that conveys the resulting gases away from McIvor Lake and Highway #28 (Gold River Highway). Burning shall take place only when the ventilation index for the Campbell River area is forecasted to exceed 33 for the period of the burn. The ventilation index is issued by the Pacific Weather Centre, Environment Canada, Vancouver, telephone 664-9032. Materials shall be charged to the facility in a manner to promote best combustion and restrict the uplift of lighter constituents. No burning shall take place during periods of fire hazard or when burning is prohibited by other government agencies.

Date issued: JUN 01 1992

Date amended:  
(most recent)

Page: 4 of 6



G. E. Oldham, P. Eng.  
Regional Waste Manager

Permit No. PR-10807

(e) Fire Control

Suitable approved devices shall be available for extinguishing fires to prevent them from spreading to surrounding areas. Such devices may include a pressurized water supply, chemical type fire extinguishers, or an earth stockpile. If an earth stockpile is contemplated for fire control, earth moving equipment shall be available at the site during burning. A fireguard shall be cleared and maintained free of combustible materials.

(f) Residue of Combustion

As soon as the residue of combustion has cooled to ambient temperature, it shall be incorporated into the adjacent landfill.

(g) Other Requirements

The Ministry of Environment, Lands and Parks has established a Smoke Management Steering Committee to review the present practice of burning wood residue. A need for additional controls, such as auxiliary forced air, or other requirements, may result from the recommendations of the Steering Committee or following the observation of any burning episode, and the Permittee shall install such equipment or take measures as may be required by the Regional Waste Manager.

The Ministry is also in the process of revising the existing pollution control objectives for municipal landfills. Based on the provisions of the new criteria, the Permittee may be required to terminate open burning at this site.


7. GROUNDWATER MONITORING WELLS

The Permittee shall install not more than two groundwater monitoring wells. The number, locations and structural details of these facilities are subject to the approval of the Regional Waste Manager.

Date issued: JUN 01 1992

Date amended:  
(most recent)

Page: 5 of 6

  
G. E. Oldham, P. Eng.  
Regional Waste Manager

Permit No. PR-10807



8. WASTE REDUCTION

The Ministry of Environment, Lands and Parks has developed a policy to reduce, recycle and reuse solid wastes. The Permittee is encouraged to segregate for recycling and reuse, where possible, materials destined for disposal at this site.

In certain landfill environments, some construction and demolition debris, may create air and water quality concerns. If problems arise at this site that are attributable to specific wastes, the Regional Waste Manager may require that alternate disposal procedures be implemented.

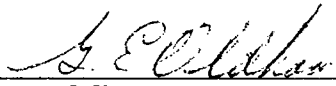
9. WASTE MANAGEMENT PLANNING

The Permittee is advised that the Regional District of Comox-Strathcona is developing a Solid Waste Management Plan which may have an impact on the discharge authorized by this Permit.

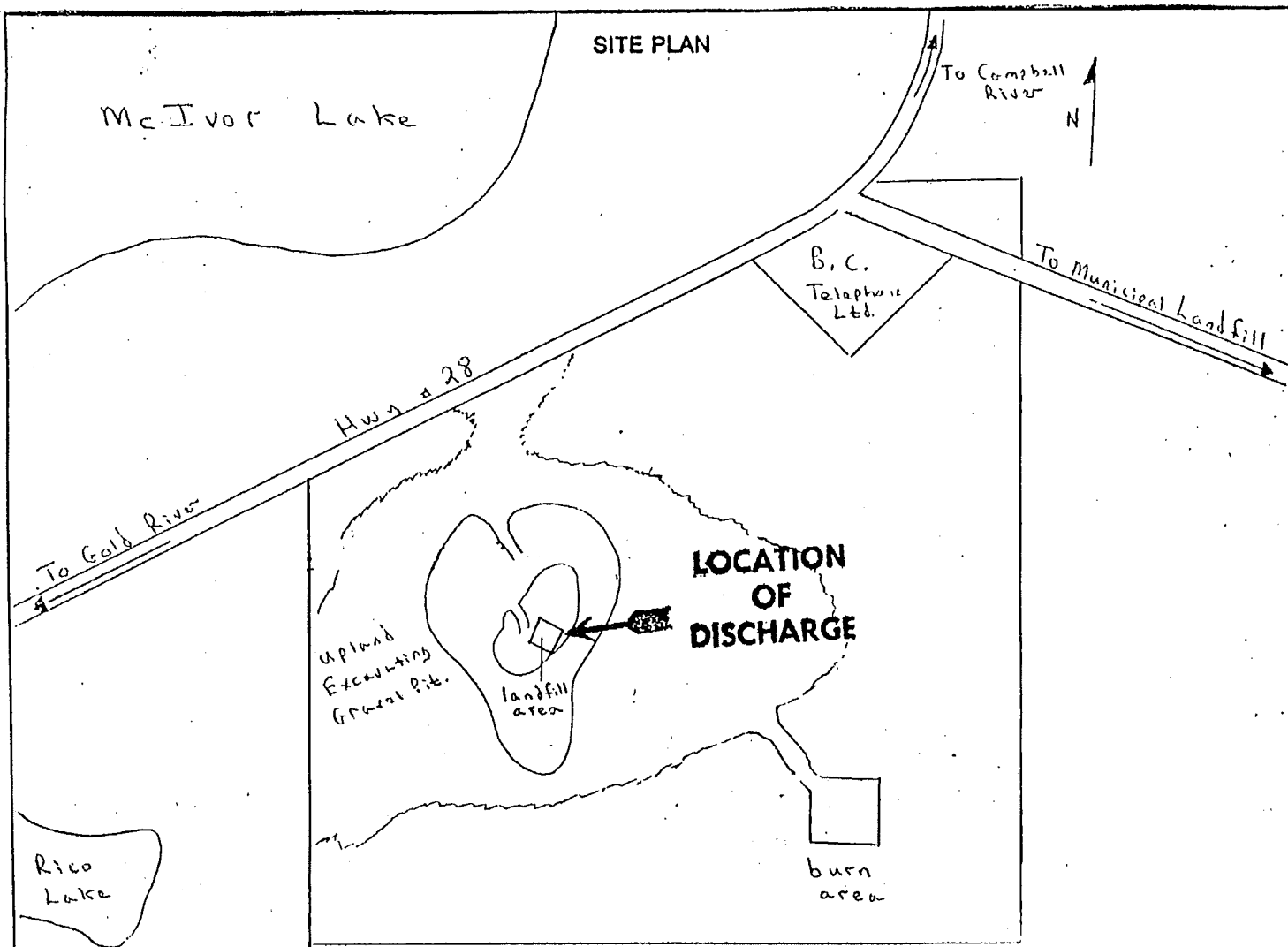
Date issued: JUN 01 1992

Date amended:  
(most recent)

Page: 6 of 6

  
\_\_\_\_\_  
G. E. Oldham, P. Eng.  
Regional Waste Manager

Permit No. PR-10807

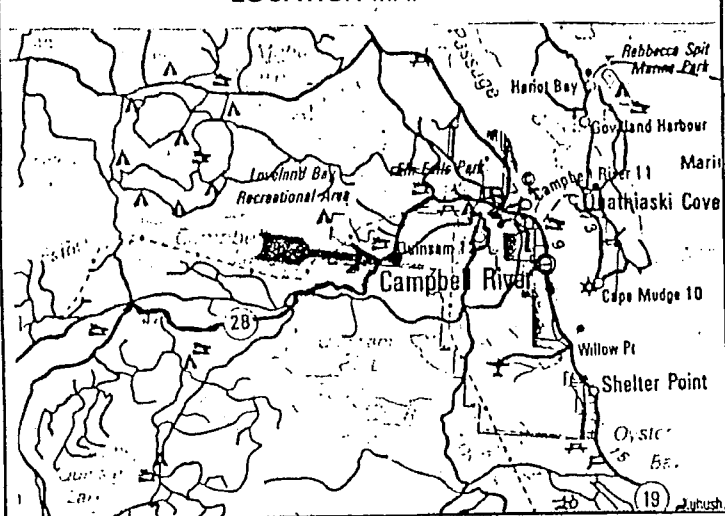


SCALE:  $\approx 1:8,500$

LEGAL DESCRIPTION:

Lot A, District Lot 85, Plan 30709,  
Sayward District

LOCATION MAP



Upland Excavating Ltd.

Name of Permittee

Appendix A-1 to Permit No. PR-10807

Approval No.

Date Issued

JUN 01 1992

Date Amended

Regional Waste Manager

*[Signature]*

# Appendix C

## Surface Water Management Plan Supporting Documents

idf\_CAMPBELL\_RIVER\_A.txt  
Environnement Canada/Environnement 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

2012/02/09

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CAMPBELL RIVER A BC 1021261  
(composition)  
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)

\*\*\*\*\*

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.	1.5	2.2	2.5	3.1	3.5	3.6	7.1	10.1	13.2

idf_CAMPBELL_RIVER_A.txt									
Écart-type	0.45	0.75	0.62	0.35	0.86	1.84	0.21	0.06	0.50
Skew.									
Di ssymétrie									
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	Durati on/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

\*\*\*\*\*

Durati on/Durée	2	5	10	25	50	100	#Years
	yr/ans	yr/ans	yr/ans	yr/ans	yr/ans	yr/ans	Années
5 mi n	3.6	4.9	5.8	7.0	7.8	8.6	21
10 mi n	5.0	6.9	8.1	9.7	10.9	12.1	21
15 mi n	6.0	8.2	9.7	11.5	12.9	14.2	21
30 mi n	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

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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%

\*\*\*\*\*

Durati on/Durée	2	5	10	25	50	100	#Years
	yr/ans	yr/ans	yr/ans	yr/ans	yr/ans	yr/ans	Années
5 mi n	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 mi n	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 mi n	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 mi n	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:  $R = A \cdot T^B$

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	5	10	25	50	100
	yr/ans	yr/ans	yr/ans	yr/ans	yr/ans	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 Design  
2016 Design, Operations, and Closure Plan  
Uplands Excavating Ltd.  
Proposed Upland Landfill  
Campbell River, British Columbia**

**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=	3501	m <sup>3</sup>
Sediment Forebay Volume=	10% of Infiltration Basin Volume	
Sediment Forebay Volume=	350	m <sup>3</sup>
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.



**Design Calculations - Infiltration Pond  
2016 Design, Operations, and Closure Plan  
Uplands Excavating Ltd.  
Proposed Upland Landfill  
Campbell River, British Columbia**

**East and West Infiltration Pond  
Stage/Storage Relationship**

<b>Elevation</b>		<b>Area</b>		<b>Depth</b>		<b>Total Storage</b>	
<b>(m)</b>	<b>(ft)</b>	<b>(m<sup>2</sup>)</b>	<b>(ft<sup>2</sup>)</b>	<b>(m)</b>	<b>(ft)</b>	<b>(m<sup>3</sup>)</b>	<b>(ft<sup>3</sup>)</b>
150	492.1	2682	28873	0			
150.20	492.8	2951	31760	0.2	0.7	563	19893
150.40	493.4	3246	34936	0.4	1.3	1186	41869
150.60	494.1	3570	38430	0.6	2.0	1876	66243
150.80	494.8	3927	42273	0.8	2.6	2644	93367
151.00	495.4	4320	46500	1	3.3	3501	123643

Note:

\* Volume for an interval calculated by Average End Area Method.

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

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## Element Count

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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

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## Raingage Summary

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Name	Data Source	Data Type	Recording Interval
100yr_SCS_24h_Type_IA_118.2mm	100yr_SCS_24h_Type_IA_118.2mm	INTENSITY	15 min.
10yr_SCS_24h_Type_IA_90mm	10yr_SCS_24h_Type_IA_90mm	INTENSITY	15 min.
5yr_SCS_24h_Type_IA_81.2mm	5yr_SCS_24h_Type_IA_81.2mm	INTENSITY	15 min.
6month_SCS_24h_Type_IA_61.61mm	6month_SCS_24h_Type_IA_61.61mm	INTENSITY	15 min.

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## Subcatchment Summary

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Name	Area	width	%Imperv	%Slope	Rain Gage	Outlet
101	0.79	196.75	0.00	45.0000	5yr_SCS_24h_Type_IA_81.2mm	J5
102	0.08	21.05	0.00	45.0000	5yr_SCS_24h_Type_IA_81.2mm	J5
103	0.13	33.30	0.00	45.0000	5yr_SCS_24h_Type_IA_81.2mm	J4
104	1.35	245.89	0.00	35.0000	5yr_SCS_24h_Type_IA_81.2mm	J8
105	0.20	67.73	0.00	20.0000	5yr_SCS_24h_Type_IA_81.2mm	J7
106	0.95	146.54	0.00	22.0000	5yr_SCS_24h_Type_IA_81.2mm	J2
107	0.51	146.63	0.00	30.0000	5yr_SCS_24h_Type_IA_81.2mm	J5
108	0.53	150.14	0.00	30.0000	5yr_SCS_24h_Type_IA_81.2mm	J8
109	0.92	141.63	0.00	22.0000	5yr_SCS_24h_Type_IA_81.2mm	J3
110	0.18	40.56	0.00	22.0000	5yr_SCS_24h_Type_IA_81.2mm	J1
111	0.19	42.33	0.00	22.0000	5yr_SCS_24h_Type_IA_81.2mm	J1
112	0.46	185.00	100.00	15.0000	5yr_SCS_24h_Type_IA_81.2mm	
POND_East						
113	0.29	82.37	0.00	30.0000	5yr_SCS_24h_Type_IA_81.2mm	J9
114	0.50	200.56	100.00	15.0000	5yr_SCS_24h_Type_IA_81.2mm	
POND_West						
115	0.28	81.14	0.00	30.0000	5yr_SCS_24h_Type_IA_81.2mm	J6

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## Node Summary

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Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
J1	JUNCTION	164.50	0.50	0.0	
J10	JUNCTION	164.50	0.50	0.0	
J2	JUNCTION	164.30	0.50	0.0	
J3	JUNCTION	164.30	0.50	0.0	
J4	JUNCTION	164.00	0.50	0.0	
J5	JUNCTION	156.00	0.50	0.0	
J6	JUNCTION	153.00	0.50	0.0	
J7	JUNCTION	164.00	0.50	0.0	
J8	JUNCTION	156.00	0.50	0.0	
J9	JUNCTION	153.00	0.50	0.0	

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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

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#### 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	5.8374	0.0300
OL1	POND_West	OF1	OUTLET			
OL2	POND_East	OF2	OUTLET			

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#### Cross Section Summary

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Conduit	Shape	Full Depth	Full Area	Hyd. Rad.	Max. Width	No. of Barrels	Full Flow
D101	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.82
D102	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.64
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	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.82
D106	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.63
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.  
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#### Analysis Options

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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 hectare-m	Depth mm
Runoff Quantity Continuity		
Total Precipitation .....	0.599	81.198
Evaporation Loss .....	0.000	0.000
Infiltration Loss .....	0.055	7.447
Surface Runoff .....	0.543	73.627

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Final Storage .....	0.001	0.124
Continuity Error (%) .....	0.000	

	Volume hectare-m	Volume 10^6 ltr
*****	-----	-----
Flow Routing Continuity .....	0.000	0.000
*****		
Dry Weather Inflow .....	0.000	0.000
Wet Weather Inflow .....	0.543	5.434
Groundwater Inflow .....	0.000	0.000
RDII Inflow .....	0.000	0.000
External Inflow .....	0.000	0.000
External Outflow .....	0.551	5.509
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 (%) .....	-1.377	

\*\*\*\*\*  
Highest Continuity Errors  
\*\*\*\*\*  
Node POND\_East (-1.39%)  
Node POND\_West (-1.36%)

\*\*\*\*\*  
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  
\*\*\*\*\*

-----		Total	Total	Total	Total	Total	Total
Peak	Runoff	Precip	Runon	Evap	Infil	Runoff	Runoff
Runoff	Coeff						
Subcatchment		mm	mm	mm	mm	mm	10^6 ltr
CMS							
-----							
101		81.20	0.00	0.00	7.91	73.29	0.58
0.03	0.903						
102		81.20	0.00	0.00	7.91	73.29	0.06
0.00	0.903						
103		81.20	0.00	0.00	7.91	73.29	0.10
0.00	0.903						
104		81.20	0.00	0.00	7.94	73.26	0.99
0.05	0.902						
105		81.20	0.00	0.00	7.92	73.28	0.15
0.01	0.903						
106		81.20	0.00	0.00	9.05	72.14	0.69
0.03	0.889						
107		81.20	0.00	0.00	8.92	72.28	0.37
0.02	0.890						
108		81.20	0.00	0.00	8.92	72.28	0.38
0.02	0.890						

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109		81.20	0.00	0.00	9.05	72.14	0.66
0.03	0.889						
110		81.20	0.00	0.00	8.98	72.22	0.13
0.01	0.889						
111		81.20	0.00	0.00	8.98	72.22	0.14
0.01	0.889						
112		81.20	0.00	0.00	0.00	80.25	0.37
0.02	0.988						
113		81.20	0.00	0.00	8.92	72.28	0.21
0.01	0.890						
114		81.20	0.00	0.00	0.00	80.25	0.40
0.02	0.988						
115		81.20	0.00	0.00	8.92	72.28	0.21
0.01	0.890						

\*\*\*\*\*  
Node Depth Summary  
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Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Time of Max Occurrence days hr:min	Reported Max Depth Meters
J1	JUNCTION	0.00	0.07	164.57	0 08:00	0.02
J10	JUNCTION	0.00	0.00	164.50	0 00:00	0.00
J2	JUNCTION	0.02	0.22	164.52	0 08:00	0.07
J3	JUNCTION	0.01	0.19	164.49	0 08:00	0.06
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	0.11	153.11	0 08:00	0.03
J7	JUNCTION	0.00	0.04	164.04	0 08:00	0.01
J8	JUNCTION	0.01	0.14	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	0.17	150.17	0 10:03	0.05
POND_West	STORAGE	0.01	0.16	150.16	0 09:59	0.05

\*\*\*\*\*  
Node Inflow Summary  
\*\*\*\*\*

Flow		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
Balance						
Error						
Node	Type					
Percent						
J1	JUNCTION	0.013	0.013	0 08:00	0.269	0.269
-0.027						
J10	JUNCTION	0.000	0.000	0 00:00	0	0
0.000 ltr						
J2	JUNCTION	0.033	0.046	0 08:00	0.687	0.957
0.010						
J3	JUNCTION	0.032	0.032	0 08:00	0.664	0.664
0.006						
J4	JUNCTION	0.005	0.051	0 08:00	0.0976	1.05
-0.001						
J5	JUNCTION	0.049	0.099	0 08:00	1.01	2.06
-0.003						
J6	JUNCTION	0.010	0.109	0 08:00	0.205	2.27
0.002						
J7	JUNCTION	0.007	0.039	0 08:00	0.149	0.813
-0.003						
J8	JUNCTION	0.066	0.105	0 08:00	1.37	2.18
-0.004						
J9	JUNCTION	0.010	0.115	0 08:00	0.208	2.39
0.003						
OF1	OUTFALL	0.000	0.044	0 04:04	0	2.71
0.000						
OF2	OUTFALL	0.000	0.044	0 04:01	0	2.8
0.000						
POND_East	STORAGE	0.016	0.131	0 08:00	0.371	2.76
-1.375						
POND_West	STORAGE	0.018	0.127	0 08:00	0.402	2.67

-1.342

\*\*\*\*\*  
Node Surge Summary  
\*\*\*\*\*

No nodes were surcharged.

\*\*\*\*\*  
Node Flooding Summary  
\*\*\*\*\*

No nodes were flooded.

\*\*\*\*\*  
Storage Volume Summary  
\*\*\*\*\*

	Average	Avg	Evap	Exfil	Maximum	Max	Time of Max
Maximum	Volume	Pcnt	Pcnt	Pcnt	Volume	Pcnt	Occurrence
Outflow Storage Unit CMS	1000 m3	Full	Loss	Loss	1000 m3	Full	days hr:min
POND_East 0.044	0.024	1	0	0	0.475	14	0 10:03
POND_West 0.044	0.021	1	0	0	0.439	13	0 09:59

\*\*\*\*\*  
Outfall Loading Summary  
\*\*\*\*\*

Outfall Node	Flow Freq Pcnt	Avg Flow CMS	Max Flow CMS	Total Volume 10^6 ltr
OF1	14.95	0.035	0.044	2.708
OF2	15.17	0.036	0.044	2.802
System	15.06	0.071	0.088	5.509

\*\*\*\*\*  
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	0.02	0.29
D102	CONDUIT	0.046	0 08:00	0.38	0.07	0.27
D103	CONDUIT	0.051	0 08:00	0.75	0.01	0.18
D104	CONDUIT	0.099	0 08:00	0.96	0.05	0.24
D105	CONDUIT	0.000	0 00:00	0.00	0.00	0.19
D106	CONDUIT	0.032	0 08:00	0.33	0.05	0.23
D107	CONDUIT	0.039	0 08:00	0.57	0.01	0.18
D108	CONDUIT	0.105	0 08:00	0.99	0.06	0.24
D109	CONDUIT	0.109	0 08:00	1.27	0.04	0.21
D110	CONDUIT	0.115	0 08:00	1.39	0.03	0.20
OL1	DUMMY	0.044	0 04:04			
OL2	DUMMY	0.044	0 04:01			

\*\*\*\*\*  
Flow Classification Summary  
\*\*\*\*\*

Adjusted /Actual	Fraction of Time in Flow Class					
	Up	Down	Sub	Sup	Up	Down Norm Inlet

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Conduit	Length	Dry	Dry	Dry	Crit	Crit	Crit	Crit	Ltd	Ctrl
D101	1.00	0.45	0.34	0.00	0.21	0.00	0.00	0.00	0.98	0.00
D102	1.00	0.45	0.01	0.00	0.55	0.00	0.00	0.00	0.00	0.00
D103	1.00	0.45	0.15	0.00	0.40	0.00	0.00	0.00	0.49	0.00
D104	1.00	0.45	0.00	0.00	0.54	0.02	0.00	0.00	0.09	0.00
D105	1.00	0.44	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D106	1.00	0.44	0.01	0.00	0.56	0.00	0.00	0.00	0.00	0.00
D107	1.00	0.44	0.16	0.00	0.41	0.00	0.00	0.00	0.50	0.00
D108	1.00	0.44	0.00	0.00	0.53	0.03	0.00	0.00	0.03	0.00
D109	1.00	0.67	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00
D110	1.00	0.68	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00

\*\*\*\*\*  
 Conduit Surcharge Summary  
 \*\*\*\*\*

No conduits were surcharged.

Analysis begun on: Wed May 04 12:56:40 2016  
 Analysis ended on: Wed May 04 12:56:48 2016  
 Total elapsed time: 00:00:08



## 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_24h_Type_IA_118.2mm	100yr_SCS_24h_Type_IA_118.2mm	INTENSITY	15 min.
10yr_SCS_24h_Type_IA_90mm	10yr_SCS_24h_Type_IA_90mm	INTENSITY	15 min.
5yr_SCS_24h_Type_IA_81.2mm	5yr_SCS_24h_Type_IA_81.2mm	INTENSITY	15 min.
6month_SCS_24h_Type_IA_61.61mm	6month_SCS_24h_Type_IA_61.61mm	INTENSITY	15 min.

\*\*\*\*\*

## Subcatchment Summary

\*\*\*\*\*

Name	Area	width	%Imperv	%Slope	Rain Gage	Outlet
101	0.79	196.75	0.00	45.0000	10yr_SCS_24h_Type_IA_90mm	J5
102	0.08	21.05	0.00	45.0000	10yr_SCS_24h_Type_IA_90mm	J5
103	0.13	33.30	0.00	45.0000	10yr_SCS_24h_Type_IA_90mm	J4
104	1.35	245.89	0.00	35.0000	10yr_SCS_24h_Type_IA_90mm	J8
105	0.20	67.73	0.00	20.0000	10yr_SCS_24h_Type_IA_90mm	J7
106	0.95	146.54	0.00	22.0000	10yr_SCS_24h_Type_IA_90mm	J2
107	0.51	146.63	0.00	30.0000	10yr_SCS_24h_Type_IA_90mm	J5
108	0.53	150.14	0.00	30.0000	10yr_SCS_24h_Type_IA_90mm	J8
109	0.92	141.63	0.00	22.0000	10yr_SCS_24h_Type_IA_90mm	J3
110	0.18	40.56	0.00	22.0000	10yr_SCS_24h_Type_IA_90mm	J1
111	0.19	42.33	0.00	22.0000	10yr_SCS_24h_Type_IA_90mm	J1
112	0.46	185.00	100.00	15.0000	10yr_SCS_24h_Type_IA_90mm	
POND_East						
113	0.29	82.37	0.00	30.0000	10yr_SCS_24h_Type_IA_90mm	J9
114	0.50	200.56	100.00	15.0000	10yr_SCS_24h_Type_IA_90mm	
POND_West						
115	0.28	81.14	0.00	30.0000	10yr_SCS_24h_Type_IA_90mm	J6

\*\*\*\*\*

## Node Summary

\*\*\*\*\*

Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
J1	JUNCTION	164.50	0.50	0.0	
J10	JUNCTION	164.50	0.50	0.0	
J2	JUNCTION	164.30	0.50	0.0	
J3	JUNCTION	164.30	0.50	0.0	
J4	JUNCTION	164.00	0.50	0.0	
J5	JUNCTION	156.00	0.50	0.0	
J6	JUNCTION	153.00	0.50	0.0	
J7	JUNCTION	164.00	0.50	0.0	
J8	JUNCTION	156.00	0.50	0.0	
J9	JUNCTION	153.00	0.50	0.0	

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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	5.8374	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	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.82
D102	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.64
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	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.82
D106	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.63
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 hectare-m	Depth mm
Runoff Quantity Continuity		
Total Precipitation .....	0.664	89.999
Evaporation Loss .....	0.000	0.000
Infiltration Loss .....	0.055	7.455
Surface Runoff .....	0.608	82.420

Final Storage ..... 0.001 0.124  
 Continuity Error (%) ..... 0.000

```

*****
Flow Routing Continuity
*****
Volume      Volume
hectare-m   10^6 ltr
-----
Dry Weather Inflow ..... 0.000 0.000
Wet Weather Inflow ..... 0.608 6.084
Groundwater Inflow ..... 0.000 0.000
RDII Inflow ..... 0.000 0.000
External Inflow ..... 0.000 0.000
External Outflow ..... 0.613 6.127
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 (%) ..... -0.714
  
```

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

\*\*\*\*\*  
 Highest Flow Instability Indexes  
 \*\*\*\*\*  
 Link OL1 (3)  
 Link OL2 (2)

\*\*\*\*\*  
 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  
 \*\*\*\*\*

Peak Runoff	Total Precip	Total Runon	Total Evap	Total Infil	Total Runoff	Total Runoff
Runoff Coeff Subcatchment CMS	mm	mm	mm	mm	mm	10^6 ltr
101	90.00	0.00	0.00	7.92	82.08	0.65
0.03 0.912						
102	90.00	0.00	0.00	7.92	82.08	0.07
0.00 0.912						
103	90.00	0.00	0.00	7.92	82.08	0.11
0.01 0.912						
104	90.00	0.00	0.00	7.95	82.05	1.11
0.05 0.912						
105	90.00	0.00	0.00	7.93	82.07	0.17
0.01 0.912						
106	90.00	0.00	0.00	9.06	80.94	0.77
0.04 0.899						
107	90.00	0.00	0.00	8.93	81.07	0.42
0.02 0.901						
108	90.00	0.00	0.00	8.93	81.07	0.43
0.02 0.901						
109	90.00	0.00	0.00	9.06	80.94	0.75
0.04 0.899						
110	90.00	0.00	0.00	8.99	81.01	0.15
0.01 0.900						
111	90.00	0.00	0.00	8.99	81.01	0.15
0.01 0.900						
112	90.00	0.00	0.00	0.00	89.05	0.41

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0.02	0.989						
113		90.00	0.00	0.00	8.93	81.07	0.23
0.01	0.901						
114		90.00	0.00	0.00	0.00	89.05	0.45
0.02	0.989						
115		90.00	0.00	0.00	8.93	81.07	0.23
0.01	0.901						

\*\*\*\*\*  
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	0.07	164.57	0 08:00	0.02
J10	JUNCTION	0.00	0.00	164.50	0 00:00	0.00
J2	JUNCTION	0.02	0.23	164.53	0 08:00	0.07
J3	JUNCTION	0.02	0.20	164.50	0 08:00	0.06
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	0.21	150.21	0 10:35	0.06
POND_West	STORAGE	0.01	0.20	150.20	0 10:24	0.06

\*\*\*\*\*  
Node Inflow Summary  
\*\*\*\*\*

Flow		Maximum	Maximum		Lateral	Total
Balance		Lateral	Total	Time of Max	Inflow	Inflow
Error		Inflow	Inflow	Occurrence	Volume	Volume
Node	Type	CMS	CMS	days hr:min	10^6 ltr	10^6 ltr
Percent						
J1	JUNCTION	0.015	0.015	0 08:00	0.302	0.302
-0.026						
J10	JUNCTION	0.000	0.000	0 00:00	0	0
0.000 ltr						
J2	JUNCTION	0.037	0.051	0 08:00	0.771	1.07
0.010						
J3	JUNCTION	0.036	0.036	0 08:00	0.745	0.745
0.006						
J4	JUNCTION	0.005	0.056	0 08:00	0.109	1.18
-0.001						
J5	JUNCTION	0.054	0.110	0 08:00	1.13	2.31
-0.003						
J6	JUNCTION	0.011	0.121	0 08:00	0.23	2.54
0.002						
J7	JUNCTION	0.008	0.043	0 08:00	0.167	0.912
-0.003						
J8	JUNCTION	0.073	0.116	0 08:00	1.54	2.45
-0.004						
J9	JUNCTION	0.011	0.127	0 08:00	0.234	2.68
0.003						
OF1	OUTFALL	0.000	0.044	0 03:42	0	3.02
0.000						
OF2	OUTFALL	0.000	0.044	0 03:31	0	3.11
0.000						
POND_East	STORAGE	0.018	0.146	0 08:00	0.412	3.09
-0.528						
POND_West	STORAGE	0.020	0.141	0 08:00	0.446	2.99
-0.895						

\*\*\*\*\*  
Node Surcharge Summary  
\*\*\*\*\*

No nodes were surcharged.

\*\*\*\*\*  
Node Flooding Summary  
\*\*\*\*\*

No nodes were flooded.

\*\*\*\*\*  
Storage Volume Summary  
\*\*\*\*\*

	Average	Avg	Evap	Exfil	Maximum	Max	Time of Max
Maximum	Volume	Pcnt	Pcnt	Pcnt	Volume	Pcnt	Occurrence
Outflow Storage Unit CMS	1000 m3	Full	Loss	Loss	1000 m3	Full	days hr:min
POND_East 0.044	0.038	1	0	0	0.600	17	0 10:35
POND_West 0.044	0.033	1	0	0	0.558	16	0 10:24

\*\*\*\*\*  
Outfall Loading Summary  
\*\*\*\*\*

Outfall Node	Flow Freq Pcnt	Avg Flow CMS	Max Flow CMS	Total Volume 10^6 ltr
OF1	15.48	0.038	0.044	3.017
OF2	15.57	0.039	0.044	3.110
System	15.52	0.076	0.088	6.127

\*\*\*\*\*  
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	0.015	0 08:00	0.10	0.02	0.31
D102	CONDUIT	0.051	0 08:00	0.40	0.08	0.28
D103	CONDUIT	0.056	0 08:00	0.78	0.01	0.19
D104	CONDUIT	0.110	0 08:00	0.99	0.06	0.25
D105	CONDUIT	0.000	0 00:00	0.00	0.00	0.20
D106	CONDUIT	0.035	0 08:00	0.35	0.06	0.24
D107	CONDUIT	0.043	0 08:00	0.59	0.01	0.19
D108	CONDUIT	0.116	0 08:00	1.02	0.06	0.26
D109	CONDUIT	0.121	0 08:00	1.31	0.04	0.22
D110	CONDUIT	0.127	0 08:00	1.43	0.04	0.22
OL1	DUMMY	0.044	0 03:42			
OL2	DUMMY	0.044	0 03:31			

\*\*\*\*\*  
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	0.45	0.34	0.00	0.21	0.00	0.00	0.00	0.98	0.00
D102	1.00	0.44	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00
D103	1.00	0.45	0.15	0.00	0.40	0.00	0.00	0.00	0.49	0.00
D104	1.00	0.45	0.00	0.00	0.54	0.02	0.00	0.00	0.09	0.00
D105	1.00	0.44	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00



## 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_24h_Type_IA_118.2mm	100yr_SCS_24h_Type_IA_118.2mm	INTENSITY	15 min.
10yr_SCS_24h_Type_IA_90mm	10yr_SCS_24h_Type_IA_90mm	INTENSITY	15 min.
5yr_SCS_24h_Type_IA_81.2mm	5yr_SCS_24h_Type_IA_81.2mm	INTENSITY	15 min.
6month_SCS_24h_Type_IA_61.61mm	6month_SCS_24h_Type_IA_61.61mm	INTENSITY	15 min.

\*\*\*\*\*

## Subcatchment Summary

\*\*\*\*\*

Name	Area	Width	%Imperv	%Slope	Rain Gage	Outlet
101	0.79	196.75	0.00	45.0000	100yr_SCS_24h_Type_IA_118.2mm	J5
102	0.08	21.05	0.00	45.0000	100yr_SCS_24h_Type_IA_118.2mm	J5
103	0.13	33.30	0.00	45.0000	100yr_SCS_24h_Type_IA_118.2mm	J4
104	1.35	245.89	0.00	35.0000	100yr_SCS_24h_Type_IA_118.2mm	J8
105	0.20	67.73	0.00	20.0000	100yr_SCS_24h_Type_IA_118.2mm	J7
106	0.95	146.54	0.00	22.0000	100yr_SCS_24h_Type_IA_118.2mm	J2
107	0.51	146.63	0.00	30.0000	100yr_SCS_24h_Type_IA_118.2mm	J5
108	0.53	150.14	0.00	30.0000	100yr_SCS_24h_Type_IA_118.2mm	J8
109	0.92	141.63	0.00	22.0000	100yr_SCS_24h_Type_IA_118.2mm	J3
110	0.18	40.56	0.00	22.0000	100yr_SCS_24h_Type_IA_118.2mm	J1
111	0.19	42.33	0.00	22.0000	100yr_SCS_24h_Type_IA_118.2mm	J1
112	0.46	185.00	100.00	15.0000	100yr_SCS_24h_Type_IA_118.2mm	
POND_East						
113	0.29	82.37	0.00	30.0000	100yr_SCS_24h_Type_IA_118.2mm	J9
114	0.50	200.56	100.00	15.0000	100yr_SCS_24h_Type_IA_118.2mm	
POND_West						
115	0.28	81.14	0.00	30.0000	100yr_SCS_24h_Type_IA_118.2mm	J6

\*\*\*\*\*

## Node Summary

\*\*\*\*\*

Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
J1	JUNCTION	164.50	0.50	0.0	
J10	JUNCTION	164.50	0.50	0.0	
J2	JUNCTION	164.30	0.50	0.0	
J3	JUNCTION	164.30	0.50	0.0	
J4	JUNCTION	164.00	0.50	0.0	
J5	JUNCTION	156.00	0.50	0.0	
J6	JUNCTION	153.00	0.50	0.0	
J7	JUNCTION	164.00	0.50	0.0	
J8	JUNCTION	156.00	0.50	0.0	
J9	JUNCTION	153.00	0.50	0.0	



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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	5.8374	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	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.82
D102	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.64
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	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.82
D106	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.63
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 hectare-m	Depth mm
Runoff Quantity Continuity		
Total Precipitation .....	0.872	118.198
Evaporation Loss .....	0.000	0.000
Infiltration Loss .....	0.055	7.471
Surface Runoff .....	0.816	110.603

Final Storage ..... 0.001 0.124  
 Continuity Error (%) ..... 0.000

```

*****
Flow Routing Continuity
*****
Volume      Volume
hectare-m   10^6 ltr
-----
Dry weather Inflow ..... 0.000 0.000
Wet weather Inflow ..... 0.816 8.164
Groundwater Inflow ..... 0.000 0.000
RDII Inflow ..... 0.000 0.000
External Inflow ..... 0.000 0.000
External Outflow ..... 0.817 8.168
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 (%) ..... -0.052

```

\*\*\*\*\*  
 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  
 \*\*\*\*\*

Peak	Runoff	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff 10^6 ltr
Runoff Coeff	Subcatchment						
CMS							
101		118.20	0.00	0.00	7.94	110.26	0.87
0.04	0.933						
102		118.20	0.00	0.00	7.94	110.26	0.09
0.00	0.933						
103		118.20	0.00	0.00	7.94	110.26	0.15
0.01	0.933						
104		118.20	0.00	0.00	7.97	110.22	1.49
0.07	0.933						
105		118.20	0.00	0.00	7.95	110.25	0.22
0.01	0.933						
106		118.20	0.00	0.00	9.08	109.12	1.04
0.05	0.923						
107		118.20	0.00	0.00	8.94	109.26	0.56
0.03	0.924						
108		118.20	0.00	0.00	8.94	109.26	0.57
0.03	0.924						
109		118.20	0.00	0.00	9.08	109.12	1.00
0.05	0.923						
110		118.20	0.00	0.00	9.00	109.19	0.20
0.01	0.924						
111		118.20	0.00	0.00	9.00	109.19	0.21
0.01	0.924						
112		118.20	0.00	0.00	0.00	117.25	0.54

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0.02	0.992						
113		118.20	0.00	0.00	8.94	109.26	0.31
0.01	0.924						
114		118.20	0.00	0.00	0.00	117.25	0.59
0.03	0.992						
115		118.20	0.00	0.00	8.94	109.26	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	0.08	164.58	0 08:00	0.03
J10	JUNCTION	0.00	0.02	164.52	0 07:59	0.01
J2	JUNCTION	0.02	0.26	164.56	0 08:00	0.08
J3	JUNCTION	0.02	0.22	164.52	0 08:00	0.07
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	0.04	0.38	150.38	0 12:46	0.12
POND_West	STORAGE	0.04	0.36	150.36	0 12:32	0.11

\*\*\*\*\*  
Node Inflow Summary  
\*\*\*\*\*

Flow		Maximum	Maximum		Lateral	Total
Balance		Lateral	Total	Time of Max	Inflow	Inflow
Error		Inflow	Inflow	Occurrence	Volume	Volume
Node	Type	CMS	CMS	days hr:min	10^6 ltr	10^6 ltr
Percent						
J1	JUNCTION	0.019	0.019	0 08:00	0.407	0.407
-0.025						
J10	JUNCTION	0.000	0.001	0 07:22	0	0.000649
0.867						
J2	JUNCTION	0.049	0.068	0 08:00	1.04	1.45
0.009						
J3	JUNCTION	0.047	0.047	0 08:00	1	1.01
0.005						
J4	JUNCTION	0.007	0.074	0 08:00	0.147	1.59
-0.001						
J5	JUNCTION	0.071	0.145	0 08:00	1.52	3.11
-0.003						
J6	JUNCTION	0.015	0.160	0 08:00	0.31	3.43
0.002						
J7	JUNCTION	0.010	0.057	0 08:00	0.224	1.23
-0.003						
J8	JUNCTION	0.096	0.153	0 08:00	2.06	3.29
-0.003						
J9	JUNCTION	0.015	0.168	0 08:00	0.315	3.61
0.002						
OF1	OUTFALL	0.000	0.044	0 02:42	0	4.02
0.000						
OF2	OUTFALL	0.000	0.044	0 02:27	0	4.15
0.000						
POND_East	STORAGE	0.024	0.192	0 08:00	0.542	4.15
-0.007						
POND_West	STORAGE	0.026	0.186	0 08:00	0.588	4.01
-0.098						

\*\*\*\*\*  
Node Surcharge Summary  
\*\*\*\*\*

No nodes were surcharged.

\*\*\*\*\*  
Node Flooding Summary  
\*\*\*\*\*

No nodes were flooded.

\*\*\*\*\*  
Storage Volume Summary  
\*\*\*\*\*

	Average	Avg	Evap	Exfil	Maximum	Max	Time of Max
Maximum	Volume	Pcnt	Pcnt	Pcnt	Volume	Pcnt	Occurrence
Outflow Storage Unit CMS	1000 m3	Full	Loss	Loss	1000 m3	Full	days hr:min
POND_East 0.044	0.124	4	0	0	1.130	33	0 12:46
POND_West 0.044	0.110	3	0	0	1.050	31	0 12:32

\*\*\*\*\*  
Outfall Loading Summary  
\*\*\*\*\*

Outfall Node	Flow Freq Pcnt	Avg Flow CMS	Max Flow CMS	Total Volume 10^6 ltr
OF1	18.21	0.043	0.044	4.017
OF2	18.77	0.043	0.044	4.151
System	18.49	0.085	0.088	8.168

\*\*\*\*\*  
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	0.35
D102	CONDUIT	0.068	0 08:00	0.43	0.11	0.32
D103	CONDUIT	0.074	0 08:00	0.85	0.01	0.22
D104	CONDUIT	0.145	0 08:00	1.07	0.08	0.29
D105	CONDUIT	0.001	0 07:22	0.01	0.00	0.25
D106	CONDUIT	0.047	0 08:00	0.38	0.07	0.27
D107	CONDUIT	0.057	0 08:00	0.65	0.01	0.22
D108	CONDUIT	0.153	0 08:00	1.10	0.08	0.29
D109	CONDUIT	0.160	0 08:00	1.41	0.05	0.26
D110	CONDUIT	0.168	0 08:00	1.55	0.05	0.25
OL1	DUMMY	0.044	0 02:42			
OL2	DUMMY	0.044	0 02:27			

\*\*\*\*\*  
Flow Classification Summary  
\*\*\*\*\*

Conduit	Adjusted /Actual Length	----- Dry		Up Dry		Down Dry		Sub Crit		Sup Crit		Up Crit		Down Crit		Norm Ltd	Inlet Ctrl
D101	1.00	0.44	0.34	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.98	0.00
D102	1.00	0.44	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D103	1.00	0.44	0.15	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00
D104	1.00	0.44	0.00	0.00	0.53	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00
D105	1.00	0.43	0.50	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.00

		88877_100yr_PCSWMM_Output.rpt									
D106	1.00	0.43	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00
D107	1.00	0.43	0.16	0.00	0.41	0.00	0.00	0.00	0.00	0.51	0.00
D108	1.00	0.43	0.00	0.00	0.50	0.07	0.00	0.00	0.00	0.03	0.00
D109	1.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00
D110	1.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00

\*\*\*\*\*  
Conduit Surcharge Summary  
\*\*\*\*\*

No conduits were surcharged.

Analysis begun on: Wed May 04 12:46:54 2016  
Analysis ended on: Wed May 04 12:47:03 2016  
Total elapsed time: 00:00:09

# Appendix D

## HELP Model Inputs and Outputs

**HELP Model Input Parameters  
Design, Operations, and Closure Plan  
Upland Landfill  
Campbell River, British Columbia**

Description of Cover System	Layer Type	Layer Description
<b>Daily Cover</b>		
	Vegetative Coverage	Bare (Leaf Area Index 0)
	Evaporative Zone Depth	150 mm
	Slope	10 % slope
Sand-Daily Cover	Vertical Percolation Layer	150 mm of Sand (Soil Texture No. 2), Hyd.Cond. $5.8 \times 10^{-3}$ cm/sec
Municipal Waste	Vertical Percolation Layer	24 m if Municipal Solid Waste (Soil Texture No. 18), Hyd.Cond. $1 \times 10^{-3}$ 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. $3 \times 10^{-1}$ cm/sec
HDPE Base Liner	Flexible Membrane Liner	HDPE (model default, Soil Texture No. 35), Hyd.Cond. $2 \times 10^{-13}$ cm/sec, Good placement quality, 2 pinholes/hectare, 6 installation defects/hectare
Geosynthetic Clay Liner	Barrier Soil Liner	Bentonite Mat (model default, Soil Texture No. 17), Hyd.Con. $3 \times 10^{-9}$ cm/sec
<b>Intermediate Cover</b>		
	Vegetative Coverage	Bare (Leaf Area Index 1)
	Evaporative Zone Depth	300 mm
	Slope	10 % slope
Sand-Intermediate Cover	Vertical Percolation Layer	300 mm of Sand (Soil Texture No. 2), Hyd.Cond. $5.8 \times 10^{-3}$ cm/sec
Municipal Waste	Vertical Percolation Layer	24 m if Municipal Solid Waste (Soil Texture No. 18), Hyd.Cond. $1 \times 10^{-3}$ 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. $3 \times 10^{-1}$ cm/sec
HDPE Base Liner	Flexible Membrane Liner	HDPE (model default, Soil Texture No. 35), Hyd.Cond. $2 \times 10^{-13}$ cm/sec, Good placement quality, 2 pinholes/hectare, 6 installation defects/hectare
Geosynthetic Clay Liner	Barrier Soil Liner	Bentonite Mat (model default, Soil Texture No. 17), Hyd.Con. $3 \times 10^{-9}$ cm/sec



```

*****
*****
**
**
**          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\DLYT.D10
OUTPUT DATA FILE:        C:\HELP3\88877\DLYTO.OUT

```

TIME: 13:53      DATE: 2/16/2016

```

*****

```

TITLE: Upland Landfill - Daily Cover Top

```

*****

```

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 =      0.1380 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC

```

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 1.80  
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

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	=	0.3176	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	=	0.0366	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	=	6.00	HOLES/HECTARE
FML PLACEMENT QUALITY	=	3 - GOOD	

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	=	1.380	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	=	767.418	CM
TOTAL INITIAL WATER	=	767.418	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	=	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	12.660	20.060	2.466	0.416	0.328	0.233
	0.299	0.455	0.126	5.843	10.749	10.233
STD. DEVIATIONS	20.906	62.288	9.155	0.999	1.081	0.594
	0.916	2.784	0.580	7.616	13.502	9.764
EVAPOTRANSPIRATION						
-----						
TOTALS	7.957	13.239	35.662	52.059	38.419	35.466
	19.931	19.089	23.855	21.140	9.810	7.396
STD. DEVIATIONS	2.404	4.037	5.541	12.702	16.460	16.450
	13.694	13.506	11.262	4.414	1.406	1.741
PERCOLATION/LEAKAGE THROUGH LAYER 2						
-----						
TOTALS	192.0256	132.3064	107.2921	52.8757	29.9468	26.5194
	19.2414	18.7330	28.2144	134.6477	191.5514	204.7322

STD. DEVIATIONS	63.5898	56.8081	43.3949	28.0032	20.9888	18.9106
	18.2090	17.7337	20.4606	61.0302	63.7523	60.8738

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	67.4621	89.1076	113.0098	134.5437	142.3553	125.1200
	120.0066	108.1710	86.8786	55.0754	43.9157	49.8206

STD. DEVIATIONS	21.6337	32.3856	32.5588	29.3513	25.6001	19.5805
	16.4382	14.8682	13.8073	15.9821	15.0656	14.6495

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	62.4320	85.4965	109.2216	130.5754	143.0746	127.6704
	121.2699	110.6171	89.7698	62.5023	44.2309	48.5235

STD. DEVIATIONS	18.8837	29.4818	29.8007	29.3624	25.4275	20.3398
	15.9735	15.3262	13.1352	15.6702	14.7172	13.3482

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.0003	0.0004	0.0006	0.0007	0.0008	0.0007
	0.0006	0.0006	0.0004	0.0003	0.0002	0.0002

STD. DEVIATIONS	0.0001	0.0002	0.0002	0.0002	0.0002	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.1847	0.1400	0.1058	0.0572	0.0315	0.0293
	0.0184	0.0195	0.0314	0.1352	0.1906	0.1933

STD. DEVIATIONS	0.0651	0.0596	0.0448	0.0316	0.0229	0.0235
	0.0189	0.0183	0.0243	0.0621	0.0670	0.0631

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0728	0.1047	0.1207	0.1480	0.1515	0.1378
	0.1278	0.1153	0.0957	0.0596	0.0497	0.0542

STD. DEVIATIONS	0.0226	0.0374	0.0346	0.0321	0.0272	0.0215
	0.0175	0.0158	0.0151	0.0167	0.0159	0.0153

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	3.1084	4.6701	5.4380	6.7179	7.1236	6.5685
	6.0379	5.5075	4.6186	3.1119	2.2756	2.4159

STD. DEVIATIONS	0.9402	1.6024	1.4838	1.5107	1.2660	1.0465
	0.7953	0.7631	0.6758	0.7802	0.7572	0.6646

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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	63.869 ( 79.6342)		638.69	4.298
EVAPOTRANSPIRATION	284.022 ( 37.6888)		2840.22	19.114
PERCOLATION/LEAKAGE THROUGH LAYER 2	1138.08618 (171.59268)		11380.861	76.59047
AVERAGE HEAD ON TOP OF LAYER 2	0.947 ( 0.154)			
PERCOLATION/LEAKAGE THROUGH LAYER 4	1135.46631 (133.15610)		11354.663	76.41415
AVERAGE HEAD ON TOP OF LAYER 4	1.031 ( 0.120)			
LATERAL DRAINAGE COLLECTED FROM LAYER 5	1135.38354 (132.39745)		11353.836	76.40858
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00581 ( 0.00082)		0.058	0.00039
AVERAGE HEAD ON TOP OF LAYER 6	47.995 ( 5.607)			
CHANGE IN WATER STORAGE	2.657 ( 7.4268)		26.57	0.179

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PEAK DAILY VALUES FOR YEARS		1 THROUGH	100
		(MM)	(CU. METERS)
PRECIPITATION		128.90	1289.000
RUNOFF		78.302	783.0215
PERCOLATION/LEAKAGE THROUGH LAYER	2	67.475616	674.75616
AVERAGE HEAD ON TOP OF LAYER	2	24.195	
PERCOLATION/LEAKAGE THROUGH LAYER	4	9.021939	90.21939
AVERAGE HEAD ON TOP OF LAYER	4	2.979	
DRAINAGE COLLECTED FROM LAYER	5	7.94444	79.44437
PERCOLATION/LEAKAGE THROUGH LAYER	7	0.000050	0.00050
AVERAGE HEAD ON TOP OF LAYER	6	122.620	
MAXIMUM HEAD ON TOP OF LAYER	6	174.168	
LOCATION OF MAXIMUM HEAD IN LAYER	5		
(DISTANCE FROM DRAIN)		23.2 METERS	
SNOW WATER		304.80	3048.0220
MAXIMUM VEG. SOIL WATER (VOL/VOL)			0.3936
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	0.9824	0.0982
2	2.1850	0.4370
3	788.5034	0.3285
4	0.0000	0.0000
5	1.8657	0.0622
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\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\INTT.D10
OUTPUT DATA FILE:         C:\HELP3\88877\INTTO.OUT

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TIME: 13:23      DATE: 2/16/2016

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TITLE: Upland Landfill - Intermediate Cover Top

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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           =      25.00   CM
POROSITY             =      0.4370 VOL/VOL
FIELD CAPACITY       =      0.0620 VOL/VOL
WILTING POINT       =      0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.1357 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC

```

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 1.80  
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

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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	=	0.3173	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	=	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	=	0.0365	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	=	6.00	HOLES/HECTARE
FML PLACEMENT QUALITY	=	3 - GOOD	

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

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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	=	3.393	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	=	768.748	CM
TOTAL INITIAL WATER	=	768.748	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	=	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	11.574	18.198	2.272	0.361	0.245	0.168
	0.181	0.355	0.090	5.606	10.318	9.448
STD. DEVIATIONS	19.223	57.911	8.408	0.813	0.823	0.470
	0.653	2.106	0.455	7.529	12.881	9.076
EVAPOTRANSPIRATION						
-----						
TOTALS	7.839	13.211	40.185	68.052	57.834	51.460
	33.136	29.011	34.211	23.100	9.498	7.224
STD. DEVIATIONS	2.333	3.950	4.776	12.918	21.465	22.204
	21.304	19.806	17.068	4.939	1.334	1.683
PERCOLATION/LEAKAGE THROUGH LAYER 2						
-----						
TOTALS	194.2538	134.2317	105.0295	43.2416	15.1362	11.1932
	8.2510	6.4076	15.2898	122.9946	191.3676	205.0231

STD. DEVIATIONS	63.5373	55.0831	44.4712	28.1301	15.5597	13.6235
	12.5512	11.6952	16.4097	61.0493	64.1833	60.0784

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	54.1586	77.1800	102.0399	130.6695	143.5367	123.6345
	114.5949	102.9147	82.3963	48.5532	32.8072	38.0974

STD. DEVIATIONS	18.9922	29.9075	32.6631	29.7576	24.0855	19.2459
	16.7116	17.2591	16.5870	16.0111	12.8274	12.1295

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	49.7162	73.3875	97.7029	124.7242	143.9364	126.5635
	117.0358	104.8597	85.6843	56.8653	33.3237	36.7255

STD. DEVIATIONS	16.2902	27.1451	29.6063	29.6055	24.7124	20.3401
	15.8836	17.3139	16.4285	16.3566	12.3817	11.1638

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.0002	0.0004	0.0005	0.0007	0.0008	0.0007
	0.0006	0.0005	0.0004	0.0003	0.0001	0.0002

STD. DEVIATIONS	0.0001	0.0002	0.0002	0.0002	0.0002	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.2005	0.1563	0.1128	0.0482	0.0159	0.0122
	0.0087	0.0070	0.0165	0.1245	0.2085	0.2126

STD. DEVIATIONS	0.0670	0.0645	0.0480	0.0312	0.0166	0.0147
	0.0134	0.0151	0.0184	0.0652	0.0723	0.0631

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0586	0.0908	0.1088	0.1439	0.1528	0.1361
	0.1220	0.1095	0.0907	0.0525	0.0374	0.0417

STD. DEVIATIONS	0.0198	0.0342	0.0346	0.0328	0.0256	0.0211
	0.0178	0.0184	0.0183	0.0168	0.0137	0.0124

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	2.4753	4.0083	4.8645	6.4169	7.1665	6.5115
	5.8271	5.2209	4.4084	2.8313	1.7145	1.8285

STD. DEVIATIONS	0.8111	1.4739	1.4741	1.5232	1.2304	1.0465
	0.7908	0.8621	0.8452	0.8144	0.6370	0.5558

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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	58.816 ( 74.0490)	588.16	3.958
EVAPOTRANSPIRATION	374.760 ( 52.5743)	3747.60	25.220
PERCOLATION/LEAKAGE THROUGH LAYER 2	1052.41980 (167.61417)	10524.198	70.82533
AVERAGE HEAD ON TOP OF LAYER 2	0.936 ( 0.146)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	1050.58301 (131.30502)	10505.830	70.70171
AVERAGE HEAD ON TOP OF LAYER 4	0.954 ( 0.119)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	1050.52466 (130.58589)	10505.246	70.69778
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00534 ( 0.00078)	0.053	0.00036
AVERAGE HEAD ON TOP OF LAYER 6	44.395 ( 5.518)		
CHANGE IN WATER STORAGE	1.830 ( 7.3837)	18.30	0.123

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PEAK DAILY VALUES FOR YEARS		1 THROUGH	100
		(MM)	(CU. METERS)
PRECIPITATION		128.90	1289.000
RUNOFF		77.348	773.4814
PERCOLATION/LEAKAGE THROUGH LAYER	2	65.043274	650.43274
AVERAGE HEAD ON TOP OF LAYER	2	49.208	
PERCOLATION/LEAKAGE THROUGH LAYER	4	8.488104	84.88104
AVERAGE HEAD ON TOP OF LAYER	4	2.803	
DRAINAGE COLLECTED FROM LAYER	5	7.54004	75.40035
PERCOLATION/LEAKAGE THROUGH LAYER	7	0.000047	0.00047
AVERAGE HEAD ON TOP OF LAYER	6	116.378	
MAXIMUM HEAD ON TOP OF LAYER	6	166.852	
LOCATION OF MAXIMUM HEAD IN LAYER	5		
(DISTANCE FROM DRAIN)		22.6 METERS	
SNOW WATER		304.80	3048.0220
MAXIMUM VEG. SOIL WATER (VOL/VOL)			0.3446
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	2.8031	0.1121
2	2.1850	0.4370
3	779.9935	0.3250
4	0.0000	0.0000
5	1.6204	0.0540
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\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\OP2T.D10
OUTPUT DATA FILE:        C:\HELP3\88877\OP2TO.OUT

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TIME: 14:13      DATE: 2/16/2016

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TITLE: Upland Landfill - Option 2 Top

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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 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 =      0.1961 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.170000002000E-02 CM/SEC

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NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 1.80  
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

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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	=	0.3198	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	=	0.1248	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 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 # 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	=	5.349	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	=	726.712	CM
TOTAL INITIAL WATER	=	726.712	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 37.45	144.89 39.26	142.48 52.65	102.27 167.86	67.19 220.02	62.06 233.79
STD. DEVIATIONS	63.32 28.36	48.38 30.28	46.44 30.04	37.98 68.74	33.77 74.24	32.53 69.47
RUNOFF						
-----						
TOTALS	3.023 0.000	14.326 0.000	1.112 0.000	0.000 0.004	0.000 0.187	0.000 0.083
STD. DEVIATIONS	14.285 0.000	56.396 0.000	8.204 0.000	0.000 0.024	0.000 1.005	0.000 0.549
EVAPOTRANSPIRATION						
-----						
TOTALS	7.766 37.501	13.095 30.032	40.089 34.741	69.854 23.416	63.253 9.256	57.535 7.128
STD. DEVIATIONS	2.300 24.850	3.857 20.964	4.513 17.630	11.371 4.444	20.360 1.325	23.171 1.653
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
-----						
TOTALS	208.8775 6.8537	152.6560 4.5603	126.3396 7.2992	68.4861 69.9399	26.0513 170.0754	11.7623 204.2333
STD. DEVIATIONS	55.0937 7.9709	54.4171 8.9878	40.7682 11.3421	28.3134 41.8334	14.7437 60.3282	11.4592 52.8479
PERCOLATION/LEAKAGE THROUGH LAYER 3						
-----						
TOTALS	3.2637 0.1848	2.3996 0.1497	2.0055 0.1888	1.1213 1.1461	0.4773 2.6695	0.2570 3.1925
STD. DEVIATIONS	0.8402 0.1215	0.8297 0.1370	0.6212 0.1730	0.4314 0.6375	0.2247 0.9196	0.1746 0.8054
PERCOLATION/LEAKAGE THROUGH LAYER 6						
-----						
TOTALS	3.2174 0.6480	2.8545 0.4966	2.5191 0.3453	1.9535 0.1309	1.4044 0.3817	0.8755 2.2334
STD. DEVIATIONS	0.8987 0.1322	0.7407 0.1053	0.7315 0.1073	0.4757 0.1103	0.3160 0.4791	0.1823 1.0848
LATERAL DRAINAGE COLLECTED FROM LAYER 7						
-----						
TOTALS	3.1041	2.9213	2.6231	2.0436	1.5197	0.9493



	0.6875	0.5199	0.3711	0.1792	0.2378	1.9007
STD. DEVIATIONS	0.8970	0.7042	0.7303	0.5095	0.3373	0.2020
	0.1382	0.1057	0.1030	0.1080	0.3185	1.0535

PERCOLATION/LEAKAGE THROUGH LAYER 9

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	23.7706	19.0715	14.3755	8.0524	2.9642	1.3830
	0.7799	0.5189	0.8582	7.9581	19.9984	23.2390
STD. DEVIATIONS	6.2740	6.8228	4.6388	3.3290	1.6776	1.3473
	0.9070	1.0227	1.3336	4.7600	7.0955	6.0140

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.0032	0.0031	0.0025	0.0020	0.0014	0.0009
	0.0006	0.0005	0.0004	0.0001	0.0004	0.0022
STD. DEVIATIONS	0.0009	0.0008	0.0007	0.0005	0.0003	0.0002
	0.0001	0.0001	0.0001	0.0001	0.0005	0.0011

DAILY AVERAGE HEAD ON TOP OF LAYER 8

AVERAGES	0.1545	0.1596	0.1306	0.1051	0.0757	0.0488
	0.0342	0.0259	0.0191	0.0089	0.0122	0.0946
STD. DEVIATIONS	0.0447	0.0387	0.0364	0.0262	0.0168	0.0104
	0.0069	0.0053	0.0053	0.0054	0.0164	0.0525

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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	18.735	( 67.9096)	187.35	1.261
EVAPOTRANSPIRATION	393.665	( 55.5687)	3936.65	26.493
LATERAL DRAINAGE COLLECTED FROM LAYER 2	1057.13489	(173.09804)	10571.349	71.14264
PERCOLATION/LEAKAGE THROUGH LAYER 3	17.05568	( 2.63860)	170.557	1.14781
AVERAGE HEAD ON TOP OF LAYER 3	102.475	( 16.885)		
PERCOLATION/LEAKAGE THROUGH LAYER 6	17.06026	( 2.57652)	170.603	1.14811
AVERAGE HEAD ON TOP OF LAYER 6	0.014	( 0.002)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	17.05735	( 2.53267)	170.573	1.14792
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00011	( 0.00001)	0.001	0.00001
AVERAGE HEAD ON TOP OF LAYER 8	0.725	( 0.108)		
CHANGE IN WATER STORAGE	-0.655	( 2.1752)	-6.55	-0.044

\*\*\*\*\*

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PEAK DAILY VALUES FOR YEARS		1 THROUGH	100
		(MM)	(CU. METERS)
PRECIPITATION		128.90	1289.000
RUNOFF		77.176	771.7640
DRAINAGE COLLECTED FROM LAYER 2		18.08482	180.84816
PERCOLATION/LEAKAGE THROUGH LAYER 3		0.292863	2.92863
AVERAGE HEAD ON TOP OF LAYER 3		671.935	
MAXIMUM HEAD ON TOP OF LAYER 3		916.679	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)		10.9 METERS	
PERCOLATION/LEAKAGE THROUGH LAYER 6		0.296422	2.96422
AVERAGE HEAD ON TOP OF LAYER 6		0.079	
DRAINAGE COLLECTED FROM LAYER 7		0.20740	2.07401
PERCOLATION/LEAKAGE THROUGH LAYER 9		0.000001	0.00001
AVERAGE HEAD ON TOP OF LAYER 8		3.201	
MAXIMUM HEAD ON TOP OF LAYER 8		6.205	
LOCATION OF MAXIMUM HEAD IN LAYER 7 (DISTANCE FROM DRAIN)		2.5 METERS	
SNOW WATER		304.80	3048.0220
MAXIMUM VEG. SOIL WATER (VOL/VOL)			0.3998
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	2.4238	0.1616
2	13.1710	0.2195
3	0.4500	0.7500
4	1.8267	0.1218
5	700.8000	0.2920
6	0.0000	0.0000
7	1.0401	0.0347
8	0.0000	0.0000
9	0.4500	0.7500
SNOW WATER	0.000	

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# Appendix E

## Contaminating Lifespan Assessment Calculations

**Chloride (1st Order)**  
**British Columbia CSR and Water Quality Criteria**

**Drinking Water Supply Guidelines**

**Maximum Anticipated Concentration**

$C_t$	250	mg/L	
$C_B$	1500	mg/L	
$\lambda$	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

## Chloride - Rowe Model

### British Columbia CSR Contaminating Life Span of Chloride

#### Rowe Model - Drinking Water Supply Guidelines

	Scenario 1	Scenario 2	Units	Comments
$C_t$	250	250	mg/L	Target concentration
$C_t$	0.25	0.25	kg/m <sup>3</sup>	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 <sup>2</sup>	Unit area <sup>2</sup>
$V_o$	506,000	506,000	m <sup>3</sup>	Volume of landfill
$C_o$	1500	1500	mg/L	Chloride concentration (peak or average)
$C_o$	1.5	1.5	kg/m <sup>3</sup>	Chloride concentration (peak or average)
$r_{dw}$	1300	1300	kg/m <sup>3</sup>	Dry density of waste
$M_o$	657,800,000	657,800,000	kg	
$H_r$	4.87	7.80	m	Reference height of leachate
$\lambda$	0.065	0.065	y <sup>-1</sup>	First Order decay constant
$k$	0.0685	0.0672	y <sup>-1</sup>	
$k$	0.0035	0.0022	y <sup>-1</sup>	
<b>t</b>	<b>26.16</b>	<b>26.67</b>	<b>years</b>	
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*

**Sulphate 1st Order****Drinking Water Supply Guidelines****Maximum Anticipated Concentration**

$C_t$	500	mg/L	
$C_B$	1000	mg/L	
$\lambda$	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



**Copper - 1st Order**  
**British Columbia CSR and Water Quality Criteria**

**Drinking Water Supply Guidelines**

**Maximum Anticipated Concentration**

$C_t$	1	mg/L	
$C_B$	0.05	mg/L	
$\lambda$	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	
$\lambda$	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 F

## HELP Model Results for Downgradient Ground

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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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**
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```

PRECIPITATION DATA FILE: C:\DATA4.D4
TEMPERATURE DATA FILE: C:\DATA7.D7
SOLAR RADIATION DATA FILE: C:\DATA13.D13
EVAPOTRANSPIRATION DATA: C:\DATA11.D11
SOIL AND DESIGN DATA FILE: C:\DOWNGRAD.D10
OUTPUT DATA FILE: C:\downgrad.OUT

```

TIME: 10:23 DATE: 2/ 9/2016

```

*****
TITLE: 88877 - Uplands 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 = 600.00 CM
POROSITY = 0.4170 VOL/VOL
FIELD CAPACITY = 0.0450 VOL/VOL
WILTING POINT = 0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.1659 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 A  
POOR STAND OF GRASS, A SURFACE SLOPE OF 20.%  
AND A SLOPE LENGTH OF 360. METERS.

SCS RUNOFF CURVE NUMBER	=	63.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.0000	HECTARES
EVAPORATIVE ZONE DEPTH	=	5.0	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	0.323	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	2.085	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.090	CM
INITIAL SNOW WATER	=	0.000	CM
INITIAL WATER IN LAYER MATERIALS	=	99.541	CM
TOTAL INITIAL WATER	=	99.541	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA  
-----

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM  
CAMPBELL RIVER BC

STATION LATITUDE	=	49.57	DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00	
START OF GROWING SEASON (JULIAN DATE)	=	130	
END OF GROWING SEASON (JULIAN DATE)	=	275	
EVAPORATIVE ZONE DEPTH	=	5.0	CM
AVERAGE ANNUAL WIND SPEED	=	40.00	KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	76.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	58.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	48.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	78.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING  
COEFFICIENTS FOR SPOKANE 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 SPOKANE 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 SPOKANE WASHINGTON  
AND STATION LATITUDE = 47.62 DEGREES

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AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 25

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
-----	-----	-----	-----	-----	-----	-----
PRECIPITATION						
-----						
TOTALS	216.32	139.21	147.40	83.73	77.60	50.99
	40.90	46.34	56.42	136.09	268.74	197.46
STD. DEVIATIONS	78.64	57.02	56.43	39.95	43.22	33.06
	35.95	36.46	26.69	84.41	128.23	75.90
RUNOFF						
-----						
TOTALS	48.172	27.803	7.247	0.000	0.000	0.000
	0.000	0.000	0.001	0.118	4.570	6.821
STD. DEVIATIONS	87.547	61.896	25.637	0.000	0.000	0.000
	0.000	0.000	0.005	0.332	14.923	16.278
EVAPOTRANSPIRATION						
-----						
TOTALS	27.049	24.334	31.839	29.733	30.848	20.828

	11.683	15.816	18.500	18.072	26.805	25.705
STD. DEVIATIONS	12.128	7.677	9.827	13.362	18.545	13.299
	8.679	11.331	9.211	10.612	9.798	6.595

PERCOLATION/LEAKAGE THROUGH LAYER 1

TOTALS	172.5043	118.7660	110.9785	94.0518	68.1352	54.5743
	48.2951	40.0832	32.9067	52.8103	119.0647	179.1750
STD. DEVIATIONS	63.3334	47.1576	43.5795	30.3350	23.6949	16.0736
	14.9971	12.5108	15.5031	25.8124	66.1278	65.1755

\*\*\*\*\*

\*\*\*\*\*

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 25

	MM		CU. METERS	PERCENT
	-----		-----	-----
PRECIPITATION	1485.94	( 204.274)	14612.0	100.00
RUNOFF	94.731	(120.5474)	947.31	6.483
EVAPOTRANSPIRATION	281.210	( 40.1774)	2812.10	19.245
PERCOLATION/LEAKAGE THROUGH LAYER 1	1091.34521	(191.63982)	10913.452	74.68828
CHANGE IN WATER STORAGE	-6.087	( 2.8642)	-60.87	-0.417

\*\*\*\*\*

\*\*\*\*\*

PEAK DAILY VALUES FOR YEARS	1 THROUGH	25
	(MM)	(CU. METERS)
PRECIPITATION	173.20	1732.000
RUNOFF	83.736	837.3560
PERCOLATION/LEAKAGE THROUGH LAYER 1	29.591078	295.91077
SNOW WATER	418.19	4181.9121
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.4170
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0180

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\*\*\*\*\*

FINAL WATER STORAGE AT END OF YEAR 25

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LAYER	(CM)	(VOL/VOL)
----	-----	-----
1	81.4093	0.1357

SNOW WATER 2.916

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\*\*\*\*\*



# Appendix G

## Fire Safety and Emergency Contingency Plan

# **FIRE SAFETY AND EMERGENCY CONTINGENCY PLAN**

**UPLAND LANDFILL  
CAMPBELL RIVER, BRITISH COLUMBIA**

**Prepared For: Upland Excavating Ltd.  
Gold River Highway  
Campbell River, British Columbia**

**MAY 12, 2016  
REF. NO. 088877 (01) APPG**

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## LIST OF FIGURES

FIGURE 2.1                      EMERGENCY HOSPITAL ROUTE (INCLUDED IN TEXT)

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## REVISIONS

DATE	REVISION NO.	AUTHOR/COMPANY	

## **1.0 INTRODUCTION**

The operators of the proposed Upland 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 Upland 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 Upland Landfill is owned and operated by Upland Excavating Ltd. (UEL).

The Upland Landfill currently operates under Permit PR-10807. The current landfill operation predominantly receives land clearing waste. The wood waste loads are sorted to remove isolated quantities of metal, white goods, tires, plastics, and other materials which are recycled. The demolition and construction wood waste, excluding clean wood wastes, are shredded on-site and stockpiled for subsequent use as "hog fuel" for energy fuel for off Site market purposes.

The proposed operations include the acceptance of construction, demolition waste, land clearing debris, and contaminated soil. The contaminated soil will predominately be composed of metals and hydrocarbon impacted soil

The following sections detail the Fire Safety and Emergency Contingency Plan for waste disposal operations at the Upland 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 Upland Landfill

This Plan will be reviewed by all on-Site personnel and kept at the Upland 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.

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## 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 2<sup>nd</sup> 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  
MOE 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

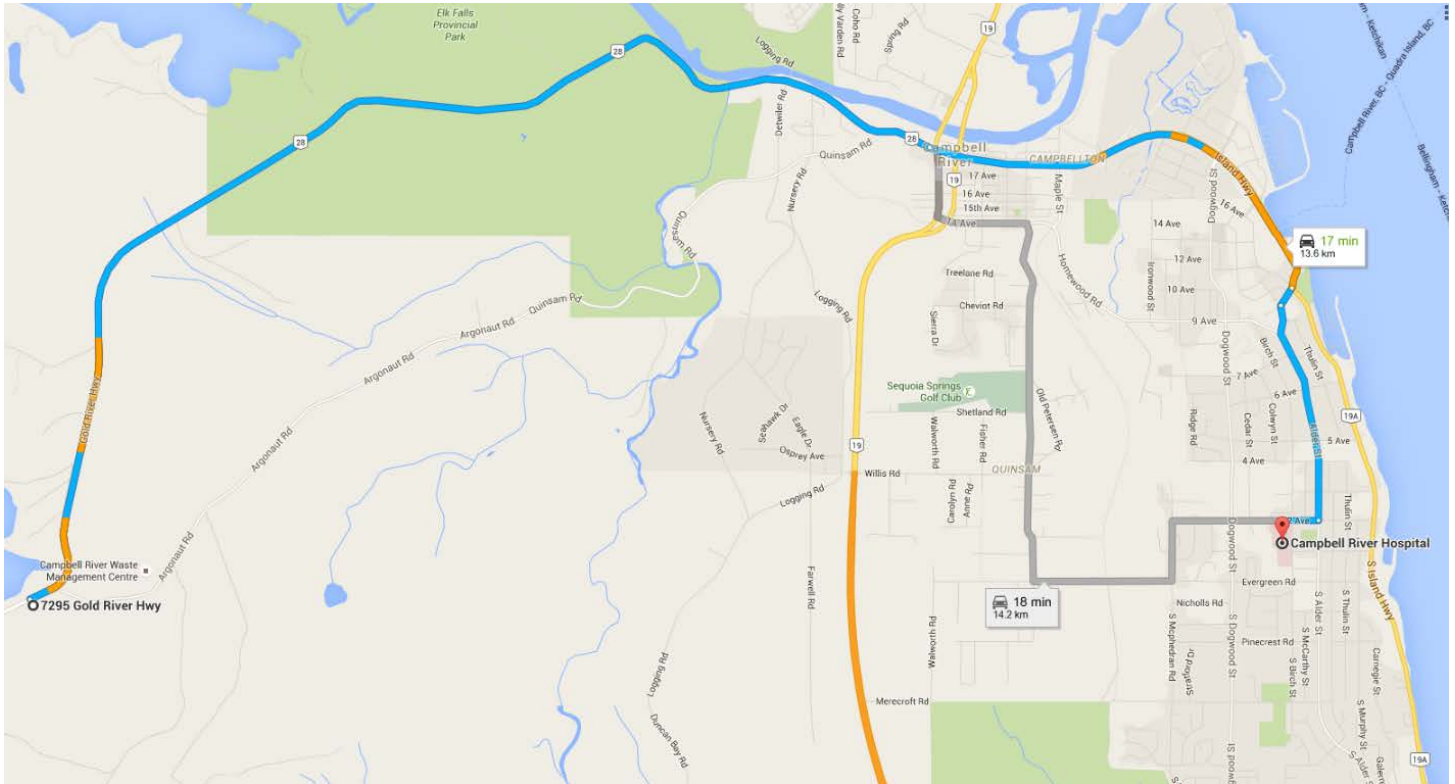
### Upland Excavating Ltd. (Upland Landfill Operator)

- Site Managers(Mark Stuart) 250-287-0738 (Cell)
- Site Manager (Terry Stuart) 250-286-1148 (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 2<sup>nd</sup> 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 time to pump water from the wash plant pond for emergency use.

#### **4.0 EMERGENCY ROUTES AND ASSEMBLY POINTS**

The Upland 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.

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## 5.0 MEDICAL EMERGENCIES

The Upland 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 Upland Landfill during normal operating hours.

The Upland 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 Upland 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 Upland 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 Upland 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.

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## 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 Upland 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 Upland 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 Upland 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 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

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.

***Note: Any spillage of demolition and construction wood waste or land clearing waste received at the Upland Landfill will be collected and transported to the waste segregation and sorting area.***

## 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 Upland 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 Upland 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 Upland 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 Upland 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 Upland 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 Upland 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 Upland 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 (MSDS) for the material.

As part of Site operations, the Upland 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 Upland 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.

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