Campbell Mountain Landfill
Design Operations and Closure Plan

FINAL REPORT

PREPARED FOR: REGIONAL DISTRICT OKANAGAN SIMILKAMEEN

PREPARED BY: SPERLING HANSEN ASSOCIATES

July 2016

PRJ15061

SPERLING HANSEN ASSOCIATES

REGIONAL DISTRICT RDOS OKANAGAN-SIMILKAMEEN

- Landfill Services
- Land Reclamation
- Corporate Management
- Groundwater Hydrogeology

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- Landfill Engineering
- Solid Waste Planning
- Environmental Monitoring
- Landfill Fire Control

July 5th, 2016 PRJ15061

Ms. Liisa Bloomfield, P.Eng.
Engineer/Engineering Supervisor
Regional District of Okanagan-Similkameen
101 Martin Street, Penticton
BC, V2A 5J9

Dear Ms. Bloomfield,

Re: Campbell Mountain Landfill Design, Operations and Closure Plan – Final Report

Sperling Hansen Associates (SHA) is pleased to submit the *Campbell Mountain Landfill Design, Operations and Closure Plan.* As outlined in our proposal we have provided analysis and reporting on the Site Characterization, Regulatory Requirements, Proposed Landfill Design, Lifespan Analysis, Filling Plan, Environmental Control System, Materials Management, Operations Plan, Closure Plan, Environmental Monitoring, Cost Analysis, Fire Safety and Emergency Response Plan. We trust that the plan meets your expectations.

Yours truly,

SPERLING HANSEN ASSOCIATES

July 5th 2016

Dr. Tony Sperling, P.Eng.
President

Sperling Hansen Associates Inc. · #8 – 1225 East Keith Road · North Vancouver · British Columbia · V7J 1G4
Phone (604) 986 7723 · Fax (604) 986 7734 · Internet sperling@sperlinghansen.com

EXECUTIVE SUMMARY

INTRODUCTION (Chapter 1)

This report presents Sperling Hansen Associates' (SHA) assessment of waste management opportunities available at the Campbell Mountain Landfill (CMLF), and our recommendations for optimizing the landfill expansion design to meet the long term needs of the Regional District of Okanagan-Similkameen (RDOS). Strategies for improving environmental controls, complying with regulatory requirements, progressive closure and reducing operating costs are also provided. It is the aim of this plan to provide long term guidance to the RDOS in the development of the CMLF.

Key long-term objectives for this Design and Operations Plan are:

- developing an efficient design for the expansion of the landfill
- developing lifespan estimates for the proposed expansion,
- developing a detailed fill plan,
- preparing a phase by phase development plan,
- preparing a detailed material management plan,
- assessing the current cover material practice and identifying cover material needs,
- reviewing and providing recommendations on the current on-site waste reduction services,
- reviewing and providing recommendations on the environmental control system for surface water, groundwater, landfill gas (LFG), leachate, etc. and planning respective management strategies,
- providing guidance on operational strategies such as landfill methodology, road systems, nuisance controls, security requirements, surface water management systems, and buffering requirements,
- developing a detailed conceptual closure plan,
- developing a monitoring program,
- developing plan to ensure health and safety at the site,
- developing a plan for managing fire risk at the site, and
- providing cost estimates including capital and operational budget, closure, and post-closure costs for the life of the site and developing a cash flow model to estimate a break-even tipping fee.

The scope of work was divided into the following key categories for preparation of the report:

1. Introduction
2. Site History and Conditions
3. Landfill Design
4. Geotechnical Considerations
5. Lifespan Analysis
6. Filling Plan
7. Environmental Control Systems
8. Materials Management Plan
9. Operations Plan

10. Closure Plan
11. Environmental Monitoring
12. Cost Analysis
13. Fire Safety and Emergency Response Plan

SITE HISTORY AND CONDITIONS (Chapter 2)

The Campbell Mountain Landfill (CMLF) is located approximately 4.5 km northeast of Penticton, British Columbia on the western slope of Campbell Mountain overlooking Okanagan Lake. The landfill property is approximately 62 hectares in size at an elevation of approximately 630 m.

Landfill operations at the site were initiated in 1972 under the Permit PR-1597 issued by the then Ministry of Environment, Lands and Parks on July 4th, 1972 and amended on June 1st, 1992 and then on September 24th, 1992 by the Ministry of Environment (MoE). The maximum quantity of refuse that could be discharged was 50,000 tonnes per year.

The average annual precipitation is approximately 346 mm with about 299 mm of rain and 59 cm of snowfall. The average annual temperature is about 9.5^{o}C with an average peak of 21.0^{o}C occurring in July and the minimum average of -1.1^{o}C occurring in December. The maximum average snowfall of 21.1 cm occurs in December.

Dr. Iqbal Bhuiyan and Scott Garthwaite from SHA visited the site on December 1st, 2015 to review site conditions and operations with RDOS staff, Don Hamilton. Scott Garthwaite subsequently visited the site on March 10th, 2016 to conduct a GPS ground survey as well as review site conditions. During SHA's site visits, the site appeared to be very well run by the landfill contractor, SSG Environmental. During their visit, it was noted that the ditch from the composting area flows into the surface water ditch. Therefore, any pollutants that the compost may contain will also be contaminating the surface water in the ditch. Preventing run-on to this facility operating on a paved pad and recirculating all leachate generated should be a top priority.

With an anticipation that leachate from the landfill may be impacting the residences downstream, a notice of migration (NOM) was submitted by the RDOS to the Ministry of Environment (MoE) on November 13th, 2015. In addition to the NOM, a Site Risk Classification Report was completed for the affected or potentially affected land parcels identified in the NOM (Western Water, 2015). In response to the NOM, the MoE asked RDOS to address the issues as per the Contaminated Site Regulations (CSR) guidelines. The contamination investigation and remediation is underway by Western Water Associates Ltd.

LANDFILL DESIGN (Chapter 3)

This chapter presents the landfill development strategy for the CMLF, including an access road network, phase by phase development plan and in-footprint borrow area. The design is presented in a sequence of contour drawings that show the current surface and proposed final surface of the landfill, cut and fill contours and volumetric quantities.

The final contour geometry will consist of 3H:1V outside slopes delineated by two midslope berm roads to be developed during progressive and final closure construction. The lower road will be created at approximately 595 m and the second at approximately 620 m. These roads will carry grades of no less than 2% and will be graded up and down to facilitate surface water runoff from the slopes into road side ditches before discharging to the landfill toe ditch. A ramp road along the northwest slope will aid in connecting the midslope roads and provide access to the landfill crest during filling and post closure monitoring events. The crest will be finalized with the high point in the middle with minimum grades of 4%, shedding surface water to the slopes and roadside ditches.

GEOTECHNICAL CONSIDERATIONS (Chapter 4)

During the hydrogeological evaluation of the CMLF site conducted by Golder in 1994, the surficial deposits are categorized into two different classes, an Upper Granular Deposit and a Lower Granular Deposit as described in Chapter 2. This granular material overlies bedrock which mainly consists of layers of gneiss. The thickness of the Upper Granular Deposit layer ranges anywhere from 0.7 to 3.0 m.

Long term settlement is an issue at most landfills as the organic content of the solid waste stream deposited in the landfill decomposes. It has been SHA's experience that MSW landfills initially settle at a rate of about 2% per year (2 cm settlement per 1 m of refuse thickness). Additional settlement can also occur in the foundation soils beneath the landfill due to the surcharge of overlying waste.

The proposed design is stable for all static loading conditions with FOS values exceeding 1.50, the standard mentioned before. For the seismic loading conditions, FOS greater than 1.0 are obtained at all the cross sections.

LIFESPAN ANALYSIS (Chapter 5)

Chapter 5 describes the analysis and assumptions used to determine the lifespan of the CMLF, including the volume analysis, population, waste disposal rate, waste to cover ratio, settlement, compaction and the lifespan analysis.

The total lifespan of CMLF is projected from 88 years to 91 years under different scenarios as summarized below:

Lifespan Analysis Summary

	Scenario -1: Waste to Cover of 3.07:1			**Scenario – 2: Waste to Cover of 4:1**		
Phase	**Start**	**End**	**Lifespan**	**Start**	**End**	**Lifespan**
1	2016	2020	4	2016	2021	5
2	2020	2032	12	2021	2033	12
3	2032	2035	3	2033	2037	4
4	2035	2067	32	2037	2069	32
5	2067	2104	37	2069	2107	38
Total	**2016**	**2104**	**88**	**2016**	**2107**	**91**

Scenario 1 presents the lifespan analysis based on a waste to cover ratio of 3.07:1, and as such it is estimated the landfill's airspace will be depleted by 2104, allowing for another 88 years of filling.

If the waste to cover ratio was to increase from 3.07:1 to 4:1, as outlined by Scenario 2, another 3 years of operating life can be expected from the landfill, and the closure date would be extended to 2107.

FILLING PLAN (Chapter 6)

As part of the Fill Plan preparation, the waste cell dimensions were optimized using the Landfill Cell Wizard. This determined that the recommended cell size for the CMLF was an active face width of 20 m with a lift thickness of 3 m.

In the place of daily soil cover, use of an ADC helps to extend the life of the landfill. SHA recommends the continued use of steel plates, Revelstoke Iron Grizzly (RIG), as an alternative cover at the CMLF.

A detailed lift by lift filling sequence was completed for Phase 1 and a portion of Phase 2. Fill plans for the remaining Phases should be developed as part of the detailed design of those phases. Seven different lifts are recommended to complete Phase 1.

ENVIRONMENTAL CONTROL SYSTEMS (Chapter 7)

CMLF receives about 346 mm of precipitation annually. Therefore, potential leachate impact issues at the site are expected to be moderate and manageable. However, historical disposal of septage and poor management of run-on has exacerbated the water quality problem at the site, leading to the formation of a leachate plume.

The leachate management concept for the CMLF has been developed to achieve the following objectives:

- Keep clean water clean by diverting run-on and run-off; and
- Minimize percolation by designing an evaporative cover system that minimizes the infiltration.

SHA recommends that the base of future Phases be lined with 60 mil High Density Polyethylene (HDPE) geomembrane underlain by a low permeability soil such as a silt or clay.

Surface water management will be implemented as the landfill develops to ensure that clean water is kept clean. Upstream flows will be diverted around the landfill footprint into existing natural water ways. Any water that falls on closed portions of the landfill will be directed to the storm water pond to the south of the site.

SHA believes that for the relatively semi-arid/ arid climate in Penticton, overall GHG impacts of solid waste management can be better managed by focusing on organics diversion and controlling of fugitive methane emissions using a biocover system than by implementing an active gas collection system.

The planned organic diversion program will achieve a total of 73% diversion rate which includes further diversion of 75% of wood waste, yard waste and paper waste that is currently being deposited into CMLF, as well as 50% diversion of food waste. The fabricated biocover will be placed at the landfill to oxidize the remaining fugitive methane that would otherwise vent to the atmosphere. With implementation of these initiatives, the RDOS will exceed the goals of the landfill gas (LFG) regulation while avoiding the large costs of an active LFG collection system at the CMLF.

MATERIALS MANAGEMENT (Chapter 8)

This section presents the materials management plan for the CMLF including the material requirements and the available material volume throughout the life of the landfill.

To provide soil for daily operations, the internal access road construction and final closure, we envision developing three borrow areas within the lateral expansion footprint. Borrow areas have been designed to maximize the available airspace on the current landfill footprint (fenced perimeter). The borrow areas designed will provide approximately 1,498,200 m^3 of soil throughout the lifespan of the site.

The closure requirements consist mainly of a closure system 1.1 m thick, which include, a 600 mm compacted low permeability soil barrier/evaporative layer, a 200 mm crushed glass LFG diffusion layer, and a 300mm biocover layer.

Operational materials for daily and intermediate cover consume a significant portion of the available airspace at the site. With the use of the RIG cover materials have been reduced significantly.

OPERATIONS PLAN (Chapter 9)

The recommended active face width, as discussed in Chapter 6, is approximately 19.5 m wide. This dimension is based on the use of the RIG alternate daily cover system. Typically for small and medium landfills, the smaller the active face, the more efficiently cover materials are used.

The landfill operator should be familiar with all materials that are accepted and banned from the landfill and should inspect the waste for any suspicious materials as it is unloaded and spread out. Any loads that cause concern should be isolated and cordoned off with flagging tape. Drivers should be identified and questioned as to the nature of the suspicious items and the CMLF supervisor should be alerted prior to taking any action.

The CMLF currently uses a CAT 826 C steel-wheeled compactor to compact its waste and it is estimated that a compaction density close to 0.80-0.85 tonnes/m^3 is achieved.

The current location of the scale, office and associated buildings cannot be maintained at this location throughout the progressive expansion and closure at the CMLF. The scale will be required to be relocated further south during Phase 3 filling and borrowing which is predicted to occur during 2032 as per Lifespan Analysis - Scenario 1.

CLOSURE PLAN (Chapter 10)

A 600 mm compacted low permeability soil/evaporative cap with a 300 mm topsoil/biocover layer and a 200 mm gas collection layer could be used provided a local low permeability soil source with adequate amount of soil in reserve can be secured. SHA recommends a low permeability soil/evaporative cap at CMLF as we believe that the application of biocover, would reduce the emissions of LFG gas from the landfill and that this cover system will also be the cheaper option.

ENVIRONMENTAL MONITORING PROGRAM (Chapter 11)

Currently there are eleven groundwater monitoring wells at the CMLF , nine of which were monitored in 2015. There is also one offsite residential well (DW1655) and one off-site monitoring well (MW15-01) that were monitored in 2015.

With the dry climate in the area, it is anticipated that the majority of the leachate in the pond will evaporate, leaving relatively small quantities needing treatment. Since the phytoremediation area will consist of a poplar plantation, it will be important to regularly monitor the salinity and/or the conductivity of the leachate prior to it being discharge to the plantation as high salinity can be de detrimental to the health of the poplar trees.

Offsite lateral migration of LFG from the CMLF is currently being monitored in a number of gas migration monitoring probes along the northern perimeter of the site. The probes currently being monitored are: GP-1, -2, -3, -14, -15, 16, -17 and -18, of which gas probes GP-1, -2, -17 and -18 are nested with two or three probes set at different depths at each monitoring location. In addition to the above mentioned monitoring probes, gas composition is also being monitored in eight monitoring probes (GP98-1 to -8) in the area referred to as the North Ravine.

The data from the existing monitoring probes show no signs that landfill gas is migrating beyond the property line at the probe locations. SHA is of the opinion that lateral migration is currently not a big concern, but could become a problem as the landfill expands, or if development occurs on neighbouring properties within the 300 m buffer zone.

COST ANALYSIS (Chapter 12)

A detailed cost estimate was prepared for the project based on the estimated quantities and unit rates from other similar projects in BC and unit rates obtained from relevant contracting firms. A cash flow analysis was conducted for the lifespan of the project which factored in all capital, closure, operating and post closure costs. The outcome of this cash flow analysis was the calculation of a break even tipping fee which is the fee that needs to be charged per tonne of waste in order for the landfill to run cost neutral over its entire lifespan and 30 years post closure.

FIRE SAFETY AND EMERGENCY RESPONSE PLAN (Chapter 13)

This section presents a Fire Safety and Emergency Response Plan to minimize the risk of a landfill fire during operations at the CMLF, and establishes protocols for quick control and extinguishment of any fire that can develop.

The first response crew for a landfill fire will be the operational staff on site. A water tanker should be on site at all times in order to immediately suppress any fires. The most effective method for immediate fire suppression is to excavate to the source of the fire and saturate the area with water.

During site inspections, if a landfill fire is suspected Landfill Fire Control Inc (LFCI) should be contacted to investigate. If monitoring indicates that temperature and Carbon Monoxide (CO) levels are above normal then a more detailed investigation will be initiated with additional drilling and instrumentation requirements will be determined.

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APPENDICES

1. INTRODUCTION

Sperling Hansen Associates (SHA) have been retained by the Regional District of Okanagan-Similkameen (RDOS) to provide a Design, Operations, and Closure Plan for the Campbell Mountain Landfill (CMLF). This report presents our assessment and recommendations with regard to the design and operational considerations for the CMLF. This report builds on the existing conditions and future filling plan objectives as well as a plan to develop the final contour design for the landfill that meets all stability constraints and provides opportunity for optimum airspace utilization while maintaining a minimum footprint. Furthermore, this report provides a lifespan analysis and gives details on the environmental control systems. The report also contains a material management plan, an operations plan, environmental monitoring plan, closure plan and an economic analysis for the CMLF.

Photo 1-1 Entrance to Campbell Mountain Landfill

1.1 Background

The Campbell Mountain Landfill is located approximately 4.5 km northeast of Penticton, British Columbia on the western slope of Campbell Mountain overlooking Okanagan Lake. Including the property that the RDOS recently bought from a private owner on the south, the total landfill property is currently 62 hectares.

The CMLF operates as a natural control facility and currently accepts residential, commercial, and light industrial waste from the City of Penticton and surrounding areas.

Waste filling operations at the Campbell Mountain site are currently located in the central portion of the property. The current waste footprint occupies approximately 22.0 HA as shown on Figure 2-9.

The proposed Design and Operation and Closure Plan, which reflects SHA's innovative design concept to optimize available airspace on the current operating footprint of the CMLF site, will provide the RDOS guidance in development, operations and environmental controls for the landfill.

1.2 Objectives

The key objectives for the Campbell Mountain Landfill Design Operations and Closure Plan (DOCP) are:

- Developing a road network to provide proper access to the crest,
- preparing a phase by phase development plan,
- developing lifespan estimates for the proposed phase sequencing,
- developing in-footprint borrow areas,
- considering geotechnical factors and completing slope stability analysis,
- developing a fill plan,
- reviewing and providing recommendations on the environmental control system (surface water, groundwater, landfill gas (LFG), leachate, etc.) and planning leachate, surface water, and landfill gas management strategies,
- preparing a material management plan,
- providing guidance on operational strategies such as landfill methodology, road systems, nuisance controls, and buffering requirements, etc,
- developing a progressive closure plan,
- developing an environmental monitoring program,
- preparing a cost analysis and developing a cash flow model that includes all capital, operating, closure and post closure costs.

1.3 Report Organization

In order to incorporate the aforementioned information seamlessly into the proposed Design and Operations Plan, the report was organized with the following topic specific chapters:

Chapter 1: Introduction
Chapter 2: Site Conditions
Chapter 3: Landfill Design
Chapter 4: Geotechnical Considerations
Chapter 5: Lifespan Analysis
Chapter 6: Filling Plan
Chapter 7: Environmental Control Systems
Chapter 8: Materials Management
Chapter 9: Operations Plan
Chapter 10: Closure Plan
Chapter 11: Environmental Monitoring
Chapter 12: Cost Analysis
Chapter 13: Fire Safety and Response Plan
Chapter 14: Limitations
Chapter 15: References

Project Start-Up: At the onset of the project, SHA and the RDOS staff discussed the scope of work required. An internal project start-up meeting was held between SHA staff working on the project to review the project and coordinate our efforts efficiently.

Site Conditions (Chapter 2): SHA reviewed the history of the project and all of the relevant project reports and summarized them in this chapter. A review of all the information pertinent to site conditions was also performed to help develop the current DOCP plan effectively. A cursory summary of the existing site characterization, geology and hydrogeology previously presented in other reports is provided in this section. SHA's Dr. Iqbal Bhuiyan and Scott Garthwaite conducted a field visit on December 1st, 2015 to review site conditions and operations with RDOS's staff Don Hamilton. The observations made during the field visits and a summary of existing environmental issues have also been provided in this chapter.

Landfill Design (Chapter 3): As a part of this task we summarized the regulatory requirements, design objectives and developed the final design contours for the CMLF using standard landfill design concepts with an in-footprint borrow area. This section details the final contour plan for the site and a detailed phasing plan with internal access road network to ensure vehicular access to all waste filling and borrow areas.

Geotechnical Considerations (Chapter 4): SHA reviewed the past geotechnical assessment reports on the CMLF and gathered necessary information and data. Based on the available geological information, shear strength parameters, and pore pressure data, SHA conducted a detailed slope stability assessment and concluded that CMLF can be safely expanded vertically to the proposed final contours. This chapter includes information about the local and regional geology, review of the previous assessments, SHA's stability assessment results and conclusions and recommendations.

Lifespan Analysis (Chapter 5): SHA has used its knowledge and experience gained at other landfills to determine the lifespan analysis parameters for the CMLF. These parameters include contributory population, population growth rate, waste generation rate, diversion rate, settlement rate, compaction and waste to cover ratio. SHA has completed the lifespan analysis based on two scenarios; one with the current waste to cover ratio and another with the target waste to cover ratio.

The optimum waste-to-cover ratio was used in combination with disposal rate, diversion rate, population data and assumed landfill settlement rates to produce lifespan analysis spreadsheets that project future landfill volume consumption rates. The total lifespan of the landfill and the completion dates were determined based on the net volume of waste and cover material entering the landfill for different scenarios.

Filling Plan (Chapter 6): SHA completed an analysis to determine the optimum cell dimensions for filling based on current and expected future practices at the landfill. From this analysis, cell dimensions are recommended to achieve the optimal waste to cover ratio. A detailed filling plan for Phase 1 has been included in this chapter.

Environmental Control Systems (Chapter 7): Environmental controls that include leachate management, surface water management and landfill gas management are discussed in this chapter.

SHA uses the philosophy of "keep clean water clean." Based on this concept, SHA has proposed the surface water management system at the site. Leachate control is to be achieved by minimizing leachate production through progressive closure and capturing leachate by a series of pumping wells. LFG management system has been recommended based on the RDOS's current target for organics diversion and applying an effective cover system to reduce LFG emissions from the landfill.

Materials Management Plan (Chapter 8): SHA developed a material management plan for the landfill including material requirements and available material volume. The volume of materials available onsite was assessed from the proposed borrow plan, site investigations and previous reports completed by the RDOS. An estimate of the material requirements for the site is provided in this section.

Operations Plan (Chapter 9): SHA has provided a detailed operations plan to reflect the new landfill design. The plan focuses on three main areas; operations at the active face and compaction, daily and intermediate cover soil usage and control of fires, litter, dust and vectors.

Current operations were reviewed and recommendations were provided on operations at the active face and waste compaction. SHA has made recommendations on the most efficient and economic use of daily and intermediate covers to meet the regulatory and lifespan requirements. Also provided in this section are options to minimize the risk of landfill fires and control litter, dust, vectors and birds at the landfill.

Closure Plan (Chapter 10): SHA has prepared a detailed conceptual closure plan that addresses final cover design, final topography, visual impacts, soil salvaging, re-vegetation, leachate and landfill gas control, post closure monitoring and site access control. Based on the on-site material availability and quality, a recommended closure system is provided. SHA has also developed a progressive closure plan, highlighting areas of the landfill that can be closed once they reach final design grades.

Environmental Monitoring Program (Chapter 11): An environmental monitoring program is essential for determining if the facility is having impact on the surrounding environment. The main components of an environmental monitoring program include groundwater, surface water, LFG and odor emissions monitoring. It also includes the geotechnical assessment of the site.

Cost Analysis (Chapter 12): SHA has prepared a detailed cost analysis which considers required capital investment, operational costs, closure costs and post closure costs. Based on the development of the landfill, SHA has prepared cost estimates for all capital works throughout the lifespan of the landfill. Annual operating costs of the landfill are provided and are based on typical costs at other landfills throughout the region and previous operating costs at the site provided by the RDOS. Estimated closure costs based on the recommended closure system include post closure costs such as environmental controls, monitoring and reporting.

Additionally, a detailed cash flow analysis was completed that projects all costs to the end of the post closure period. To ensure that the RDOS will have sufficient funds in place to operate and to close the landfill a detailed cash flow analysis was carried out that includes all capital, operating, closure and post closure costs. By identifying when large capital expenditures such as landfill closures will be required, the cash flow analysis will assist in long-term budget planning.

Fire Safety and Emergency Response Plan (Chapter 13): This chapter provides a comprehensive plan for responding to any fire emergencies that may occur during the excavation, compaction, or placing of MSW. This chapter discusses Risk Mitigation and Monitoring Program, Fire Fighting Resources, Landfill Fire Alert Levels, Unified Command Structure, and Fire Fighting Methods. SHA has also outlined the development of an Emergency Response Plan.

2. SITE CONDITIONS

2.1 Site Layout and Operation

The Campbell Mountain Landfill (CMLF) is located approximately 4.5 km northeast of Penticton, British Columbia on the western slope of Campbell Mountain overlooking Okanagan Lake. The landfill property is approximately 62 hectares in size at an elevation of approximately 630 m. Figure 2-1 shows the location of the site.

Landfill operations at the site were initiated in 1972 under the Permit PR-1597 issued by the then Ministry of Environment, Lands and Parks on July 4th, 1972 and amended on June 1st, 1992 and then on September 24th, 1992 by the Ministry of Environment (MoE). The maximum quantity of refuse that could be discharged was 50,000 tonnes per year. The following types of waste were not authorized without special approval:

- Special wastes (currently defined as hazardous waste as per the Hazardous Waste Regulations)
- Bulk liquids or semi-solid waste which contain free liquids including septage, raw sewage, and sewage treatment sludge
- Anatomical, pathological, and untreated biomedical wastes
- Slaughter house waste

The Operational Certificate (OC) 15274 was issued by the MoE on January 8, 2015 for the CMLF that supersedes the Permit PR - 1597 (03). The maximum rate of discharge as per the recently issued OC remains the same (50,000 tonnes per year). The following types of wastes have been added to the aforementioned list of un-authorized waste in the current OC:

- domestic wastewater;
- explosives;
- hog fuel, log yard debris and chipped wood waste. The reuse of these materials for temporary roads, dust control, or a component of alternative daily cover is permitted;
- radioactive waste;
- recyclable material (automobiles, white goods, other large metallic objects, and tires);
- dead animals and slaughter house, fish hatchery, and farming wastes or cannery wastes and by-products.

A copy of the OC is presented in Appendix A.

2.2 Historical Fill Plan

To date, waste filling operations at the CMLF have been typically located in the central portion of the site. The landfill has been receiving waste since 1972. The current waste footprint occupies approximately 22 HA and is located mainly in the north portion of the site.

When filling began in 1972, waste was first placed in the central region of the landfill for several years. Subsequently filling was relocated to the North Ravine running from the northwest to southeast until the mid-1980s. Since then, the majority of filling has been concentrated in vertical expansion of the central portion of the site.

Based on the operational certificate (OC-15274) issued on January 8th, 2015, the CMLF is currently permitted to discharge 50,000 tonnes of waste per year. With the implementation of recycling and composting programs, the rate of disposal has decreased in recent years. The CMLF site currently receives approximately 29,000-30,000 tonnes per year.

Based on scale data provided by the RDOS, from 2009 to 2014 an average of 28,962 tonnes of waste was disposed at the CML annually. This correlates to an average airspace consumption of 37,500 m^3/year using an approximate waste density of 0.80 tonnes/m^3. The waste density was approximated based off SHA's experience with landfills of similar size and the compaction equipment that is used at the CMLF which is a CAT 826-C Compactor. The historical waste tonnages that were disposed at the CMLF can be seen in Table 2-1 below.

Table 2-1: Historical Waste Filling Data

Year	Waste (tonnes)
2009	31,482
2010	29,959
2011	32,569
2012	29,925
2013	26,035
2014	23,800
Average	**28,962**

2.3 Climate

The Campbell Mountain Landfill is located in a semiarid region of the province. The temperature and precipitation data for 1981 to 2010 were sourced from the Environment Canada website using the nearest weather station to the site and summarized in Table 2-2 below. The average annual precipitation is approximately 346 mm with about 299 mm of rain and 59 cm of snowfall. The average annual temperature is about 9.5°C with an average peak of 21.0°C occurring in July and the minimum average of -1.1°C occurring in December. The maximum average snowfall of 21.1 cm occurs in

December. Table 2-2 presents the average monthly precipitation and temperature for the Penticton Airport Weather Station that represents the CMLF.

Table 2-2 Climate Data for Penticton Airport Station, 1981 to 2010 (Environment Canada, 2016)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	12.6	14.0	20.3	25.4	39.3	46.3	28.7	28.3	24.6	26.0	21.8	11.4	298.5
Snowfall (cm)	18.3	7.6	3.5	0.6	0	0	0	0	0	0.1	7.5	21.1	58.7
Precipitation (mm)	26.9	19.8	23.6	26.0	39.3	46.3	28.7	28.3	24.6	26.0	28.1	28.6	346
Daily Average (°C)	-0.6	1.0	5.0	9.1	13.9	17.7	21.0	20.4	15.1	8.8	3.2	-1.1	9.5

2.4 Water Balance

A key aspect of this project was to conduct a water budget analysis and evaluate the existing and future leachate generation potential from the CMLF. A Water Balance was performed for the landfill site using the Thornthwaite Model and HELP modeling. The results of the analysis are discussed in the following section.

2.4.1 Thornthwaite Model

Currently, CMLF depends on the natural attenuation. To estimate the amount of leachate generated, SHA conducted a water balance analysis for the site using the Thornthwaite and Mather (1957) numerical method. This method is used to determine leachate production potential for the landfill site.

The water balance examines the relationship between precipitation and evapotranspiration, the process involving the return of water to the atmosphere through evaporation and transpiration by vegetation. During the winter months, precipitation will typically exceed evapotranspiration resulting in a moisture surplus. During the summer months, precipitation rates will be less than evapotranspiration rates thereby resulting in a moisture deficit. A moisture surplus will result in water flowing over the landfill surface as runoff, being retained in storage (i.e. snow or soil moisture) or infiltrating and generating leachate. During a moisture deficit, water is drawn out of surface soils, thereby decreasing the soil moisture content.

Table 2-3 and Figure 2-2 at the end of this section present a summary of the water balance by the Thornthwaite and Mather (1957) numerical method. For a typically rolling slope, a 300 mm intermediate silty cover and a runoff coefficient of 0.35, the predicted generation of percolated leachate based on the water balance method is only 28 mm/year. A representative soil moisture retention capacity for the site of 100 mm was chosen to represent the soil conditions expected at the site when the refuse is capped by a bare intermediate cover layer of silt. The water budget analysis suggests that, there will be a large water deficit and percolation into the landfill will be limited to the winter months of Dec, Jan, Feb and March.

Using the Thornthwaite-Mather water balance analysis results, SHA estimates that currently the landfill footprint of approximately 22 ha is producing about 27,310 m^3(0.87 L/s) of leachate per year from precipitation alone when surface run-off is considered to contribute to leachate generation as the worst case scenario (Appendix C-1). This value does not include possible leachate generation as a result of up gradient ground water seepage or run-on to the waste footprint.

As such, Campbell Mountain Landfill is one of the driest sites in BC, making it a prime candidate for leachate management via phytoremediation and evaporation. If run-off were to be diverted, the leachate generation due to percolation would be only 652 m^3/year (0.02 L/s) after all the water is absorbed to field capacity (Appendix C-2). As discussed later in Chapter 7, this site is relatively dry with low leachate generation potential. As the precipitation follows seasonal variability, the amount of run-off, leachate percolation and evapotranspiration will also vary. The highest amount of run-off and leachate percolation is expected during the winter season and the lowest in the summer. As shown in Table 2-3, the peak monthly leachate production occurs in January according to the Thornthwaite model. The peak monthly leachate production rate is 19.9 mm/month. This equates to a peak monthly leachate production rate of 4,378 m^3/month or 0.78 L/s.

2.4.2 HELP Model

The leachate generation estimation was also performed using the Hydrologic Evaluation of Landfill Performance (HELP) model. HELP is a quasi-two dimensional hydrologic model of water movement across, into, through and out of landfills. The model accepts weather, soil and design data and uses solution techniques that account for the effect of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetation growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through liners. HELP modelling of leachate production for existing conditions, documented in Chapter 10, forecasts higher average annual leachate production rate of 37.47 mm/year or 8,243 m^3/year (0.26 L/s), primarily because the HELP model forecasts significantly less run-off (24.45 mm vs. 121 mm) and the potential leachate generation estimate is calculated in the model with a different method. But the results are comparable. The HELP model has the option to define the geometry and the hydrogeological properties of different layers which may also result in a variation in run-off and leachate generation estimation. Since the HELP model is especially designed for landfill systems including various combinations of vegetation, cover soils, waste cells, lateral drain layers, low permeability barrier soils, and synthetic geomembrane liner, the results from this model are used for all further analysis.

The HELP modeling results for the existing conditions are presented in Figure 2-3. Table 10-2 and Table 2-4 below show a comparison between the key results found using the Thornthwaite method and the HELP model.

Table 2-4: Comparison between Thornthwaite Method and HELP Model Results

Method	Evapotranspiration		Run-off		Percolation	
	mm/yr	%	mm/yr	%	mm/yr	%
Thornthwaite	197.0	57.0	121.0	35.0	28.0	8.0
HELP	281.5	81.6	24.5	7.1	37.5	11.9

2.5 Geology

The Campbell Mountain Landfill site is situated on top of the Monashee Group bedrock and mainly consists of "layered gneiss", which is a high grade metamorphic rock, with localized areas of less metamorphosed sedimentary rock. According the Golder's 1994 report, there are areas of the site where this bedrock protrudes the surface, although the majority of the site is overlain with granular deposits which are known as either outwash terraces or meltwater channel deposits.

The granular material overlying the bedrock was classified by Golder into two different classes. The first layer was defined as an upper granular deposit that consists primarily of an interlayered sequence of medium to fine sand and a well-graded sand and gravel with variable cobble component. The second layer was defined as compact, dense well-graded sand with some silt grading to a silty sand and gravel. In SHA's 1997 report, the first layer was referred to as the 'Upper Outwash Deposits' and had a thickness ranging from 0.7 to 3.0 m, thinning out towards the north, and the second layer was referred to as the "Lower Outwash Deposits" and was found to overlie the bedrock throughout most of the site. Figure 2-4 shows surficial geology interpretation by SHA.

2.6 Hydrogeology

In the 1994 Hydrogeological and Geotechnical Evaluation of the site, produced by Golder, five boreholes were installed and it was found that groundwater was within 1 to 2 meters of the bedrock surface. The depths of the boreholes ranged from 4 to 27 m below the ground surface. According to Golder's report in 2002, the groundwater flow is expected to mimic the bedrock surface. The estimated daily groundwater flow under the site is approximately 3.4 L/min and flows in a southwesterly direction towards Okanagan Lake. The water table at the site ranges up to 30 m in the area where the ravine was previously located.

For Golder's 2002 report, hydraulic conductivities for each layer were estimated from previous reports. The results indicated that the sites materials have an average hydraulic conductivity of approximately 2.18×10^{-4} m/s. The estimated hydraulic conductivities of different layers from Golder's 2002 Fill Plan are outlined in Table 2-5 below.

Table 2-5: Estimates for Hydraulic Conductivities of Material at the Campbell Mountain Landfill

Layer	Description	Hydraulic Conductivity	Source
Upper Granular Deposit	An interlayered sequence of medium to fine sand and a well-graded sand and gravel with variable cobble component	N/A	N/A
Lower Granular Deposit	A compact, dense, well-graded sand with some silt grading to a silty sand and gravel	8.9×10^{-5} m/s	SHA (1997)
Fractured Bedrock	Metamorphic	1.1×10^{-6} m/s for first test, 1×10^{-4} to 1×10^{-3} m/s for second test	Golder (1994)
Competent Bedrock	Metamorphic	6.9×10^{-10} m/s to 9×10^{-10} m/s	Golder (1994)

Figure 2-5 shows the location of a profile presented in Figure 2-6 to portray different layers of formation and the water table that have been approximated from the borehole logs presented in Appendix B.

2.7 Water Quality

2.7.1 Surface Water Quality

During 2015, the only site that was sampled was Lank Springs, located downstream of the CMLF, during October and November 2015. Exceedances of the BC Water Quality Guidelines for Aquatic Life, Wildlife and Agriculture were found in the following parameters: uranium, chloride, pH, total dissolved solids, fluoride, and magnesium. The RDOS regained access to Randolph Springs in 2016 and should be included during future sampling events.

2.7.2 Groundwater Monitoring well locations

Figure 2-7 shows the groundwater monitoring wells locations on the property.

2.7.3 Water Level Measurements

The groundwater monitoring program was conducted onsite on a quarterly basis by Western Water Associates Ltd (WWAL). There are currently 11 monitoring wells located at the CMLF and one residential off-site well (DW-1655), and one new off-site monitoring well. A total of eleven wells were monitored during 2015, nine of which were located onsite, the one residential off-site well, and the one off-site monitoring well. Two of the wells (BH-102 and BH-2000-1) were dry and could not be sampled which have proved to be similar in the past. Figure 2-8 shows groundwater elevations at the wells during drilling in red and during 2015 monitoring in blue including groundwater contours drawn with the help of those elevations. The groundwater contours indicate that the groundwater flow direction is toward the southwest.

2.7.4 Leachate Quality

Landfill leachate typically has elevated concentrations of ammonia, BOD, chloride, conductivity, and dissolved metals; in particular iron and manganese. Conductivity is a measure of the total amount of dissolved minerals in the water sample and is therefore routinely used to track impacts of landfill leachate. Chloride is also routinely used as a leachate indicator at municipal landfills since it is a common constituent of materials disposed of in MSW, it is non reactive and has low affinity to soil or other matter meaning that it stays in solution after it enters the system. Raw leachate from municipal landfills typically has very high chloride concentrations with up to several hundred milligrams per litre. The chloride concentrations typically drop as the leachate mixes with the groundwater.

In Western Water's 2015 Monitoring Report, it was outlined that there has been a continuous increasing trend of leachate indicating parameters at the down-gradient monitoring wells. Therefore, there is ongoing concern that leachate is migrating offsite.

2.7.5 Water Quality Results

The latest monitoring report for the CMLF was prepared in 2015 by Western Water Associates Ltd (Western Water, 2015). During the 2015 sampling event, arsenic was found to only have one exceedance in BH04-4. Arsenic concentrations have been variable at this location but have shown a minor decrease since 2006 (0.02 mg/L) to 2015 (0.014 mg/L).

Chloride concentrations were found to exceed drinking water guidelines at four locations during 2015. These locations include BH04-4, BH-101, BH-103, and BH-2000-2. Exceedances for BH-2000-2 and BH04-4 have been occurring since 2010. At BH-103, the chloride concentration has been steadily increasing and exceeded the guideline in 2012. BH-101 also exceeded the guideline in 2012. Chloride concentrations at these wells have been rising since 2006, indicating that there is an impact due to landfill operations.

Manganese concentrations consistently exceeded the aquatic guideline at six locations during the 2015 monitoring event; BH04-4, BH-103, BH2000-2, BH2000-3, BH2000-4, and MW15-01. BH04-4 and BH2000-4 have showed consistent concentrations around 5 mg/L since 2006. A steady increase of manganese concentrations was noted in the BH2000-2 from 2012 to 2015. The concentration of manganese at BH-103 spiked in 2013 and has shown a steady increase in concentration since then. The concentration of manganese was also found to be increasing at BH2000-3.

Sodium concentrations exceeded the aquatic and drinking water guideline at BH2000-02 in August 2015. This exceedance has not occurred before and should continue to be monitored in future sampling events for an increasing trend.

Overall, BH4-04, BH-103, BH-104, BH2000-2, BH2000-3, and BH2000-4 all show signs of landfill leachate impact. DW-1655 had a water quality similar to what has been noted in the past and may be impacted from the landfill.

2.8 LFG Quality

2.8.1 Landfill Gas Monitoring

Landfill gas can migrate great distances from landfills under favorable conditions. Landfill gas will migrate along the path of least resistance, by convection, from areas of high pressure to areas of low pressure, or by diffusion, from areas of higher concentration to areas of lower concentration. If vertical venting to the atmosphere is restricted, lateral migration can occur through coarse-grained soils or along other pathways such as conduits, drain tile and sewers.

There are two main components in landfill gas, methane (CH_4), and carbon dioxide (CO_2), each present at maximum concentrations of 40-60%. There are also a number of less pronounced components such as oxygen (O_2), nitrogen (N_2), ammonia (NH_4), carbon monoxide (CO), hydrogen sulphide (H_2S) and volatile organic compounds (VOCs). These compounds can occur at concentrations from a few percent for oxygen and nitrogen components, to only a few parts per million (ppm) for VOCs. Oxygen (O_2) can normally be found in landfill gas during the initial stage of the landfill development, and in landfills which have a thin layer of refuse, covered with a permeable cover material.

Methane can become explosive when the gas is diluted with atmospheric oxygen and nitrogen to concentrations between 5 and 15% on a volume basis. This range corresponds to the lower explosive limit (LEL) and the upper explosive limits (UEL). Methane is lighter than air, which means that it can migrate up through the ground and accumulate in buildings and other structures at or around the landfill.

The main danger with carbon dioxide is that this gas is heavier than air and can therefore displace the air from structures such as manholes and wells, which could cause asphyxiation for someone entering such a structure without properly checking the conditions and using confined space entry procedures.

Carbon monoxide (CO) can appear in landfill gas at low concentrations under certain conditions. This gas is highly toxic at higher concentrations (> 500 ppm) and will cause headaches and nausea at concentrations of less than 100 ppm. The presence of carbon monoxide above 500 ppm is a very strong indicator of a potential underground landfill fire. Carbon monoxide is formed when organic material is incompletely combusted, which is often the case with underground fires.

2.8.2 Landfill Gas Quality

Landfill gas consists of principal gases of CO_2 and CH_4 (in large amounts) and trace gases in very small amounts (e.g., N_2, S_2, O_2, etc.). Depending on number of factors including waste composition and age of the Landfill, the exact percentage of each component of LFG varies but typically municipal solid waste landfill gas comprises 45- 60% methane (CH_4), 40- 60% carbon dioxide (CO_2), small amounts of nitrogen (N_2), oxygen (O_2), ammonia (NH_3), hydrogen sulfide (H_2S), hydrogen (H_2), sulfides (S_2), carbon monoxide (CO), and non-methane organic compounds (NMOCs) such as trichloroethylene, benzene, and vinyl chloride (Tchobanoglous et al., 1993). Approximate percentages as well as a brief explanation about characteristics of each of these components are presented in Table 2-6.

Table 2-6 Typical Landfill Gas Components*

Component	% dry Volume	Characteristics
methane	45 - 60	Methane is a naturally occurring gas. It is colorless and odorless. Main GHG in waste sector.
carbon dioxide	40 - 60	Carbon dioxide is naturally found at small concentrations in the atmosphere (0.03%). It is colorless, odorless, and slightly acidic.
nitrogen	2 - 5	Nitrogen comprises approximately 79% of the atmosphere. It is odorless, tasteless, and colorless.
oxygen	0.1 - 1	Oxygen comprises approximately 21% of the atmosphere. It is odorless, tasteless, and colorless.
ammonia	0.1 - 1	Ammonia is a colorless gas with a pungent odor.
NMOCs (non-methane organic compounds)	0.01 - 0.6	NMOCs may occur naturally or be formed by synthetic chemical processes. NMOCs most commonly found in landfills include acrylonitrile, benzene, 1,1-dichloroethane, 1,2-cis dichloroethylene, dichloromethane, carbonyl sulfide, ethyl-benzene, hexane, methyl ethyl ketone, tetrachloroethylene, toluene, trichloroethylene, vinyl chloride, and xylenes.
sulfides	0 -1	Sulfides (e.g., hydrogen sulfide, dimethyl sulfide, mercaptans) are naturally occurring gases that give the landfill gas mixture its rotten-egg smell. Sulfides can cause unpleasant odors even at very low concentrations.
hydrogen	0 - 0.2	Hydrogen is an odorless, colorless gas.
carbon monoxide	0 - 0.2	Carbon monoxide is an odorless, colorless gas.

Source: (Tchobanoglous, Theisen et al., 1993), *Percentage distribution varies with the age of the LF.

There are number of factors affecting quantities and rates of LFG generation most important of which are landfilled solid waste density, moisture content, composition and age, as well as landfill design aspects with regard to leachate management system and landfill cover.

In the last LFG Assessment done by Conestoga-Rovers and Associates in 2011 (CRA, 2011), it was noted that the CMLF was producing just over the threshold of a regulated site at 1,380 tonnes of methane per year. The RDOS is currently continuing to investigate alternatives to the installation of an Active LFG Management System such as diversion of organic material and the installation of a passive biocover system. Chapter 7 describes proposed alternatives to an Active LFG Management System.

2.9 Site Inspection

Dr. Iqbal Bhuiyan and Scott Garthwaite from SHA visited the site on December 1st, 2015 to review site conditions and operations with RDOS staff, Don Hamilton. Scott Garthwaite subsequently visited the site on March 10th, 2016 to conduct a GPS ground survey as well as review site conditions. During SHA's site visits, the site appeared to be very well run by the landfill contractor, SSG Environmental. However, as shown in the photo below, the eastern slope is over steepened and the cover material has been eroded. Seepage of groundwater is also currently occurring from the eastern slope. SHA recommends that the RDOS regrade this slope to a grade of 3H:1V, install erosion control measures and apply hydroseed to the area. SHA will address this issue during the on-going detailed design of the drainage facilities to be upgraded for the site that SHA has been retained for.

Photo 2-1 Eastern Slope at the Campbell Mountain Landfill

Photo 2-2 below shows the active face at the City of Penticton (CoP) biosolids composting area at the Campbell Mountain Landfill. As shown in this photo, the ditch from the composting area flows into the surface water ditch on the left hand side of the photo. Therefore, any pollutants that the compost may contain will also be contaminating the surface water once the ditch from the compost area reaches the surface water ditch. Preventing run-on to this facility operating on a paved pad and recirculating all leachate generated should be a top priority.

Photo 2-2 CoP Biosolids Compost Area at Campbell Mountain Landfill

SHA also noted that operational materials were blocking the surface water drainage within the wood waste area as shown in Photo 2-3 below. Ponding of water is also occurring in the wood waste area shown in Photo 2-3, allowing for it to infiltrate into the waste cells. SHA recommends the removal of the operational materials from the surface water ditches and providing better drainage throughout the wood waste area. Surface water ditches should be well maintained and unblocked at all times.

Photo 2-3 Operational Materials blocking Surface Water Drainage

Photo 2-4 below shows a large amount of ponding water in the yard and garden waste storage area. There is currently no drainage in this area and the run-off from the yard and garden waste may be potentially contaminating the ground water due to infiltration of the ponding run-off. SHA recommends that surface water diversion controls be installed within the yard and garden waste storage area.

Photo 2-4 Ponding of Surface Water in Yard and Garden Waste Storage Area

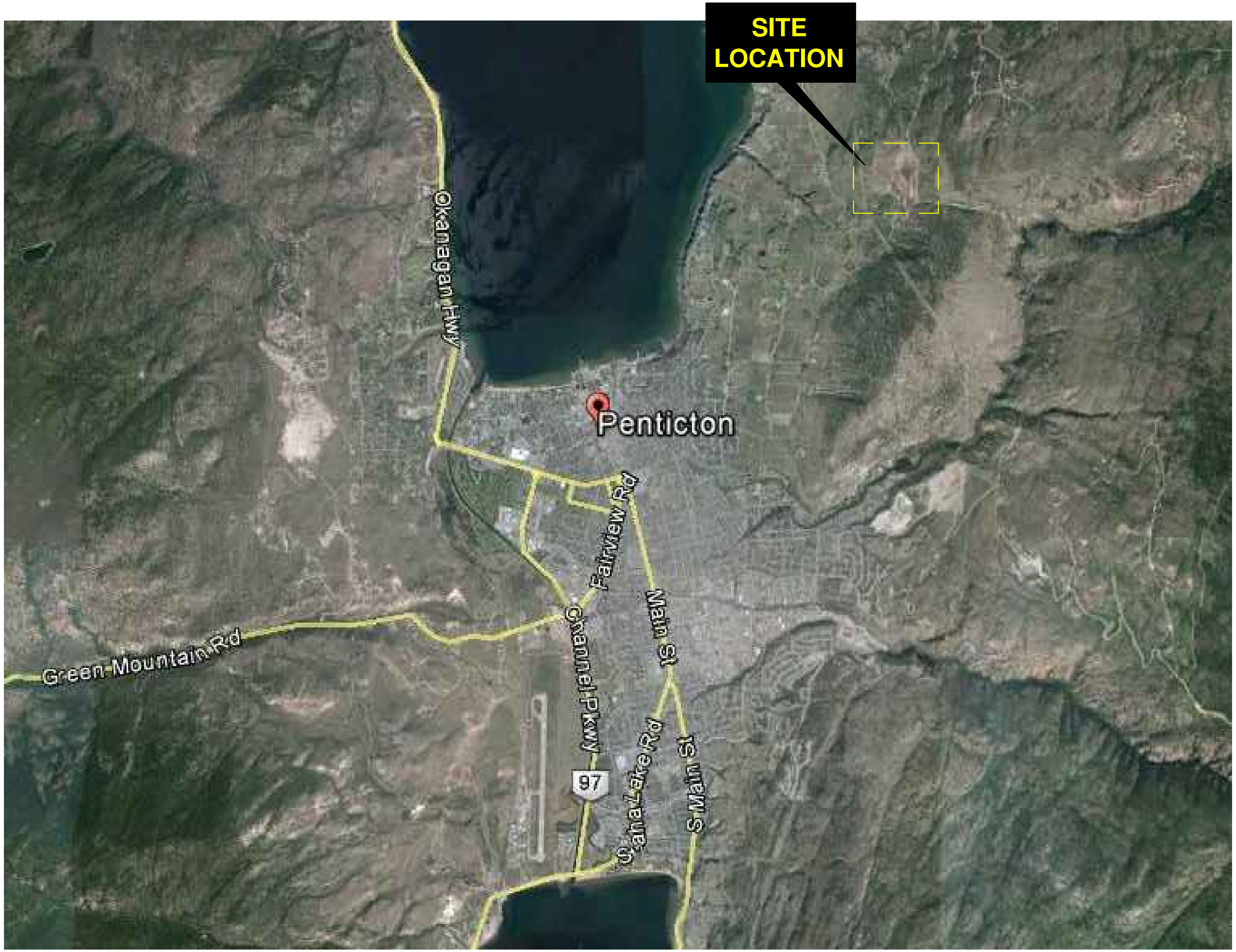
SHA is of the opinion that the historic information of septage, and the large release of highly impacted organic leachate from the compost area have been major contributors to the leachate migration problems at Campbell Mountain Landfill.

2.10 Environmental Concerns

With an anticipation that leachate from the landfill may be impacting the residences downstream, a notice of migration (NOM) was submitted by the RDOS to the Ministry of Environment (MoE) on November 13th, 2015. In addition to the NOM, a Site Risk Classification Report was completed for the affected or potentially affected land parcels identified in the NOM (Western Water, 2015). In response to the NOM, the MoE asked RDOS to address the issues as per the Contaminated Site Regulations (CSR) guidelines. The contamination investigation and remediation is underway by Western Water Associates Ltd. SHA has been retained to develop a Leachate Management Plan as part of this DOCP and design a system that would help stop/reduce the contamination at the source. Our proposed Leachate Management Plan is described in Chapter 7.

2.11 Buffer Requirements and Setbacks

Golder Associates conducted an analysis and documented the factors to be considered in setting buffer zones for the CML (Golder, 2010) during the process of developing an application for the OC. As per the



SPERLING HANSEN ASSOCIATES

Landfill Services Group
Landfill Siting
Design & Operations Plans
Landfill Siting
Environmental Monitoring

#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

CLIENT: REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT: RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN, OPERATIONS, AND CLOSURE PLAN

TITLE: LOCATION MAP (MAY 27, 2016)

SCALE:	DATE:	PROJECT NO:
.	2015/12/01 (yyyy/mm/dd)	PRJ15061

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DRAWN	MG	
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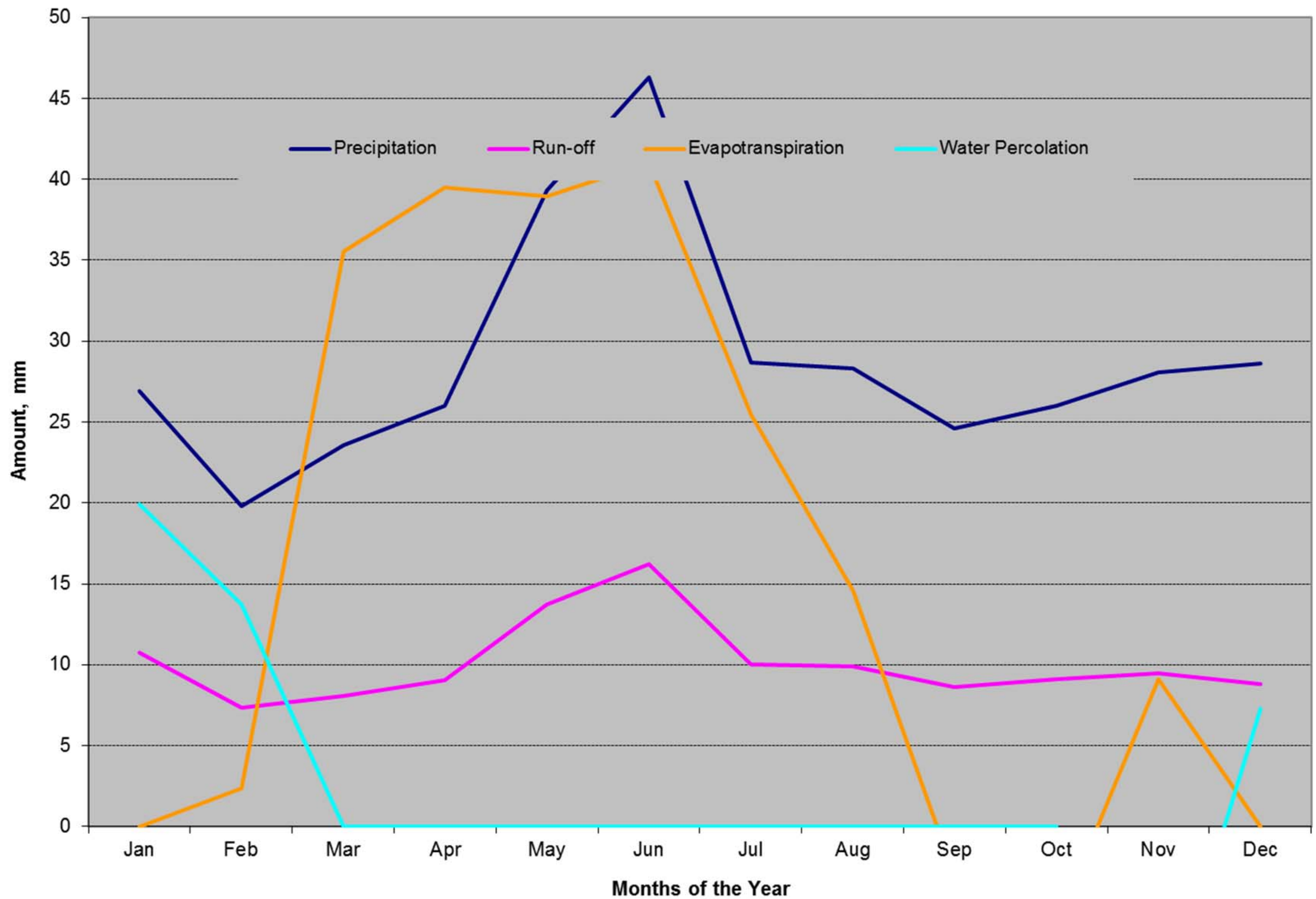

SPERLING HANSEN ASSOCIATES	CLIENT: Regional District of Okanagan-Similkameen	PROJECT: CAMPBELL MOUNTAIN LANDFILL DESIGN, OPERATIONS & CLOSURE PLAN	TITLE: **Water Budget Analysis**	SCALE: NTS	DATE: 2016/04/13 (yyyy/mm/dd)	PROJECT NO: PRJ1 5061
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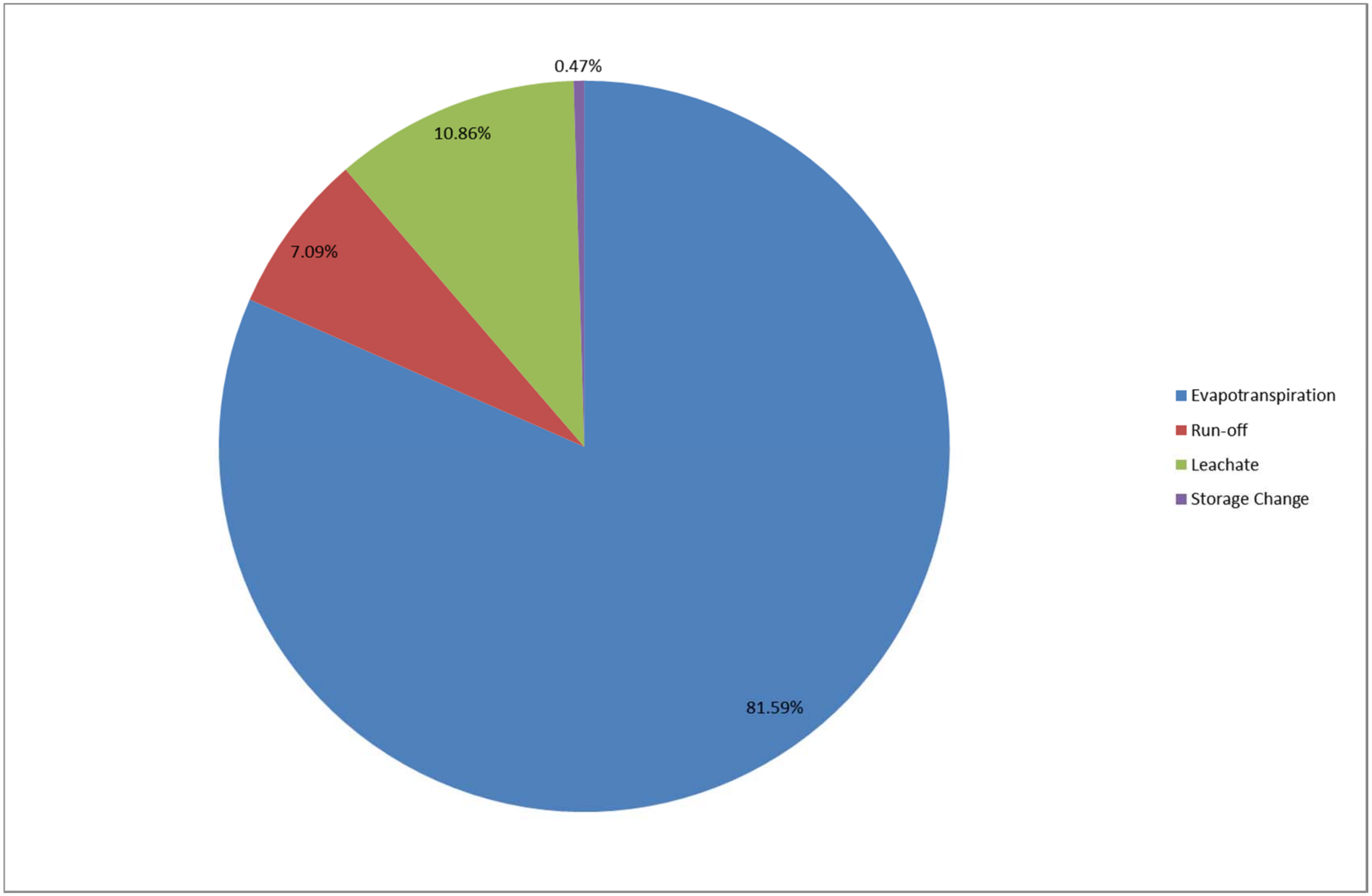
				DRAWN	MG	**FIGURE 2-2**
				CHECKED	TS	



SPERLING HANSEN ASSOCIATES	CLIENT: Regional District of Okanagan-Similkameen	PROJECT: CAMPBELL MOUNTAIN LANDFILL DESIGN, OPERATIONS & CLOSURE PLAN	TITLE: **Help Results- Existing Condition**	SCALE: NTS	DATE: 2016/04/13 yyyy/mm/dd	PROJECT NO: PRJ1 5061
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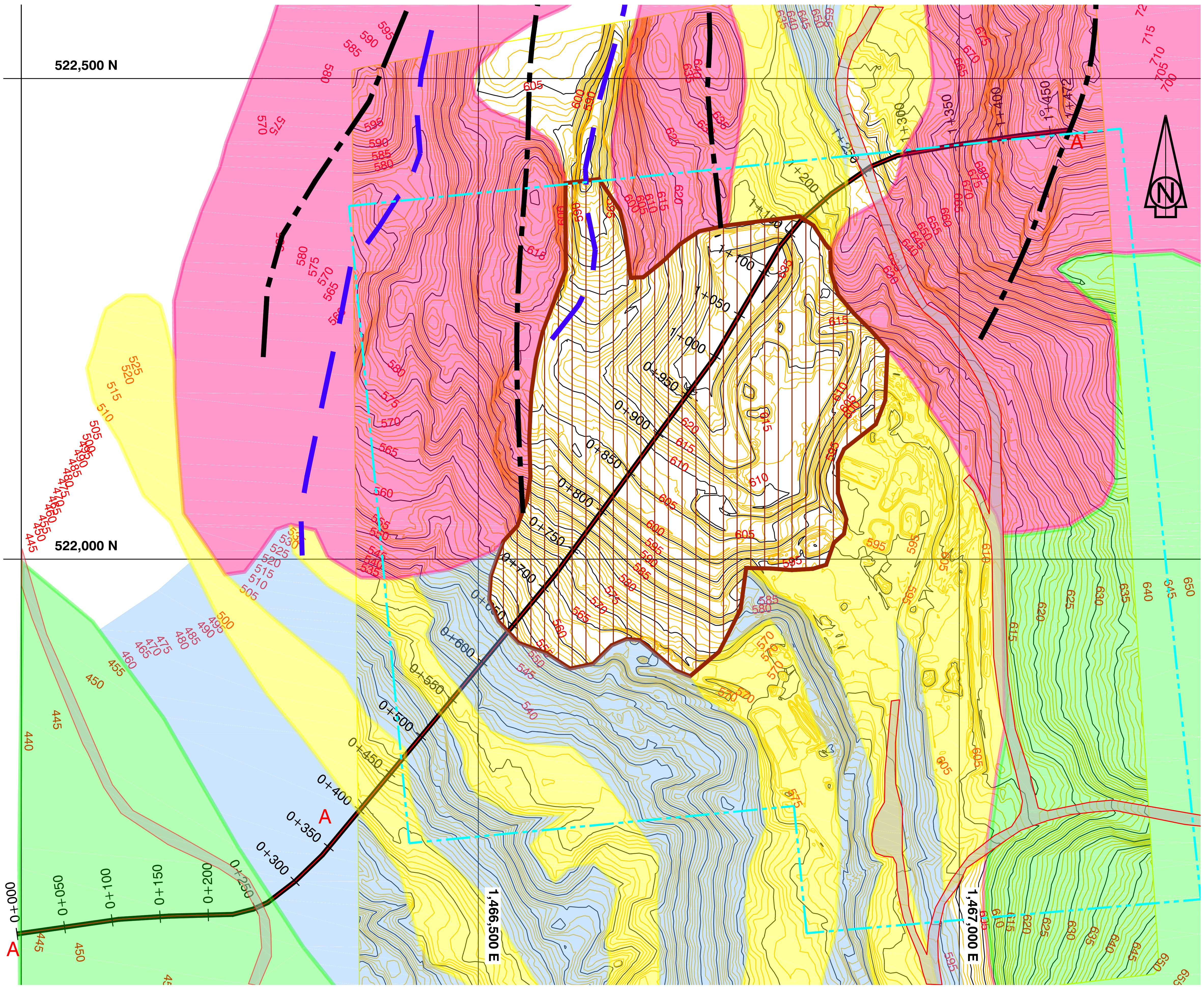
				DRAWN MG		
				CHECKED TS		



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- Environmental Monitoring

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North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:
- ROAD
- GLACIAL TILL
- OUTWASH DEPOSIT TERRACE
- OUTWASH DEPOSIT ESCARPMENT
- BEDROCK
- MUNICIPAL SOLID WASTE LANDFILL
- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- VALLEY
- RIDGE

CLIENT: REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT: RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN, OPERATIONS AND CLOSURE PLAN

TITLE: SURFICIAL GEOLOGY INTERPRETATION WITH LOCATION OF SECTION A-A'

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DRAWN	MG	
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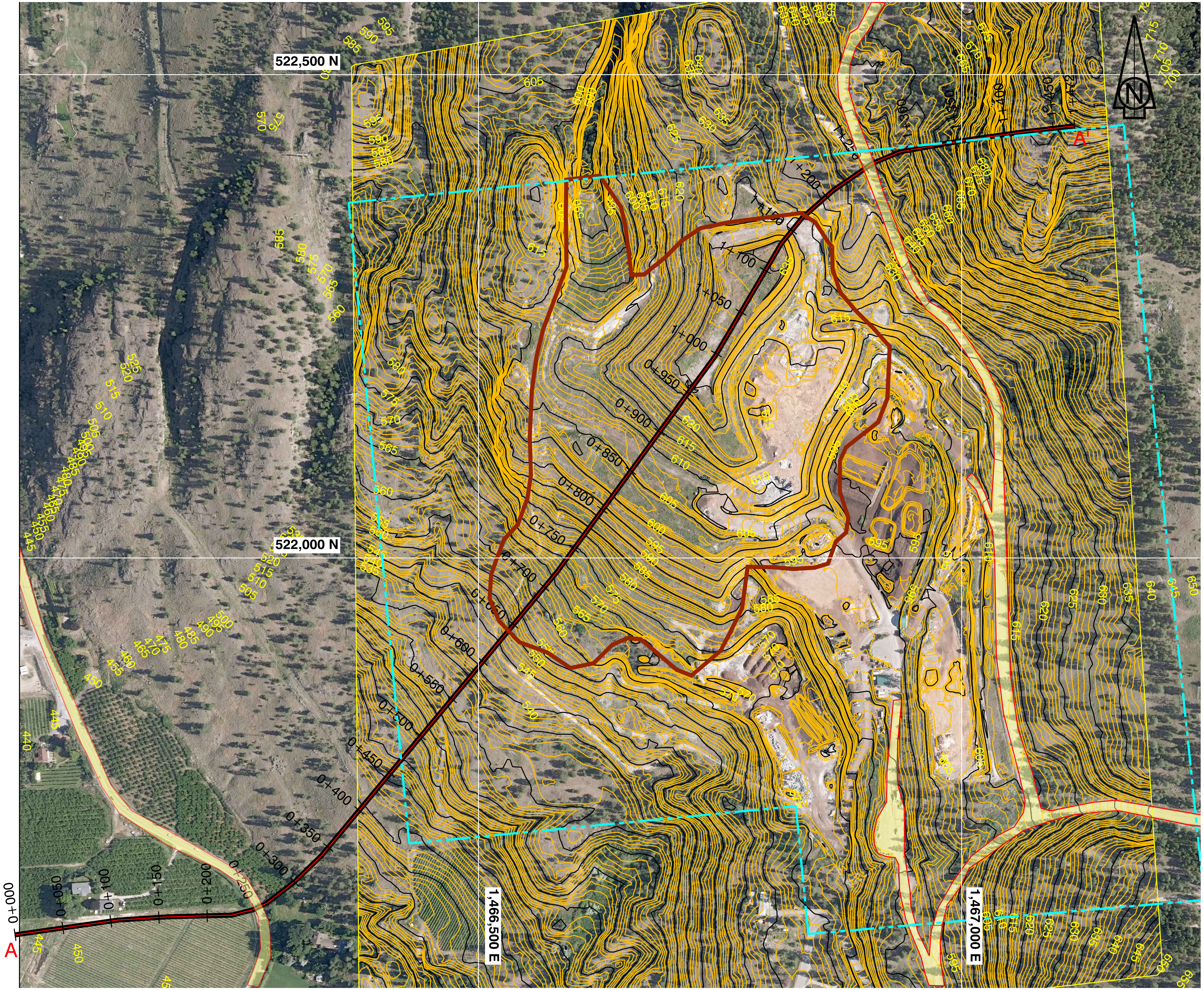

Sperling Hansen Associates

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Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- 5m EXISTING CONTOUR
- ROAD
- PROPERTY BOUNDARY
- MUNICIPAL SOLID WASTE LANDFILL

CLIENT:

REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:

RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN, OPERATIONS AND CLOSURE PLAN

TITLE:

BASE MAP AND SECTION A-A' LOCATION WITH AERIAL PHOTO

SCALE:	DATE:	PROJECT NO:
1:4000	2016/05/20 yyyy/mm/dd	PRJ15061

DESIGNED	-	DRAWING NO: FIGURE 2-5
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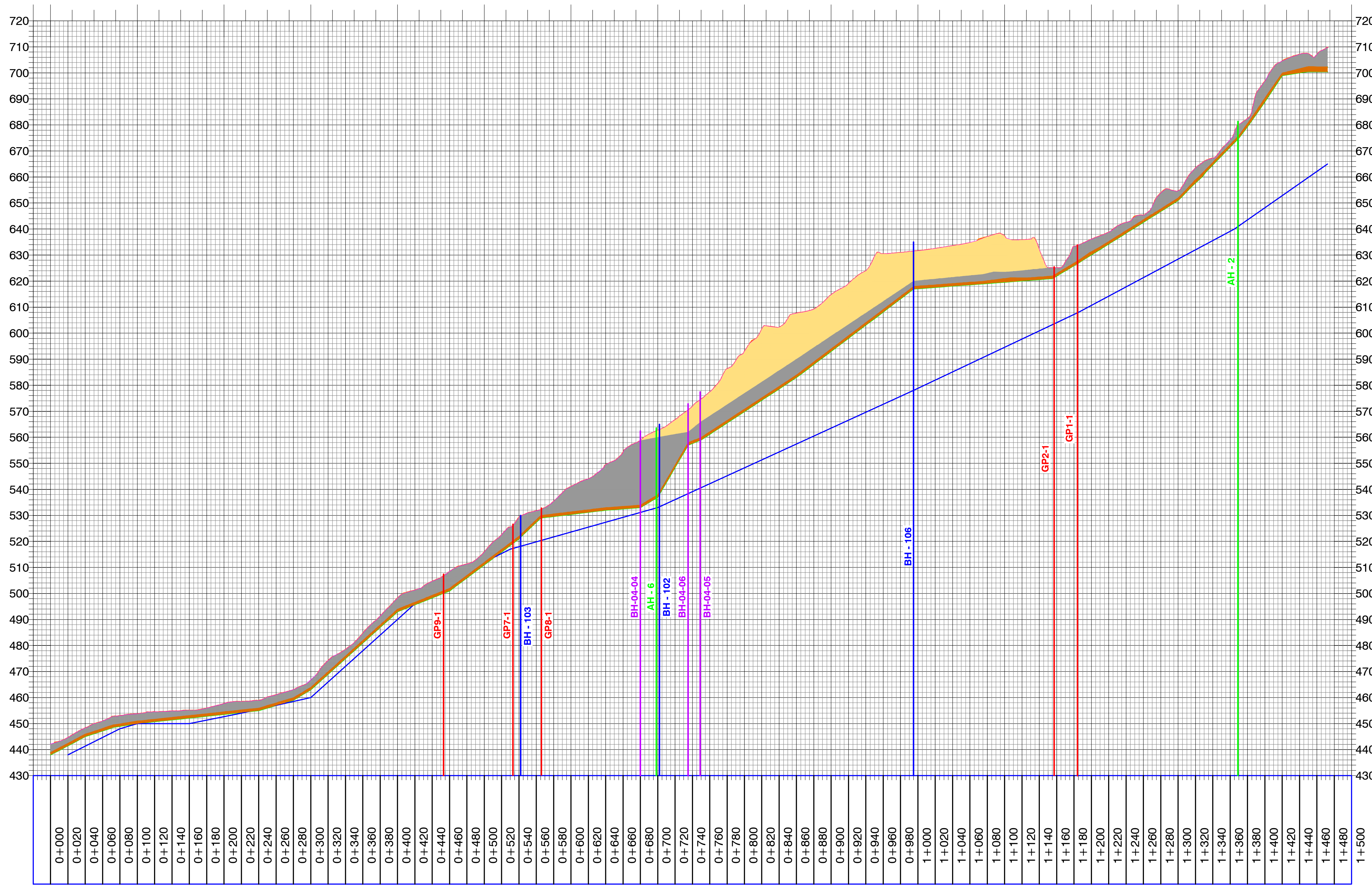
CHECKED	IB	



SCALE: 1:5000 HORIZONTAL
1:15000 VERTICAL

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#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- WASTE
- SAND
- BEDROCK
- APPROX. WATER TABLE

CLIENT:
REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN, OPERATIONS AND CLOSURE PLAN

TITLE:
DETAILED GEOLOGIC CROSS SECTION A-A'

SCALE:	DATE:	PROJECT NO:
AS NOTED	2016/05/20 yyyy/mm/dd	PRJ15061

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DESIGNED	-	FIGURE 2-6
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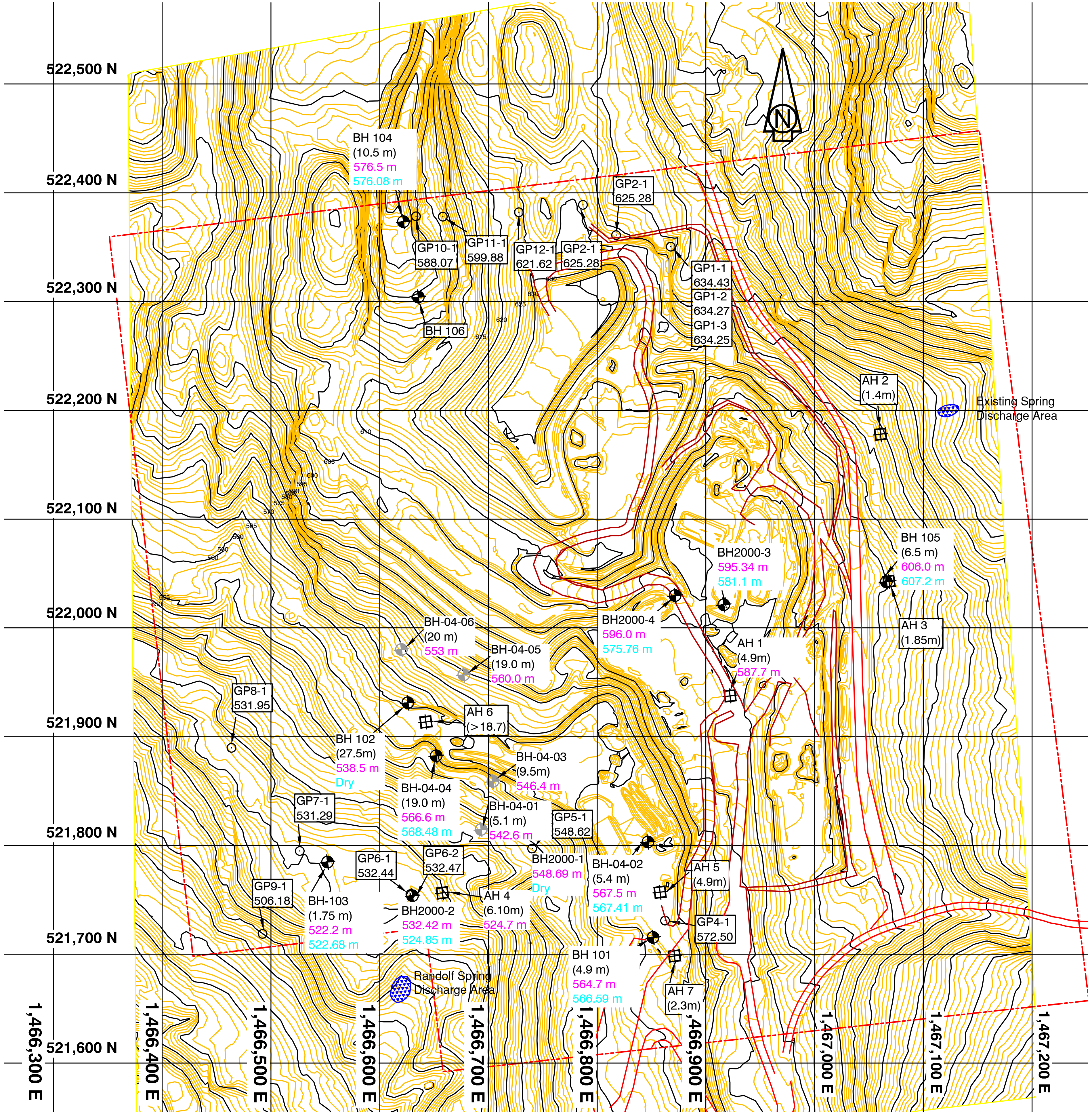

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North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- ROAD
- PROPERTY BOUNDARY
- GROUNDWATER MONITORING WELLS
- BH2000-4 GROUNDWATER ELEVATIONS
  - 596.0 m GW Elevation during drilling
  - 575.76 m 2014 GW Elevation
- DECOMMISSIONED MONITORING WELLS
- AUGER HOLES
- GAS PROBES

CLIENT: REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT: CAMPBELL MOUNTAIN LANDFILL DESIGN, OPERATIONS AND CLOSURE PLAN

TITLE: MONITORING WELL AND GAS PROBE LOCATIONS

SCALE:	DATE:	PROJECT NO:
1:4000	2016/05/25 (yyyy/mm/dd)	PRJ15061

DESIGNED	-	DRAWING NO:
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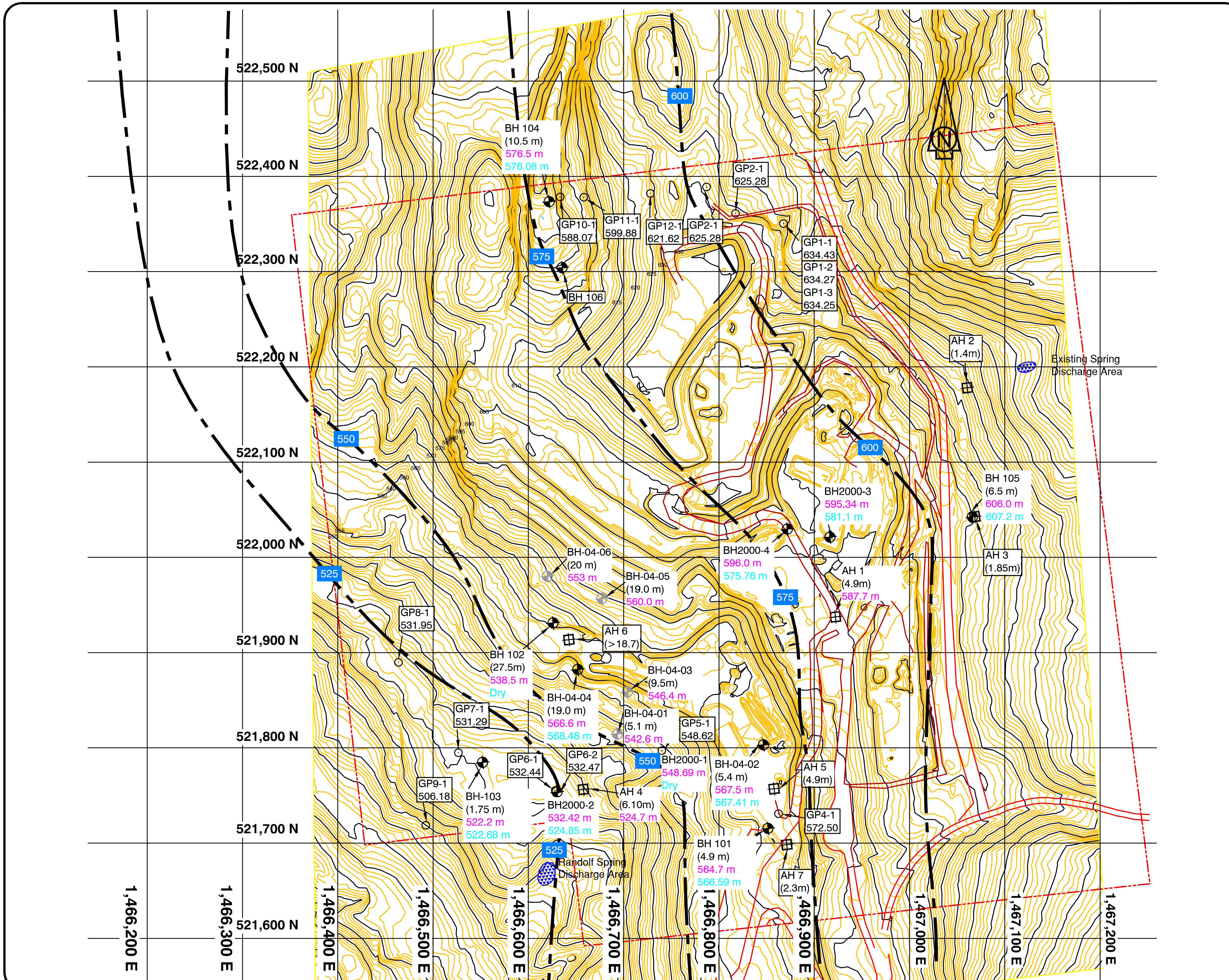
CHECKED	IB	



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North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- ROAD
- PROPERTY BOUNDARY
- GROUNDWATER CONTOURS AT 25 m INTERVALS
- GROUNDWATER MONITORING WELLS
- BH2000-4 GROUNDWATER ELEVATIONS
  - 596.0 m GW Elevation during drilling
  - 575.76 m 2014 GW Elevation
- DECOMMISSIONED MONITORING WELLS
- AUGER HOLES
- GAS PROBES

CLIENT: REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT: CAMPBELL MOUNTAIN LANDFILL DESIGN, OPERATIONS AND CLOSURE PLAN

TITLE: GROUNDWATER MONITORING CONTOURS

SCALE:	DATE:	PROJECT NO:
1:4000	2016/05/25 (yyyy/mm/dd)	PRJ15061

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DESIGNED	-	FIGURE 2-8
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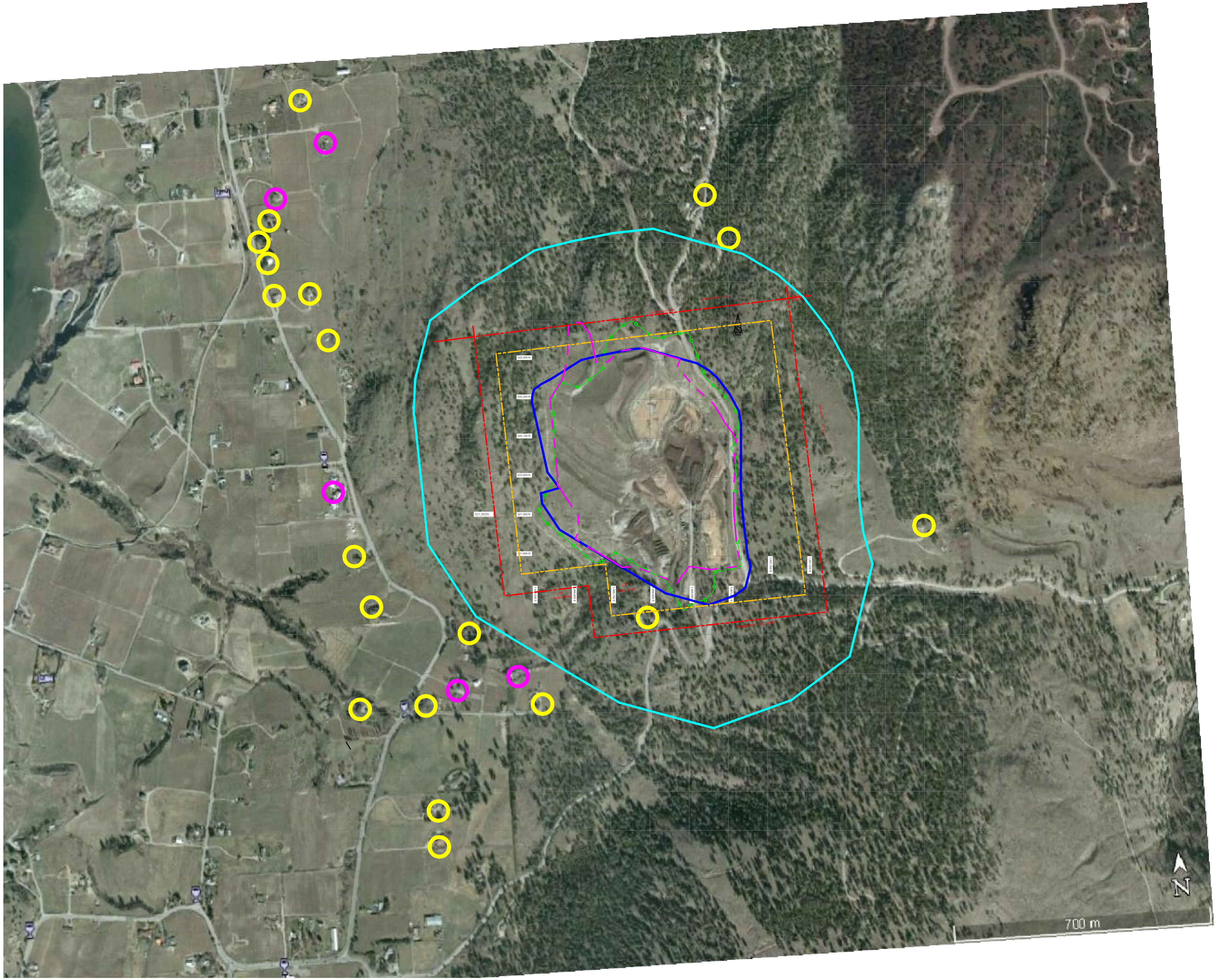

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#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3

Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- ROAD
- FENCE
- PROPERTY LINE
- 50m BUFFER FROM PROP LINE
- EXTENT OF EXISTING WASTE
- PROPOSED LANDFILL FOOTPRINT
- 300m OFFSET OF FOOTPRINT
- APPROXIMATE LOCATION OF RESIDENCE (GOOGLE MAP)
- PROBABLE MIXED USE RESIDENCE/WINERY/ AGRICULTURE

CLIENT:
REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN, OPERATIONS AND CLOSURE PLAN

TITLE:
LANDFILL FOOTPRINT WITH 300m BUFFER AND NEIGHBOURING RESIDENCES

SCALE:	DATE:	PROJECT NO:
1:10,000	2016/02/24 yyyy/mm/dd	PRJ15061

		DRAWING NO:
DESIGNED	TS	**FIGURE 2-9**
DRAWN	NL	
CHECKED	TS	

TABLE 2-3: Water Budget Analysis
Campbell Landfill Site - 100 mm Soil Moisture

Component		Jan 31	Feb 28	Mar 31	Apr 30	May 31	Jun 30	Jul 31	Aug 31	Sep 30	Oct 31	Nov 30	Dec 31	Annual
Precipitation														
Rainfall (mm)		12.6	14.0	20.3	25.4	39.3	46.3	28.7	28.3	24.6	26.0	21.8	11.4	299
Snowfall (cm)		18.3	7.6	3.5	0.6	0.0	0.0	0.0	0.0	0.0	0.1	7.5	21.1	59
Total Precipitation (mm)	P	26.9	19.8	23.6	26.0	39.3	46.3	28.7	28.3	24.6	26.0	28.1	28.6	346.2
Standard Deviation (mm)		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Avg. Temperature (^{o}C)	T	-0.6	1.0	5.0	9.1	13.9	17.7	21.0	20.4	15.1	8.8	3.2	-1.1	9.5
Snow Storage and Melt														
Month End Snow Cover (cm)		1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	5.0	
Change in Snow Cover (cm)		-4.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	4.0	
Snow Melt (cm)		22.3	8.6	3.5	0.6	0.0	0.0	0.0	0.0	0.0	0.1	6.5	17.1	
Available Precipitation (mm)	AP	30.6	21.0	23.1	25.9	39.3	46.3	28.7	28.3	24.6	26.1	27.1	25.2	346
Evapotranspiration														
Heat Index	"i"	0.00	0.09	1.00	2.48	4.70	5.22	8.78	8.41	5.28	2.35	0.51	0.00	38.8
Unadjusted Potential ET (mm)	UPET	0.0	0.1	0.9	1.7	2.2	2.9	3.5	3.4	2.4	1.3	0.4	0.0	
Monthly Duration Corr.	r	22.5	23.7	30.6	34.5	39.6	40.2	40.5	37.2	31.5	27.6	22.8	21.3	
Adjusted Potential ET (mm)	PET	0.0	2.4	26.0	58.7	87.1	116.6	141.8	126.5	75.6	35.9	9.1	0.0	680
Runoff														
Co-efficient of run-off*	Cro	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	
Run-off (mm)	RO	10.7	7.3	8.1	9.1	13.8	16.2	10.0	9.9	8.6	9.1	9.5	8.8	**121**
Infiltration & Water Shortage														
Infiltration (mm)	INF	19.9	13.6	15.0	16.8	25.5	30.1	18.7	18.4	16.0	17.0	17.6	16.4	
Water Available for Storage (mm)	INF-PET	19.9	11.3	-11.0	-41.8	-61.6	-86.5	-123.1	-108.1	-59.6	-18.9	8.5	16.4	-455
Cumulative Water Shortage (mm)	ACCWL				-1.4	-63.0	-149.5	-272.6	-380.6	-440.3				
Storage														
Soil Storage (mm)	ST	100.0	97.5	77.0	54.3	40.9	30.0	23.2	27.0	46.0	69.1	90.9	100.0	
Change in Soil Storage (mm)	DeltaST	0.0	-2.5	-20.5	-22.7	-13.4	-10.9	-6.8	3.8	19.0	23.1	21.8	9.1	
Actual ET (mm)	AET	0.0	2.4	35.5	39.5	38.9	41.0	25.5	14.6	-3.0	-6.1	9.1	0.0	**197**
Percolation														
Percolation (mm)	PERC	19.9	13.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-13.3	7.3	**28**

* value of Run-Off Co-efficient taken from BC Agriculture Drainage Manual 1997 (Rolling slope 5-10% Clay and Silt Loam)

3 LANDFILL DESIGN

This chapter presents the landfill development strategy for the Campbell Mountain Landfill (CMLF), including an access road network, phase by phase development plan and in-footprint borrow area. The design is presented in a sequence of contour drawings that show the current surface and proposed final surface of the landfill, cut and fill contours and volumetric quantities.

3.1 Regulatory Requirements and Design Objectives

3.1.1 Landfill Criteria for Municipal Solid Waste

The new B.C. MOE Landfill Criteria for Municipal Solid Waste is about to be released. The new criteria outline specific requirements that must be satisfied during landfill design, operations and closure. The most important criteria, which are applicable to the development and closure of the CMLF are summarized below:

- *Service Life and Contaminating Lifespan*: The landfill site is to be designed such that the service life of the facility exceeds the contaminating lifespan.
- *Site Layout*: The distance between the discharged MSW and the nearest residence, water supply well, water supply intake, hotel, restaurant, food processing facility, school, church or public park is to be a minimum of 500 m for new sites. Setbacks at existing sites are grandfathered at 300 m the existing sites (300 m). Greater or lesser separation distances may be approved where justified.

  A buffer zone of 50 m is to be maintained between the landfill footprint and the property boundary of which the 30 m closest to the landfill site boundary shall be reserved for landscape screening and 20 m closest to the landfill footprint should be used for access roads, firebreaks, leachate and landfill gas management and monitoring works, as required.

- *Landfill Base:* The landfill base shall be placed in stable soils or rock, with a minimum distance of 1.5 m above groundwater at all times. The landfill base that provides the foundation for construction of the landfill base liner and leachate collection system is to be graded to provide a minimum 2% grade for the leachate collection piping and minimum 0.5% for the drainage blanket.
- *Landfill Base Liner:* The minimum specifications for the base liner are:
  - 60 mil HDPE geomembrane primary liner
  - Service life of 100 years for geomembrane
  - meet or exceed industry standard QA/QC programs
  - A 750 mm thick compacted clay liner with $k \leq 1x10^{-7}$ cm/sec or GCL as secondary liner
- *Leachate Collection System:* The leachate collection system is to provide a free draining layer that allows for collection of leachate and eliminates the buildup of a leachate head on the landfill

base liner. It is to be constructed of a continuous 300 mm thick gravel drainage blanket with perforated or slotted collector pipes (minimum 150 mm diameter) placed at a minimum slope of 2% with protective geotextile layers underlain by a filter layer.

- *Surface Water Management Works*: All components of a surface water management system are to be designed in a manner such that surface water runoff away from the active operation area within the landfill footprint is discharged as clean water and to minimize potential for on-site erosion and sediment loading to downstream courses. Surface water ditches and retention ponds are to be designed for the control and retention of a 1:100-year, 24-hour storm event. All ditches are to be armoured with appropriate protection and to maintain a minimum 1% grade.

- *Landfill Gas Management Works*: The new Landfill Gas Management (LFG) Regulations apply to landfills that have accepted municipal solid waste (MSW) on or after January 1st, 2009. The Regulation requires that if the quantity of waste in place is equal to or greater than 100,000 tonnes or if the annual quantity of waste received exceeds 10,000 tonnes/year before January 1, 2009, a landfill gas generation assessment report had to be submitted to the MOE by January 1st, 2011. Landfills that are determined to produce more than 1,000 tonnes of methane per year in the assessment will be required to develop a landfill gas facilities design plan (LFG design plan) within one year of submitting the initial landfill gas assessment. The landfill gas management system specified in the LFG design plan must be commissioned within four years of the LFG design plan being submitted to MOE.

  Before the Regulation came into effect, British Columbia Landfill Criteria for Municipal Solid Waste (1993) required an assessment of the potential emissions of Non Methane Organic Compounds (NMOCs) for landfills having more than 100,000 tonnes of refuse in place to determine if a LFG recovery and management system was required. If the assessment indicated that the emission of NMOCs exceeded or was expected to exceed 150 tonnes/year, the installation and operation of a landfill gas recovery and management system was mandatory.

  As per the LFG Management Regulation the landfill gas management facilities are to be designed, constructed, and operated in accordance with the BC Landfill Gas Management Facilities Design Guideline.

- *Final Cover Design*: The minimum final cover is to consist of a 0.6 m thick compacted barrier layer, providing a maximum hydraulic conductivity of 1×10^{-5} cm/sec as the landfill site is located in an arid/semi-arid region and a minimum 0.15 m thick topsoil layer capable of establishment and sustained growth of the vegetative cover. A lower permeability barrier layer or the addition of a geomembrane, may be required to control leachate generation rates to be consistent with those identified in the Leachate Management Plan.

- *Final Contours*: Final contours of the landfill are to be constructed at grades not steeper than 3H:1V (33 %). The recommended design criteria for the top plateau of the landfill is a slope not less than 10H:1V (10 %) for cover systems using a soil barrier layer. The grade for the top plateau can be reduced up to 25H:1V (4%) for cover systems using a durable geomembrane or composite barrier layer with an overlying drainage layer above the final landfill side slope.

- *Site Security and Fencing:* Fencing is required around the perimeter of the landfill. Security fencing is to be established around the entire perimeter of the operational footprint of the landfill. The minimum size fence is to be a 1.2 m post and wire fence. Along the landfill site boundary where vehicle access can be achieved from the outside a minimum 2 m chain link fence is recommended. All access points are to have locking gates.
- *Access Roads:* An appropriately constructed and maintained access road to the landfill site and a road system within the landfill site capable of supporting all vehicles hauling waste are required during the operating life of the landfill. The following design criteria should be adopted in designing an access road:
  - Access road traffic surface to be minimum 4 m wide for one lane and 7 m for two lanes.
  - Roads for public and commercial traffic should not exceed 8 percent grade.
  - Roads for construction / internal off-road equipment traffic should not exceed 15 percent grade.
  - All roads sloped steeper than 2 percent should have armoured ditches.
- *Vector and Wildlife Management:* Landfills are to be operated so as to minimize the attraction of wildlife such as bears and birds by applying cover at required frequencies and instituting a good housekeeping program. Further control measures, such as bear control fences and bird control devices, may be specified by the Manager.

It has been made clear in the new criteria that the criteria are not mandatory requirements but are recommended practices and they may become legally enforceable if incorporated into solid waste management plans, operational certificates and permits issued under the Environmental Management Act. The Operational Certificate (OC) 15274 stipulates some specific requirements. The important design requirements are summarized as follows:

- At least 50 m buffer of which 15 m closest to the landfill footprint reserved for natural or

  landscape screening
- 300 m setback between the landfill foot print and sensitive land use
- 100 m distance between the landfill footprint and the nearest surface water
- Bottommost solid waste cell is to be at least 1.2 m above the seasonal high water table
- At least 2 m thick layer of low permeability soil with a k≤ of $1x10^{-6}$ cm/s
-

3.1.2 Design Objectives and Constraints

SHA considered a number of regulatory and design objectives during the preparation of this Design and Operating Plan, and wherever possible, applied these objectives to the analysis and development of the site. The following objectives have been developed by SHA from working with the Landfill Criteria and other sites throughout British Columbia:

Regulatory Objectives

- To ensure that landfill development complies with the operating permit and follows the general principles of the Draft 2nd Edition of the B.C. MOE Landfill Criteria.

Environmental Objectives

- To provide a waste disposal facility where residuals from commercial and residential waste streams can be safely deposited and contained without adverse impacts on the environment.
- To minimize the social impacts on adjacent land owners through consideration of site aesthetics and compatible land use.
- To minimize the volumes of leachate generated at the site and to prevent detrimental impact on ground water and surface water resources downgradient of the site.
- To minimize the opportunity for landfill gas migration beyond the property boundary, and to reduce the overall greenhouse gas and NMOC emissions to the atmosphere.
- To ensure action for reaching compliance at the site boundary with water and leachate monitoring.
- To develop an environmental monitoring plan that will monitor impacts of the landfill on its surroundings throughout the landfill lifespan, and for at least 30 years after its closure.

Operational Objectives

- To maximize landfill capacity through the use of alternate daily cover systems in order to ensure that the facility will serve the community for the longest possible time, thereby postponing any extra costs associated with additional landfill site selection and development.
- To propose an effective and systematic method of landfill construction.
- To ensure optimum waste compaction for efficient use of space and to minimize landfill settlement and fire risk.
- To ensure access roads will be able to accommodate commercial vehicles.
- To provide effective fire, litter, dust, security, wildlife and vector control.

Closure Objectives

- To provide a final contour design of the closed landfill.
- To identify an effective final cover system that will minimize leachate generation.
- To use locally derived cover material wherever possible.
- To provide a plan for revegetation and reduction of erosion.
- To plan for closure and post-closure monitoring.

3.1.3 Assessment of the Campbell Mountain Landfill

Overall, the CMLF is sited in a very good location for a landfill facility. The landfill is located in a relatively sparsely populated area with minimal impact on neighbouring properties. The hydrogeologic setting consists of an upper granular deposit that consists primarily of an interlayered sequence of medium to fine sand and a well-graded sand and gravel with variable cobble component and a lower granular deposit that was defined as compact, dense well-graded sand with some silt grading to a silty sand and gravel. The annual precipitation is only 346 mm per year, which qualifies the site as a low leachate generation potential site (sites with less than 500 mm precipitation per year). The water table ranges from 7.3 m to 23.0 m below the ground. The distance to the nearest surface water bodies is greater than 100 m.

In consideration of these attributes, the landfill is relatively well sited. However, there was a residence within 300 m of the landfill footprint which the RDOS has recently purchased.

3.2 Site Specific Design Objectives

In updating the final contour design for the CMLF, SHA set out to develop a filling strategy that would achieve the following:

- To maximize the landfill capacity within the current operating footprint;
- To source available cover material resources from within the landfill footprint, as much as possible, for use as operational cover;
- To maintain all finished surface landfill slopes no steeper than 3H:1V, as required by the MOE Landfill Criteria;
- To develop an access road network to provide both in and out access for large vehicles with minimal turns and sharp switchbacks;
- All roads to be 8% or flatter to allow safe travel in winter conditions;
- Optimizing soil excavation and usage to maximize waste-to-cover ratio and multiple handling of materials;
- Storm water ditching to be provided adjacent to the access road for erosion control;
- Storm water retention ponds for sediment control and storage for landfill fire control;
- Reducing GHG emissions and complying with the MoE requirements for LFG management

3.3 Filling History

The CML site has been in operations since 1972 when waste filling activities were first initiated. The RDOS began filling in the ravine that runs northwest to southeast (North Ravine) in 1975. The materials that were landfilled at this time included municipal and industrial solid waste as well as liquid waste. During the mid-1980s, the RDOS installed a liquid waste facility which was then decommissioned in 2008.

In 1994, the CoP installed and operated a bio-solids composting facility at the CMLF and in 2000 an aeration system was added to the facility. This composted material is currently sold at the site.

In 1998, a landfill fire started in the North Ravine which lead the RDOS to install twelve gas monitoring ports within the ravine and eight gas monitoring probes around the perimeter of the site.

The CMLF was surveyed by Accuas Inc., an aerial survey company, in June 2015 and the topography is shown in Figure 3-1. SHA personnel also completed a GPS ground survey on March 10th, 2016 of the operational areas including the current active waste cell, soil stockpiles, roads and old waste cells to get a better understanding of the current topography onsite. This updated survey was tied in with the Accuas survey and is presented in Figure 3-2.

3.4 Final Contour Design

The final contour design for the CMLF is presented in Figure 3-4. The design involves a vertical expansion, rising to a crest elevation of 645m ASL, about 100m above the landfill toe.

The design was developed to maximize capacity within the current lease property while taking advantage of natural topography features to contain the waste. This design will provide a final footprint of 26.3 ha.

The design has been developed so that all expansion areas will maintain a buffer of 50 m from the existing property boundaries and of that 50 m buffer at least 30 m will be vegetation.

The final contour geometry will consist of 3H:1V outside slopes delineated by two midslope berm roads to be developed during progressive and final closure construction. The lower road will be created at approximately 595 m and the second at approximately 620 m. These roads will carry grades of no less than 2% and will be graded up and down to facilitate surface water runoff from the slopes into road side ditches before discharging to the landfill toe ditch. A ramp road along the northwest slope will aid in connecting the midslope roads and provide access to the landfill crest during filling and post closure monitoring events.

The crest will be finalized with the high point in the middle with minimum grades of 4%, shedding surface water to the slopes and roadside ditches.

3.5 Design Capacity

The volumetric capacity of the final landfill design is shown in Figure 3-3 as a cut and fill diagram. The figure shows that the waste thickness ranges up to 65 m, with an average waste thickness of about 20 m. A couple areas along the northern perimeter will require a small amount of cut to enable the construction of the Crest Road to ensure adequate road grades of maximum 8%. A cut is also shown in the southeast corner for the installation of a small infiltration pond. These cuts will be undertaken in native soil.

In total, the new design will result in a net fill capacity of 3,846,483 m^3, for MSW, operational cover and environmental control system layers such as a liner system, leachate collection systems and a final cover veneer. Over all, on a phase by phase basis, the calculated fill volume is 3, 883,400 m^3.

3.6 Mid-Slope and Crest Roads

The two mid-slope roads will aid in providing both in and out traffic for vehicular access to the active face in each phase of the landfill's development. The access road network is designed at 10 m wide with adequate ditching for stormwater on the upslope side of each road to divert run-on away from the waste footprint during development and prevent erosion on the slopes during post-closure.

The design grades do not exceed 8% ensuring adequate vehicular access, even during winter months. SHA envisions the access road be developed in stages, as the landfill phases develop, to keep capital costs spread out over the lifespan of the site.

3.7 Borrow Plan

A borrow pit has been designed for Phases 2, 3 and 4. The Phase 2 borrow area is located to the south of Phase 2, in the current wood and concrete diversion area, and will reach a final elevation 546 m. The Phase 2 borrow area will provide approximately 264,600 m^3 of material for landfilling operations in Phase 1 and 2. Figure 3-5 shows the cut and fill for the Phase 2 borrow area. The Phase 3 borrow area will be developed to the east of Phase 3 and will be constructed to an elevation of 566 m. This borrow area will provide approximately 304,600 m^3 of material for Phase 3 landfilling operations. Figure 3-6 shows the cut and fill for the Phase 3 borrow area. The Phase 4 borrow area will be developed to the north of Phase 4, in the current composting area, and will be constructed to an elevation of 584 m. By this time composting activities will be decommissioned at the CMLF. This borrow area will provide approximately 929,000 m^3 of material for Phase 4 and 5 landfilling operations. Figure 3-7 shows the cut and fill for the Phase 4 borrow area.

Each borrow pit will also become the base of the subsequent Phase once borrowing reaches design grades. A basal liner system will be constructed at the base of each borrow pit and waste filling operations will piggy-back against the previously filled Phase. In order to construct the basal liner system, the side slopes of the borrow pits have been designed at 2.5H : 1V, allowing for application of a geo composite system, leachate collection and aggregate drainage layers.

3.8 Phasing Plan

The filling sequence proposed to achieve final contours begins with the filling of Phase 1 and progresses through Phase 2, 3, 4, and 5. This filling succession has been designed to enable the development of each borrow pit in native ground to aid in the borrowing of in-footprint cover soil.

Phase 1 is shown in Figure 3-4 and will build overtop of previously placed waste vertically to a design elevation of 635m. All slopes of Phase 1 will be developed as internal slopes carrying grades of 2.5H : 1V. The Phase 1 capacity is shown in a cut and fill drawing on Figure 3-4, resulting in an overall fill of 178,000 m^3. Excluding the Phase 2 intermediate biocover/glass LFG diffusion system volume of 13,450 m^3 (Phase 2 Biocover will be placed in the Phase 1 filling area), the net phase capacity or airspace available for Phase 1 is 164,550 m^3.

Phase 2 will be developed directly west of Phase 1 and will piggy-back against its west side slope, as outlined in Figure 3-5. It will build off of old waste cells and climb vertically to an elevation of 640 m. Access to Phase 2 will be from the east and will build off of the Phase 1 access. The development of the two mid-slopes berms will be initiated in along the west side as Phase 2 develops. The capacity of Phase 2 is shown in Figure 3-5, resulting in an overall fill of 424,800 m^3. Excluding closure volume of 75,716 m^3 and Phase 1 intermediate biocover/glass LFG diffusion system volume of 41,423 m^3, the net phase capacity or airspace available for Phase 2 is 307,661 m^3.

Phase 3 will be developed directly south of Phase 2 and will build off of the Phase 2 borrow pit. This phase will piggy-back against Phase 2 and will build off a base elevation of 546 m and ascend to a crest elevation of 565 m as shown in Figure 3-6. The capacity of Phase 3 is shown in Figure 3-6, resulting in an overall fill of 155,600 m^3. Before filling is to commence in Phase 3, the Phase 2 Borrow Area will be exhausted to design contours / elevations and the area re-graded for installation of a subsurface leachate collection system. Excluding closure volume of 24,654 m^3 and basal liner volume of 35, 625 m^3 for this phase, the net phase capacity or airspace available for Phase 3 is 95,321 m^3.

Phase 4 will be developed directly east of Phase 3 and will build off of the Phase 3 borrow pit. This phase will piggy-back against Phase 3 and will build off a base elevation of 566 m and ascend to a crest elevation of 615 m as shown in Figure 7. The capacity of Phase 4 is shown in Figure 3-7, resulting in an overall fill of 1,187,000 m^3. Before filling is to commence in Phase 4, the Phase 3 Borrow Area will be exhausted to design contours / elevations and the area re-graded for installation of a subsurface leachate collection system. Excluding closure volume of 78,956 m^3, an intermediate biocover/glass LFG diffusion system volume of 6,421 m^3, and a basal liner volume of 44,175 m^3 for this phase, the net phase capacity or airspace available for Phase 4 is 1,057,448 m^3.

Phase 5 will conclude the filling of the CMLF and its geometry is shown on Figure 3-8. This final phase will develop the crest of the landfill building overtop of the Phase 4 borrow pit and previous phases from a base elevation of 584 m to a crest elevation of 645 m. Access will be provided via the mid-slope roads which will climb along the southern side slope towards the west. With an overall waste thickness of approximately 65 m, the phase 5 geometry allows for 1,938,000 m^3 of airspace for MSW, cover soil and final cover system as shown in Figure 3-19. Excluding closure volume of 110,273 m^3 for this phase, intermediate biocover/glass LFG diffusion system volume of 16,500 m^3, and the basal liner volume is 50,825 m^3, the net phase capacity or airspace available for Phase 5 is 1,760,402 m^3.

Table 3-1 below summarizes the volume of each phase mentioned above, including the volumes for closure and operational and construction soil available in the borrow area.

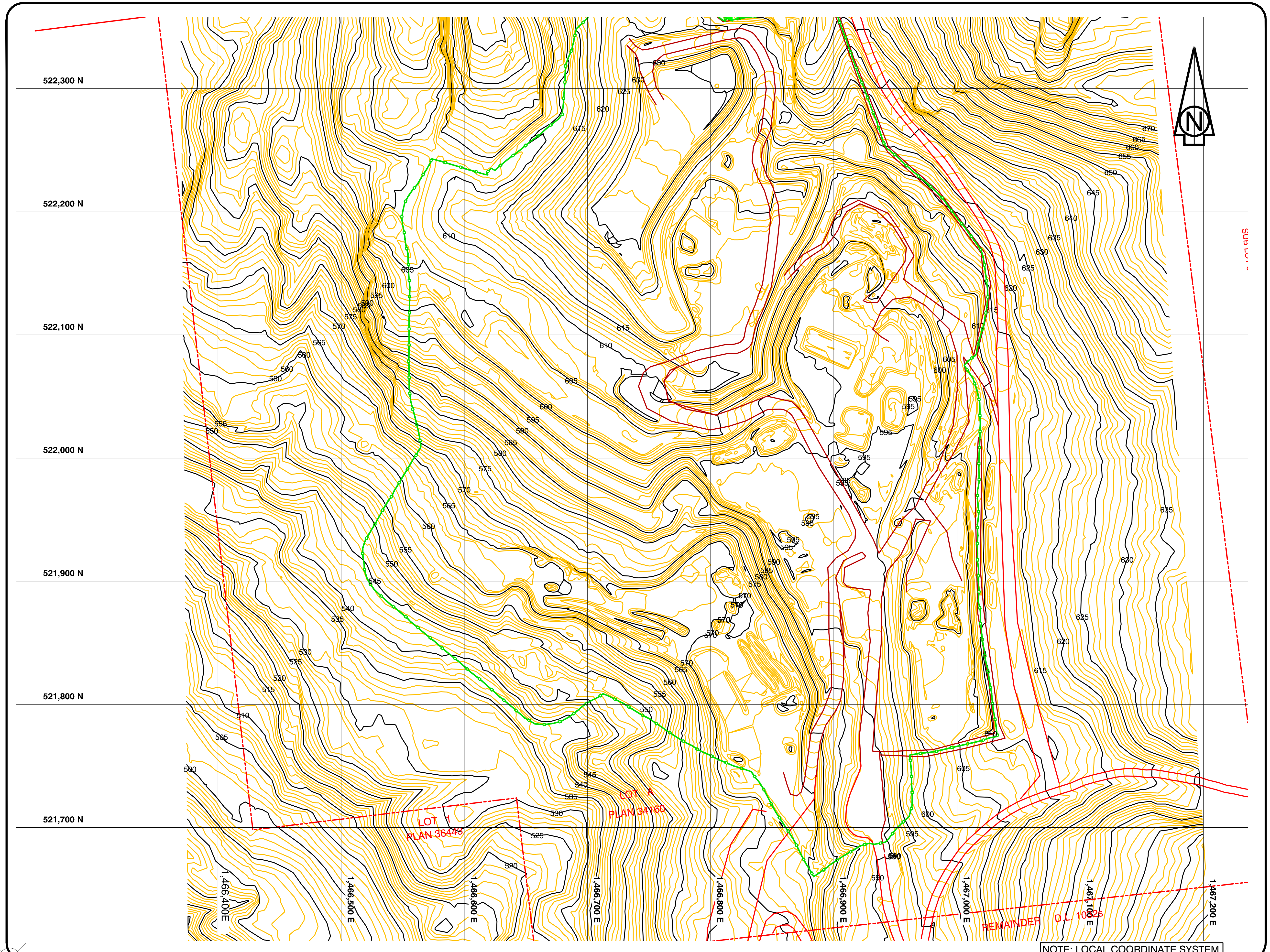
Table 3-1 Summary of Landfill Capacity for MSW, including Borrow Area

Phase	Total Phase Volume (m^3)	Intermediate Biocover/Gas Collection Layer Area (m^2)	Intermediate Biocover/Gas Collection Layer Volume (m^3)	Closure Areas (m^2)	Closure System Volume (m^3)	Basal Liner / Leachate Collection System Area (m^2)	Basal Liner / Leachate Collection System Volume (0.95 m Thick) (m^3)	Net Phase Capacity (m^3)	Cum. Phase Capacity (m^3)	Cut (m^3)
1	178,000	26,900	13,450	-	-	N/A	N/A	164,550	164,550	
2	424,800	82,846	41,423	68,833	75,716	N/A	N/A	307,661	472,211	
3	155,600			22,413	24,654	37,500	35,625	95,321	567,531	
4	1,187,000	12,842	6,421	71,778	78,956	46,500	44,175	1,057,448	1,624,980	
5	1,938,000	33,000	16,500	100,248	110,273	53,500	50,825	1,760,402	3,385,382	
Borrow 1										264,600
Borrow 2										304,600
Borrow 3										929,000
Total	**3,883,400**	**155,588**	**77,794**	**263,272**	**289,599**	**137,500**	**130,625**	**3,385,382**		**1,498,200**

3.9 Geomembrane Liner vs. Natural Control

A Natural Control Landfill is an existing landfill that does not have an engineered or natural clay barrier to contain leachate. Instead, natural attenuation and renovation processes within the groundwater flow system are relied on to ensure that water quality objectives are not exceeded. Development of new natural attenuation landfills will no longer be authorized in British Columbia when the new landfill criteria are introduced in 2016, unless exemptions are justified by a Qualified Professional.

In order to meet regulatory requirements and to contain leachate so as to limit future groundwater impairment SHA recommends that all new phases of the landfill be constructed with basal liners, beginning with Phase 3 in 2033, as per lifespan Scenario-1 (2034 as per lifespan Scenario-2). Prior to the expansion of each phase, soil will be excavated from within the proposed expansion area, creating a smooth base and proper design grades, resulting in increased airspace for landfilling and preparing the new phase for the basal liner. SHA recommends that the base of each phase in the lateral expansion be lined with 60 mil High Density Polyethylene (HDPE) geomembrane underlain by a low permeability soil such as a silt or clay (likely on-site material). Further details for the basal liner system are included in the Environmental Control section (Chapter 6).



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#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

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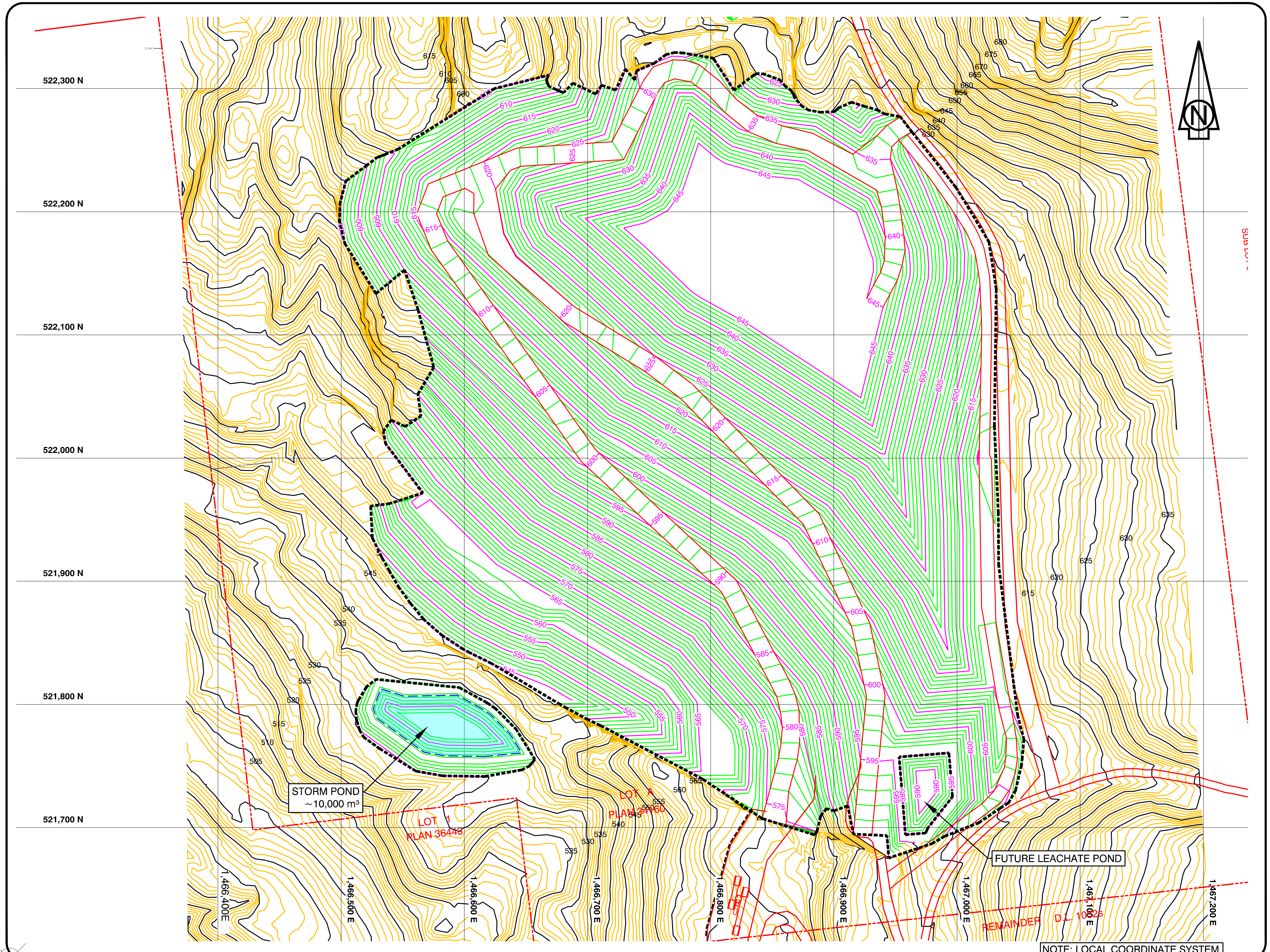
PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE:
2015 EXISTING TOPOGRAPHY

SCALE:	DATE:	PROJECT NO:
1:3000	2016/03/22 (yyyy/mm/dd)	PRJ15061

		DRAWING NO:
DESIGNED	TS	FIGURE 3-1
DRAWN	NL	
CHECKED	TS	



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#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3

Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE

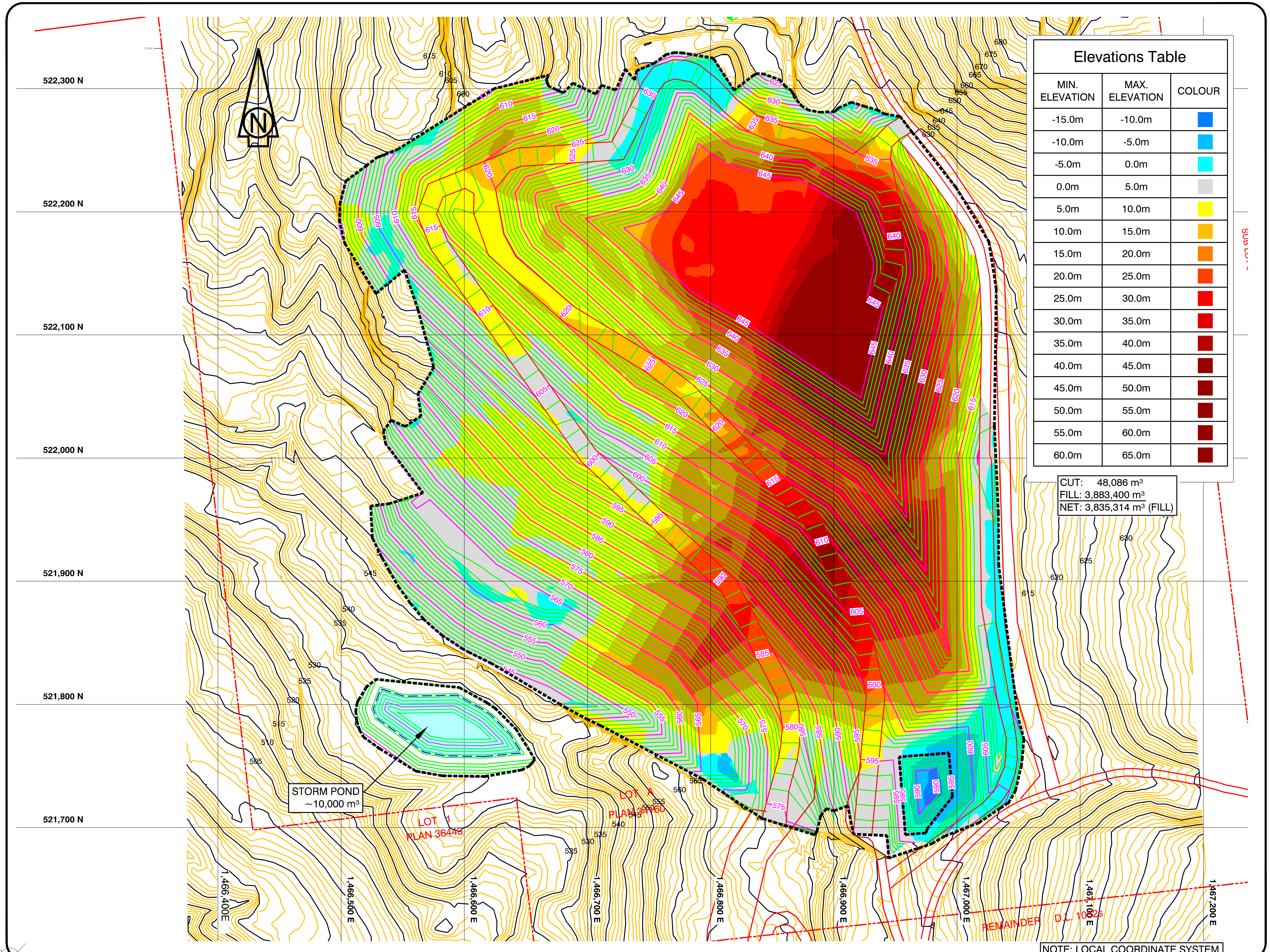
CLIENT:
REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE:
FINAL CONTOUR DESIGN

SCALE:	DATE:	PROJECT NO:
1:3000	2016/03/22 (yyyy/mm/dd)	PRJ15061

DESIGNED	TS	DRAWING NO:
DRAWN	NL	**FIGURE 3-2**
CHECKED	TS	



Elevations Table

MIN. ELEVATION	MAX. ELEVATION	COLOUR
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-10.0m	-5.0m	
-5.0m	0.0m	
0.0m	5.0m	
5.0m	10.0m	
10.0m	15.0m	
15.0m	20.0m	
20.0m	25.0m	
25.0m	30.0m	
30.0m	35.0m	
35.0m	40.0m	
40.0m	45.0m	
45.0m	50.0m	
50.0m	55.0m	
55.0m	60.0m	
60.0m	65.0m	

CUT: 48,086 m^3
FILL: 3,883,400 m^3
NET: 3,835,314 m^3 (FILL)

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LEGEND:
- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE

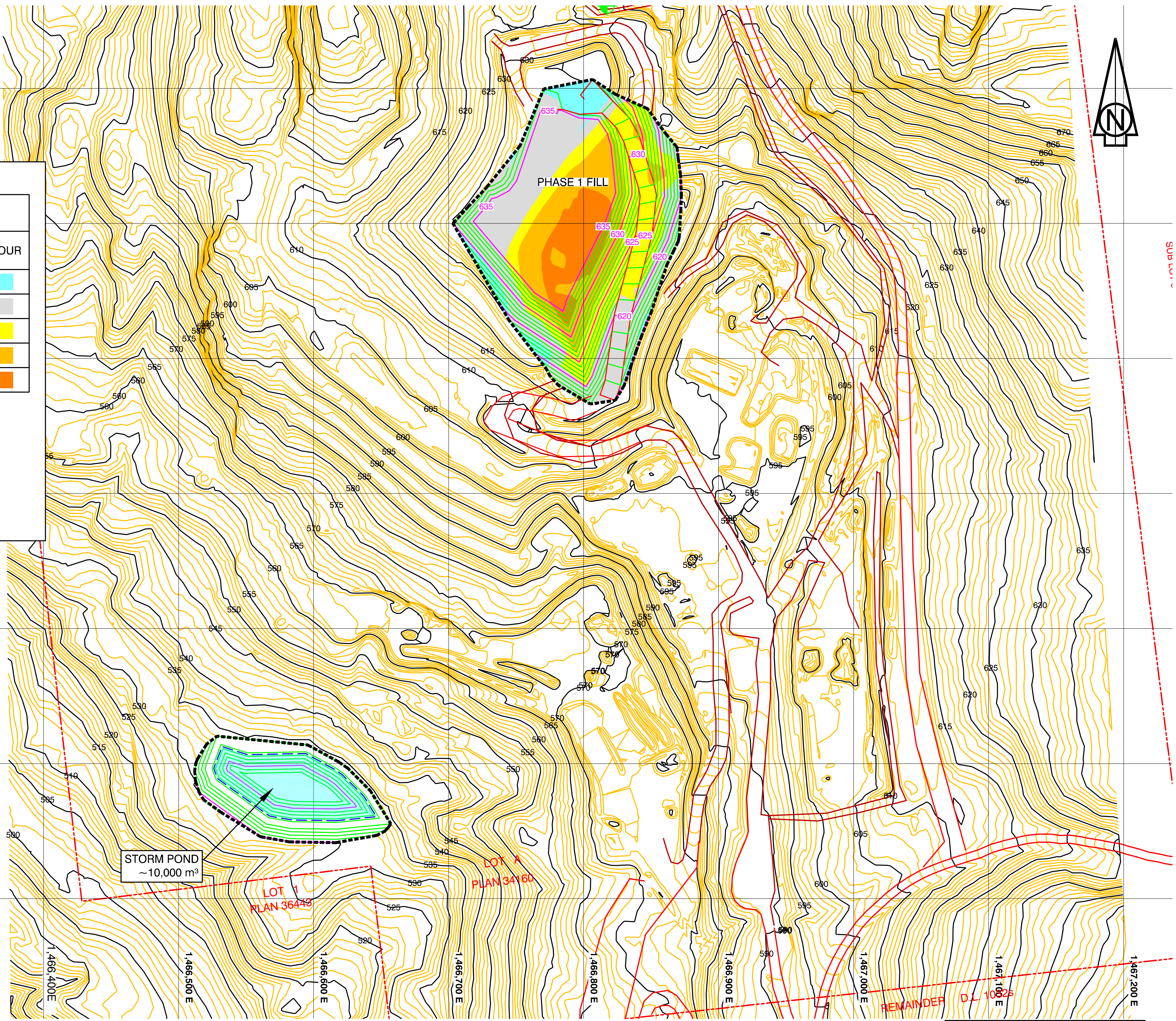
CLIENT: REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT: RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE: **CUT AND FILL FINAL CONTOURS VERSUS ORIGINAL GROUND INCLUDING BORROW AREAS**

SCALE:	DATE:	PROJECT NO:
1:3000	2016/03/22 (yyyy/mm/dd)	PRJ15061

DESIGNED	TS	DRAWING NO:
DRAWN	NL	**FIGURE 3-3**
CHECKED	TS	



PHASE 1 FILL

Elevations Table

MIN. ELEVATION	MAX. ELEVATION	COLOUR
-5.0m	0.0m	(cyan)
0.0m	5.0m	(grey)
5.0m	10.0m	(yellow)
10.0m	15.0m	(light orange)
15.0m	20.0m	(orange)

CUT: 1,800 m³
FILL: 178,000 m³
NET: 177,000 m³ (FILL)

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LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE

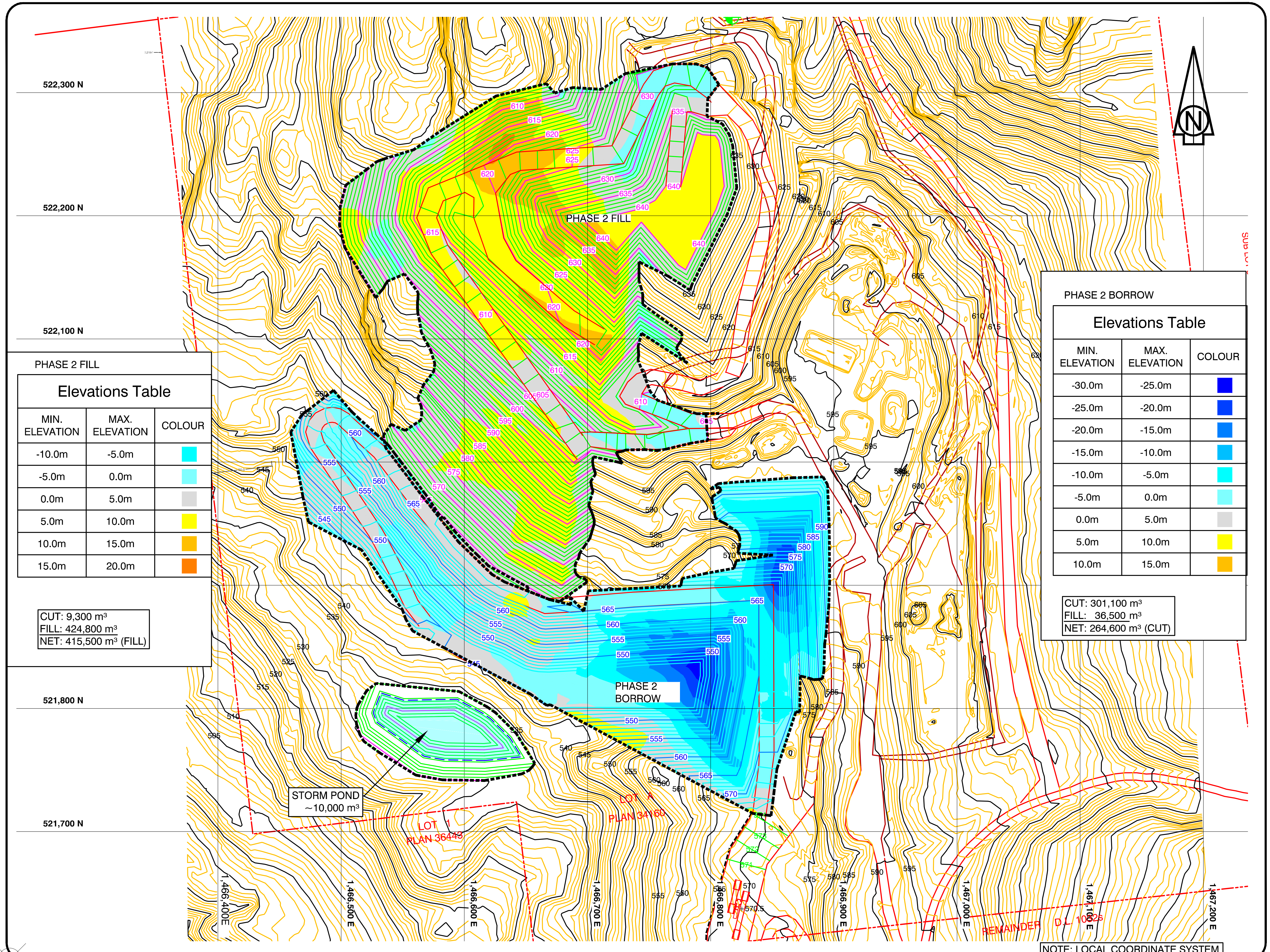
CLIENT:
REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE:
PHASE 1 FINAL CONTOURS AND CUT AND FILL VERSUS ORIGINAL GROUND

SCALE:	DATE:	PROJECT NO:
1:3000	2016/02/10 (yyyy/mm/dd)	PRJ15061

DESIGNED	TS	DRAWING NO:
DRAWN	NL	**FIGURE 3-4**
CHECKED	TS	



PHASE 2 FILL

Elevations Table

MIN. ELEVATION	MAX. ELEVATION	COLOUR
-10.0m	-5.0m	
-5.0m	0.0m	
0.0m	5.0m	
5.0m	10.0m	
10.0m	15.0m	
15.0m	20.0m	

CUT: 9,300 m³
FILL: 424,800 m³
NET: 415,500 m³ (FILL)

PHASE 2 BORROW

Elevations Table

MIN. ELEVATION	MAX. ELEVATION	COLOUR
-30.0m	-25.0m	
-25.0m	-20.0m	
-20.0m	-15.0m	
-15.0m	-10.0m	
-10.0m	-5.0m	
-5.0m	0.0m	
0.0m	5.0m	
5.0m	10.0m	
10.0m	15.0m	

CUT: 301,100 m³
FILL: 36,500 m³
NET: 264,600 m³ (CUT)

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Fax: (604) 986-7734

LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE

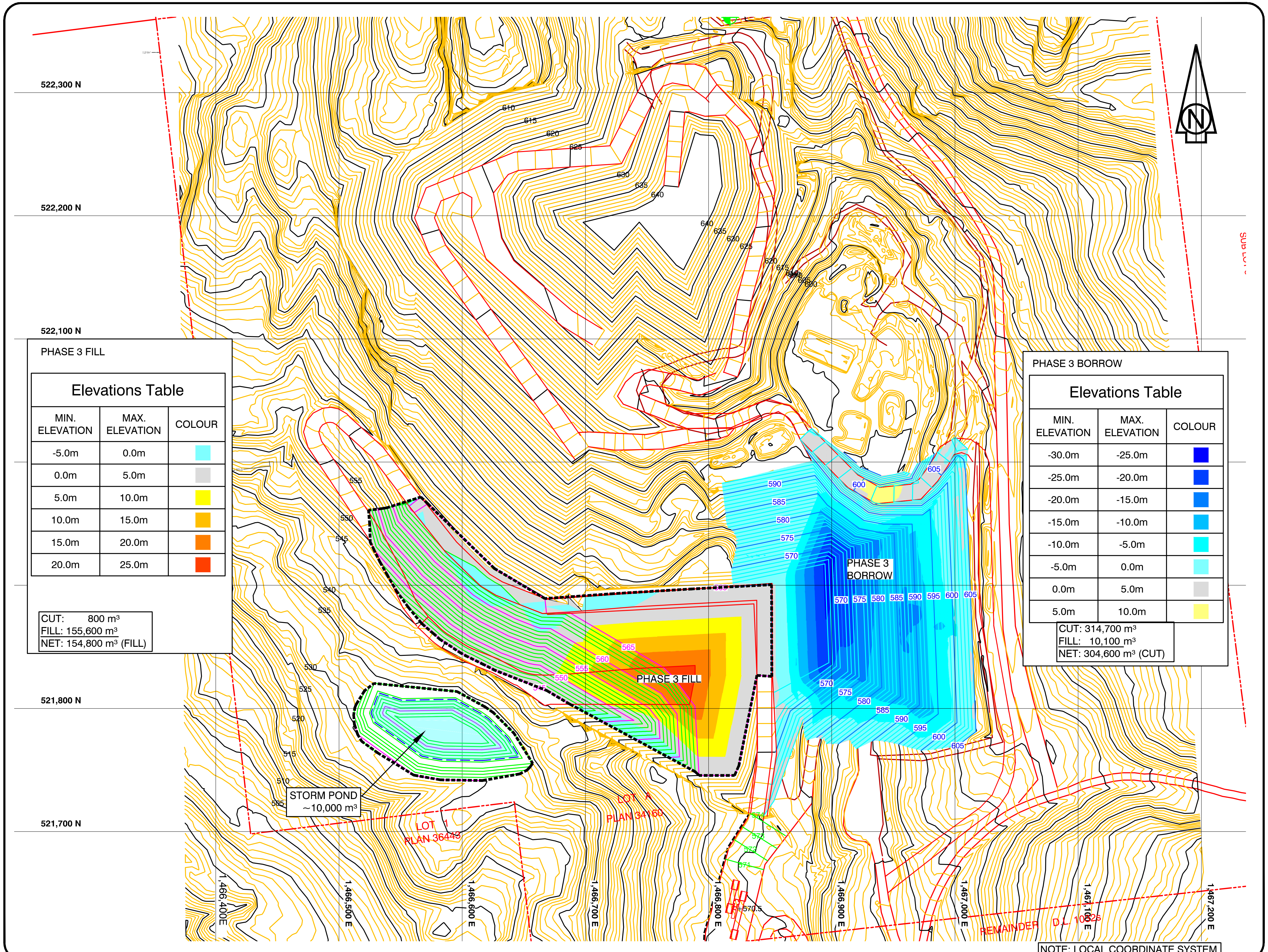
CLIENT:
REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE:
PHASE 2 FINAL CONTOURS & PHASE 2 BORROW CONTOURS & CUT AND FILL VERSUS EXISTING GROUND

SCALE:	DATE:	PROJECT NO:
1:3000	2016/03/22 (yyyy/mm/dd)	PRJ15061

DESIGNED	TS	DRAWING NO:
DRAWN	NL	**FIGURE 3-5**
CHECKED	TS	



PHASE 3 FILL

Elevations Table

MIN. ELEVATION	MAX. ELEVATION	COLOUR
-5.0m	0.0m	
0.0m	5.0m	
5.0m	10.0m	
10.0m	15.0m	
15.0m	20.0m	
20.0m	25.0m	

CUT: 800 m³
FILL: 155,600 m³
NET: 154,800 m³ (FILL)

PHASE 3 BORROW

Elevations Table

MIN. ELEVATION	MAX. ELEVATION	COLOUR
-30.0m	-25.0m	
-25.0m	-20.0m	
-20.0m	-15.0m	
-15.0m	-10.0m	
-10.0m	-5.0m	
-5.0m	0.0m	
0.0m	5.0m	
5.0m	10.0m	

CUT: 314,700 m³
FILL: 10,100 m³
NET: 304,600 m³ (CUT)

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Phone: (604) 986-7723
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LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE

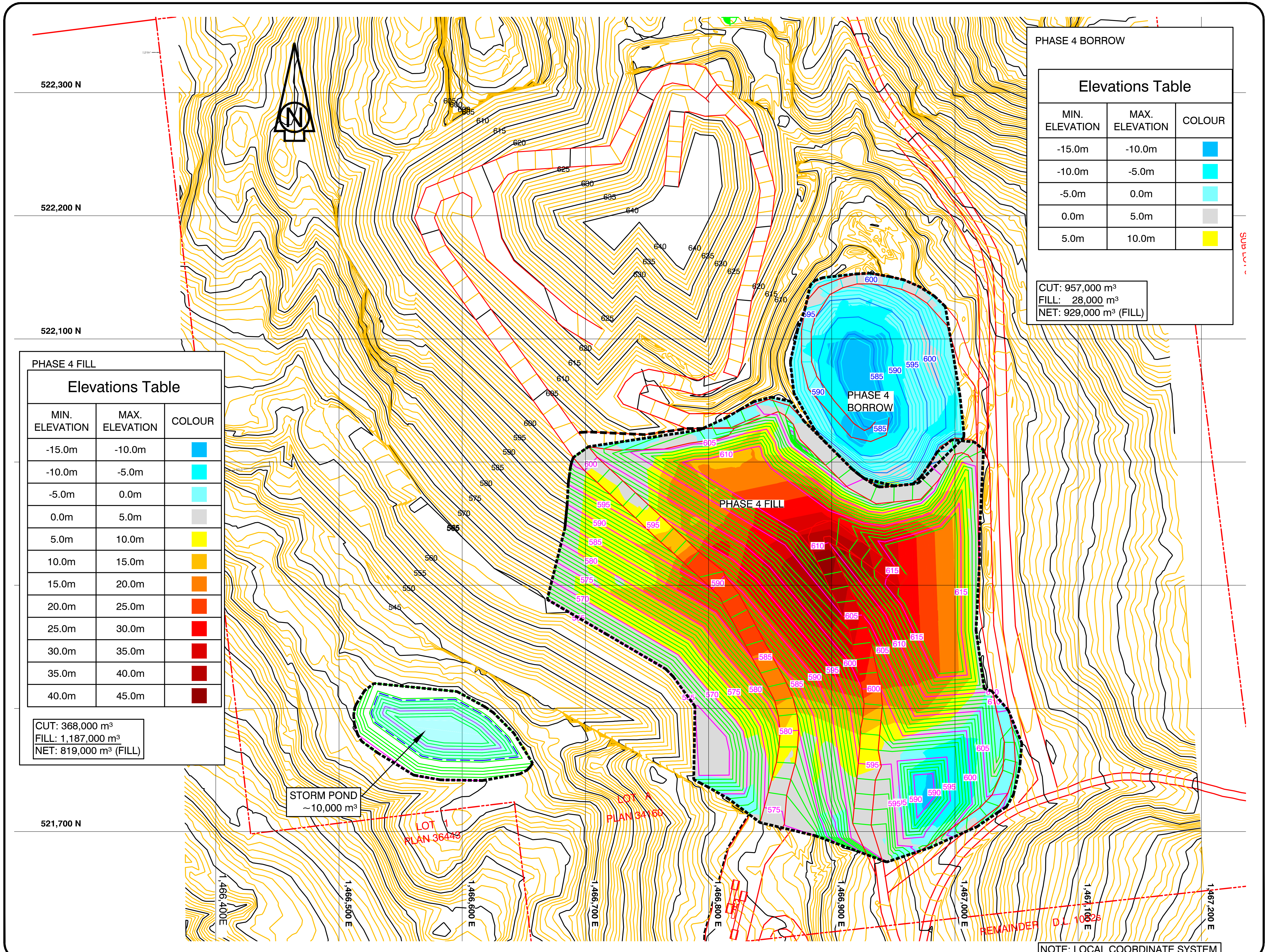
CLIENT: REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT: RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE: PHASE 3 FINAL CONTOURS & PHASE 3 BORROW CONTOURS & CUT AND FILL VERSUS EXISTING GROUND

SCALE:	DATE:	PROJECT NO:
1:3000	2016/03/22 (yyyy/mm/dd)	PRJ15061

DESIGNED	TS	DRAWING NO: FIGURE 3-6
DRAWN	NL	
CHECKED	TS	



PHASE 4 BORROW

Elevations Table

MIN. ELEVATION	MAX. ELEVATION	COLOUR
-15.0m	-10.0m	
-10.0m	-5.0m	
-5.0m	0.0m	
0.0m	5.0m	
5.0m	10.0m	

CUT: 957,000 m³
FILL: 28,000 m³
NET: 929,000 m³ (FILL)

PHASE 4 FILL

Elevations Table

MIN. ELEVATION	MAX. ELEVATION	COLOUR
-15.0m	-10.0m	
-10.0m	-5.0m	
-5.0m	0.0m	
0.0m	5.0m	
5.0m	10.0m	
10.0m	15.0m	
15.0m	20.0m	
20.0m	25.0m	
25.0m	30.0m	
30.0m	35.0m	
35.0m	40.0m	
40.0m	45.0m	

CUT: 368,000 m³
FILL: 1,187,000 m³
NET: 819,000 m³ (FILL)

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North Vancouver, B.C. V7J 1J3
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Fax: (604) 986-7734

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- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE

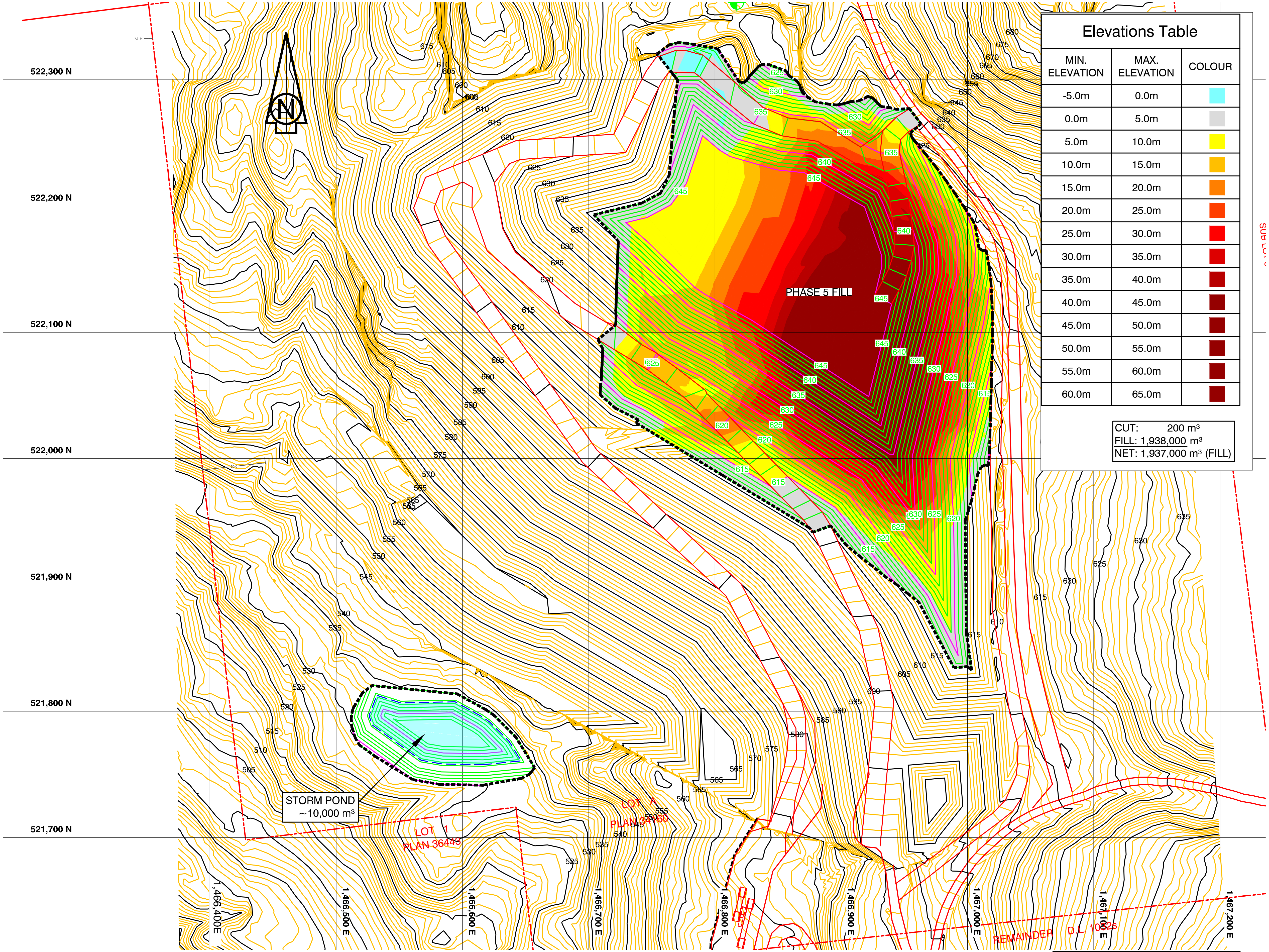
CLIENT: REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT: RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE: PHASE 4 FINAL CONTOURS & PHASE 4 BORROW CONTOURS & CUT AND FILL VERSUS EXISTING GROUND

SCALE:	DATE:	PROJECT NO:
1:3000	2016/03/22 (yyyy/mm/dd)	PRJ15061

DESIGNED	TS	DRAWING NO: FIGURE 3-7
DRAWN	NL	
CHECKED	TS	



Elevations Table

MIN. ELEVATION	MAX. ELEVATION	COLOUR
-5.0m	0.0m	
0.0m	5.0m	
5.0m	10.0m	
10.0m	15.0m	
15.0m	20.0m	
20.0m	25.0m	
25.0m	30.0m	
30.0m	35.0m	
35.0m	40.0m	
40.0m	45.0m	
45.0m	50.0m	
50.0m	55.0m	
55.0m	60.0m	
60.0m	65.0m	

CUT: 200 m³
FILL: 1,938,000 m³
NET: 1,937,000 m³ (FILL)

X:\Admin\LOGOS\Shamoose2000.bmp

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North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:
- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE

CLIENT: REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT: RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE: **PHASE 5 FINAL CONTOURS AND CUT AND FILL VERSUS EXISTING GROUND**

SCALE:	DATE:	PROJECT NO:
1:3000	2016/03/22 (yyyy/mm/dd)	PRJ15061

DESIGNED	TS	DRAWING NO:
DRAWN	NL	**FIGURE 3-8**
CHECKED	TS	

4 GEOTECHNICAL CONSIDERATIONS

4.1 Underlying Stratigraphy

During the hydrogeological evaluation of the CMLF site conducted by Golder in 1994, the surficial deposits are categorized into two different classes, an Upper Granular Deposit and a Lower Granular Deposit as described in Chapter 2. This granular material overlies bedrock which mainly consists of layers of gneiss. The thickness of the Upper Granular Deposit layer ranges anywhere from 0.7 to 3.0 m.

4.2 Settlement Issues

4.2.1 Overview

Long term settlement is an issue at most landfills as the organic content of the solid waste stream deposited in the landfill decomposes. It has been SHA's experience that MSW landfills initially settle at a rate of about 2% per year (2 cm settlement per 1 m of refuse thickness). Additional settlement can also occur in the foundation soils beneath the landfill due to the surcharge of overlying waste. For example, at Vancouver Landfill at Delta, BC, settlement of up to 6.0 m was experienced in the foundations.

4.2.2 Expected Settlement

Settlement is expected to continue to occur at the site into the long term, 25 to 50 years into the future. It also depends on the height of the landfill. We anticipate settlement rates of 1.3 m/year for a height of 30 m for the initial 5 years after reaching the final grades in each phase, then 0.6 m per year for up to 10 years subsequently, and then 0.3 m per year up to 20 years. SHA recommends that the RDOS install 2 or 3 settlement hubs in each phase to monitor the settlement and to establish actual monitoring rates at the site.

4.2.3 Slope Stability Analysis Preformed by Golder

In Golder's 1994 Hydrogeological and Geotechnical Evaluation report, a final slope with a grade of 3H:1V and a total vertical height of 70 m was used in Golder's slope stability analysis using their CSlope program. Based on their experience with landfills in BC and Alberta, Golder chose a friction angle of 20 degrees, a cohesion value of 15 kPa, and a unit weight of 12 kN/m^3 for the waste.

Analyses for both static load conditions and seismic load conditions were performed. The results determined that the minimum factor of safety for static load conditions and seismic load conditions was 1.55 and 1.21, respectively. Golder's analyses indicate that the landfill slopes will remain stable even under seismic load conditions.

4.3 SHA Slope Stability Analysis

The purpose of this section is to prove that the proposed final design for the CMLF will maintain acceptable factors of safety against failure. Stability of the site was modeled using the program SLIDE 4.0 designed for 2D slope stability analysis for soil and rock slopes.

4.3.1 Instability History

Based on the available information no record of instability was found. Furthermore, a geotechnical inspection was conducted during site inspection on December 12th, 2015. No sign of instability was noticed during the investigation.

4.3.2 Slope Stability Model

To verify stability of the proposed regrading, SHA conducted a detailed analysis using computer program SLIDE. The slope stability models discussed below have been developed largely from strength parameters that we have used for similar conditions.

Three cross-sections were selected through representative sloped areas of the Campbell Mountain Landfill. The cross sections were developed from the existing topography based on the survey performed in November 2015 and the proposed design contours shown in Figure 4-1. The cross section locations analyzed are identified in plan view in the Figure. The cross sections shown in Figure 4-1 and used in the stability analysis are located in Figures F-1 to F-2 in Appendix F and show the underlying geology of the landfill, the proposed profile and the material parameters used in the analysis. The analysis was performed using the limit equilibrium technique and Bishop Simplified method of analysis. Materials are modeled using a Mohr-Coulomb strength envelope. The soil profile for each cross section was developed from ground investigations performed by Golder Associates.

Failure scenarios were modeled for both static and seismic (earthquake) conditions for the proposed and existing profiles. The following factors of safety (FOS) for slope failure have been adopted as minimum standards:

- Static Conditions adjacent to Developed Land and Infrastructure 1.5
- Static Conditions adjacent to Undeveloped Land 1.3
- Seismic (Earthquake) Loading 1.0

A pseudo-static analysis was performed to determine if the slopes would be stable during an earthquake when subjected to peak ground acceleration expected for the area. The National Building Code of Canada 2010, Volume 2 provides seismic values for a number of locations across Canada. The peak horizontal ground acceleration (PGA) of 0.28 g for the Penticton area was found. This PGA has a probability of exceedance of 2% in 50 years.

The PGA acts momentarily in one direction and its use with static material properties may yield very low and incorrect factors of safety. The United States Environmental Protection Agency document "RCRA Subtitle D (258) Seismic Design Guidance for Municipal Waste Landfill Facilities (1995)" recommends using a seismic coefficient k_s of 50% of the PGA, in combination with the dynamic shear strength properties of the materials. However, the PGA for this area being low, a design PGA of 0.28 g was used in the analysis. A vertical acceleration was also applied to the model and is typically between 60% and 75% of the horizontal acceleration. Therefore, 0.17 g for the vertical acceleration was chosen.

A number of assumptions were made in the process of simplifying complex situations in the field to a computer model:

- Strength characteristics of the ground materials were generalized;
- Stabilizing effects of vegetative cover on the side slopes were not included;
- Ground water levels were assumed to be slightly mounded in the centre of the landfills.

4.3.3 Soil Strength Parameters

Table 4-1 outlines the geotechnical parameters used for the modeled materials. Three types of materials were chosen to represent the site conditions for global stability analysis: waste, sand and fractured bed rock. Figures F1 and F2 in Appendix F show the x-sections 1-1′ and 2-2′ used in the analysis. Section 1-1′ represents the entire profile, while Section 2-2′ represents a local critical slope.

All parameters of the underlying foundation material used in this analysis were taken from previous reports or were chosen from SHA's previous experience.

Table 4-1 Geotechnical Parameters for SLIDE

Material	Unit Weight, γ (kN/m^3)		Cohesion, c' (kN/m^2)	Internal Friction Angle, φ' (degrees)
	Saturated	Unsaturated		
Fractured bedrock	20	20	0	32
Sand	16	18	0	32
Waste	10	12	10	25

4.3.4 Ground Water Conditions

From the borehole logs presented in Appendix B it was found that the depth to the water table ranges from 3 to 25 m deep in the study area. Figure 2-5 in Chapter 2 also presents groundwater level contours at the site. The figure also indicates that the groundwater level is shallow near the toe of the landfill footprint.

4.3.5 Global Slope Stability Results

Results of the SLIDE analysis for the proposed grading design and existing conditions (applicable and shown only for Section 1-1) can be found in Appendix G, Figures G-1 to G-3. Each figure shows the soil profile, the resultant failure circle, the minimum FOS and the deep-seated FOS if the minimum FOS is a shallow slump failure. The following table summarizes the lowest FOS obtained for each cross section, the FOS of the deep-seated failure, the FOS under seismic conditions.

Table 4-2 Results from Slope Stability Analysis

Slope Cross Section	Condition	Slope Height (m)	Slope Angle (H:V)	FOS Static Shallow	FOS Static Deep-seated	FOS Seismic Shallow	FOS Seismic Deep-seated	Maximum Seismic Displacement (mm)*
1-1'	Existing **Proposed**	70 **85**	3:1 **3:1**	1.58 **2.35**	2.69 **2.46**	1.91 **1.91**	2.68 **1.986**	- **8.97**
2-2'	- **Proposed**	- **45**	- **3.3:1**	- **2.23**	- **2.23**	- **1.20**	- **1.20**	- **2.93**

- Displacements determined by Newmark Method. See Appendix H.

The proposed design is stable for all static loading conditions with FOS values exceeding 1.50, the standard mentioned before. For the seismic loading conditions, FOS greater than 1.0 are obtained at all the cross sections. The seismic results are presented in Appendix G from G-4 to G-6.

SHA is confident that the parameters and water tables used in the analysis were conservative and that the actual FOS's are likely higher. Over the long term, it is anticipated that the FOS will increase as settlement occurs within the landfill and the water mounding elevation decreases as a result of the closure barrier layer and installation of extraction wells.

FOS values are expected to be slightly higher than reported in the FOS Static Shallow column in Table 4-2 as a vegetative cover will be grown on the side slopes after closure. This vegetative cover adds a significant amount of strength to the upper surface of the slopes, reducing the likelihood of minor, shallow slumps and erosion. A good vegetation community can be established within a month of installing the topsoil/biocover, provided it is done during the spring or summer months. Additionally, use of an erosion control mat on the western slope of the northern site will ensure shallow slumping will not occur and increase overall FOS.

4.4 Veneer Stability Analysis

A detailed slope stability analysis was conducted to verify that the cover system proposed for a typical slope at Campbell Mountain Landfill would remain stable at different expected mounding depths above the barrier layer. The analysis was conducted for both static conditions and for seismic conditions as would be experienced during an earthquake.

The longest continuous veneer slope to receive final cover will be 45 m in vertical height with a maximum slope of 3.0 H: 1V. Stability of this veneer geometry was modeled using the program SLIDE 4.0 designed to be used for 2D slope stability analysis for soil and rock slopes. Figure J-1 in Appendix J shows the section used for veneer stability analysis.

The following industry standard factors of safety (FOS) for slope failure have been adopted as design goals:

- Static Conditions 1.5
- Seismic Loading (pseudo-static analysis) 1.0

4.4.1 Mounding and Cover System Shear Strength Parameter Review

Two mounding scenarios namely for 30 mm and 300 mm were considered for veneer stability analysis.

Table 4-3 outlines the geotechnical parameters expected within various materials in the cover system. All parameters selected are considered conservative and have been obtained either through past experience, review of literature, testing done by Golder Associates in the past, and estimations of expected strength.

Table 4-3 Material Properties used in SLIDE

Material	Unit Weight, γ (kN/m^3)		Cohesion, c (kN/m^2)	Internal Friction Angle, φ (degrees)
	Saturated	Unsaturated		
Topsoil/Biocover	14	15	2	30
Clay	15	16	10	20
Crushed Glass	18	18	0	35
Waste	10	12	10	25

The selected topsoil unit weight was adopted from a typical soil blend comprised of one part wood chips, one part biosolids and one part sand (biocover blend) while the strength properties were estimated.

4.4.2 SLIDE Stability Analysis for Cover Veneer

Veneer stability analysis was performed using SLIDE for a Clay cover system. The x-section used in the veneer analysis is presented in Appendix I. The static FOS for the clay cover option for 30 mm and 300 mm mounding depths was found to be 1.8. The results of the SLIDE analysis are presented in Table 4-4 and in Figures J-1 to J-2 in Appendix J.

Table 4-4 SLIDE Veneer Stability Analysis Results

Mounding Depth (mm)	Static FOS	Seismic FOS
30	1.8	0.966
300	1.8	0.965

Static	Seismic	
≥1.5	≥1.0	**Stable**
1.0 to 1.49	0.6 to 1	**Elevated Risk**
<1.0	<1.0	**Unstable**

4.4.3 Seismic Considerations

The proposed design is stable for all static loading conditions. For the seismic loading conditions, FOS close to 1.0 are obtained at all the cross sections. The seismic results are summarized in Table 4-2 and also presented in Figures J-3 to G-4 in Appendix G and discussed below.

The result for the 30 mm and, 300 mm mounding scenarios for the clay cover system show that the seismic FOS are 0.966 and 0.965 respectively. The FOS are close to the minimum requirement of 1.0 for all mounding scenarios. The deep rooted FOS are greater than the minimum requirement of 1.0 for all mounding scenarios. The veneer is found to be stable (i.e. FOS>1.0) for strength parameters as shown in Table 4-3 and used in the analyses. SHA recommends that erosion control mats/straw wattles be used on the slopes to control erosion so that the mounding can be minimized in the topsoil and subsoil layer.

Based on our closure construction experience, it is recommended that backfill materials be placed with a very light LGP Dozer with a total machine weight of less than 8 tonnes (e.g., John Deere 450J).

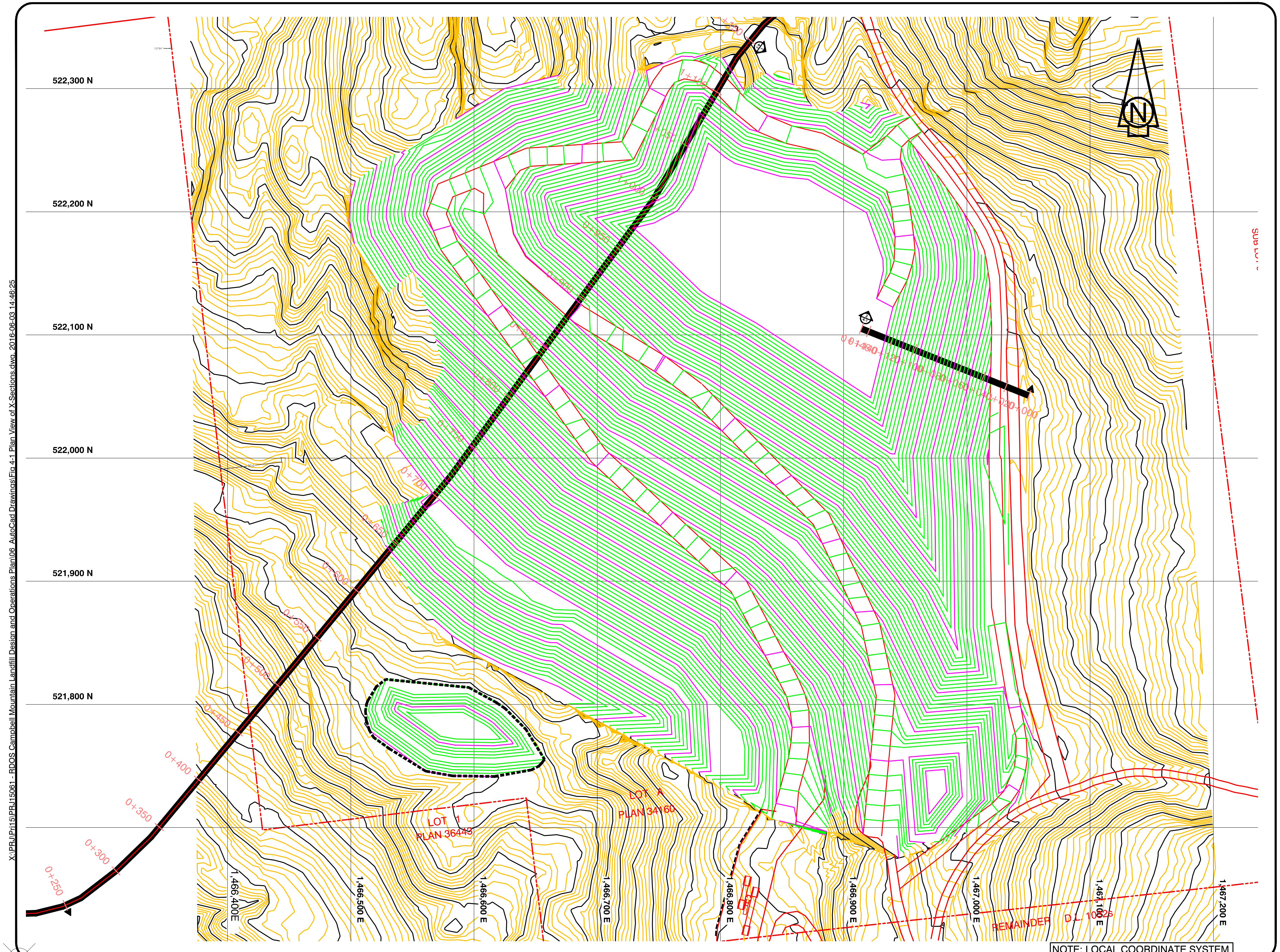
4.4.4 Newmark Seismic Displacement Analysis

As there is no way to prevent instability of the slopes in a seismic event, dynamic displacements were calculated using the Newmark Method (1965) to see if the movement of the failed slope would be significant. For each case, SLIDE was used to calculate the yield horizontal acceleration resulting in a static FOS of 1.0. Calculations are provided in Appendix H. The Newmark equation was then solved for the expected displacement during the design earthquake. It was found that the resultant deformation of a seismic event would not produce major movement in the slope. As shown in Table 4-2, between 2.93 and 8.97 mm of horizontal movement is expected for a 1 in 475 year event, which is a minor amount. The expected movement, as a result of slope failure, is considered minimal in this area.

4.5 Possible End Uses

As discussed in more detail in Chapter 8, the preferred end use for the Campbell Mountain Landfill will be a green space.

Due to the potential for landfill gas migration and settlement, SHA does not recommend that any type of load bearing structure be contemplated on top of the landfills without detailed engineering design to address the key challenges of differential settlement and landfill gas migration, as described in this chapter and Chapter 7.



X:\PRJ\Pr(15)\PRJ15061 - RDOS Campbell Mountain Landfill Design and Operations Plan\06 AutoCad Drawings\Fig 4-1 Plan View of X-Sections.dwg, 2016-06-03 14:46:25

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#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE

CLIENT: REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT: RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE: PLAN VIEW OF LANDFILL FINAL DESIGN WITH CROSS SECTIONS

SCALE:	DATE:	PROJECT NO:
1:3000	2016/05/25 (yyyy/mm/dd)	PRJ15061

DESIGNED	TS	DRAWING NO:
DRAWN	MG	FIGURE 4-1
CHECKED	TS	

5. LIFESPAN ANALYSIS

5.1 Volume Analysis

This section outlines the expected lifespan and airspace consumption from 2016 until closure. The year 2016 was selected as the reference year because the most recent survey was performed on March 10th, 2016. An estimate is presented using target levels of operation such as waste to cover and compaction.

The airspace estimates are shown in Table 5-1. The airspace consumed by the closure system is calculated using a calculated area of 26.3 Ha (3D Area) at a thickness of 1.1 m.

Table 5-1: Volume Estimates

Phase	Total Phase Volume (m^3)	Intermediate Biocover/Gas Collection Layer Area (m^2)	Intermediate Biocover/Gas Collection Layer Volume (m^3)	Closure Areas (m^2)	Closure System Volume (m^3)	Basal Liner / Leachate Collection System Area (m^2)	Basal Liner / Leachate Collection System Volume (0.95 m Thick) (m^3)	Net Phase Capacity (m^3)	Cum. Phase Capacity (m^3)	Cut (m^3)
1	178,000	26,900	13,450	-	-	N/A	N/A	164,550	164,550	
2	424,800	82,846	41,423	68,833	75,716	N/A	N/A	307,661	472,211	
3	155,600			22,413	24,654	37,500	35,625	95,321	567,531	
4	1,187,000	12,842	6,421	71,778	78,956	46,500	44,175	1,057,448	1,624,980	
5	1,938,000	33,000	16,500	100,248	110,273	53,500	50,825	1,760,402	3,385,382	
Borrow 1										264,600
Borrow 2										304,600
Borrow 3										929,000
Total	**3,883,400**	**155,588**	**77,794**	**263,272**	**289,599**	**137,500**	**130,625**	**3,385,382**		**1,498,200**

5.2 Lifespan Analysis Parameters

The operational lifespan of the CML was calculated using the following parameters:

- Service Area Population
- Population Growth
- Per-Capita Waste Generation
- Waste to Cover Ratio
- Settlement
- Waste Density
- Waste Diversion Rate

An explanation of each parameter and the data used is provided below:

Service Area Population
The current service area of the CMLF includes Penticton, the Penticton Indian Band, Upper and Lower Similkameen Bands, Naramata, West Bench/Sage Mesa, Westwood/Husula, Redwing, Kaleden, Lakeshore Highlands/Heritage Hills, Skaha Estates, Okanagan Falls, Twin Lakes, Olalla, Keremeos, Hedley, and Cawston. As per Statistics Canada, 1996, 2001, 2006 and 2011 total populations for the service areas are 43,917, 44,657, 46,695 and 48,018 respectively.

Population Growth
Based on the data from 1996, 2001, 2006 and 2011, the population growth rate was considered to be 1.0% for the lifespan analysis.

Per Capita Waste Generation
Per capita waste generation of 1.14 tonnes/capita/year was used for the lifespan analysis based on AECOM's 2011 Landfill Life Cycle Cost Assessment. To estimate the waste diversion rate for the service area, we followed the approach given below:

In the 2015 Annual Report, Western Water reported that approximately 23 tonnes of the following recyclables were collected under the Blue bag program:

- Glass
- Tin
- Paper
- Cardboard
- Plastic milk jugs

During the 2014 reporting period, a total of approximately 20,081 tonnes of the following materials were diverted at the Landfill:

- Agricultural Plastic
- Asphalt Roofing
- Batteries
- Blue Bag Recycling
- Cardboard
- Concrete
- Gyproc
- Metal
- Tree Stumps
- White Wood
- Organics

With an estimated growth rate of 1% since 2011, the 2015 service population was calculated to be 49,968. Based on this estimated population and the aforementioned waste generation rate, the total tonnage of material produced within the service area of the CMLF was calculated to be 56,963 tonnes during 2015. The 2015 Annual Report indicated that 44,982 tonnes of waste and recyclables were received at the CMLF, which comprised of 20,081 tonnes of diverted material and 24,901 tonnes of landfilled MSW. Therefore, a diversion rate of 56% was calculated for 2015. With an annual increase of 5% in diverted materials at the CMLF, a diversion rate of 73% can be achieved during 2019 which was projected in the lifespan analysis.

Waste to Cover Ratio

Based on the information provided by the RDOS, the landfill currently uses the R.I.G. alternative daily cover. Cells are constructed at a width of approximately 12 m. As per the 2015 Annual Report, the RDOS used approximately 3,839 tonnes of cover material in the active filling area. As mentioned previously, 24,901 tonnes of waste material were landfilled in the active filling area during 2015 and using a density of 0.8 tonnes/m^3 for both waste and soil combined, a waste to cover ratio was calculated to be 6.49 : 1 for 2015. In 2013, the waste to cover ratio was calculated to be 9.18: 1. Based on SHA's previous experience in landfill operation and design, with ADC systems, these waste to cover ratios are high and therefore, SHA used the waste to cover ratio of 3.07:1 calculated from the 2014 Annual Report for Scenario 1. As a conservative approach, SHA believes that this landfill can comfortably and consistently achieve a waste/cover ratio of 4 : 1 with ADC system and based on the new filling sequence and landfilling approach outlined in this report while meeting the operational goals of adequate daily cover. SHA used a waste to cover ratio of 3.07 : 1 in the lifespan analysis for Scenario 1 and a waste to cover ratio of 4 : 1 in the lifespan analysis for Scenario 2.

Photo 5-1 RIG ADC system at the CMLF

Settlement
Based on SHA's experience at numerous landfill sites, landfills settle over time creating additional air space. To account for the additional air space that will be created as a result of this settlement, our analysis factors in a 10% settlement rate.

Compaction
The density of waste at the CMLF was estimated to be 0.60 tonnes/m³ in the 2014 Annual Report completed by WWAL. However, cover material was excluded from consideration for the aforementioned compaction density. Alternately, a compaction density of 0.9 tonnes/m^3 was used in the 2011 Lifecycle Cost Assessment completed by AECOM. However, this compaction density did not account for settlement.

It is SHA's understanding that the landfill has a CAT 826-C Compactor, which is well suited to waste compaction, as shown in Photo 5-2 below. By taking settlement into account, SHA feels that moving forward a compaction density of 0.8 tonnes/m³ for both MSW and soil combined is achievable and therefore has carried this value in the lifespan calculations for the site.

Photo 5-2 Compaction Equipment at the Campbell Mountain Landfill

Diversion Rate
As mentioned above, the total amount of waste diverted from this landfill during 2015 was estimated at 56% using a 2015 Population of 49,968 based on the 2011 Census and an annual growth rate of 1.0%, a

waste generation rate of 1.14 tonnes/capita/year (AECOM, 2011) and a landfilled MSW tonnage of 24,901tonnes (WWAL, 2014).

According to the RDOS Solid Waste Management Plan (SWMP), a diversion rate of 73% is to be achieved by the year 2016. Based on the diversion rate of 56% achieved in 2015, SHA feels that the RDOS should be able to achieve their target of 73% in 2019 with an increase in diversion by 5% per year.

5.3 Lifespan Analysis

Two scenarios in the lifespan analysis are presented in this section. The first scenario maintains a waste to cover ratio of 3.07:1 (Status Quo) until closure, and the second scenario uses a waste to cover ratio of 4:1. Both scenarios will use a diversion rate of 58% until 2017, where the diversion rate will then increase by 5% annually until 2019 where a diversion rate of 73% will then be maintained until closure. The results of the analysis showing progressive closure dates are summarized in Table 5-2.

Table 5-2 Deterministic Analysis Results

	Scenario -1: Waste to Cover of 3.07:1			Scenario – 2: Waste to Cover of 4:1		
Phase	**Start**	**End**	**Lifespan**	**Start**	**End**	**Lifespan**
1	2016	2020	4	2016	2021	5
2	2020	2032	12	2021	2033	12
3	2032	2035	3	2033	2037	4
4	2035	2067	32	2037	2069	32
5	2067	2104	37	2069	2107	38
Total	**2016**	**2104**	**88**	**2016**	**2107**	**91**

Scenario 1 presents the capabilities of the current collection system, and as such it is estimated the landfill's airspace will be depleted by 2104, allowing for another 88 years of filling. This analysis is outlined in detail, year-by-year, showing the expected closures of each phase and final closure as a highlighted line item in Table 5-3.

If the waste to cover ratio was to increase from 3.07:1 to 4:1, as outlined by Scenario 2, another 3 years of operating life can be expected from the landfill, and the closure date would be extended to 2107. This analysis is outlined in Table 5-4, highlighting the duration of each phase and the final closure date.

Table 5-3: Lifespan (Scenario 1 - Existing Waste to Cover Ratio)

Year	Growth Rate	Contributing Population	Waste Generation		Waste Disposal		Settlement Reduction	Cover Volume	Cumulative Cover Volume	Residuals to Landfill	Cumulative Residual to Landfill	Cumulative Tonnage to Landfill	Phase Volume	Cumulative Phase Volume	Phase Ends
			tonnes	m^3	Tonnes	m^3	m^3	m^3	m^3	m^3 (waste+cover)	m^3 (waste+cover)	tonne (waste)	m^3	m^3	
2014	1	49,473	56,399.22	70,499.03	23,800.47	29,750.59	2,975.06	9,690.75	9,690.75	36,466.28					
2015	1	49,968	56,963.21	71,204.02	24,038.48	30,048.09	3,004.81	9,787.65	19,478	36,830.94	18,415	24,038			
2016	1	50,467	57,532.84	71,916.06	24,278.86	30,348.58	3,034.86	9,885.53	29,364	37,199.25	55,615	48,317			
2017	1	50,972	58,108.17	72,635.22	21,500.02	26,875.03	2,687.50	8,754.08	38,118	32,941.61	88,556	69,817			
2018	1	51,482	58,689.25	73,361.57	18,780.56	23,475.70	2,347.57	7,646.81	45,765	28,774.94	117,331	88,598			
2019	1	51,997	59,276.15	74,095.18	16,004.56	20,005.70	2,000.57	6,516.51	52,281	24,521.64	141,853	104,602			
2020	**1**	**52,517**	**59,868.91**	**74,836.14**	**16,164.61**	**20,205.76**	**2,020.58**	**6,581.68**	**58,863**	**24,766.86**	**166,620**	**120,767**	**164,550**	**164,550**	**Phase 1 Ends/Phase 2 Starts**
2021	1	53,042	60,467.60	75,584.50	16,326.25	20,407.81	2,040.78	6,647.50	65,511	25,014.53	191,634	137,093			
2022	1	53,572	61,072.27	76,340.34	16,489.51	20,611.89	2,061.19	6,713.97	72,224	25,264.67	216,899	153,583			
2023	1	54,108	61,683.00	77,103.75	16,654.41	20,818.01	2,081.80	6,781.11	79,006	25,517.32	242,416	170,237			
2024	1	54,649	62,299.83	77,874.78	16,820.95	21,026.19	2,102.62	6,848.92	85,855	25,772.49	268,189	187,058			
2025	1	55,195	62,922.82	78,653.53	16,989.16	21,236.45	2,123.65	6,917.41	92,772	26,030.22	294,219	204,047			
2026	1	55,747	63,552.05	79,440.07	17,159.05	21,448.82	2,144.88	6,986.59	99,759	26,290.52	320,510	221,206			
2027	1	56,305	64,187.57	80,234.47	17,330.64	21,663.31	2,166.33	7,056.45	106,815	26,553.43	347,063	238,537			
2028	1	56,868	64,829.45	81,036.81	17,503.95	21,879.94	2,187.99	7,127.02	113,942	26,818.96	373,882	256,041			
2029	1	57,437	65,477.74	81,847.18	17,678.99	22,098.74	2,209.87	7,198.29	121,140	27,087.15	400,969	273,720			
2030	1	58,011	66,132.52	82,665.65	17,855.78	22,319.73	2,231.97	7,270.27	128,411	27,358.02	428,327	291,576			
2031	1	58,591	66,793.85	83,492.31	18,034.34	22,542.92	2,254.29	7,342.97	135,754	27,631.60	455,959	309,610			
2032	**1**	**59,177**	**67,461.78**	**84,327.23**	**18,214.68**	**22,768.35**	**2,276.84**	**7,416.40**	**143,170**	**27,907.92**	**483,867**	**327,825**	**307,661**	**472,211**	**Phase 2 Ends/Phase 3 Starts**
2033	1	59,769	68,136.40	85,170.50	18,396.83	22,996.04	2,299.60	7,490.57	150,660	28,187.00	512,054	346,222			
2034	1	60,366	68,817.77	86,022.21	18,580.80	23,226.00	2,322.60	7,565.47	158,226	28,468.87	540,522	364,802			
2035	**1**	**60,970**	**69,505.94**	**86,882.43**	**18,766.60**	**23,458.26**	**2,345.83**	**7,641.13**	**165,867**	**28,753.56**	**569,276**	**383,569**	**95,321**	**567,532**	**Phase 3 Ends/Phase 4 Starts**
2036	1	61,580	70,201.00	87,751.25	18,954.27	23,692.84	2,369.28	7,717.54	173,585	29,041.09	598,317	402,523			
2037	1	62,196	70,903.01	88,628.77	19,143.81	23,929.77	2,392.98	7,794.71	181,379	29,331.50	627,649	421,667			
2038	1	62,818	71,612.04	89,515.05	19,335.25	24,169.06	2,416.91	7,872.66	189,252	29,624.82	657,273	441,002			
2039	1	63,446	72,328.16	90,410.21	19,528.60	24,410.76	2,441.08	7,951.39	197,203	29,921.07	687,195	460,531			
2040	1	64,080	73,051.45	91,314.31	19,723.89	24,654.86	2,465.49	8,030.90	205,234	30,220.28	717,415	480,255			
2041	1	64,721	73,781.96	92,227.45	19,921.13	24,901.41	2,490.14	8,111.21	213,345	30,522.48	747,937	500,176			
2042	1	65,368	74,519.78	93,149.72	20,120.34	25,150.43	2,515.04	8,192.32	221,538	30,827.70	778,765	520,296			
2043	1	66,022	75,264.98	94,081.22	20,321.54	25,401.93	2,540.19	8,274.24	229,812	31,135.98	809,901	540,618			
2044	1	66,682	76,017.63	95,022.03	20,524.76	25,655.95	2,565.59	8,356.99	238,169	31,447.34	841,348	561,143			
2045	1	67,349	76,777.80	95,972.25	20,730.01	25,912.51	2,591.25	8,440.56	246,610	31,761.81	873,110	581,873			
2046	1	68,022	77,545.58	96,931.98	20,937.31	26,171.63	2,617.16	8,524.96	255,135	32,079.43	905,190	602,810			
2047	1	68,703	78,321.04	97,901.30	21,146.68	26,433.35	2,643.34	8,610.21	263,745	32,400.23	937,590	623,957			
2048	1	69,390	79,104.25	98,880.31	21,358.15	26,697.68	2,669.77	8,696.31	272,441	32,724.23	970,314	645,315			
2049	1	70,084	79,895.29	99,869.11	21,571.73	26,964.66	2,696.47	8,783.28	281,224	33,051.47	1,003,365	666,887			
2050	1	70,784	80,694.24	100,867.80	21,787.45	27,234.31	2,723.43	8,871.11	290,095	33,381.99	1,036,747	688,674			
2051	1	71,492	81,501.19	101,876.48	22,005.32	27,506.65	2,750.67	8,959.82	299,055	33,715.81	1,070,463	710,679			
2052	1	72,207	82,316.20	102,895.25	22,225.37	27,781.72	2,778.17	9,049.42	308,105	34,052.96	1,104,516	732,905			
2053	1	72,929	83,139.36	103,924.20	22,447.63	28,059.53	2,805.95	9,139.91	317,245	34,393.49	1,138,910	755,352			
2054	1	73,659	83,970.75	104,963.44	22,672.10	28,340.13	2,834.01	9,231.31	326,476	34,737.43	1,173,647	778,024			
2055	1	74,395	84,810.46	106,013.08	22,898.82	28,623.53	2,862.35	9,323.63	335,800	35,084.80	1,208,732	800,923			
2056	1	75,139	85,658.57	107,073.21	23,127.81	28,909.77	2,890.98	9,416.86	345,216	35,435.65	1,244,168	824,051			
2057	1	75,890	86,515.15	108,143.94	23,359.09	29,198.86	2,919.89	9,511.03	354,727	35,790.01	1,279,958	847,410			
2058	1	76,649	87,380.30	109,225.38	23,592.68	29,490.85	2,949.09	9,606.14	364,334	36,147.91	1,316,106	871,003			
2059	1	77,416	88,254.11	110,317.63	23,828.61	29,785.76	2,978.58	9,702.20	374,036	36,509.39	1,352,615	894,831			
2060	1	78,190	89,136.65	111,420.81	24,066.89	30,083.62	3,008.36	9,799.22	383,835	36,874.48	1,389,489	918,898			
2061	1	78,972	90,028.01	112,535.02	24,307.56	30,384.45	3,038.45	9,897.22	393,732	37,243.23	1,426,733	943,206			
2062	1	79,762	90,928.29	113,660.37	24,550.64	30,688.30	3,068.83	9,996.19	403,728	37,615.66	1,464,348	967,757			
2063	1	80,559	91,837.58	114,796.97	24,796.15	30,995.18	3,099.52	10,096.15	413,825	37,991.81	1,502,340	992,553			
2064	1	81,365	92,755.95	115,944.94	25,044.11	31,305.13	3,130.51	10,197.11	424,022	38,371.73	1,540,712	1,017,597			
2065	1	82,179	93,683.51	117,104.39	25,294.55	31,618.19	3,161.82	10,299.08	434,321	38,755.45	1,579,467	1,042,891			
2066	1	83,000	94,620.35	118,275.43	25,547.49	31,934.37	3,193.44	10,402.07	444,723	39,143.00	1,618,610	1,068,439			
2067	**1**	**83,830**	**95,566.55**	**119,458.19**	**25,802.97**	**32,253.71**	**3,225.37**	**10,506.09**	**455,229**	**39,534.43**	**1,658,145**	**1,094,242**	**1,057,448**	**1,624,980**	**Phase 4 Ends/Phase 5 Starts**
2068	1	84,669	96,522.22	120,652.77	26,061.00	32,576.25	3,257.62	10,611.16	465,840	39,929.78	1,698,074	1,120,303			
2069	1	85,515	97,487.44	121,859.30	26,321.61	32,902.01	3,290.20	10,717.27	476,557	40,329.08	1,738,404	1,146,624			
2070	1	86,370	98,462.31	123,077.89	26,584.82	33,231.03	3,323.10	10,824.44	487,382	40,732.37	1,779,136	1,173,209			
2071	1	87,234	99,446.94	124,308.67	26,850.67	33,563.34	3,356.33	10,932.68	498,314	41,139.69	1,820,276	1,200,060			
2072	1	88,106	100,441.40	125,551.76	27,119.18	33,898.97	3,389.90	11,042.01	509,356	41,551.09	1,861,827	1,227,179			
2073	1	88,988	101,445.82	126,807.27	27,390.37	34,237.96	3,423.80	11,152.43	520,509	41,966.60	1,903,793	1,254,569			
2074	1	89,877	102,460.28	128,075.35	27,664.27	34,580.34	3,458.03	11,263.96	531,773	42,386.26	1,946,180	1,282,234			
2075	1	90,776	103,484.88	129,356.10	27,940.92	34,926.15	3,492.61	11,376.60	543,149	42,810.13	1,988,990	1,310,175			
2076	1	91,684	104,519.73	130,649.66	28,220.33	35,275.41	3,527.54	11,490.36	554,640	43,238.23	2,032,228	1,338,395			
2077	1	92,601	105,564.93	131,956.16	28,502.53	35,628.16	3,562.82	11,605.26	566,245	43,670.61	2,075,899	1,366,897			
2078	1	93,527	106,620.57	133,275.72	28,787.56	35,984.44	3,598.44	11,721.32	577,966	44,107.32	2,120,006	1,395,685			
2079	1	94,462	107,686.78	134,608.48	29,075.43	36,344.29	3,634.43	11,838.53	589,805	44,548.39	2,164,554	1,424,760			
2080	1	95,407	108,763.65	135,954.56	29,366.19	36,707.73	3,670.77	11,956.92	601,762	44,993.87	2,209,548	1,454,127			
2081	1	96,361	109,851.28	137,314.11	29,659.85	37,074.81	3,707.48	12,076.48	613,838	45,443.81	2,254,992	1,483,786			
2082	1	97,324	110,949.80	138,687.25	29,956.45	37,445.56	3,744.56	12,197.25	626,036	45,898.25	2,300,890	1,513,743			
2083	1	98,298	112,059.30	140,074.12	30,256.01	37,820.01	3,782.00	12,319.22	638,355	46,357.23	2,347,247	1,543,999			
2084	1	99,281	113,179.89	141,474.86	30,558.57	38,198.21	3,819.82	12,442.41	650,797	46,820.81	2,394,068	1,574,558			
2085	1	100,273	114,311.69	142,889.61	30,864.16	38,580.19	3,858.02	12,566.84	663,364	47,289.01	2,441,357	1,605,422			
2086	1	101,276	115,454.80	144,318.51	31,172.80	38,966.00	3,896.60	12,692.51	676,057	47,761.90	2,489,119	1,636,594			
2087	1	102,289	116,609.35	145,761.69	31,484.53	39,355.66	3,935.57	12,819.43	688,876	48,239.52	2,537,359	1,668,079			
2088	1	103,312	117,775.45	147,219.31	31,799.37	39,749.21	3,974.92	12,947.63	701,824	48,721.92	2,586,081	1,699,878			
2089	1	104,345	118,953.20	148,691.50	32,117.36	40,146.71	4,014.67	13,077.10	714,901	49,209.14	2,635,290	1,731,996			
2090	1	105,388	120,142.73	150,178.42	32,438.54	40,548.17	4,054.82	13,207.87	728,109	49,701.23	2,684,991	1,764,434			
2091	1	106,442	121,344.16	151,680.20	32,762.92	40,953.65	4,095.37	13,339.95	741,449	50,198.24	2,735,189	1,797,197			
2092	1	107,507	122,557.60	153,197.00	33,090.55	41,363.19	4,136.32	13,473.35	754,922	50,700.22	2,785,889	1,830,288			
2093	1	108,582	123,783.18	154,728.97	33,421.46	41,776.82	4,177.68	13,608.09	768,530	51,207.23	2,837,097	1,863,709			
2094	1	109,668	125,021.01	156,276.26	33,755.67	42,194.59	4,219.46	13,744.17	782,274	51,719.30	2,888,816	1,897,465			
2095	1	110,764	126,271.22	157,839.02	34,093.23	42,616.54	4,261.65	13,881.61	796,156	52,236.49	2,941,052	1,931,558			
2096	1	111,872	127,533.93	159,417.41	34,434.16	43,042.70	4,304.27	14,020.42	810,176	52,758.86	2,993,811	1,965,992			
2097	1	112,991	128,809.27	161,011.59	34,778.50	43,473.13	4,347.31	14,160.63	824,337	53,286.44	3,047,098	2,000,771			
2098	1	114,120	130,097.36	162,621.70	35,126.29	43,907.86	4,390.79	14,302.23	838,639	53,819.31	3,100,917	2,035,897			
2099	1	115,262	131,398.34	164,247.92	35,477.55	44,346.94	4,434.69	14,445.26	853,084	54,357.50	3,155,275	2,071,375			
2100	1	116,414	132,712.32	165,890.40	35,832.33	44,790.41	4,479.04	14,589.71	867,674	54,901.08	3,210,176	2,107,207			
2101	1	117,578	134,039.44	167,549.30	36,190.65	45,238.31	4,523.83	14,735.61	882,410	55,450.09	3,265,626	2,143,398			
2102	1	118,754	135,379.84	169,224.80	36,552.56	45,690.70	4,569.07	14,882.96	897,293	56,004.59	3,321,630	2,179,950			
2103	1	119,942	136,733.64	170,917.05	36,918.08	46,147.60	4,614.76	15,031.79	912,324	56,564.63	3,378,195	2,216,868			
2104	**1**	**121,141**	**138,100.97**	**172,626.22**	**37,287.26**	**46,609.08**	**4,660.91**	**15,182.11**	**927,506**	**57,130.28**	**3,435,325**	**2,254,155**	**1,760,402**	**3,385,382**	**Final Closure**

Assumptions:

Compacted Waste Density	0.8 tonnes/m^3
Waste Generation Rate	1.14 tonnes/year/person Whitecourt
Waste Diversion Rate (until 2017)	58%
Waste Diversion Rate (2017)	63%
Waste Diversion Rate (2018)	68%
Waste Diversion Rate (2019 and up)	73.0%
Settlement	10% by volume
Waste to Cover Ratio (waste/cover)	3.07 vol/vol

Phase End / Start

Final Closure

Table 5-4: Lifespan Analysis (Scenario 2 - Future Target Waste to Cover Ratio)

Year	Growth Rate	Contributing Population	Waste Generation		Waste Disposal		Settlement Reduction	Cover Volume	Cumulative Cover Volume	Residuals to Landfill	Cumulative Residual to Landfill	Cumulative Tonnage to Landfill	Phase Volume	Cumulative Phase Volume	Phase Ends
			tonnes	m^3	Tonnes	m^3	m^3	m^3	m^3	m^3 (waste+cover)	m^3 (waste+cover)	tonne (waste)	m^3	m^3	
2014	1	49,473	56,399.22	70,499.03	23,800.47	29,750.59	2,975.06	7,437.65	7,437.65	34,213.18					
2015	1	49,968	56,963.21	71,204.02	24,038.48	30,048.09	3,004.81	7,512.02	14,950	34,555.31	17,278	24,038			
2016	1	50,467	57,532.84	71,916.06	24,278.86	30,348.58	3,034.86	7,587.14	22,537	34,900.86	52,179	48,317			
2017	1	50,972	58,108.17	72,635.22	21,500.02	26,875.03	2,687.50	6,718.76	29,256	30,906.28	83,085	69,817			
2018	1	51,482	58,689.25	73,361.57	18,780.56	23,475.70	2,347.57	5,868.93	35,124	26,997.06	110,082	88,598			
2019	1	51,997	59,276.15	74,095.18	16,004.56	20,005.70	2,000.57	5,001.42	40,126	23,006.55	133,088	104,602			
2020	1	52,517	59,868.91	74,836.14	16,164.61	20,205.76	2,020.58	5,051.44	45,177	23,236.62	156,325	120,767			
2021	**1**	**53,042**	**60,467.60**	**75,584.50**	**16,326.25**	**20,407.81**	**2,040.78**	**5,101.95**	**50,279**	**23,468.99**	**179,794**	**137,093**	**164,550**	**164,550**	**Phase 1 Ends/Phase 2 Starts**
2022	1	53,572	61,072.27	76,340.34	16,489.51	20,611.89	2,061.19	5,152.97	55,432	23,703.68	203,498	153,583			
2023	1	54,108	61,683.00	77,103.75	16,654.41	20,818.01	2,081.80	5,204.50	60,637	23,940.71	227,438	170,237			
2024	1	54,649	62,299.83	77,874.78	16,820.95	21,026.19	2,102.62	5,256.55	65,893	24,180.12	251,619	187,058			
2025	1	55,195	62,922.82	78,653.53	16,989.16	21,236.45	2,123.65	5,309.11	71,202	24,421.92	276,040	204,047			
2026	1	55,747	63,552.05	79,440.07	17,159.05	21,448.82	2,144.88	5,362.20	76,565	24,666.14	300,707	221,206			
2027	1	56,305	64,187.57	80,234.47	17,330.64	21,663.31	2,166.33	5,415.83	81,980	24,912.80	325,619	238,537			
2028	1	56,868	64,829.45	81,036.81	17,503.95	21,879.94	2,187.99	5,469.98	87,450	25,161.93	350,781	256,041			
2029	1	57,437	65,477.74	81,847.18	17,678.99	22,098.74	2,209.87	5,524.68	92,975	25,413.55	376,195	273,720			
2030	1	58,011	66,132.52	82,665.65	17,855.78	22,319.73	2,231.97	5,579.93	98,555	25,667.68	401,863	291,576			
2031	1	58,591	66,793.85	83,492.31	18,034.34	22,542.92	2,254.29	5,635.73	104,191	25,924.36	427,787	309,610			
2032	1	59,177	67,461.78	84,327.23	18,214.68	22,768.35	2,276.84	5,692.09	109,883	26,183.61	453,971	327,825			
2033	**1**	**59,769**	**68,136.40**	**85,170.50**	**18,396.83**	**22,996.04**	**2,299.60**	**5,749.01**	**115,632**	**26,445.44**	**480,416**	**346,222**	**307,661**	**472,211**	**Phase 2 Ends/Phase 3 Starts**
2034	1	60,366	68,817.77	86,022.21	18,580.80	23,226.00	2,322.60	5,806.50	121,438	26,709.90	507,126	364,802			
2035	1	60,970	69,505.94	86,882.43	18,766.60	23,458.26	2,345.83	5,864.56	127,303	26,976.99	534,103	383,569			
2036	1	61,580	70,201.00	87,751.25	18,954.27	23,692.84	2,369.28	5,923.21	133,226	27,246.76	561,350	402,523			
2037	**1**	**62,196**	**70,903.01**	**88,628.77**	**19,143.81**	**23,929.77**	**2,392.98**	**5,982.44**	**139,209**	**27,519.23**	**588,869**	**421,667**	**95,321**	**567,532**	**Phase 3 Ends/Phase 4 Starts**
2038	1	62,818	71,612.04	89,515.05	19,335.25	24,169.06	2,416.91	6,042.27	145,251	27,794.42	616,663	441,002			
2039	1	63,446	72,328.16	90,410.21	19,528.60	24,410.76	2,441.08	6,102.69	151,354	28,072.37	644,736	460,531			
2040	1	64,080	73,051.45	91,314.31	19,723.89	24,654.86	2,465.49	6,163.72	157,517	28,353.09	673,089	480,255			
2041	1	64,721	73,781.96	92,227.45	19,921.13	24,901.41	2,490.14	6,225.35	163,743	28,636.62	701,725	500,176			
2042	1	65,368	74,519.78	93,149.72	20,120.34	25,150.43	2,515.04	6,287.61	170,030	28,922.99	730,648	520,296			
2043	1	66,022	75,264.98	94,081.22	20,321.54	25,401.93	2,540.19	6,350.48	176,381	29,212.22	759,861	540,618			
2044	1	66,682	76,017.63	95,022.03	20,524.76	25,655.95	2,565.59	6,413.99	182,795	29,504.34	789,365	561,143			
2045	1	67,349	76,777.80	95,972.25	20,730.01	25,912.51	2,591.25	6,478.13	189,273	29,799.39	819,164	581,873			
2046	1	68,022	77,545.58	96,931.98	20,937.31	26,171.63	2,617.16	6,542.91	195,816	30,097.38	849,262	602,810			
2047	1	68,703	78,321.04	97,901.30	21,146.68	26,433.35	2,643.34	6,608.34	202,424	30,398.35	879,660	623,957			
2048	1	69,390	79,104.25	98,880.31	21,358.15	26,697.68	2,669.77	6,674.42	209,099	30,702.34	910,362	645,315			
2049	1	70,084	79,895.29	99,869.11	21,571.73	26,964.66	2,696.47	6,741.17	215,840	31,009.36	941,372	666,887			
2050	1	70,784	80,694.24	100,867.80	21,787.45	27,234.31	2,723.43	6,808.58	222,648	31,319.45	972,691	688,674			
2051	1	71,492	81,501.19	101,876.48	22,005.32	27,506.65	2,750.67	6,876.66	229,525	31,632.65	1,004,324	710,679			
2052	1	72,207	82,316.20	102,895.25	22,225.37	27,781.72	2,778.17	6,945.43	236,470	31,948.97	1,036,273	732,905			
2053	1	72,929	83,139.36	103,924.20	22,447.63	28,059.53	2,805.95	7,014.88	243,485	32,268.46	1,068,541	755,352			
2054	1	73,659	83,970.75	104,963.44	22,672.10	28,340.13	2,834.01	7,085.03	250,570	32,591.15	1,101,132	778,024			
2055	1	74,395	84,810.46	106,013.08	22,898.82	28,623.53	2,862.35	7,155.88	257,726	32,917.06	1,134,049	800,923			
2056	1	75,139	85,658.57	107,073.21	23,127.81	28,909.77	2,890.98	7,227.44	264,954	33,246.23	1,167,296	824,051			
2057	1	75,890	86,515.15	108,143.94	23,359.09	29,198.86	2,919.89	7,299.72	272,253	33,578.69	1,200,874	847,410			
2058	1	76,649	87,380.30	109,225.38	23,592.68	29,490.85	2,949.09	7,372.71	279,626	33,914.48	1,234,789	871,003			
2059	1	77,416	88,254.11	110,317.63	23,828.61	29,785.76	2,978.58	7,446.44	287,072	34,253.62	1,269,042	894,831			
2060	1	78,190	89,136.65	111,420.81	24,066.89	30,083.62	3,008.36	7,520.90	294,593	34,596.16	1,303,639	918,898			
2061	1	78,972	90,028.01	112,535.02	24,307.56	30,384.45	3,038.45	7,596.11	302,189	34,942.12	1,338,581	943,206			
2062	1	79,762	90,928.29	113,660.37	24,550.64	30,688.30	3,068.83	7,672.07	309,862	35,291.54	1,373,872	967,757			
2063	1	80,559	91,837.58	114,796.97	24,796.15	30,995.18	3,099.52	7,748.80	317,610	35,644.46	1,409,517	992,553			
2064	1	81,365	92,755.95	115,944.94	25,044.11	31,305.13	3,130.51	7,826.28	325,437	36,000.90	1,445,518	1,017,597			
2065	1	82,179	93,683.51	117,104.39	25,294.55	31,618.19	3,161.82	7,904.55	333,341	36,360.91	1,481,879	1,042,891			
2066	1	83,000	94,620.35	118,275.43	25,547.49	31,934.37	3,193.44	7,983.59	341,325	36,724.52	1,518,603	1,068,439			
2067	1	83,830	95,566.55	119,458.19	25,802.97	32,253.71	3,225.37	8,063.43	349,388	37,091.77	1,555,695	1,094,242			
2068	1	84,669	96,522.22	120,652.77	26,061.00	32,576.25	3,257.62	8,144.06	357,532	37,462.68	1,593,158	1,120,303			
2069	**1**	**85,515**	**97,487.44**	**121,859.30**	**26,321.61**	**32,902.01**	**3,290.20**	**8,225.50**	**365,758**	**37,837.31**	**1,630,995**	**1,146,624**	**1,057,448**	**1,624,980**	**Phase 4 Ends/Phase 5 Starts**
2070	1	86,370	98,462.31	123,077.89	26,584.82	33,231.03	3,323.10	8,307.76	374,066	38,215.68	1,669,211	1,173,209			
2071	1	87,234	99,446.94	124,308.67	26,850.67	33,563.34	3,356.33	8,390.84	382,456	38,597.84	1,707,808	1,200,060			
2072	1	88,106	100,441.40	125,551.76	27,119.18	33,898.97	3,389.90	8,474.74	390,931	38,983.82	1,746,792	1,227,179			
2073	1	88,988	101,445.82	126,807.27	27,390.37	34,237.96	3,423.80	8,559.49	399,491	39,373.66	1,786,166	1,254,569			
2074	1	89,877	102,460.28	128,075.35	27,664.27	34,580.34	3,458.03	8,645.09	408,136	39,767.39	1,825,933	1,282,234			
2075	1	90,776	103,484.88	129,356.10	27,940.92	34,926.15	3,492.61	8,731.54	416,867	40,165.07	1,866,098	1,310,175			
2076	1	91,684	104,519.73	130,649.66	28,220.33	35,275.41	3,527.54	8,818.85	425,686	40,566.72	1,906,665	1,338,395			
2077	1	92,601	105,564.93	131,956.16	28,502.53	35,628.16	3,562.82	8,907.04	434,593	40,972.39	1,947,637	1,366,897			
2078	1	93,527	106,620.57	133,275.72	28,787.56	35,984.44	3,598.44	8,996.11	443,589	41,382.11	1,989,020	1,395,685			
2079	1	94,462	107,686.78	134,608.48	29,075.43	36,344.29	3,634.43	9,086.07	452,675	41,795.93	2,030,816	1,424,760			
2080	1	95,407	108,763.65	135,954.56	29,366.19	36,707.73	3,670.77	9,176.93	461,852	42,213.89	2,073,029	1,454,127			
2081	1	96,361	109,851.28	137,314.11	29,659.85	37,074.81	3,707.48	9,268.70	471,121	42,636.03	2,115,665	1,483,786			
2082	1	97,324	110,949.80	138,687.25	29,956.45	37,445.56	3,744.56	9,361.39	480,482	43,062.39	2,158,728	1,513,743			
2083	1	98,298	112,059.30	140,074.12	30,256.01	37,820.01	3,782.00	9,455.00	489,937	43,493.01	2,202,221	1,543,999			
2084	1	99,281	113,179.89	141,474.86	30,558.57	38,198.21	3,819.82	9,549.55	499,487	43,927.94	2,246,149	1,574,558			
2085	1	100,273	114,311.69	142,889.61	30,864.16	38,580.19	3,858.02	9,645.05	509,132	44,367.22	2,290,516	1,605,422			
2086	1	101,276	115,454.80	144,318.51	31,172.80	38,966.00	3,896.60	9,741.50	518,873	44,810.90	2,335,327	1,636,594			
2087	1	102,289	116,609.35	145,761.69	31,484.53	39,355.66	3,935.57	9,838.91	528,712	45,259.00	2,380,586	1,668,079			
2088	1	103,312	117,775.45	147,219.31	31,799.37	39,749.21	3,974.92	9,937.30	538,650	45,711.59	2,426,297	1,699,878			
2089	1	104,345	118,953.20	148,691.50	32,117.36	40,146.71	4,014.67	10,036.68	548,686	46,168.71	2,472,466	1,731,996			
2090	1	105,388	120,142.73	150,178.42	32,438.54	40,548.17	4,054.82	10,137.04	558,823	46,630.40	2,519,097	1,764,434			
2091	1	106,442	121,344.16	151,680.20	32,762.92	40,953.65	4,095.37	10,238.41	569,062	47,096.70	2,566,193	1,797,197			
2092	1	107,507	122,557.60	153,197.00	33,090.55	41,363.19	4,136.32	10,340.80	579,403	47,567.67	2,613,761	1,830,288			
2093	1	108,582	123,783.18	154,728.97	33,421.46	41,776.82	4,177.68	10,444.21	589,847	48,043.35	2,661,804	1,863,709			
2094	1	109,668	125,021.01	156,276.26	33,755.67	42,194.59	4,219.46	10,548.65	600,395	48,523.78	2,710,328	1,897,465			
2095	1	110,764	126,271.22	157,839.02	34,093.23	42,616.54	4,261.65	10,654.13	611,050	49,009.02	2,759,337	1,931,558			
2096	1	111,872	127,533.93	159,417.41	34,434.16	43,042.70	4,304.27	10,760.68	621,810	49,499.11	2,808,836	1,965,992			
2097	1	112,991	128,809.27	161,011.59	34,778.50	43,473.13	4,347.31	10,868.28	632,679	49,994.10	2,858,830	2,000,771			
2098	1	114,120	130,097.36	162,621.70	35,126.29	43,907.86	4,390.79	10,976.97	643,655	50,494.04	2,909,324	2,035,897			
2099	1	115,262	131,398.34	164,247.92	35,477.55	44,346.94	4,434.69	11,086.73	654,742	50,998.98	2,960,323	2,071,375			
2100	1	116,414	132,712.32	165,890.40	35,832.33	44,790.41	4,479.04	11,197.60	665,940	51,508.97	3,011,832	2,107,207			
2101	1	117,578	134,039.44	167,549.30	36,190.65	45,238.31	4,523.83	11,309.58	677,249	52,024.06	3,063,856	2,143,398			
2102	1	118,754	135,379.84	169,224.80	36,552.56	45,690.70	4,569.07	11,422.67	688,672	52,544.30	3,116,401	2,179,950			
2103	1	119,942	136,733.64	170,917.05	36,918.08	46,147.60	4,614.76	11,536.90	700,209	53,069.74	3,169,470	2,216,868			
2104	1	121,141	138,100.97	172,626.22	37,287.26	46,609.08	4,660.91	11,652.27	711,861	53,600.44	3,223,071	2,254,155			
2105	1	122,353	139,481.98	174,352.48	37,660.14	47,075.17	4,707.52	11,768.79	723,630	54,136.44	3,277,207	2,291,816			
2106	1	123,576	140,876.80	176,096.00	38,036.74	47,545.92	4,754.59	11,886.48	735,517	54,677.81	3,331,885	2,329,852			
2107	**1**	**124,812**	**142,285.57**	**177,856.96**	**38,417.10**	**48,021.38**	**4,802.14**	**12,005.35**	**747,522**	**55,224.59**	**3,387,110**	**2,368,269**	**1,760,402**	**3,385,382**	**Final Closure**

Assumptions:

Compacted Waste Density	0.8	tonnes/m^3
Waste Generation Rate	1.14	tonnes/year/person Whitecourt
Waste Diversion Rate (until 2017)	58%	
Waste Diversion Rate (2017)	63%	
Waste Diversion Rate (2018)	68%	
Waste Diversion Rate (2019 and up)	73.0%	
Settlement	10%	by volume
Waste to Cover Ratio (waste/cover)	4	vol/vol

Phase End / Start
Final Closure

6. FILLING PLAN

This Chapter presents SHA's recommendations for the systematic filling approach required to bring the CML to design grades for the active Phase 1 filling area. The filling plan includes strategies for constructing individual landfill cells, for constructing strips within each 3 m thick lift, and for properly managing the outside edges of each lift so that large volumes of soil are not wasted. Additionally, a detailed lift by lift fill plan for the remainder of Phase 1 has been completed.

6.1 Cell Optimization and Geometry

The actual volume of air space that is consumed on a daily basis at the CMLF depends on the amount of incoming refuse and the amount of daily and intermediate soil cover placed. The operational soil cover is necessary to isolate the waste from the environment and to control odors and vectors such as birds and flies. In addition, if placed properly, soil cover provides an effective firebreak that minimizes the risk of fire spreading throughout the entire landfill site, as well as reduces the spontaneous combustion of the waste.

The amount of cover utilized on a daily and weekly basis is evaluated in terms of the waste to cover ratio, defined as the volume of compacted waste for each volume of soil cover utilized. Recognizing that air space is valuable, today many landfill operations attempt to optimize their soil cover in order to use as little as possible while ensuring that all of the functional objectives of soil cover continue to be achieved. This is done by compartmentalizing the refuse in cells whose dimensions are carefully optimized to match the incoming tonnage.

A waste cell is a unit of waste fully encapsulated by soil. The optimum cell dimensions vary depending on the amount of waste entering the landfill. Typically, unless the landfill's geometry creates other constraints, a landfill manager will want to optimize the ratio of waste to soil cover material. The optimum cell dimensions for the CMLF were calculated using SHA's Landfill Wizard Cell Geometry Spreadsheet.

Table 6-1 presents the Landfill Wizard analysis. In the analysis, it was assumed that the site would receive 24,000 tonnes of waste per year (close to the actual tonnage for 2014) compacted to a density of 0.80 tonnes/m^3. The site is open seven days a week during the summer months (March – November), however, it is closed on Sundays during the winter months (December – February), Boxing Day and statutory holidays (12 per year). It was also specified that 0.15 m of intermediate soil cover would be placed over the active face weekly, whereas 0.3 m of soil would be placed on the top and side slopes of each cell as it was completed. An optimal working face angle of 4H:1V was used for the analysis. The results of the analysis show that the optimum geometry would be achieved with a 18.0 m wide active face and a 7.5 m deep lift resulting in a waste to cover ratio of 7.15:1, based on the input parameters outlined above.

SHA's experience is that medium tonnage landfills do not operate well with lift heights above 3.0 m due to constraints with constructing side berms and the overall area of the active face requiring maintenance. Therefore, SHA recommends that the lift thickness be maintained at 3.0 m. SHA also recommends that the active face width be set at approximately 20 m. With a cell height of 3.0 m and a width of 20 m, a waste to cover ratio of 5.89 to 1 can be achieved. SHA recommends that the waste to cover ratio be tracked on a semi-annual basis so that it can be improved throughout the landfill life.

6.2 Existing Method of Landfill Development

Historically, the RDOS has utilized the strip method of landfill development where the waste was placed in 3 m high lifts and long narrow cells. The current waste cells are approximately 30-50m in length and approximately 2-3m in height.

The active cells are capped with cover soil on a bi-weekly basis as they advance. Cover material is being extracted from the onsite borrow area and stockpiled near the active face for use. The yard and garden grind that is stored onsite is used on the slopes for erosion control purposes and on access roads during winter months to provide traction.

Most of the waste transport vehicles accessing the active face are compactor trucks, roll off bin trucks and large commercial trucks and end dump trailers. The waste collected at the onsite drop-off (RDOS) and regional transfer stations are also hauled to the landfill's active face on a daily basis by contractors.

6.3 Strip Method of Landfill Development

It is recommended that the strip method of filling continue to be used at the CMLF. The basic concept of constructing a strip from a series of cells is shown on Figure 6-1. The figure shows the concept visually, but variations to this approach can be adapted based on the landfill and the size of the area in which filling takes place. Generally, each phase is broken down into a series of lifts, and each lift is constructed in a number of parallel strips. Waste is placed using either the Push-Up or Push-Down method of cell construction. The Push-Up method is the preferable method but the Push-Down is used where the phase geometry dictates its necessity.

At the CMLF, the strips should be maintained at a width that is equal to the width of the ADC system (R.I.G. plates), therefore, a strip width of approximately 20 m or two R.I.G. plates wide should be adopted. Photo 6-1 illustrates a typical strip under construction at Revelstoke Landfill in B.C.

Photo 6-1: Strip Under Construction at Revelstoke Landfill

6.4 Lift Edge Development

Constructing the outside edge of each lift can be difficult to achieve. The key will be to fill the cell in such a way that refuse will not cascade down the landfill side slopes. SHA recommends the approach for lift edge construction as illustrated in Figure 6-2. During the construction of each 3 m thick lift, the process involves first dumping a line of soil stockpiles along the crest of the landfill slope to a height of 1.3 m to 1.5 m to contain the refuse and to prevent spill-over. The active lift will extend up to and abut against the line of stockpiles. The operator can then cut the peak off the stockpiles and spread the excess soil up the slope as intermediate cover.

6.5 Operational Cover Soil Placement and Usage

When using soil as a cover material there are some practical methods that should be employed to ensure that soil is not lost during cover placement. The Handbook of Landfill Operations (T Bolton, N., 1995) suggests that placing cover soil on improperly finished waste cells is the greatest waste of airspace at a landfill. The Handbook suggests that, if, after the waste is compacted, proper measures be taken to manicure the waste cell before cover is placed with this approach significant savings in material can be realized. Essentially, if the active face is not prepared properly, soil will disappear into the voids in the waste face and may be spread in layers that may vary in depth. An example used in the Handbook suggests that an investigation was undertaken at a landfill where cover soil varied in depth from 5" to 3.5'. The basic idea for eliminating these potential problems is to ensure that the waste face is as smooth and even as possible before cover soil is placed. Recommendations in the Handbook include a) re-grading the active face prior to placing cover to create a smooth surface and b) to track-walk the face with a dozer to "knit" the surface of the garbage together to avoid loss of soil in the dimples created by the compactor. The goal of ensuring an even, smooth active face, with few voids, should be achieved with the available equipment.

6.6 Alternate Daily Cover Recommendation

In the place of daily soil cover, use of an ADC helps to extend the life of the landfill. SHA recommends the continued use of steel plates (Revelstoke Iron Grizzly) as an alternative cover at the CMLF. The use of steel plates for alternative daily cover has been pioneered by Bresco Industries at the Revelstoke Landfill in Revelstoke B.C. Deployment is very fast (less than 10 minutes) and the plates are not prone to wind uplift, ripping, bird damage, or snow burial. In SHA's opinion, the rigid plates are far superior to tarps. These plates also minimize scavenging and will help to prevent the spread of windblown litter.

The alternative cover system is deployed using a wheel loader or excavator at the end of each working day until a cell is completed (typically every three to four weeks) or until the final contours of the cell as outlined above are achieved. At that point a 0.3 m layer of operational cover soil should be applied on the active face. With efficient use of this alternative daily cover, the waste to cover ratio will continue to be high, as the alternative cover reduces the amount of operational material needed and increases the capacity for waste in the landfill.

In addition, this method of cover also eliminates windblown litter issues and deters vectors such as birds and small rodents from accessing the waste. Also, the steel plates are very rigid and accumulated snow has not been an issue with any of SHA's clients who are using the system.

6.7 Detailed Lift by Lift Fill Plan Sequence - Phase 1 and Phase 2

The following presents a lift by lift description of how SHA foresees Phase 1 and the initial filling of Phase 2 being developed at the CMLF site. Alterations to the orientation of cells may become apparent during construction but this will provide a basis for access road construction, phase development and borrow pit sourcing. The overall objective of the fill plan is to build vertically and keep as small a waste footprint as possible while providing access for all vehicles. The flat working deck of the lifts must provide drainage at a minimum 2% grade to discourage ponding water. All final outside slopes will be constructed at 3H : 1V and all internal slopes (slopes where the next Phase or future Phases will piggy-back against) will be built at 2.5H : 1V. Main access roads are to be completed at no greater than 8% with temporary access roads ranging from 10-12%.

Phase 1 Lift 1 (615 - 618 m):

Lift-1 is presented in Figure 6-3. The first lift in Phase 1 has already been completed and included raising the filling area from approximately 615m to 618m in elevation. The access road begins at the entrance / south end of the Phase 1 area and will continue to climb at a slope of 8% along the outside / easterly slopes of the Phase.

Phase 1 Lift 2 (618 - 621 m):

Lift-2 is presented in Figure 6-4. The second lift in Phase 2 will include raising the working deck from 618m to 621m in elevation. The RDOS is currently filling Cell 1, which includes filling a low area at the north end of the lift in a Push-Down manner. Cell 2 through Cell 4 will be completed in a Push-Up direction starting on the western most edge of the lift against the existing Phase 1 bank and working east. During the filling of Cell 4, an operational road will be required to the 621m elevation from the main access road. This temporary road will enable the filling of Cell 5 along the outer slopes of Phase 1 in a Push-Down manner off the top deck. Once the main access road is constructed to the 621m elevation, the temporary road can be removed and slopes graded to 2.5H : 1V. Temporary roads may be constructed with waste or operations fill soil material which will be re-graded or re-used when completing the main access road.

Phase 1 Lift 3 (621 - 624 m):

Lift-3 will continue to build off the previously completed lifts and will be completed in multiple cells on the east side of Phase 1, as outlined in Figure 6-5. Filling Lift-3 will raise the working deck of Phase 1 from 621m to 624m in elevation. Cell 1 to begin on the western side of the Phase, piggy-backing against the existing slope and will be completed in a Push-Up manner from south to north. Cells 2 through Cell 4 will be completed in the same fashion with the construction of a temporary access road onto the top deck of Cell 4, outlined by the dashed red lines. Cell 5 will be built from the north to south in a Push-Down manner and includes the extension of the main access road to the 624m elevation. Temporary roads may be constructed with waste or operations fill soil material which will be re-graded or re-used when completing the main access road.

Phase 1 Lift 4 (624 - 627 m):

Lift-4 is presented in Figure 6-6 and includes raising the Phase 1 filling area by 3m from 624m to 627m in elevation. Filling in Lift 4 will begin on the easterly outside slope, south of the main access road, in a Push-Up fashion from south to north. Provisions should be made during the filling of Cell 1 to include a temporary access road onto the top deck of Cell 1 to an elevation of 627m. The temporary access road will be required later in the Lift 4 filling sequence to access Cell 5. Cell 2 through Cell 4 will be completed in a Push-Up manner from south to north starting against the existing western slopes. Finally, Cell 5 will be filled in a Push-Down manner from north to south and will include the extension of the main access road to 627m elevation.

Phase 1 Lift 5 (627 - 630 m):

Lift-5 builds over top of Lift-4 and will raise the phase by an additional 3m, to 630m in elevation, as outlined in Figure 6-7. SHA foresees Lift 5 beginning in the southwest corner of the Phase with Cell 1 being constructed in a Push-Up manner against the existing western slope. Cell 2 through Cell 5 will be completed in a Push-Up manner as well from south to north. A temporary access road will again be required during Cells 4 and 5 to provide access to the top deck for the completion of Cell 5. Cell 5 will be filled in a Push-Down manner from the North West corner of the lift towards the access road. Finally, the main access road will need to be completed to the new operating deck at 630m in elevation and the temporary access road can be decommissioned and the outer east slope re-graded.

Phase 1 Lift 6 (630 - 633 m):

Lift-6 will raise the working deck of Phase 1 by 3m vertically from 630m to 633m as outlined in Figure 6-8. Lift 6 will begin by filling on the western crest of Phase 1 from south to north in a Push-Up direction. The cell thickness will transition from approximately 3m to a sliver fill as Cell 1 progresses north. Cells 2 through 5 will be completed in a Push-Up manner from south to north moving from west to the eastern internal slopes of the phase. A temporary access road will need to be included during the development of Cell 5 to ensure access to Cell 6 which will be completed in a Push-Down manner from north to south off the top deck of 633m. Finally, the temporary access road will be removed and intermediate slopes re-graded.

Phase 1 Lift 7 (633 - 635 m):

Lift-7 will be the final lift of Phase 1. As outlined in Figure 6-9, filling will bring the Phase 1 elevation to 635m. Cell 1 will begin the Lift 7 filling sequence and will be constructed along the southern edge of the phase from west to east. Cells 2 through 7 will be completed in the same Push-Up direction. During the filling of Cell 7, a temporary access road will need to be completed to enable filling of Cell 8 in a Push-Down manner to extend the main access road to the landfill crest. Once Cell 8 is complete, the temporary access road may be decommissioned and the slopes re-graded.

Phase 2 Lift 1 (563 - 565 m):

Lift-1 of Phase 2 will be the first lift of Phase 2. As outlined in Figure 6-10, filling will bring the Phase 2 elevation to 565m. Cell 1 will begin the Lift 1 filling sequence and will be constructed along the eastern edge of the phase from east to west. Cells 2 through 4 will be completed in the same Push-Down direction.

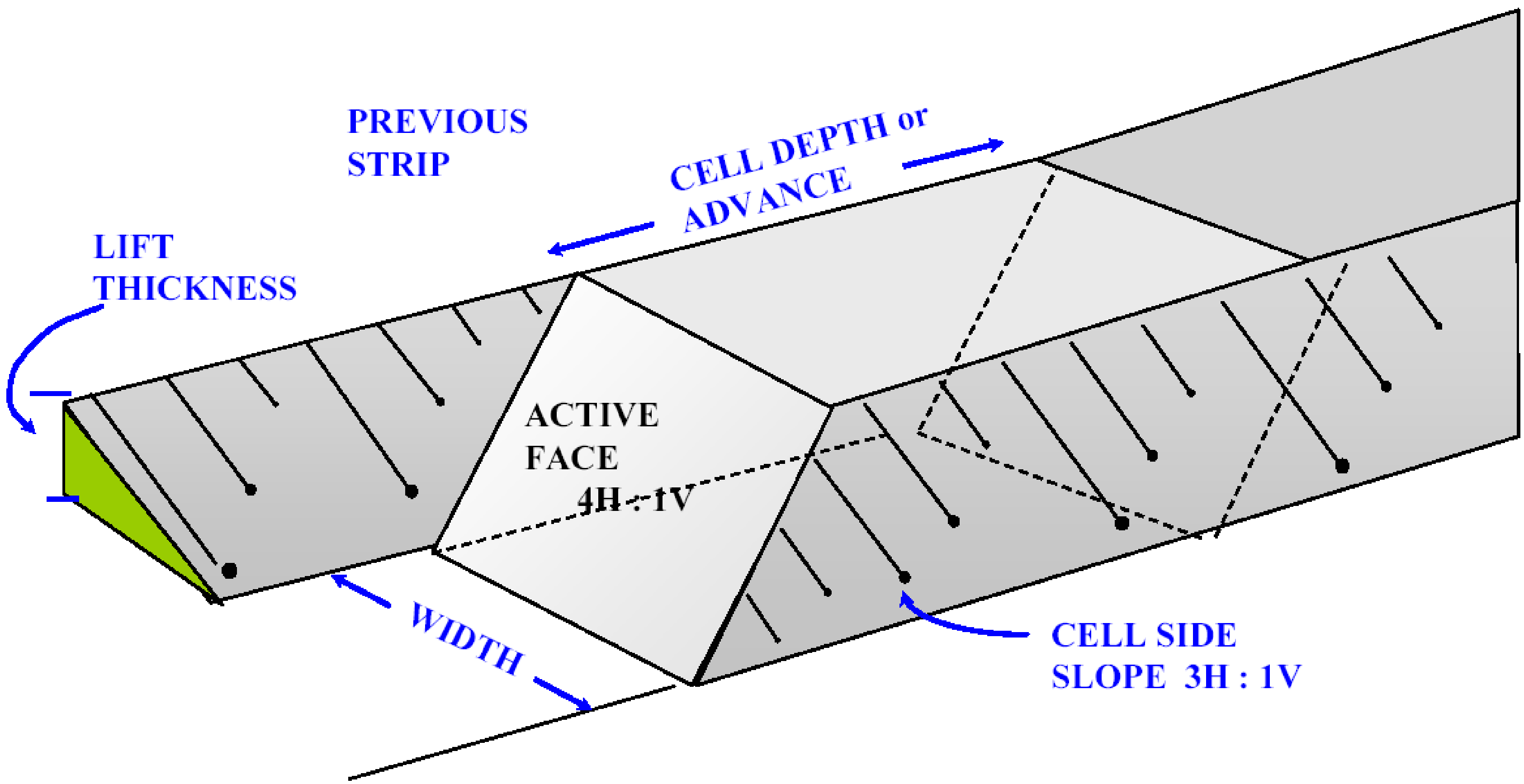
Phase 2 Lift 2 (565 - 568 m):

Lift-2 is presented in Figure 6-11. The second lift in Phase 2 will include raising the working deck from 565m to 568m in elevation. Cell 1 will begin the Lift 2 filling sequence and will be constructed along the eastern edge of the phase from east to west. Cells 2 through 4 will be completed in the same Push-Down direction.

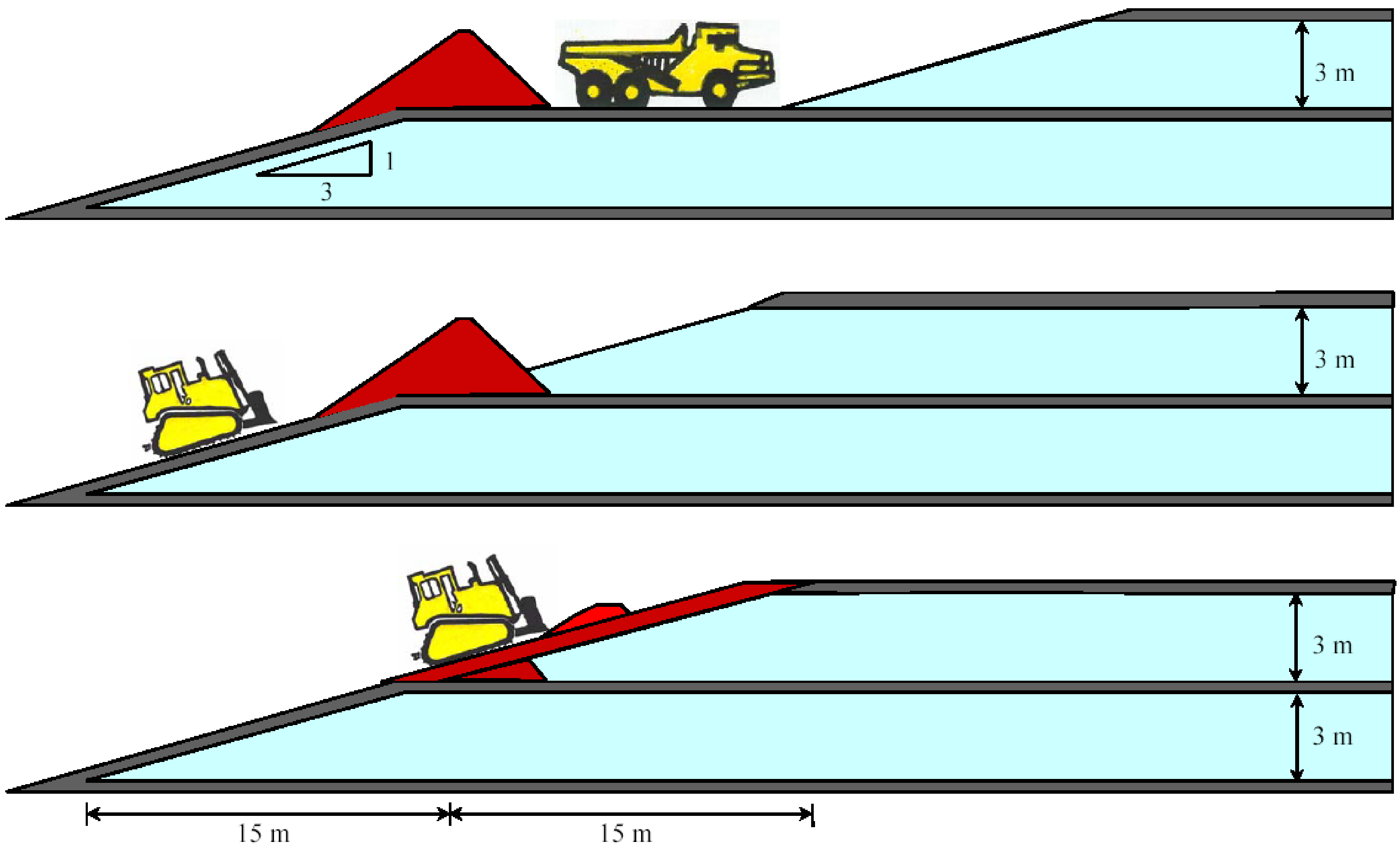
Phase 2 Lift 3 (568 - 572 m):

Lift-3 is presented in Figure 6-11. The second lift in Phase 2 will include raising the working deck from 568m to 572m in elevation. Cell 1 will begin the Lift 3 filling sequence and will be constructed along the eastern edge of the phase from east to west. Cells 2 through 6 will be completed in the same Push-Down direction. During the filling of Cell 2, a temporary access road will need to be completed to enable filling of Cells 3 to 6 in a Push-Down manner.

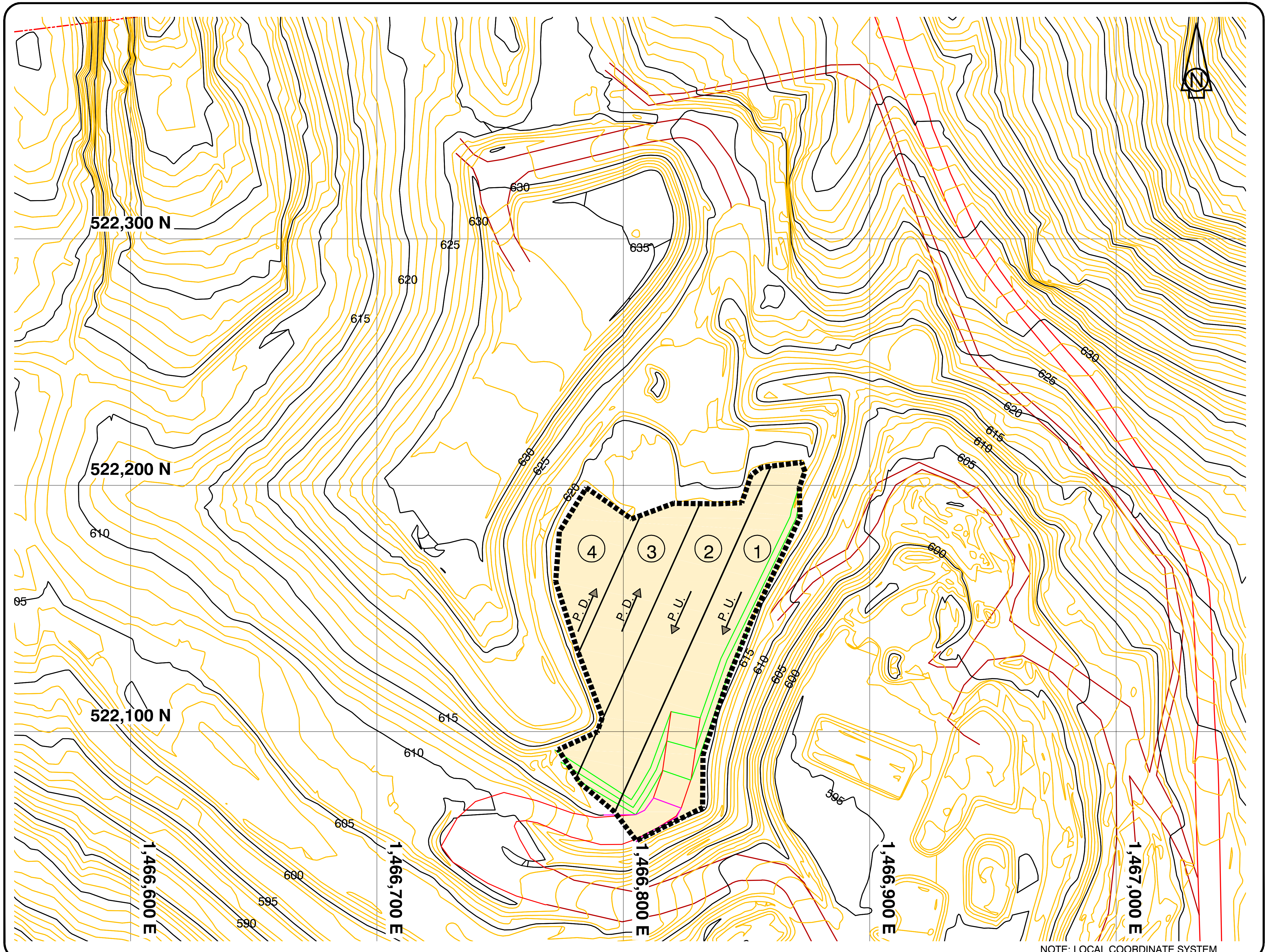
Figure 6-13 shows the traffic flow from the scale to the initial filling location of Phase 2.



Sperling Hansen Associates	Regional District of Okanagan-Similkameen	PROJECT: CAMPBELL MOUNTAIN LANDFILL DESIGN , OPERATIONS & CLOSURE PLAN	TITLE: LIFT CONSTRUCTION CONCEPT USING STRIP METHOD	SCALE: N/A; DATE: 2016/04/13 (yyyy/mm/dd); PROJECT NO: 15061; DESIGNED IB; DRAWN IB; CHECKED TS; DRAWING NO: Figure 6-1



Sperling Hansen Associates	Regional District of Okanagan-Similkameen	PROJECT: CAMPBELL MOUNTAIN LANDFILL DESIGN, OPERATIONS & CLOSURE PLAN	TITLE: LIFT EDGE DEVELOPMENT	SCALE: N/A; DATE: 2016/04/13 (yyyy/mm/dd); PROJECT NO: 15061; DESIGNED: IB; DRAWN: IB; CHECKED: TS; DRAWING NO: Figure 6-2



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- OPERATIONAL ROAD
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- 5 m EXISTING CONTOURS
- 1 m EXISTING CONTOURS
- 5 m PHASE 1 CONTOURS
- 1 m PHASE 1 CONTOURS
- FENCE
- PROPERTY BOUNDARY
- (7) LIFT REFERENCE
- LIFT BOUNDARY
- LIFT FILL AREA
- P.U. FILL DIRECTION - PUSHING UP
- P.D. FILL DIRECTION - PUSHING DOWN

CLIENT:
REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN AND OPERATIONS PLAN

TITLE:
PHASE 1 - LIFT 1 (615 m to 618 m)

SCALE:	DATE:	PROJECT NO:
1:1,500	2016/05/04 yyyy/mm/dd	PRJ15061

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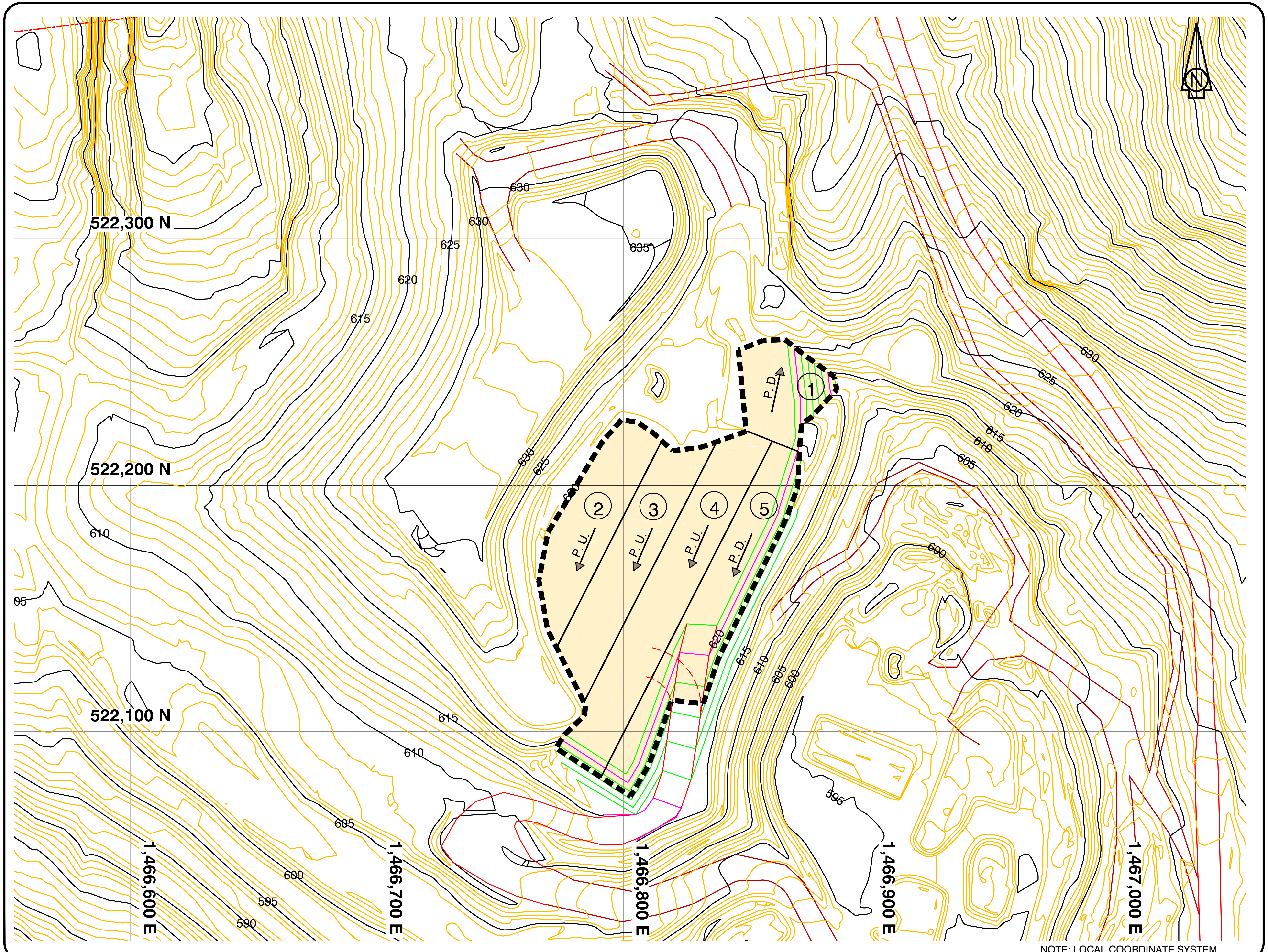

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- (7) LIFT REFERENCE
- LIFT BOUNDARY
- LIFT FILL AREA
- P. U. FILL DIRECTION - PUSHING UP
- P. D. FILL DIRECTION - PUSHING DOWN

CLIENT: REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT: RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN AND OPERATIONS PLAN

TITLE: PHASE 1 - LIFT 2 (618 m to 621 m)

SCALE:	DATE:	PROJECT NO:
1:1,500	2016/05/04 (yyyy/mm/dd)	PRJ15061

DESIGNED	SG	DRAWING NO: FIGURE 6-4
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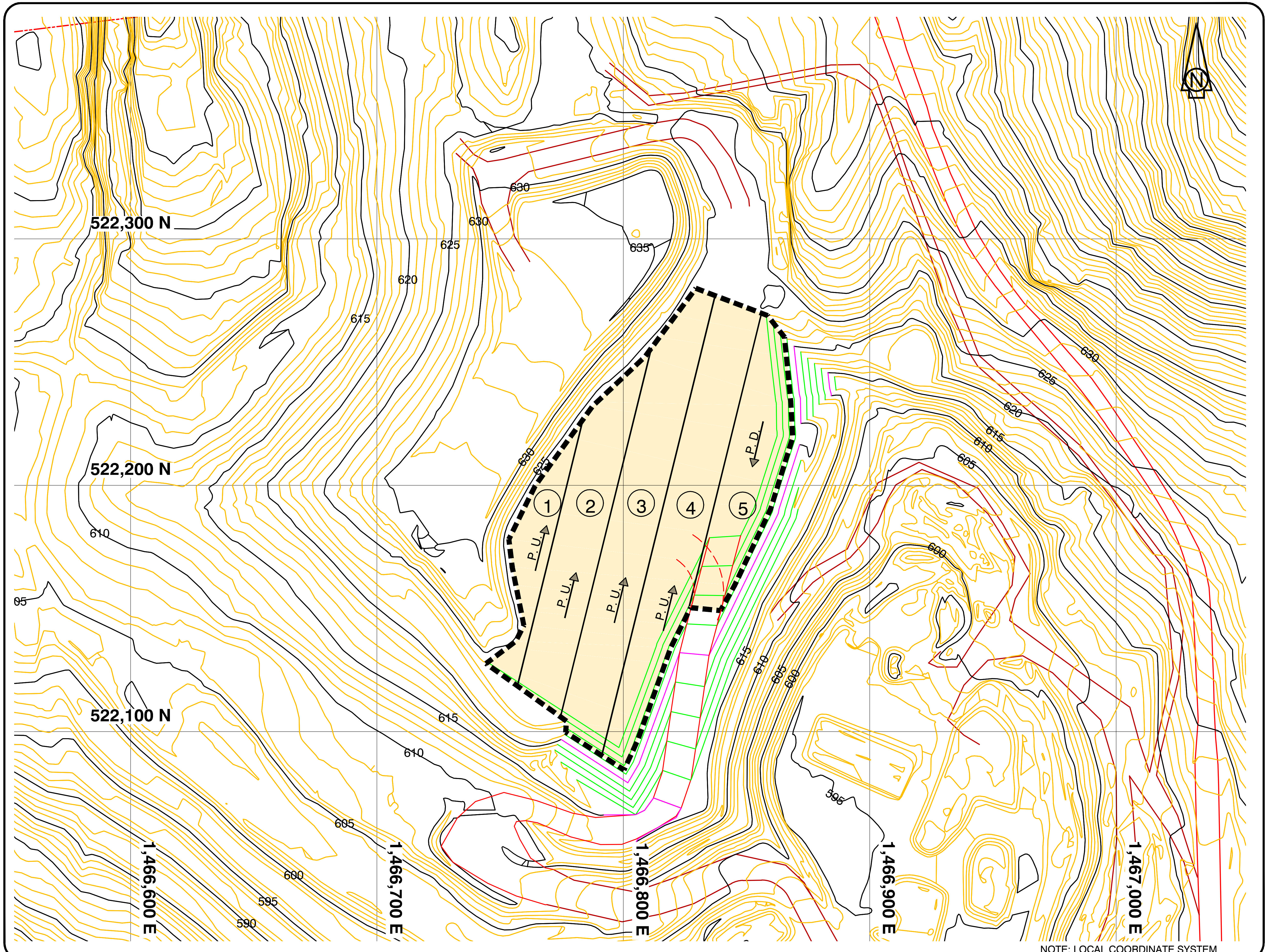

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- FENCE
- PROPERTY BOUNDARY
- 7 LIFT REFERENCE
- LIFT BOUNDARY
- LIFT FILL AREA
- P. U. FILL DIRECTION - PUSHING UP
- P. D. FILL DIRECTION - PUSHING DOWN

CLIENT:

RDOS OKANAGAN-SIMILKAMEEN

REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:

RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN AND OPERATIONS PLAN

TITLE:

PHASE 1 - LIFT 3 (621 m to 624 m)

SCALE:	DATE:	PROJECT NO:
1:1,500	2016/05/04 yyyy/mm/dd	PRJ15061

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DRAWN	SG	FIGURE 6-5
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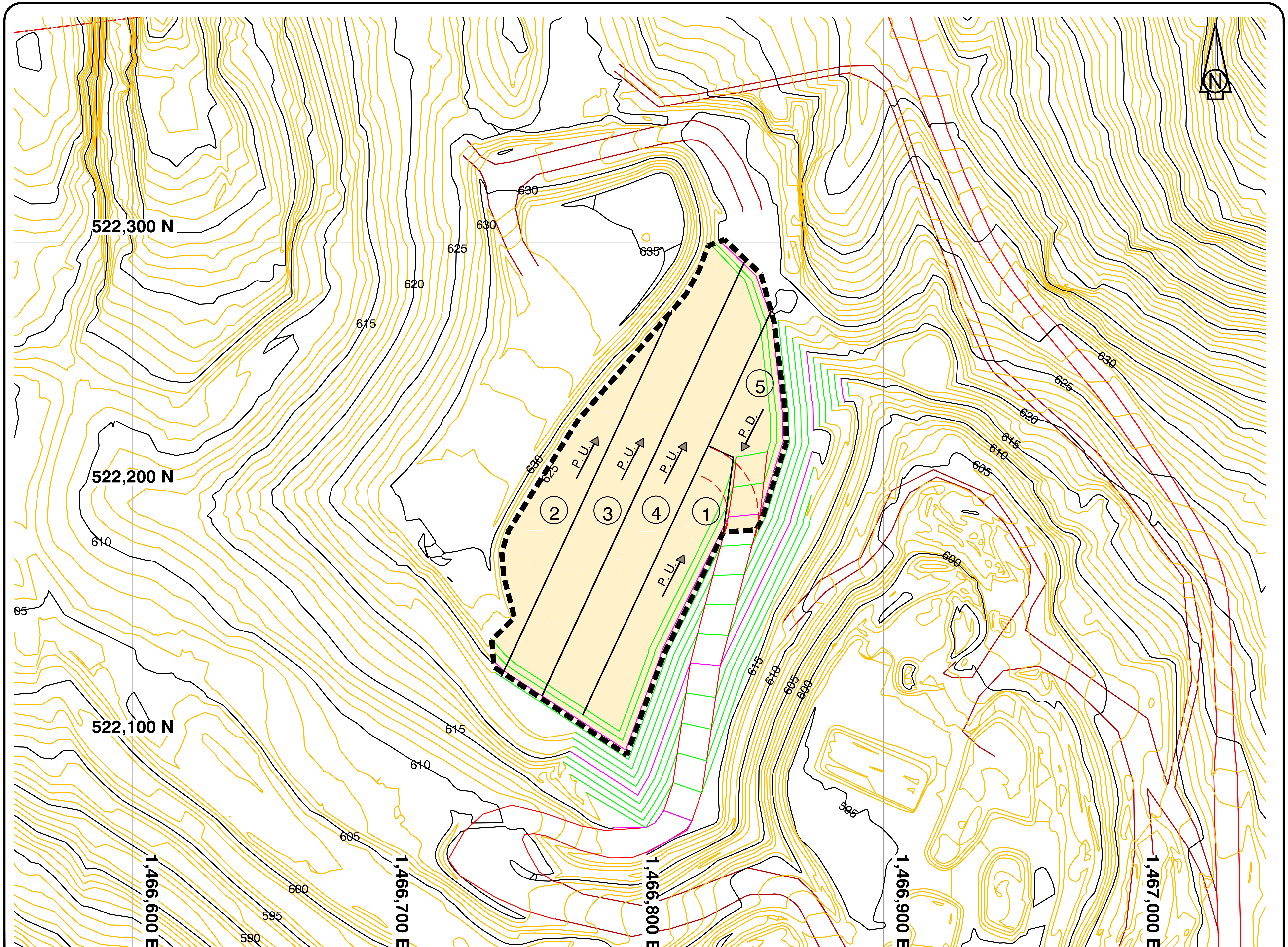

NOTE: LOCAL COORDINATE SYSTEM

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- LIFT BOUNDARY
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- P.U. FILL DIRECTION - PUSHING UP
- P.D. FILL DIRECTION - PUSHING DOWN

CLIENT:
REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN AND OPERATIONS PLAN

TITLE:
PHASE 1 - LIFT 4
(624 m to 627 m)

SCALE:	DATE:	PROJECT NO:
1:1,500	2016/05/04 yyyy/mm/dd	PRJ15061

DESIGNED	SG	DRAWING NO:
DRAWN	SG	FIGURE 6-6
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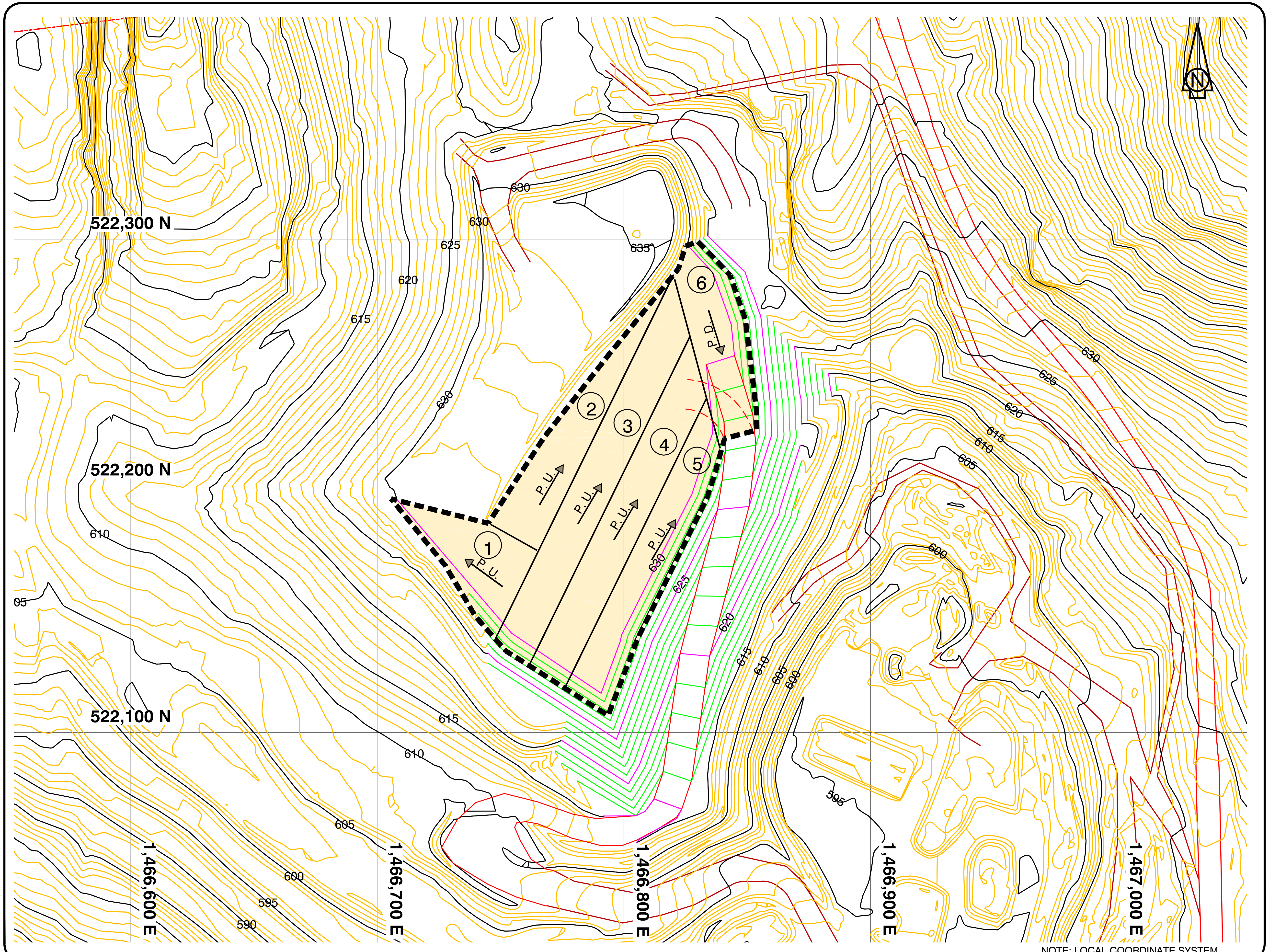

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PROJECT: RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN AND OPERATIONS PLAN

TITLE: PHASE 1 - LIFT 5 (627 m to 630 m)

SCALE:	DATE:	PROJECT NO:
1:1,500	2016/05/04 yyyy/mm/dd	PRJ15061

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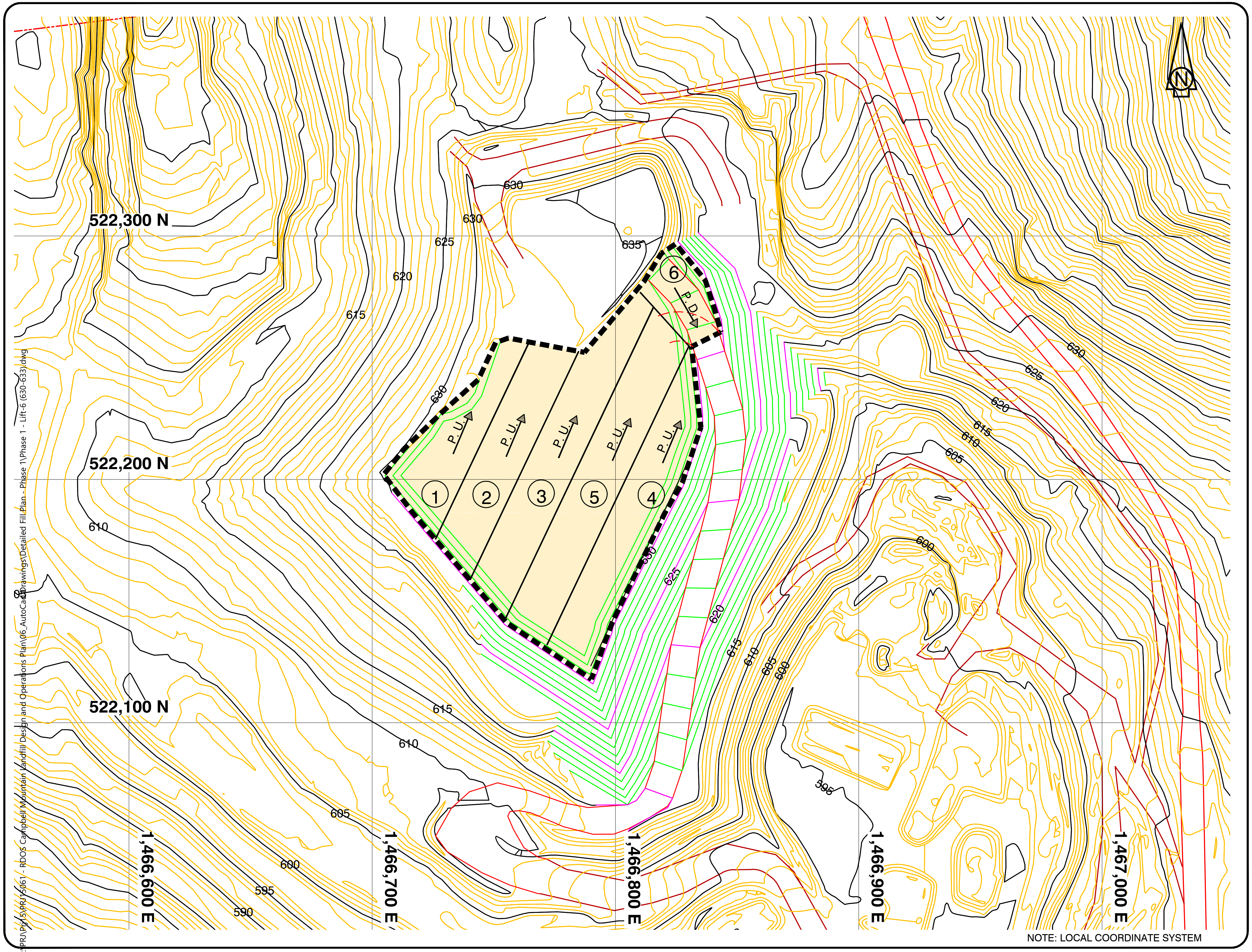

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CLIENT:

REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:

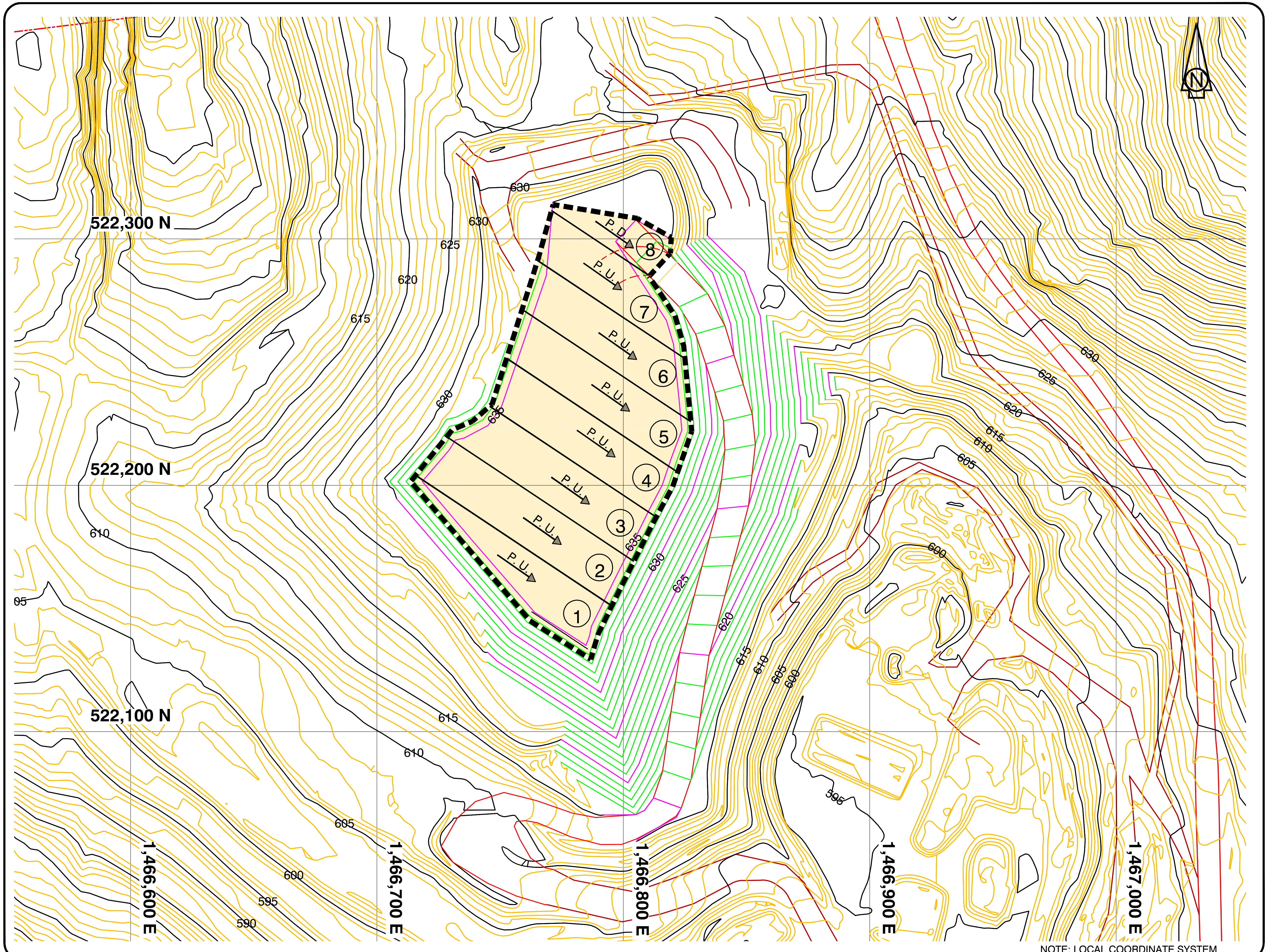
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN AND OPERATIONS PLAN

TITLE:

PHASE 1 - LIFT 6
(630 m to 633 m)

SCALE:	DATE:	PROJECT NO:
1:1,500	2016/05/04 (yyyy/mm/dd)	PRJ15061

DESIGNED	SG	DRAWING NO:
DRAWN	SG	FIGURE 6-8
CHECKED	IB	



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North Vancouver, B.C. V7J 1J3

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- LIFT BOUNDARY
- LIFT FILL AREA
- P.U. FILL DIRECTION - PUSHING UP
- P.D. FILL DIRECTION - PUSHING DOWN

CLIENT:

REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:

RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN AND OPERATIONS PLAN

TITLE:

PHASE 1 - LIFT 7
(633 m to 635 m)

SCALE:	DATE:	PROJECT NO:
1:1,500	2016/05/04 (yyyy/mm/dd)	PRJ15061

DESIGNED	SG	DRAWING NO:
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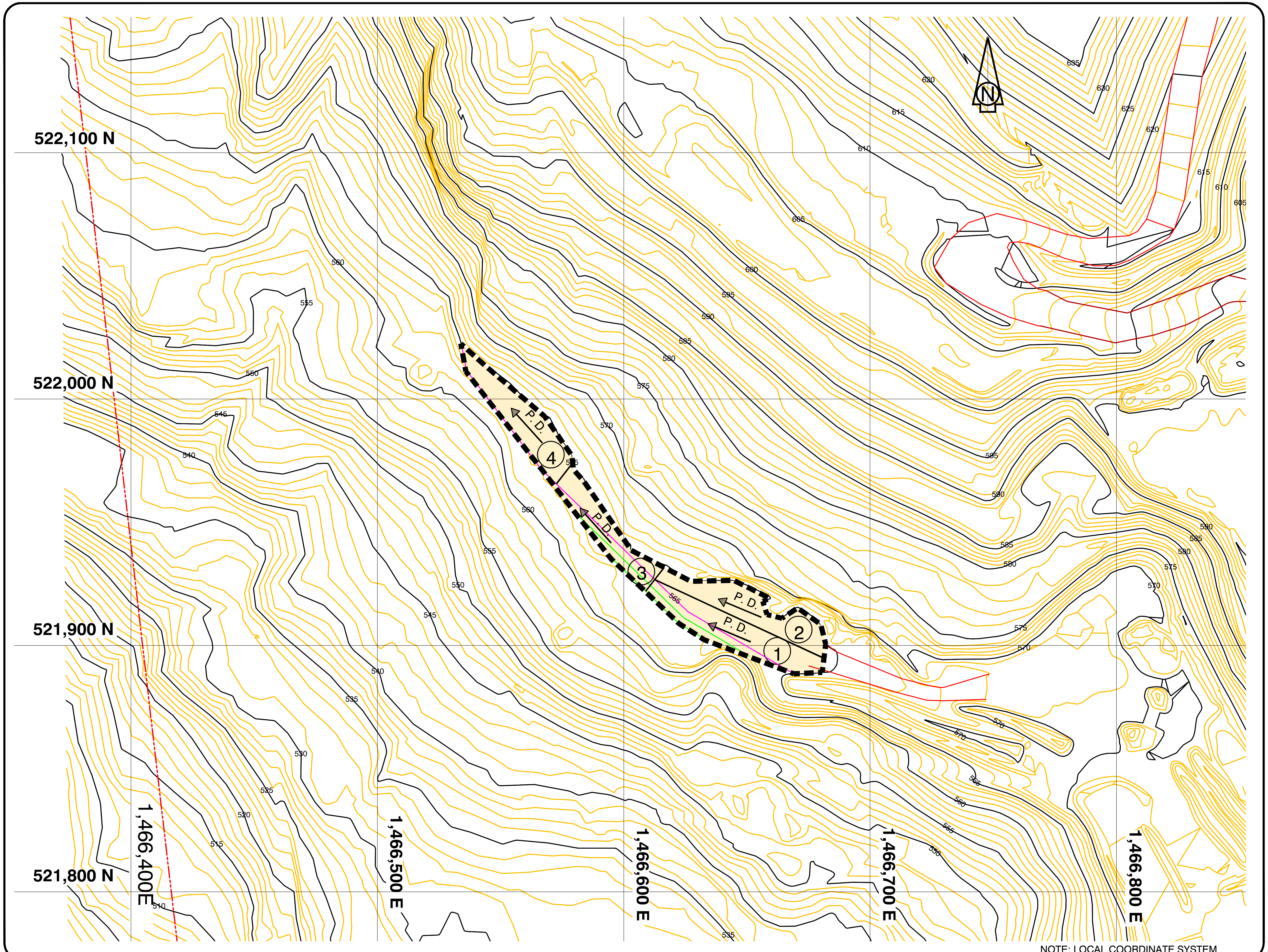
CHECKED	IB	



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- P. U. FILL DIRECTION - PUSHING UP
- P. D. FILL DIRECTION - PUSHING DOWN

CLIENT:

REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:

RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN AND OPERATIONS PLAN

TITLE:

PHASE 2 - LIFT 1(563 m to 565 m)

SCALE:	DATE:	PROJECT NO:
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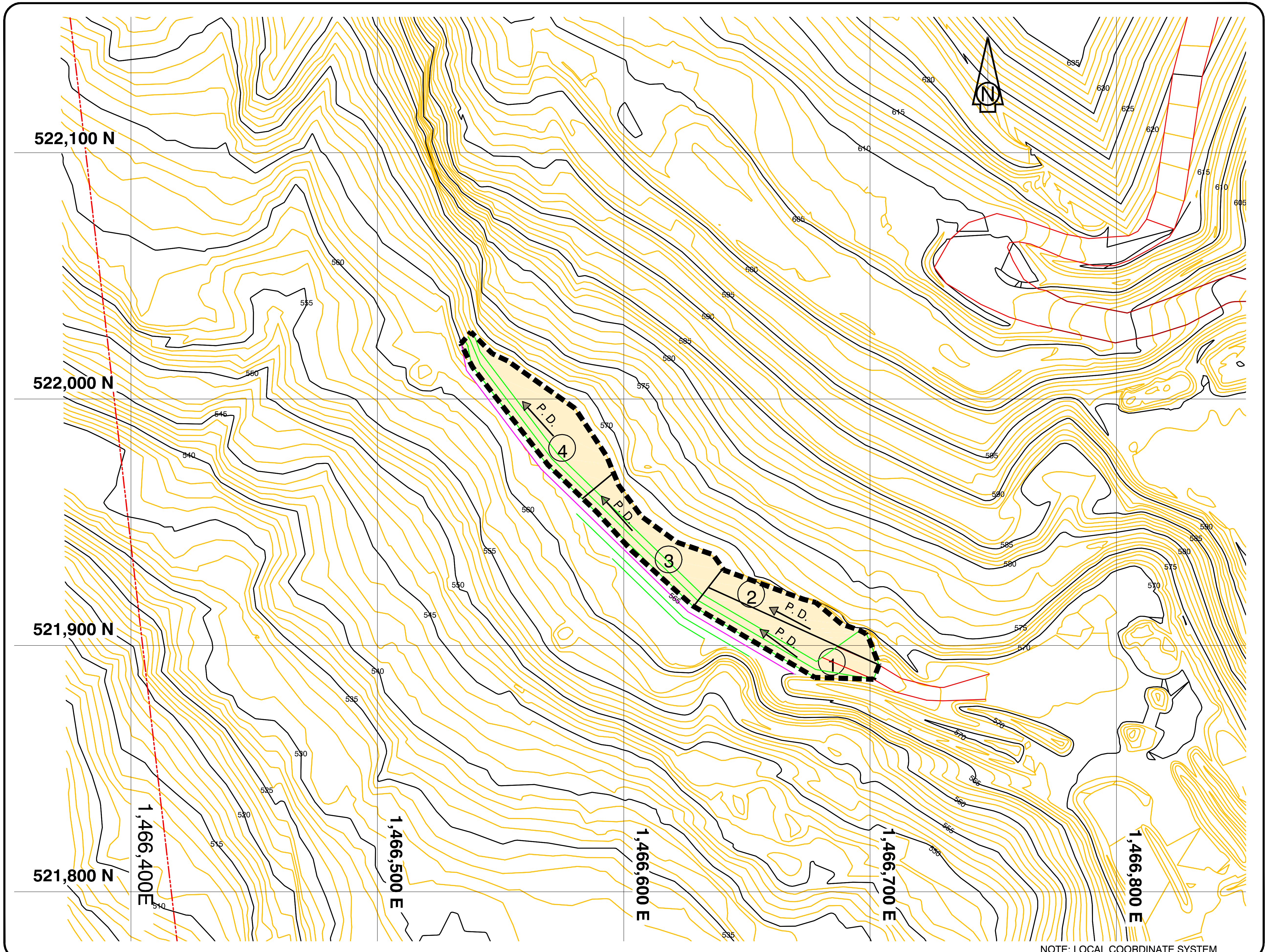
DESIGNED	SG	DRAWING NO:
DRAWN	SG	FIGURE 6-10
CHECKED	IB	



SPERLING HANSEN ASSOCIATES

Landfill Services Group

Landfill Siting
Design & Operations Plans
Landfill Closure
Environmental Monitoring

#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3

Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- OPERATIONAL ROAD
- DESIGN ROAD
- DITCH
- 5 m EXISTING CONTOURS
- 1 m EXISTING CONTOURS
- 5 m PHASE 1 CONTOURS
- 1 m PHASE 1 CONTOURS
- FENCE
- PROPERTY BOUNDARY
- 7 LIFT REFERENCE
- LIFT BOUNDARY
- LIFT FILL AREA
- P. U. FILL DIRECTION - PUSHING UP
- P. D. FILL DIRECTION - PUSHING DOWN

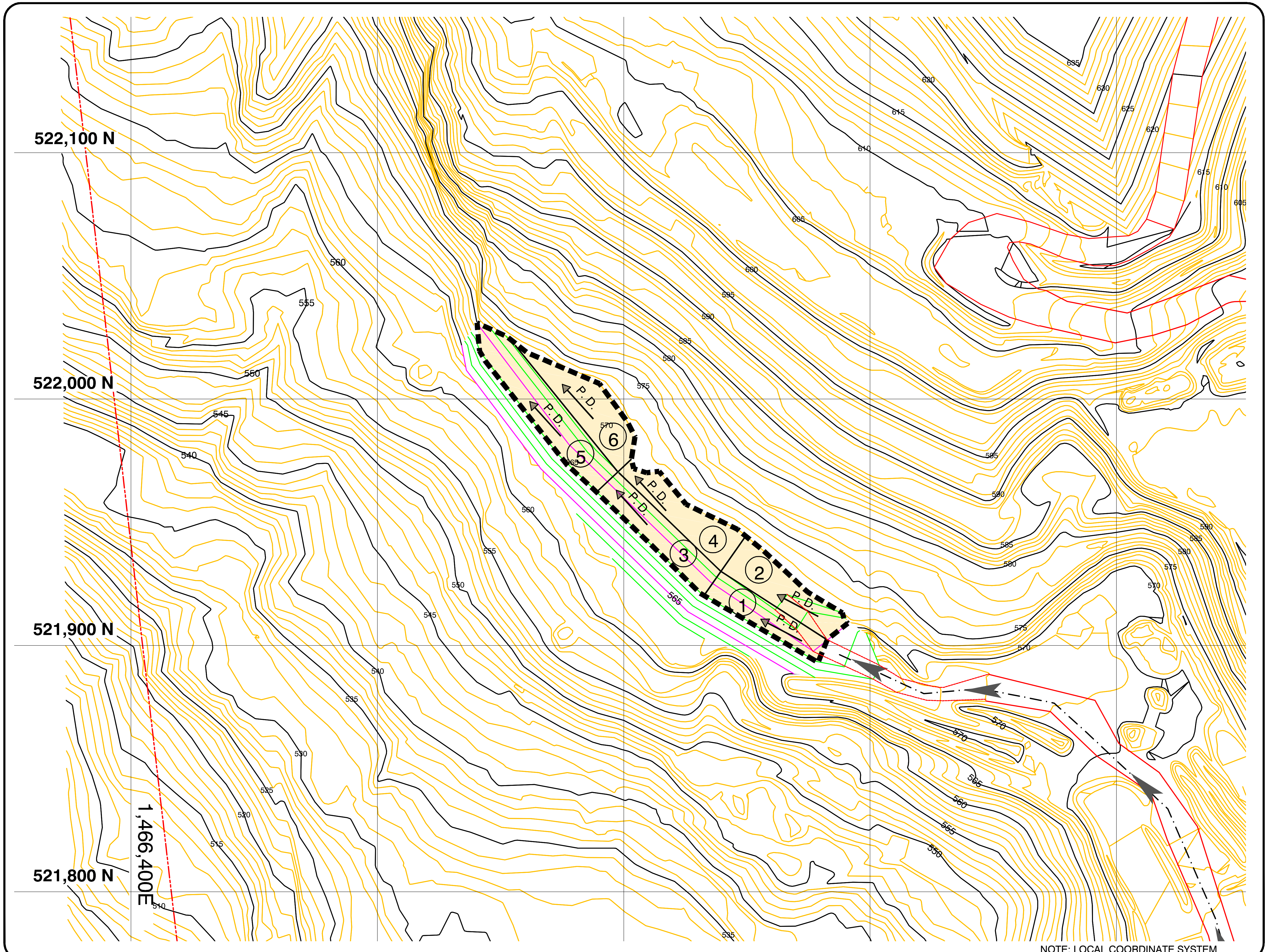
CLIENT: REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT: RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN AND OPERATIONS PLAN

TITLE: PHASE 2 - LIFT 2(565 m to 568 m)

SCALE:	DATE:	PROJECT NO:
1:1,500	2016/07/04 (yyyy/mm/dd)	PRJ15061

		DRAWING NO:
DESIGNED	SG	FIGURE 6-11
DRAWN	SG	
CHECKED	IB	



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North Vancouver, B.C. V7J 1J3

Phone: (604) 986-7723
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LEGEND:

- OPERATIONAL ROAD
- DESIGN ROAD
- DITCH
- 5 m EXISTING CONTOURS
- 1 m EXISTING CONTOURS
- 5 m PHASE 1 CONTOURS
- 1 m PHASE 1 CONTOURS
- FENCE
- PROPERTY BOUNDARY
- (7) LIFT REFERENCE
- LIFT BOUNDARY
- LIFT FILL AREA
- P. U. FILL DIRECTION - PUSHING UP
- P. D. FILL DIRECTION - PUSHING DOWN

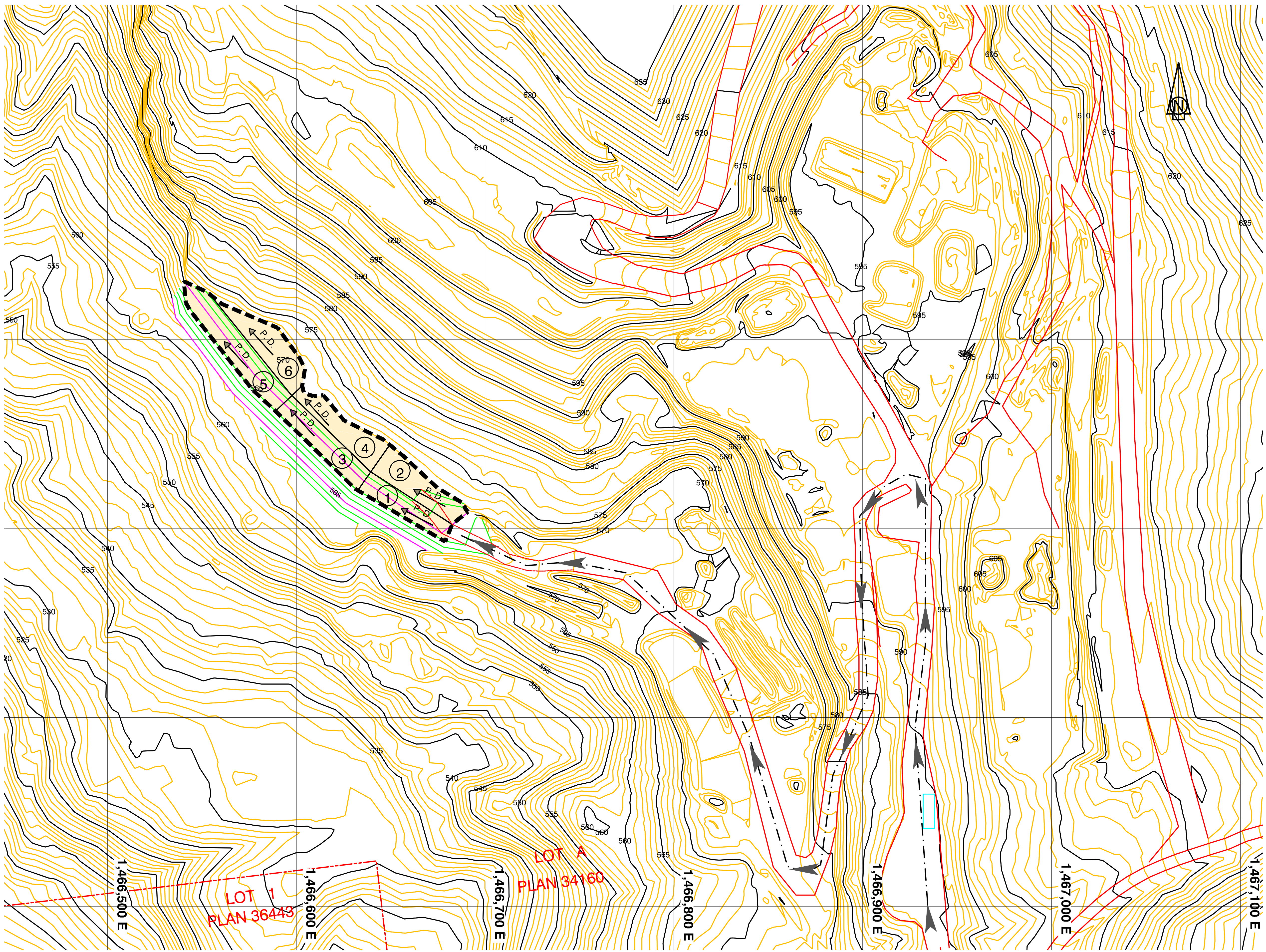
CLIENT:
REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN AND OPERATIONS PLAN

TITLE:
PHASE 2 - LIFT 3(568 m to 572 m)

SCALE:	DATE:	PROJECT NO:
1:1,500	2016/07/04 yyyy/mm/dd	PRJ15061

DESIGNED	SG	DRAWING NO:
DRAWN	SG	FIGURE 6-12
CHECKED	IB	



SPERLING HANSEN ASSOCIATES

Landfill Services Group
Landfill Siting
Design & Operations Plans
Landfill Closure
Environmental Monitoring

#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3

Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- OPERATIONAL ROAD
- DESIGN ROAD
- DITCH
- TRAFFIC FLOW TO PHASE 2
- 5 m EXISTING CONTOURS
- 1 m EXISTING CONTOURS
- 5 m PHASE 1 CONTOURS
- 1 m PHASE 1 CONTOURS
- FENCE
- PROPERTY BOUNDARY
- 7 LIFT REFERENCE
- LIFT BOUNDARY
- LIFT FILL AREA
- P. U. FILL DIRECTION - PUSHING UP
- P. D. FILL DIRECTION - PUSHING DOWN

CLIENT:
REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN AND OPERATIONS PLAN

TITLE:
PHASE 2 TRAFFIC FLOW AND ACCESS ROAD

SCALE:	DATE:	PROJECT NO:
1:1,500	2016/07/04 yyyy/mm/dd	PRJ15061

DESIGNED	SG	DRAWING NO:
DRAWN	SG	FIGURE 6-13
CHECKED	IB	

TABLE 6-1. SHA LANDFILL WIZARD CELL GEOMETRY SPREADSHEET
Campbell Mountain Landfill USING ADC FOR DAILY OPERATIONAL COVER AND SOIL COVER EVERY 4 WEEKS

Input Data:

Incoming Annual Tonnage:	30,000 tonne/yr	Daily Cover Soil Thickness:	0.3	m
Compacted Density:	0.80 tonne/m3	Intermediate Cover Soil Thickness on Top:	0.3	m
No. of days open per week:	6 days	Intermediate Cover Soil Thickness on Sides:	0.3	
Operating days between soil daily cover:	28 days	Slope Angle Ratio on Active Face:	3	
		Slope Angle Ratio on Side Slopes:	3	

Calculations:

Daily Volume of Incoming Refuse:	119.86 m3
Refuse Volume in Cell:	3356.16 m3
Active Face Multiplier:	3.16227766
Side Slope Multiplier:	3.16227766

Cell Length Calculation:

Lift Thickness (m)	Active Face Width (m) 6	9	12	15	19.5	21	25	50
0.5	1,118.72	745.81	559.36	447.49	344.22	319.63	268.49	134.25
1.0	559.36	372.91	279.68	223.74	172.11	159.82	134.25	67.12
1.5	372.91	248.60	186.45	149.16	114.74	106.54	89.50	44.75
2.0	279.68	186.45	139.84	111.87	86.06	79.91	67.12	33.56
2.5	223.74	149.16	111.87	89.50	68.84	63.93	53.70	26.85
3.0	186.45	124.30	93.23	74.58	57.37	53.27	44.75	22.37
5.0	111.87	74.58	55.94	44.75	34.42	31.96	26.85	13.42
7.5	74.58	49.72	37.29	29.83	22.95	21.31	17.90	8.95
10.0	55.94	37.29	27.97	22.37	17.21	15.98	13.42	6.71

Total Volume of Soil Summary

Lift Thickness (m)	Active Face Width (m) 6	9	12	15	19.5	21	25	50
0.5	2,547.20	2,371.74	2,284.72	2,233.08	2,185.52	2,175.28	2,152.44	2,101.09
1.0	1,543.20	1,369.16	1,283.56	1,233.34	1,187.20	1,178.39	1,156.98	1,117.96
1.5	1,210.43	1,037.81	953.64	904.84	860.13	852.73	832.74	806.06
2.0	1,045.47	874.27	791.52	744.15	700.86	694.89	676.32	661.97
2.5	947.63	777.86	696.53	650.58	608.71	604.16	587.02	585.00
3.0	883.35	715.00	635.10	590.57	550.12	547.00	531.28	541.60
5.0	760.49	597.83	523.62	484.78	450.03	452.60	442.57	502.22
7.5	707.59	552.05	484.96	453.24	425.60	435.28	432.37	553.68
10.0	688.26	539.84	479.86	455.25	434.73	451.52	455.73	638.71

Waste to Soil Ratio on Volume Basis

Lift Thickness (m)	Active Face Width (m) 6	9	12	15	18	21	25	50
0.5	1.32	1.42	1.47	1.50	1.54	1.54	1.56	1.60
1.0	2.17	2.45	2.61	2.72	2.83	2.85	2.90	3.00
1.5	2.77	3.23	3.52	3.71	3.90	3.94	4.03	4.16
2.0	3.21	3.84	4.24	4.51	4.79	4.83	4.96	5.07
2.5	3.54	4.31	4.82	5.16	5.51	5.56	5.72	5.74
3.0	3.80	4.69	5.28	5.68	6.10	6.14	6.32	6.20
5.0	4.41	5.61	6.41	6.92	7.46	7.42	7.58	6.68
7.5	4.74	6.08	6.92	7.40	7.89	7.71	7.76	6.06
10.0	4.88	6.22	6.99	7.37	7.72	7.43	7.36	5.25

(grey) Designates Recommended Cell Dimensions
(blue) Identifies Optimum Cell Dimensions

7. ENVIRONMENTAL CONTROLS

7.1 Leachate Management

Uncontrolled release of leachate into the environment, either into groundwater or streams, is frequently perceived to be the greatest potential environmental threat at landfill sites. It has been SHA's experience that leachate management can become a major environmental issue, especially at landfills located in coastal B.C. where rainfall rates are high. Examples of B.C. landfill locations where significant quantities of leachate are produced and where its management has been an engineering challenge include Hope, Terrace, Vancouver, Prince Rupert, Victoria, Nanaimo, Whistler, Squamish and Chilliwack. On the other hand, in our experience, landfills located in areas that receive less than 600 mm of precipitation annually seldom experience serious leachate management problems. These sites include Keremeos, Princeton, Prince George, Smithers, Logan Lake, Kamloops and Heffley Creek. Many landfills in the interior of B.C. operate as unlined, natural control sites without adverse groundwater or surface water impairment. CMLF receives about 346 mm of precipitation annually. Therefore, potential leachate impact issues at the site are expected to be moderate and manageable. However, historical disposal of septage and poor management of run-on has exacerbated the water quality problem at the site, leading to the formation of a leachate plume.

Landfill leachate is generated by precipitation filtering through the soil cover into the underlying refuse layers and from moisture contained in the waste being squeezed out by compaction from the weight of overlying solid waste. It may also be generated when surface water is not managed properly onsite and is allowed to infiltrate through low grade unlined ditches on when uncontrolled run-on flows onto the site. The volume of leachate depends on several factors: the most relevant are climate, the surface area of the cells and the type of cover incorporated in the refuse.

7.1.1 Leachate Generation Potential

The leachate generation potential at the CMLF is low, based on the amount of precipitation experienced in the area, annual water surplus and natural attenuation in the underlying material. Figure C-1 in Appendix C shows leachate generation potential of the CMLF site.

7.1.2 Leachate Management Strategy

The leachate management concept for the CMLF has been developed to achieve the following objectives:

- Keep clean water clean by diverting run-on and run-off; and
- Minimize percolation by designing an evaporative cover system that minimizes the infiltration.

Leachate is not being collected at the CML site at this time and the landfill is being operated as a natural attenuation landfill. In order to meet regulatory requirements and to contain leachate so as to limit future groundwater and surface water impairment, SHA recommends that future phases (Phase 2 to 4) of the landfill be constructed with basal liners as discussed in Chapter 3 and shown in Figure 7-1. Soil will be excavated from a borrow area for each phase within the landfill footprint, which will result in increased space for landfilling. SHA recommends that the base of the new phases be lined with 60 mil High Density Polyethylene (HDPE) geomembrane underlain by a low permeability soil such as a silt or clay. If low permeability soil is not readily available in the area, the secondary containment layer may include a geosynthetic clay liner.

Initially, the leachate collection system will consist of a series of leachate pumping wells or sumps developed in a row along the southwest toe of the site. Leachate which has infiltrated the groundwater table will be collected and stored in a lined pond near the pumping wells. Collected leachate will be allowed to evaporate and surplus water will be stored in the pond for dust and fire suppression requirements at the site and for irrigation of the planned phytoremediation area.

Leachate collected from the liner areas of each future phase will be conveyed through perforated and solid collection and conveyance pipes to the leachate/storm water pond at the toe of the site. Leachate collection from lined expansion areas will begin once the Phase 2 borrow area is exhausted and the area is lined in preparation for waste filling. Given the topography of the site and the location of the leachate / surface water pond, all collection and conveyance of leachate will be done by gravity. Leachate collection from the subsequent phases will be tied into the collection system installed in Phase 2. The conceptual plan showing the leachate collector system for the landfill is provided in Figure 7-2. The conceptual layout of the leachate header pipes and the leachate laterals are also shown. The excavated contours of the borrow areas for lateral expansion have been designed to allow for gravity flow of leachate for Phase 2 through 4.

In order to further eliminate the interaction of buried waste and run-on surface and ground water, the RDOS is planning to upgrade the run-on diversion ditching and infrastructure in the next 1-2 years. Run-on from Spiller Road and the upland portion of the site will be diverted around the waste filling areas to the leachate / storm water pond at the landfill toe or re-directed back into the natural water course in the ravine located to the southwest of the site.

In addition, the current biosolids composting area operated by the City of Penticton (CoP) needs to be upgraded. Currently, run-off from composting operation is allowed to infiltrate into the soil below and mix with waste as well as drain to the south and east where it is collected and conveyed offsite as clean surface water. Based on this plan, SHA envisioned the biosolids composting operations to be relocated during Phase 1 so that recycling operations can be moved to the current CoP composting area during Phase 2. SHA recommends the area be lined with an environmental containment system or be paved with asphalt. In addition, internal ditching, leachate collection and storage will need to be included in the upgrades. Lined ditches around the perimeter of the composting operation would suffice in collecting any run-off and a lined sump or tank allow for short term storage before treatment. Collected leachate from the biosolids composting operation could be irrigated back onto the composting material windrows or transported to the leachate treatment pond at the southwestern toe of the site.

7.1.3 Leachate Collection

The liner system is comprised of two parts: the leachate collection system and the leachate barrier system. The leachate collection system will be comprised of 300 mm of coarse drain rock overlain by a

150 mm filter layer to protect the system from biological clogging. This layer conveys the leachate by gravity to the header shown in Figure 7-2 which then carry the leachate to the southwest leachate/ stormwater pond. The liner system underlying the collection blanket will be protected by a geotextile separation layer and a 200 mm sand cushion layer. The barrier portion of the liner will be a geocomposite system which includes a 60 mil HDPE geomembrane in direct contact with a well compacted 300 mm low permeability soil such as silt or clay or GCL.

At the base of the landfill, leachate will be directed to the south leachate/storm water pond through sloped contouring of the cell floor and drained via solid/perforated HDPE piping. Smaller diameter feeder pipes will connect to a central header pipe. Piping will be sized to maximize the design flow and thereby minimize accumulation of biomass. The wall thickness of the pipe will be sized to withstand the overlying load. The layout of the collection and transfer piping will be kept as straight as practical, with ports and access points provided for cleanout and maintenance. After each landfill phase has reached capacity it will be capped with low permeability clay and biocover evaporative cap to virtually eliminate infiltration of precipitation and the resulting generation of leachate.

Leachate generated by the landfill will also be collected via a series of leachate pumping wells or sumps aligned along the southwest toe of the site as outlined above. It is proposed that the series of pumping well or sumps will follow an alignment where the bedrock is closest to the existing ground surface as well as where a natural ‘trough’ exists in the bedrock contours. Review of the monitoring wells borehole data shows the fractured bedrock exists approximately 10 m below the existing ground surface in the area shown by the series of pumping wells outlined on Figure 7-2. The design of leachate pumping wells will be further detailed and investigated during the proposed leachate pump test planned in the Spring / Summer of 2016.

Prior to drilling off the wells it is not possible to ascertain whether the water is flowing in the soils at the bedrock interface or within fractures in the bedrock. If water is present above the bedrock then the most efficient way to capture it will be by constructing a series of large diameter sumps with concrete well barrels. If the water flows in fractures then closely spaced wells drilled into the fractured rock mass will be required.

7.1.4 Leachate Treatment

The leachate treatment procedure recommended for the CMLF will be a combination of evaporation, leachate re-use for dust suppression and fire suppression, aeration as well as phytoremediation. Treatment techniques / options will be phased in depending on the amount of leachate collected as the landfill developed. Table 7-1 below shows phase by phase leachate generation with clay cover option and considering that the entire landfill except the closed area during a particular phase is open and generating leachate that will be collected. After Phase 2 closure, Phase 3 operation will need to be managed in such way that runoff that does not get in contact with waste remains clean and managed separately. This can be achieved by compartmentalizing the liner area for active filling.

Table 7-1 Leachate Generation Summary

	Leachate Generation:	Open		37.47	mm/yr	
	(Clay Cap)	Closed		24.2	mm/yr	
Phase	**Active Area (m^2)**	**Existing Open Area (m^2)**	**Piggy Back Area(m^2)**	**Closed Area (m^2)**	**Total Area (m^2)**	**Leachate Quantity (m^3)**
Phase 1	26,900	193,100	-	-	220,000	8,243
Phase 2	84,888	135,112	-	-	220,000	8,243
Phase 3	35,255	99,857	16,055	68,833	220,000	7,330
Phase 4	88,723	27,189	12,842	91,246	220,000	7,033
Phase 5	97,675	- 17,644	16,945	163,024	260,000	7,579
All Closed	0	0	0	260,000	260,000	6,292

The above table shows leachate generation for the clay cap option. For the gemembrane cap option, leachate generation would be significantly less with progressive closure and keeping clean water clean.

7.1.4.1 Short Term Leachate Treatment

Short term leachate treatment options are detailed below and will consist of evaporation, dust suppression and fire control, facilitating treatment and mixing with clean run-off introduction in the storm water pond to be constructed in the southwest corner. The leachate treatment system will potentially include discharge to a phytoremediation plantation if collection volumes dictate that it is necessary.

Leachate Evaporation

Due to the arid nature of the CMLF site, the leachate that is collected from the in-ground leachate pumping wells and lined areas of the site will remain stagnant during summer months. This will allow significant volume of leachate/storm water to evaporate. If the collected leachate volumes become too large to evaporate during the hot and dry summer months, a pumping system will be required to convey leachate from the southern portion of the site to the initial Phytoremediation Area – 1 to the southwest side of the site, as outlined in Figure 7-3.

The volume of leachate collected from the leachate pumping wells/sumps will be further defined during the leachate pump test. This analysis will determine whether a separate leachate pond will be required in the near future or whether it may be deferred until the basal liner in Phase 3 is constructed. If the pond is not required immediately, onsite storage may be required or it may be pumped to the Phytoremediation Area – 1 or to the local sewer collection system.

A leachate pond of volume 5,000-10,000 m^3 will likely be required at the north east corner of the site, as shown in Figure 7-2, based on the future assessment of leachate generation.

Fire and Dust Control

The leachate from the leachate/storm water collection ponds will be re-used for fire and dust control purposes in areas not travelled by the public. Options to divert clean run-on and run-off from the site to the leachate / surface water ponds should be made. This will allow for the option of both diluting collected leachate as well as ensuring sufficient storage is in place for dust suppression and fire control. Currently, there is no fire control water supply for the site. A large water source sufficient to deal with small onsite fires is urgently needed.

7.1.4.2 Long Term Leachate Treatment

Long term leachate treatment options are outlined in detail below. Treatment options will consist of active aeration treatment in the leachate pond, evaporation and phytoremediation using hybrid poplar plantation, as illustrated in Photo 7-1.

Photo 7-1: 7 Mile Landfill Leachate Treatment System in Operation, 2010

Phytoremediation

Collected leachate from the leachate pumping wells/sumps and the future lined areas of the site will be stored in the southwest leachate and storm water pond and/or in the second pond to be constructed in the northeast corner. Stored leachate will be actively treated through aeration in the storage ponds as required. Treated leachate will then be conveyed to phytoremediation areas and used to irrigate hybrid poplar plantations which will uptake the leachate at a controlled application rate.

Three phytoremediation areas are envisioned for the site. These will be constructed and brought online as required. The phytoremediation areas are presented on Figure 7-3. Phytoremediation Area – 1 is proposed to be developed on the west side of the property adjacent to the storm water pond, within the property footprint. This area may be required as soon as the leachate pumping wells volumes are established based on the pump tests and the leachate capture system is installed. Phytoremediation Area – 2 is envisioned on the Phase 2 closure area once that phase is completed and has undergone final closure. Phytoremediation Area – 3 is envisioned on the landfill crest on completion of Phase 5. The size and specifics of each phytoremediation area will need be further developed once collection volumes are known and will require further detailed design.

7.2 Surface Water Control

One of the primary objectives of the surface water management plan is to minimize leachate production by diversion. This will be achieved by diverting clean run-on, minimizing percolation through the top surface of the landfill and enhancing run-off from the landfill. Secondary objectives are to prevent erosion of the operational and final cover systems, prevent ponding of surface water on the cover system, control flooding of active landfill areas and control surface water in a manner compatible with the proposed end-uses. In order to manage the surface water from the CML site and to protect the area from erosion, toe ditches lined with an erosion control fabric can be installed along the east and west edges and the toe of the landfill footprint and along the access roads, for surface water drainage. The mid-slope drainage ditches will be constructed on the upper side of the mid-slope access roads. The mid-slope ditches will collect runoff falling on the closure areas above, and direct it to the surface water ditch running along the toe which will eventually discharge into the southwest storm water pond if needed, or will discharge into the existing ravine where runoff currently discharges.

Additionally, run-on surface water from the Spiller Road catchment area and the upland portion of the site will be addressed in the detailed design of the upslope drainage improvement upgrades currently underway.

7.2.1 Toe/ Road Ditches

In order to determine the sizing of the toe/road swales/ditches, peak flows were determined using the Rational Method, which is commonly used to determine the peak flow runoff rates in small watersheds as a conservative approach. The rationale for the method is that steady uniform rainfall intensity will cause runoff to reach its maximum rate when all parts of a watershed are contributing to the point of outflow. This is dependent on the time of concentration, which is taken as the time for water to flow to the outflow from the most remote point of the watershed. Along with the rainfall intensity and drainage area, which are relatively straightforward to determine, the peak flow is dependent on the runoff coefficient. The runoff coefficient is dependent on the final cover design. It is primarily influenced by topography, vegetation, the seasons and the subsurface material type. The method and coefficients for the analysis were obtained from the BC Agricultural Drainage Manual (1997). This method allows variations of the material types, the vegetation types and the topography (slope) conditions. The Intensity-Duration-Frequency (IDF) curve for 'Penticton A' weather station, as shown on Figure 7-4 was used to predict storm intensities.

SHA recommends toe ditches with a triangular cross section, 1.0 m depth and 2.5H:1V side slopes lined with an erosion control blanket. The design concept for the ditches can be revisited during detailed design. Figure 7-5 shows the location of the ditches, while Figure 7-5a shows a conceptual surface water ditch for CMLF.

7.2.2 Midslope Ditches

The mid-slope drainage ditches will be constructed on the upper side of all mid-slope access roads. The mid-slope ditches will collect runoff falling on the closure areas above, and direct it to the toe run-off collection ditch which will then discharge into the storm water pond as shown on Figure 7-5. Based on the run-off analysis using Rational Method, the ditches will need to be triangular in shape and have a total depth of 1.0 m, with side slopes at 2.5H:1V.

Control of erosion in the ditch is a key consideration. The bottom 0.5 m of the ditch will be filled with a 300 mm thick layer of rip rap or similar material. The remaining slope of the ditch will be covered with a biocover blend. The entire ditch will be covered with Erosion Control Blanket and on the upslope side of the ditch straw wattle will be installed. It may be possible to replace the rip rap with a less expensive erosion control mat, as shown in Photo 7-1. This should be assessed during detailed design.

7.2.3 Midslope Berm

In order to ensure stability of the landfill as well as to facilitate smooth drainage of surface water SHA usually provides midslope berms at every 15 m interval when the overall height of the landfill is more than 20 m. Photo 7-2 shows a midslope berm with ditch at Vancouver Landfill, Delta, BC.

SHA typically recommends a 4-5 m wide berm having the midslope ditch run along its inside shoulder. However, since the midslope berms will be used as the main access to the crest of the CML during post closure, SHA has designed the midslope berms, including the ditches, with a width of 15 m as shown in Figure 7-5.

Photo 7-2: Midslope Berm and ditch at Vancouver Landfill (Delta, BC)

7.2.4 Storm water Retention Ponds

The storm water retention pond cum leachate pond at the southwest toe of the site may be required in the near future depending on the findings from the leachate pump test, slated for late in the Spring of 2016. Surface water collected from the site as well as the run-on diversion flows will be directed to the southwest pond with the option of collection and storage or diversion offsite. SHA conducted an analysis to estimate the required volume for a ‘one day’ retention time for 1 in 100 year rainfall event which was found to be around 19,000 m^3. The proposed southwest pond is approximately 150m x 50m x 2m with a side slope of 2.5:1. These dimensions resulted in a volume of 10,000 m^3.

7.2.5 Upslope Surface and Ground Water Run-on Collection

SHA has been retained by the RDOS to complete a detailed review of the existing run-on diversion drainage system in place and provide comments and design for upgrades to the system. Currently, run-on from the Spiller Road catchment and the upland areas of the site is inefficiently collected in a small ditch to the east of the waste footprint and directed through a series of culverts and ditches and discharged back into the environment at the southwest corner of the site.

SHA's review and recommendations for upgrades to the system will include diversion ditches trenched into the fractured bedrock where the bedrock is within 1-3 m of the existing ground surface, shotcrete ditch liners will provide an impervious conveyance for a short term solution. For long term solutions, when waste filling is relocated to the Phase 4 and 5 filling areas, the collection and conveyance alignments will be upgraded with both perforated collection pipes and solid conveyance piping.

All collected surface and ground water will be conveyed to the southwest portion of the site with the option of discharge to the leachate / storm water pond for mixing and storage requirements or discharge offsite.

7.3 Landfill Gas Management

7.3.1 Introduction

Landfill gas (LFG) emissions and odours are a concern due to potential health issues, nuisance odours and because the LFG contributes to global climate change. If LFG is not vented, gas pressures can build up beneath a final cover, ultimately leading to uplift of the cover system. Additionally, gas can migrate from the site to nearby properties and structures if it is prevented from venting directly to the atmosphere and / or if there is a preferential pathway for the gas to travel easily off the site.

LFG is a by-product of the natural decomposition of organic materials in landfills. The most common form of LFG, which is created when biological anaerobic decomposition occurs, consists primarily of equal parts methane (CH_4) and carbon dioxide (CO_2). Other trace constituents include more than 166 different Non-Methane Organic Compounds (NMOC), nitrogen (N_2) and oxygen (O_2); the concentrations of these constituents are subject to the amount and composition of contributing waste material within the landfill, the decomposition rate of the specific contributing material, and the level of atmospheric air intrusion into the landfill.

Methane, at concentrations between 5 to 15 % by volume in air, will cause an explosion if it comes in contact with an ignition source (flame). The lower end of the range (5%) is referred to as the lower explosive limit (LEL). Combustible gases are a concern in relation to LFG migration issues.

Carbon dioxide, another major component of LFG, is found at low concentrations in atmospheric air. The main danger posed by CO_2 is that it can displace atmospheric air in confined structures such as manholes and wells. This could cause asphyxiation for someone entering such a structure without properly checking the conditions.

LFG may also contain Hydrogen Sulphide (H_2S), which originates from biological consumption of sulphur found in gypsum wallboard, depending on the sulphur content of the waste filled. Hydrogen Sulphide is highly toxic in concentrations above 50 ppm. Normally H_2S can be smelled at concentrations as low as 0.05 ppm, and by 3 ppm, a distinctive odour of rotten egg is normally noted. A concern with H_2S is the ability to smell the gas is gradually decreased during exposure. At concentrations between 10 and 50 ppm, most people experience headaches and nausea.

7.3.2 Landfill Criteria

According to the British Columbia (BC) Landfill Criteria (Landfill Criteria) for Municipal Solid Waste (1993), landfills with more than 100,000 tonnes of refuse require an assessment of the potential emissions of NMOCs. If the assessment reveals that the emission of NMOCs exceeds or is expected to surpass 150 tonnes/year, the installation and operation of a landfill gas recovery and management system is mandatory.

The new LFG Management Regulation, that came into effect on January 1st, 2009, is stricter to support BC's commitment to reduce greenhouse gases by at least 33% below the 2007 levels by 2020. The regulation applies to landfill sites that accept Municipal Solid Waste (MSW) for disposal on or after January 1st, 2009 or which have 100,000 tonnes or more of MSW in place, or receive 10,000 tonnes or more of MSW for disposal into the landfill site in any calendar year after 2008. If a landfill is determined to generate 1,000 tonnes or more of methane per year, the regulation requires that an active landfill gas management system be installed by 2016. This system, if required, is to collect LFG actively and reduce methane emissions by flaring or other methods that would result in the same amount of emission reduction as flaring. The gas management facility can be shut down if the methane generation estimate falls below 500 tonnes/year.

7.3.3 Landfill Gas Generation Estimate

There are several LFG generation models which help landfill designers, operators and regulating authorities to estimate the amount of methane generated in the landfill. Due to the highly heterogeneous nature of landfills and effects of several dynamic parameters that affect gas generation, these models are not 100% accurate. Normally, providing better quality of historical data and information to models increases the accuracy of the model output.

Among the LFG generation models, the first order decay (FOD) model has been the most widely used. In this model, it is assumed that degradable materials in the waste are decomposed at a constant rate over a period of time. The FOD model assumes that the total amount of carbon decreases gradually (consumed by the bacteria) and therefore the rate of gas generation decreases every year after it peaks in the first few years. The USEPA LandGEM model (2003) , BC MOE Landfill Gas Generation Tool (MOE Tool) (2008), the Intergovernmental Panel on Climate Change model (IPCC Model) (2006), and the UBC Integrated Model (UBCiModel) (2014) are all based on the first order decay reaction with a range of model specific parameters that makes some of these models more complicated and more accurate.

7.3.4 Previous LFG Generation Assessments

Conestoga-Rovers & Associates (CRA) completed an LFG generation assessment for CML in 2010 using the MOE Tool. Based on that generation assessment, the CML was generating about 1,400 tonnes of methane in the assessment year (CRA, 2010). The RDOS retained SHA in 2012 to undertake more advanced LFG generation modeling for this site. We utilized the IPCC model indicating that the CML was producing 1,150 tonnes of methane per year (SHA, 2012). Furthermore, SHA completed more advanced modelling in 2014 using the recently developed UBCiModel. This analysis showed that the CML was generating approximately 800 tonnes of methane per year. The results of this later analysis were further confirmed by a full-site methane emission measurement completed in CML by SHA in 2014. The emission measurement was conducted using an innovative approach developed at the University of British Columbia (Abedini, 2014). These measurements showed that the CML was realising approximately 550 tonnes of methane to the atmosphere in 2014. Due to the lower than expected methane emissions combined with the dry climate at the CMLF, this landfill is a good candidate for an alternative LFG management system as per the substituted requirements permitted in the Landfill Gas Management Regulation.

7.3.5 Updated LFG Generation Assessments (IPCC and UBCiModel)

In order to update a theoretical LFG generation assessment for the CML site, SHA used the IPCC model and the lifespan analysis presented in Chapter 5. Furthermore, we conducted the analysis using the UBCiModel which appears to provide the most realistic generation estimates based on our experience using this model for multiple sites where active gas collection systems are operational (e.g. Vancouver Landfill, Mission Flats Landfill) and the actual gas generation rates can be measured.

IPCC Model: The IPCC FOD basically relies on two parameters, the methane generation potential ($L_\circ$, m^3 CH_4 per tonne of waste), and the methane generation rate constant (k, yr^{-1}). The value of $L_\circ$ directly depends on the decomposable degradable organic carbon mass (M) landfilled each year and the value of k is primarily a function of factors such as, moisture content of the waste mass, availability of the nutrients for microorganisms that break down the waste to form methane and carbon dioxide, and pH and temperature of the waste mass, etc..

Methane Correction Factor: Methane Correction Factor (MCF) is an important parameter in the IPCC FOD model which is solely related to the type of landfill operation and management. Based on the IPCC suggestion this factor is within the range of 0.4 to 1.0 depending on depth and management scheme of the landfill. For the Campbell Mountain Landfill, MCF is assumed to be 0.4 between the years of 1972 and 1982 (waste depositions occurred more than 30 years before this assessment), 0.6 from 1983 to 1990, 0.8 from 1991 to 1999, and 1 for 2000 until the estimated closure date (i.e. 2104 as presented in lifespan analysis in Chapter 5).

Methane Generation Rate (k): In its 2006 guideline, IPCC has suggested different k values for each component of waste depending on climatic conditions. Climatic conditions for the CML is assumed to be Dry Temperate (i.e. Mean T <20˚C and the mean annual precipitation (MAP) less than the annual potential evapotranspiration (PET)). Table 7-2 presents the k values for each of the solid waste components suggested in the IPCC guideline.

Table 7-2 Default methane generation rates (k) ($year^{-1}$) for MAP/PET<1 and T<20° C (IPCC, 2006)

Methane generation rate constant (k) ($years^{-1}$)	Range	Default
Food waste / Sewage sludge	0.05 - 0.08	0.06
Garden and park waste (non-food)	0.04 - 0.06	0.05
Paper and Textiles	0.03 - 0.05	0.04
Wood and straw	0.01 - 0.03	0.02
Bulk MSW or industrial waste	0.04 - 0.06	0.05

Degradable Organic Content: Degradable Organic Content (DOC) of the landfill is one of the most important parameters in calculating the gas generation from the landfill. DOC content, which is based on the composition of waste, can be calculated from the weighted average of the carbon content of various components of the waste stream. IPCC in its 2006 guidelines for national GHG inventories has suggested the default DOC values for the major types of waste which are presented in Table 7-3 below.

Table 7-3 IPCC's default DOC content for different MSW components (% of wet waste)

Waste Stream		DOC content in % of wet waste	
		Range	Default
A.	Paper and Cardboard	36-45	40
B.	textiles† and Nappies	20-40	24
C.	Food waste	8-20	15
D.	Wood	39-46	43
E.	Garden and park waste	18-22	20
F.	Rubber and Leather‡	39	39
G.	Plastics, Metal, Glass and other inert materials	0	0

†40 percent of textiles are assumed to be synthetic

‡Natural rubbers would likely not degrade under anaerobic condition at landfills, hence only half is incorporated

Then the percent DOC (by weight) is equal to:

$$DOC = 0.4(A) + 0.24(B) + 0.15(C) + 0.43(D) + 0.2(E) + 0.39(F) \quad \text{(Eq.1)}$$

Where: A = percent MSW that is paper

B = percent MSW that is textile or nappies

C = percent MSW that is food waste

D = percent MSW that is wood

E = percent MSW that is garden and park waste

F = percent MSW that is Rubber or Leather

Accuracy in the information about waste composition deposited into the landfill plays a significant role in calculating the DOC values each year.

7.3.6 First Order Decay Model Equations

The basic equation for the FOD model is:

$$M = M_{\circ} * \exp(-kt) \quad \text{(Eq.2)}$$

where $M_{\circ}$ is the mass of decomposable DOC (DDOC) at the start of the reaction, when t = 0 and exp(-kt) = 1, k is the reaction constant and t is the time in years. M is the mass of DDOC at any time.

From Equation 2 it is easy to see that at the end of year 1 the mass that is left un-decomposed in the landfill is:

$$M(1) = M_{\circ} * \exp(-k) \quad \text{(Eq.3)}$$

therefore, the mass decomposed into CH_4 and CO_2 after 1 year will be:

$$M_d(1) = M_{\circ} * [1 - \exp(-k)] \quad \text{(Eq.4)}$$

and the amount of CH_4 generated from decomposition of DOC is equal to:

$$CH_4 \text{ generated} = M_d * F * 16/12 \quad \text{(Eq.5)}$$

Where, F = Fraction of methane by volume in generated LFG (about 50%)
16/12 = Molecular weight ratio of CH_4 and C

In a first order reaction, the amount of product (M) is always proportional to the amount of reactant ($M_{\circ}$). This means that it does not matter when the waste was deposited. This also means that when the amount of waste accumulated in the landfill is known, methane production can be calculated as if every year is year number one in the time series, then all calculations can be done by equations (Eq.3) and (Eq.4) in a simple spreadsheet.

The default assumption of the FOD model is that CH_4 generation from all the waste deposited each year begins on the 1st of January in the year after deposition. This is the same as an average six month delay until substantial methane generation begins (the time it takes for anaerobic conditions to become well established).

7.3.7 Updated LFG Generation Model Results

The IPCC model estimates that the CMLF is currently (2016) producing 1,211 tonnes of methane, equivalent to 243 scfm landfill gas. As discussed in Chapter 5, the RDOS has taken an intiative for organic diversion to reach their target. The diversion rate is expected to reach 73% by 2019. Due to implementation of high organic waste diversion rate, to waste tonnage and the relative amount of organics (hence DOC) going to the CMLF will significantly reduce by 2019. As a result, the methane generation rate will start declining as of 2020. Due to the increase in service population and waste tonnage received at the landfill, the methane generation rate will once again pick up an increasing trend as of 2050. This amount will peak in 2105 (1 year after the final closure of the site) at rate of 1,313 tonnes/year of methane (263 scfm LFG) and will decline until it drops below 500 tonnes of methane in 2132.

Figure 7-6 illustrates the estimated LFG flow rate and the annual methane generation rate at the CMLF during its lifespan using the IPCC Model.

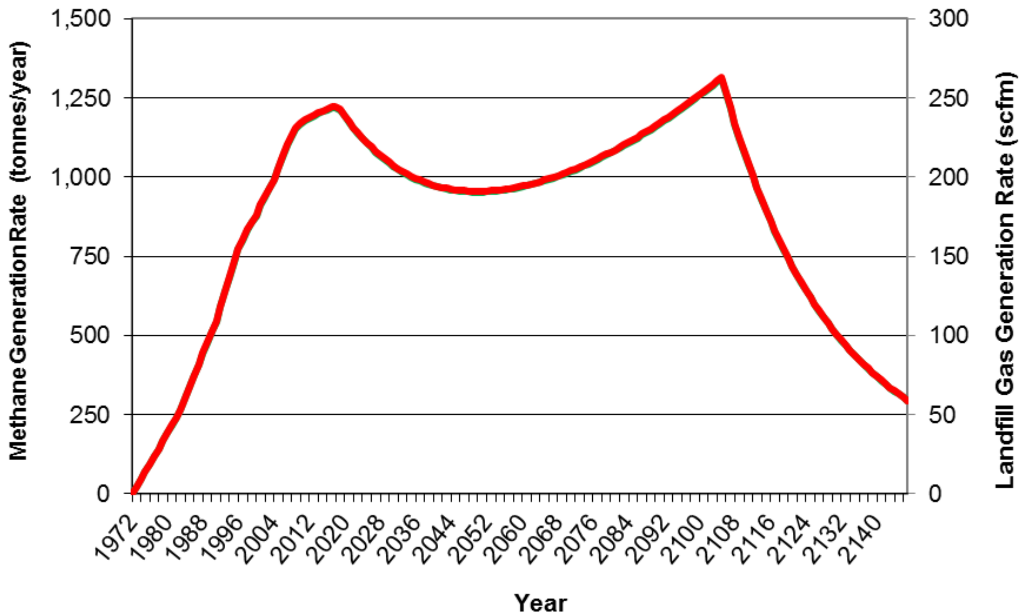


Figure 7-6 Landfill Gas and Methane Generation Estimates (IPCC Model)

UBCiModel: The UBCiModel results showed a similar trend of LFG generation during the CMLF lifespan. However, this model showed in average 31% less generation in comparison with the IPCC Model. The UBCiModel showed that the CMLF is currently producing 757 tonnes/year of methane. Implementation of the aggressive waste diversion by the RDOC will promote a temporary drop in the methane generation rates between 2019 and 2050. Eventually, the rate will peak again in 2105 at a rate of 744 tonnes/year of methane (164 scfm LFG).

Figure 7-7 illustrates the estimated LFG flow rate and the annual methane generation rate at the CMLF during its lifespan using the UBCiModel.

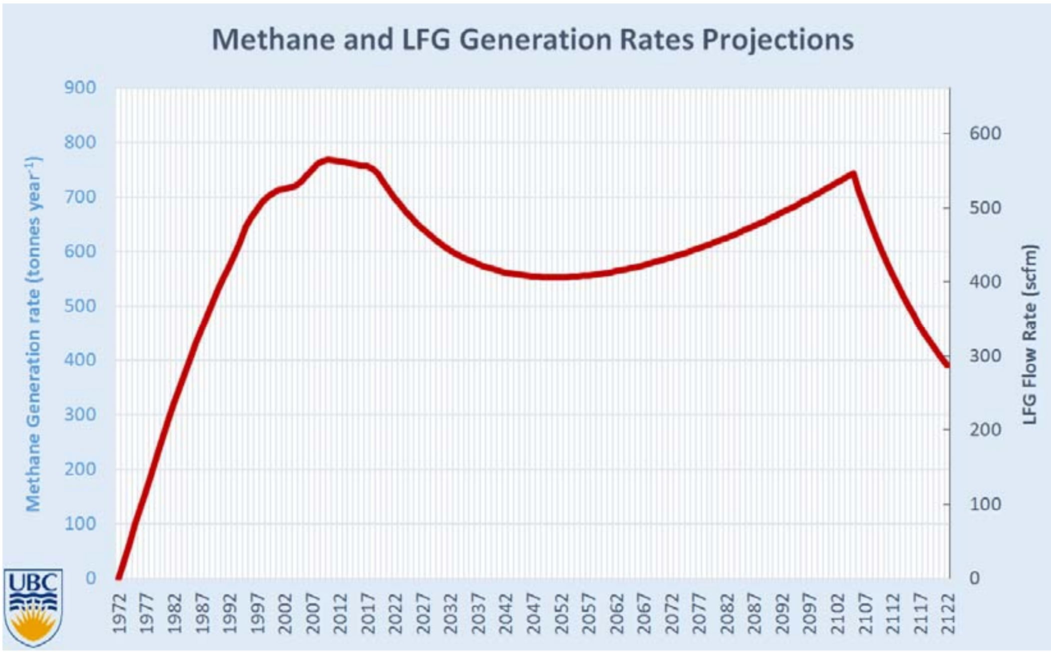


Figure 7-7 Landfill Gas and Methane Generation Estimates (UBCiModel)

Figure 7-8 shows both the IPCC Model and UBCiModel results for the CMLF for a 20 year span.

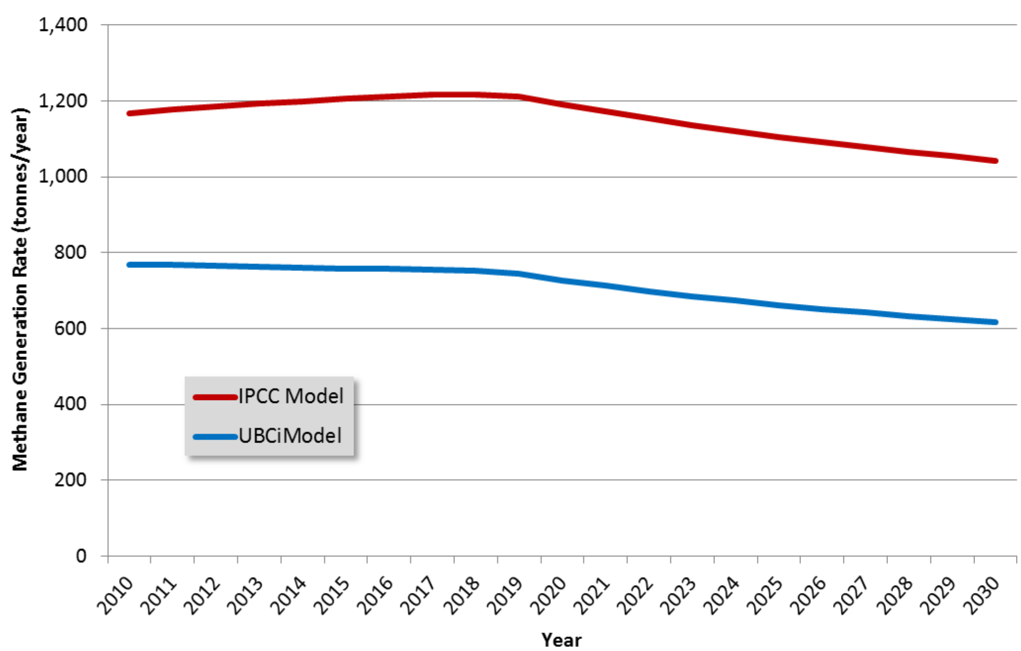


Figure 7-8 Methane Generation Estimates comparison, IPCC vs. UBCiModel, 2010-2030

7.3.8 Landfill Gas Management Strategy

As mentioned previously, the RDOS, in order to reduce the GHG emissions from the CMLF, have planned to implement an organic waste diversion program. SHA understands that the RDOS strongly believes that regional district's available resources should be focused on these waste reduction and diversion efforts. This will include diversion of 73% of organic material by 2019 that was previously decribed in Chapter 5.

Furthermore, the RDOS would prefer to use a fabricated biocover at the CMLF to oxidize any residual methane emitting to the atmosphere. SHA's several investigations and past experience have proven that from a technical perspective this strategy will result in a significant greenhouse gas (GHG) emission reduction with equal or better outcome in comparison to the construction of an active LFG collection system at CMLF.

SHA understands that according to the MOE LFG Regulation, the CMLF is required to install an active LFG management system based on the recent assessment as per the MoE Tool. This strategy would require that the RDOS invest several million in the LFG collection system and flare. Such an investment would impact the implementation of other RDOS green projects that would result in greater GHG emission reductions.

On the other hand we are aware of the over estimation issues and variation in results of LFG modeling associated with the older generation models. Our experience from existing LFG collection systems, gas generation in semi-arid areas at landfills as well as the results of the emission measurements at CMLF and the results of advanced UBCiModel show that the actual methane generation from the CMLF is about half of what is estimated using the MOE Tool. The data shows conclusively that total LFG production is well below 1,000 tonnes of methane per year which is the threshold for a LFG collection system. SHA believes that for the relatively semi-arid/ arid climate in Penticton, overall GHG impacts of solid waste management can be better managed by focusing on organics diversion and controlling of fugitive methane emissions using a biocover system than by implementing an active gas collection system.

The planned organic diversion program will achieve a total of 73% diversion rate which includes further diversion of 75% of wood waste, yard waste and paper waste that is currently being deposited into CMLF, as well as 50% diversion of food waste. The fabricated biocover will be placed at the landfill to oxidize the remaining fugitive methane that would otherwise vent to the atmosphere. With implementation of these initiatives, the RDOS will exceed the goals of the landfill gas (LFG) regulation while avoiding the large costs of an active LFG collection system at the CMLF.

In the following section, we demonstrate the long term GHG emission reduction that would be achieved under the two scenarios. These scenarios are as follow:

Scenario A - Installation and operation of an active LFG collection system.
Scenario B - Further diversion of organic waste and placement of engineered fabricated biocover

7.3.9 GHG Emissions Calculation

Methane generation and the overall emissions for the two scenarios are provided in Table 7-2 below. GHG emission reductions in Scenario A include flaring the collected methane with the active gas collection system with an efficiency of 75% and flare destruction efficiency of 99%. This system was assumed to be installed and operating starting January, 2016 as required by the BC LFG regulation. The overall GHG emissions from the CMLF in this scenario over a 20 year timeframe were about 6,600 tonnes of methane, equivalent to approximately 165,000 tonnes of CO_2-e (based on methane's global warming potential of 25).

The GHG emission reduction levels for Scenario B would be realized through two processes: (i) methane generation avoidance due to diversion of the organic wastes, and (ii) fugitive methane oxidation through a fabricated biocover. Methane avoidance due to organics diversion starts at 0% for year 1 (2016) and increases to 34% for year 20, averaging an overall 20% methane generation reduction in comparison to Scenario A. This also shows that should the analysis be conducted over a longer term, the effects of the organic waste diversion in reduction of GHG emission from CMLF could become even more significant. The overall GHG emissions from the CMLF under Scenario B over a 20 year time frame were approximately 5,100 tonnes of methane equivalent to approximately 128,000 tonnes of CO_2-e. Table 7-4 summarizes the methane generation and emission estimates for the two scenarios. Clearly, the biocover approach will result in less GHG emissions.

This analysis shows that for the relatively arid climate in Penticton, overall GHG impacts of solid waste management can be better managed by focusing on organics diversion and controlling of fugitive methane emissions using a biocover than by implementing an active gas collection system. Based on this analysis, over a 20 year time frame, implementation of Scenario B for the CMLF would result in 22% less GHG emission in comparison with Scenario A. Since methane generation avoidance due to diversion of organics from landfilling has a long term effect, this difference would be even more significant when a longer term analysis is conducted. Therefore, SHA concludes that from a technical perspective the RDOS's proposed strategy will have a better outcome while resulting in lesser overall costs. The cost comparison of the two systems is discussed in Chapter 12.

Table 7-4 Methane Generation and Emissions for Scenarios A and B

Year	Scenario A - Active LFG Collection			Scenario B - Organics Diversion and Biocover				
	CH_4			CH_4	Reduction due to Organics Diversion		Oxidized through Biocover	CH_4
	Generation	Collected	Emissions	Generation				Emissions
	tonne	tonne	tonne	tonne	tonne	%	tonne	tonne
2015	1,213	-	1,213	1,213	-	0%	-	1,213
2016	1,221	916	314	1,221	-	0%	916	305
2017	1,228	921	316	1,195	34	3%	896	299
2018	1,236	927	318	1,170	66	5%	878	293
2019	1,243	932	320	1,147	97	8%	860	287
2020	1,250	938	322	1,124	126	10%	843	281
2021	1,257	943	324	1,102	155	12%	827	276
2022	1,263	947	325	1,081	182	14%	811	270
2023	1,269	952	327	1,061	208	16%	796	265
2024	1,275	957	328	1,042	233	18%	782	261
2025	1,281	961	330	1,024	257	20%	768	256
2026	1,287	965	331	1,006	280	22%	755	252
2027	1,292	969	333	989	303	23%	742	247
2028	1,297	973	334	973	324	25%	730	243
2029	1,302	977	335	958	345	26%	718	239
2030	1,307	980	337	943	364	28%	707	236
2031	1,312	984	338	928	383	29%	696	232
2032	1,316	987	339	914	402	31%	686	229
2033	1,320	990	340	901	419	32%	676	225
2034	1,325	993	341	888	436	33%	666	222
2035	1,329	996	342	876	452	34%	657	219
Total	**25,610**	**19,208**	**6,595**	**20,545**	**5,065**	**20%**	**15,409**	**5,136**
	Collection Efficiency		75%					
	Flare Destruction Efficiency		99%					
	Biocover Oxidation Efficiency		75%					

7.3.10 Biocover System Design

Methane oxidation in landfill cover soil reduces GHG emissions from landfills. There are number of published and peer reviewed scientific research papers that have reported CH_4 oxidation fractions through operational soil cover at 22-55% (Whalen, Reeburgh et al., 1990; Chanton, Powelson et al., 2009; Chanton, Abichou et al., 2011). For engineered fabricated biocover, this rate is reported to be between 50-100%, depending on the methane loading rate provided to the biocover (Barlaz, Green et al., 2004; Stern, Chanton et al., 2007; Abichou, Mahieu et al., 2009). A number of researchers reported that in some cases, biocover even reduces the existing CH_4 concentration in the atmosphere (Hilger and Barlaz, 2007; Abichou, Mahieu et al., 2009).

SHA has designed and installed several biocovers and biofilters in a number of landfills in B.C. including:

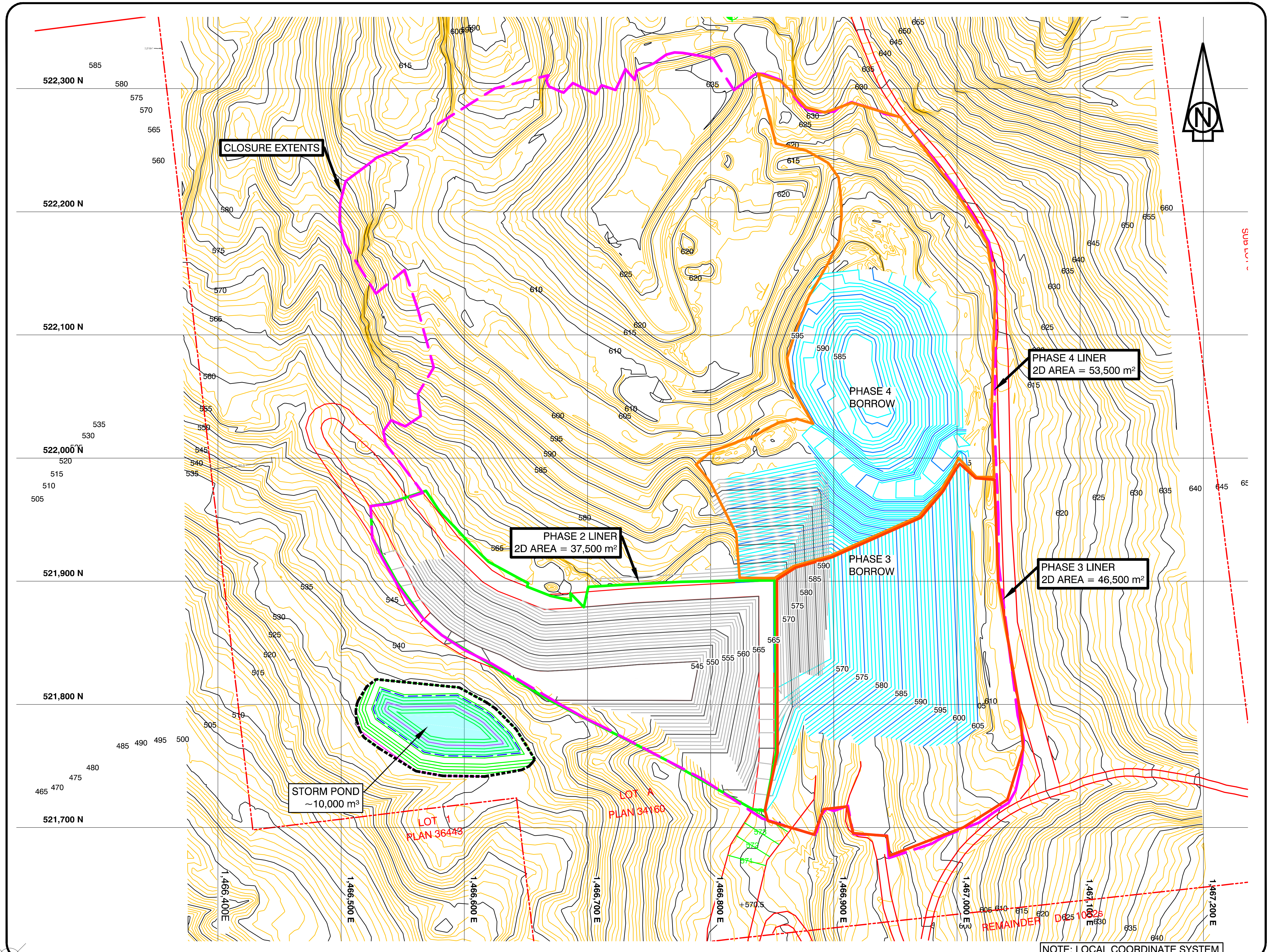
- Fernie Landfill Biofilter,
- Skimikin Landfill Biofilter,
- 7 Mile Landfill Biocover,
- Lower Nicola Landfill Biocover,
- Heffley Creek Landfill Biocover,
- Central Subregion Landfill Biocover, and
- Nanaimo Landfill.

In the aforementioned projects SHA used a fabricated media appropriate for growth of methanotrophic bacteria and results showed 80 – 100% oxidation of the fugitive methane.

SHA's field investigation at the CMLF conducted in July 2014 indicated that the average methane emission rate (MER) from this site was approximately 12 g CH_4/m^2/day. Even if the MOE tool theoretical estimates are used, this level would be within 30 to 40 g CH_4/m^2/day. We believe this level of methane loading rate can be effectively handled with a thin biocover system, including a gas distribution layer installed beneath a 300 mm thick fabricated biocover. The distribution layer will help avoid "hot spots" and high methane loading rates occurring in these areas. Accordingly, we have started implementation and field measurement of a biocover test pad at the CMLF in collaboration with the RDOS, Metro Vancouver and the University of Calgary. In this experimental work we will conduct lab analysis on various engineered biocover media (three different blends) and will install and monitor a biocover test pad onsite. The result of this work will help us further prove the effectiveness of the biocover in controlling the methane emission s from CMLF and to optimize the design of the biocover media for CMLF and using the available resources to be used in the blend.

7.3.11 Biocover System Installation

Installation of the biocover is dictated by the filling plan and phasing of the landfill. Our proposed approach for installation of the biocover at CMLF includes placement of a gas distribution layer and a biocover layer on all final outside slopes and in the areas that have not reached the final design levels but will not receive waste for at least the next two years. The areas that have reached the final design elevations (final contours) would receive a barrier layer (as required by the Landfill Criteria) and a gas distribution and biocover layers overtop of the barrier layer. Figures 7-9 to 7-12 shows the progressive biocover installation throughout the lifespan of the CMLF.



SPERLING HANSEN ASSOCIATES

Landfill Services Group
- Landfill Siting
- Design & Operations Plans
- Landfill Closure
- Environmental Monitoring

#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE

CLIENT: REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT: RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE: **BASAL LINER AREAS**

SCALE:	DATE:	PROJECT NO:
1:3000	2016/03/22 (yyyy/mm/dd)	PRJ15061

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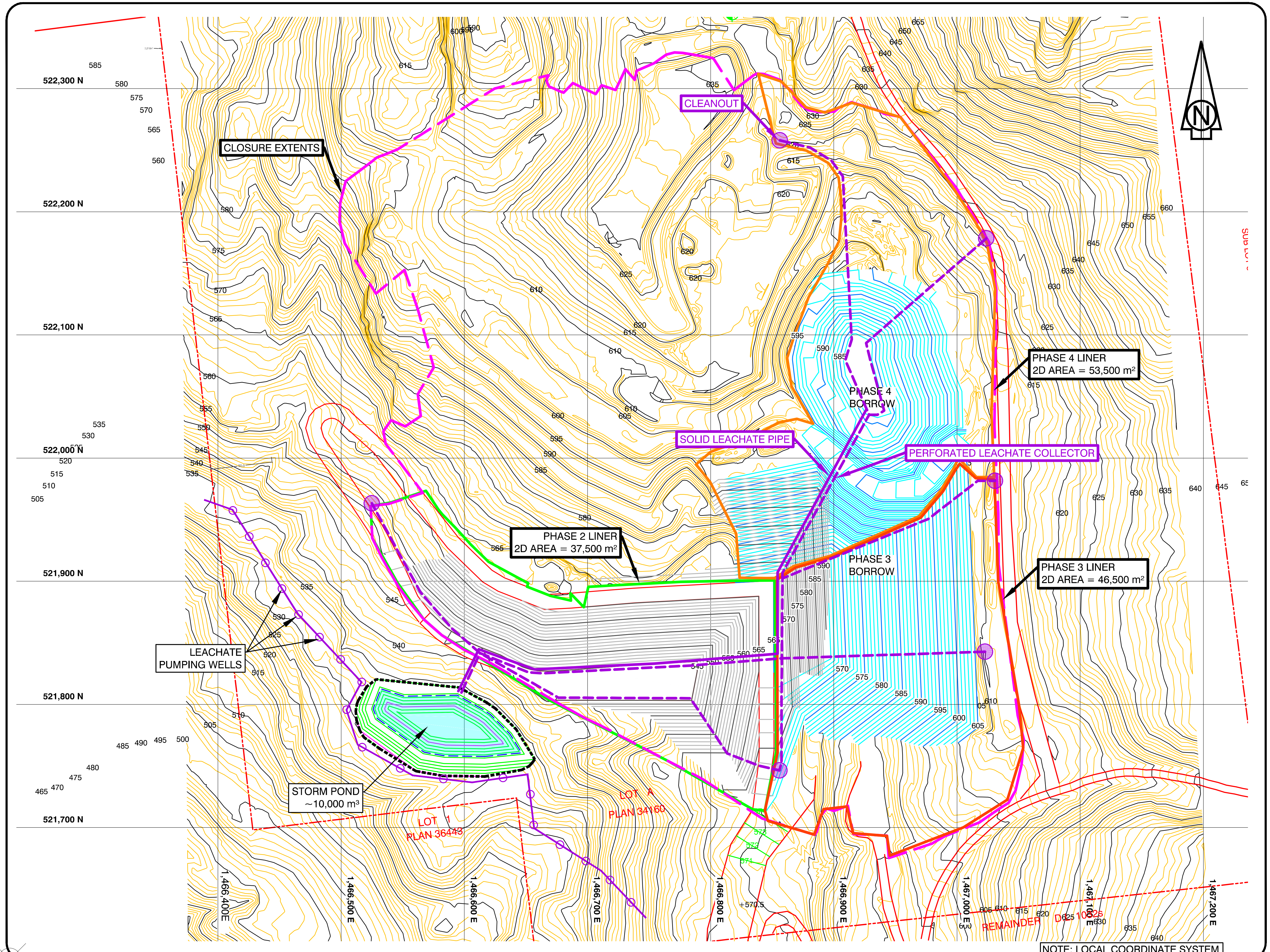
CHECKED	TS	



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Landfill Services Group
- Landfill Siting
- Design & Operations Plans
- Landfill Closure
- Environmental Monitoring

#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE
- SLOTTED LEACHATE COLLECTOR
- SOLID LEACHATE PIPE

CLIENT:
REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE:
LEACHATE COLLECTION SYSTEM DESIGN

SCALE:	DATE:	PROJECT NO:
1:3000	2016/03/22 (yyyy/mm/dd)	PRJ15061

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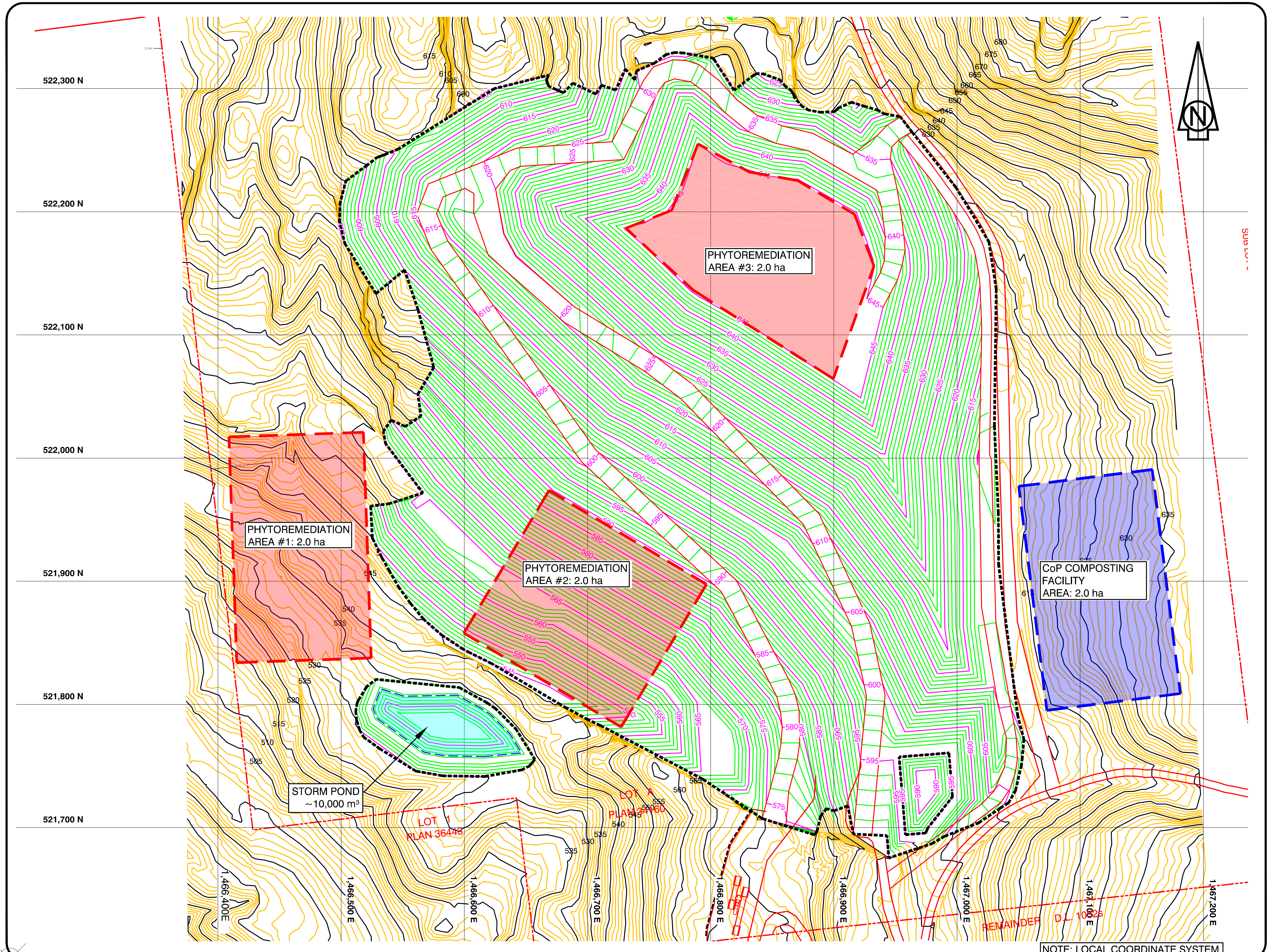
CHECKED	TS	



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Landfill Services Group
- Landfill Siting
- Design & Operations Plans
- Landfill Closure
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#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3

Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE

CLIENT:
REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE:
PHYTOREMEDIATION PLAN

SCALE:	DATE:	PROJECT NO:
1:3000	2016/03/22 yyyy/mm/dd	PRJ15061

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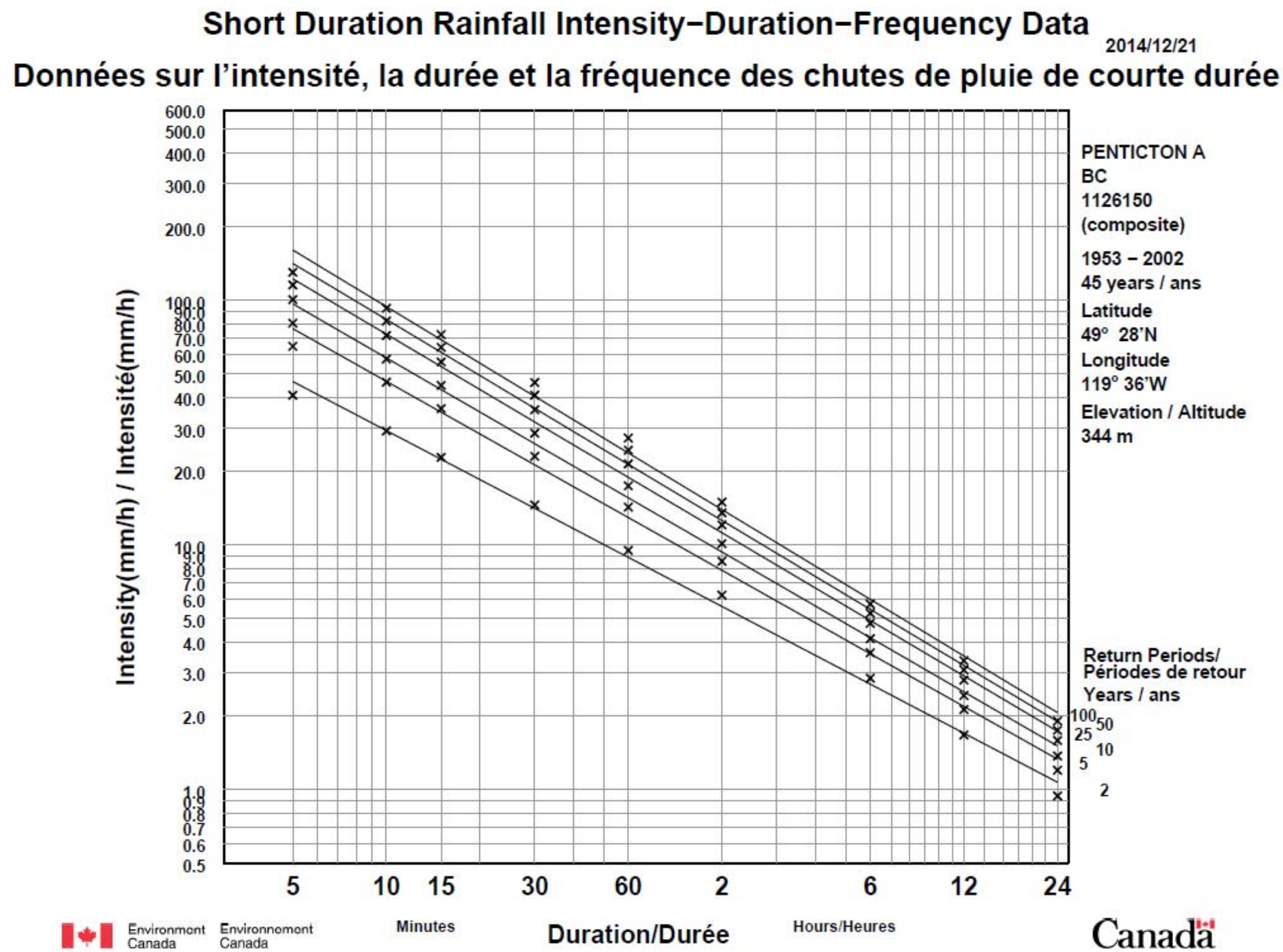
DRAWN	NL	
CHECKED	TS	



CLIENT:	PROJECT:	TITLE:	SCALE:	DATE:	PROJECT NO:
Regional District of Okanagan-Similkameen	CAMPBELL MOUNTAIN LANDFILL DESIGN, OPERATIONS & CLOSURE PLAN	IDF Curve	NTS	2016/04/13 (yyyy/mm/dd)	PRJ1 5061

Sperling Hansen Associates

DESIGNED	IB	DRAWING NO:
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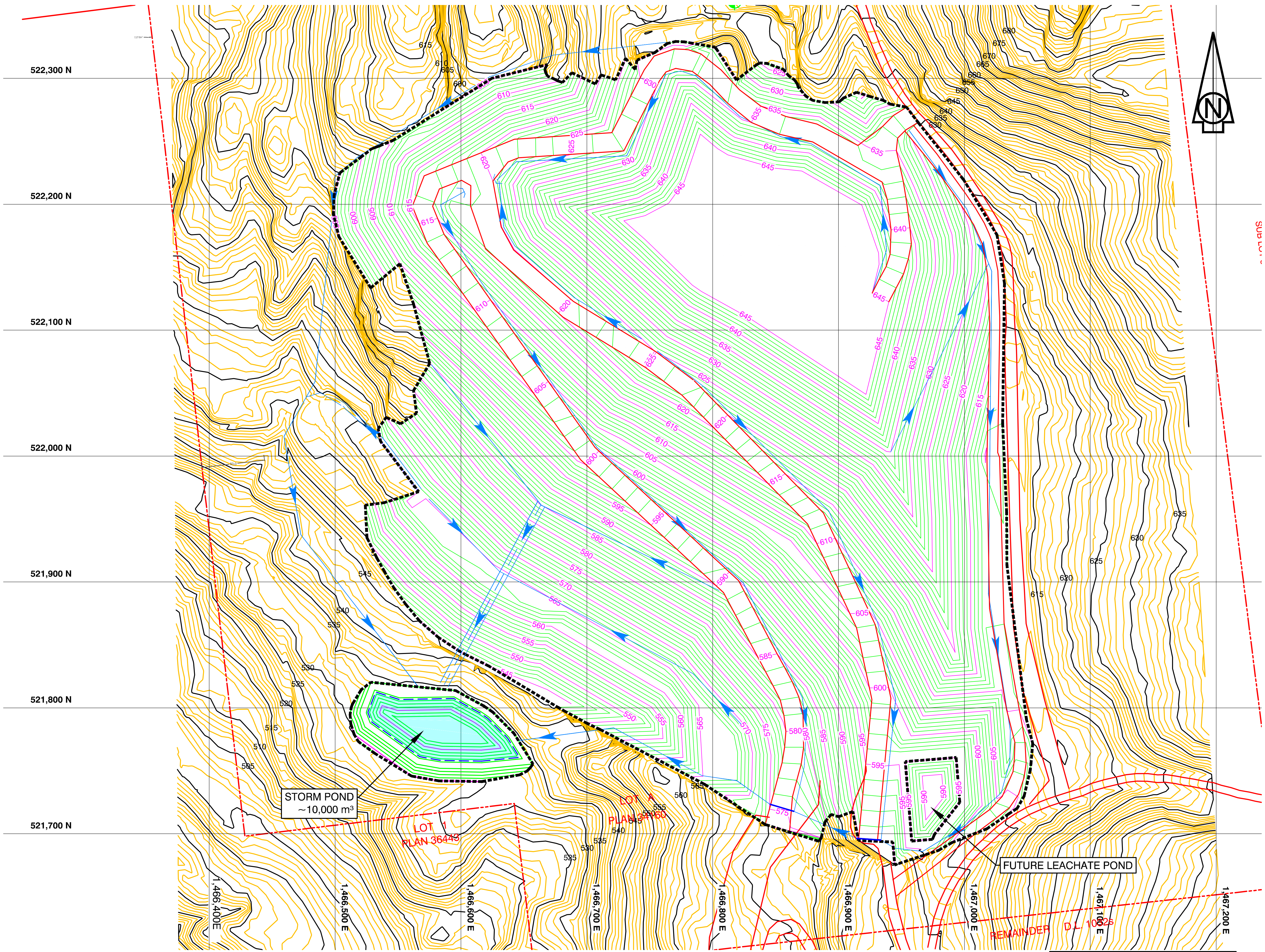
CHECKED	TS	



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Landfill Services Group
- Landfill Siting
- Design & Operations Plans
- Landfill Closure
- Environmental Monitoring

#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE
- STORM DITCH
- DOWNCHUTE

CLIENT:
REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE:
SURFACE WATER MANAGEMENT SYSTEM

SCALE:	DATE:	PROJECT NO:
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DESIGNED	TS	DRAWING NO:
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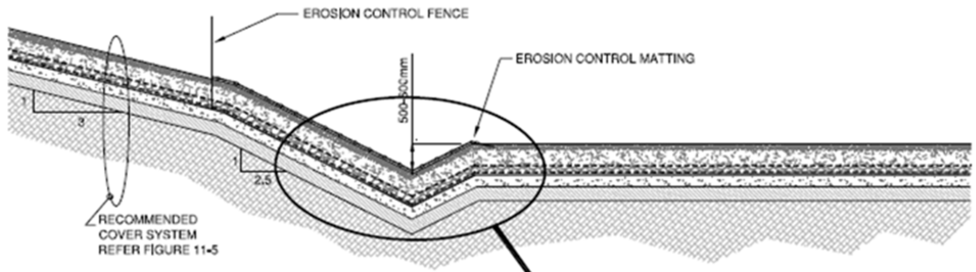
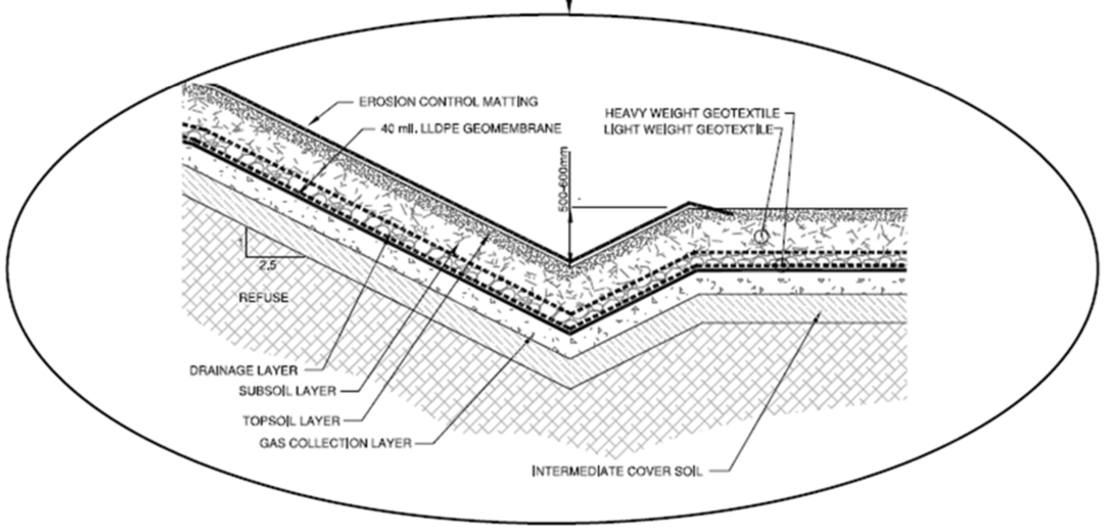
CHECKED	TS	

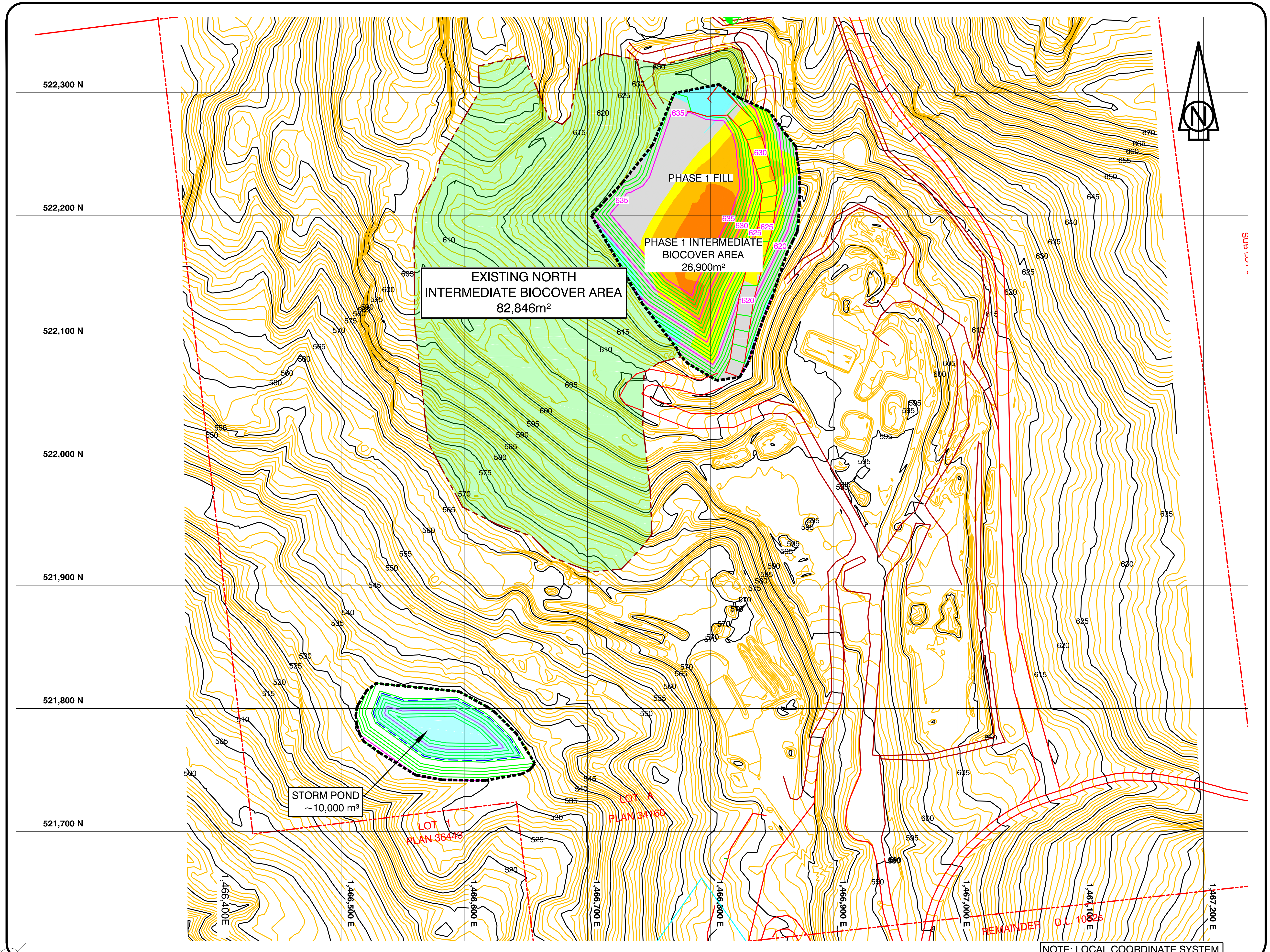


SURFACE WATER DITCHING/SWALE
NOT TO SCALE



DETAIL 'B'
DITCH COMPLETION DETAILS
NOT TO SCALE

SPERLING HANSEN ASSOCIATES	CLIENT: Regional District of Okanagan-Similkameen	PROJECT: **CAMPBELL MOUNTAIN LANDFILL DESIGN, OPERATIONS & CLOSURE PLAN**	TITLE: **Conceptual Ditch System**	SCALE: NTS; DATE: 2016/04/13 (yyyy/mm/dd); PROJECT NO: PRJ1 5061; DESIGNED: BR; DRAWN: TS; CHECKED: TS; DRAWING NO: **FIGURE 7-5a**



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Landfill Services Group
- Landfill Siting
- Design & Operations Plans
- Landfill Closure
- Environmental Monitoring

#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE

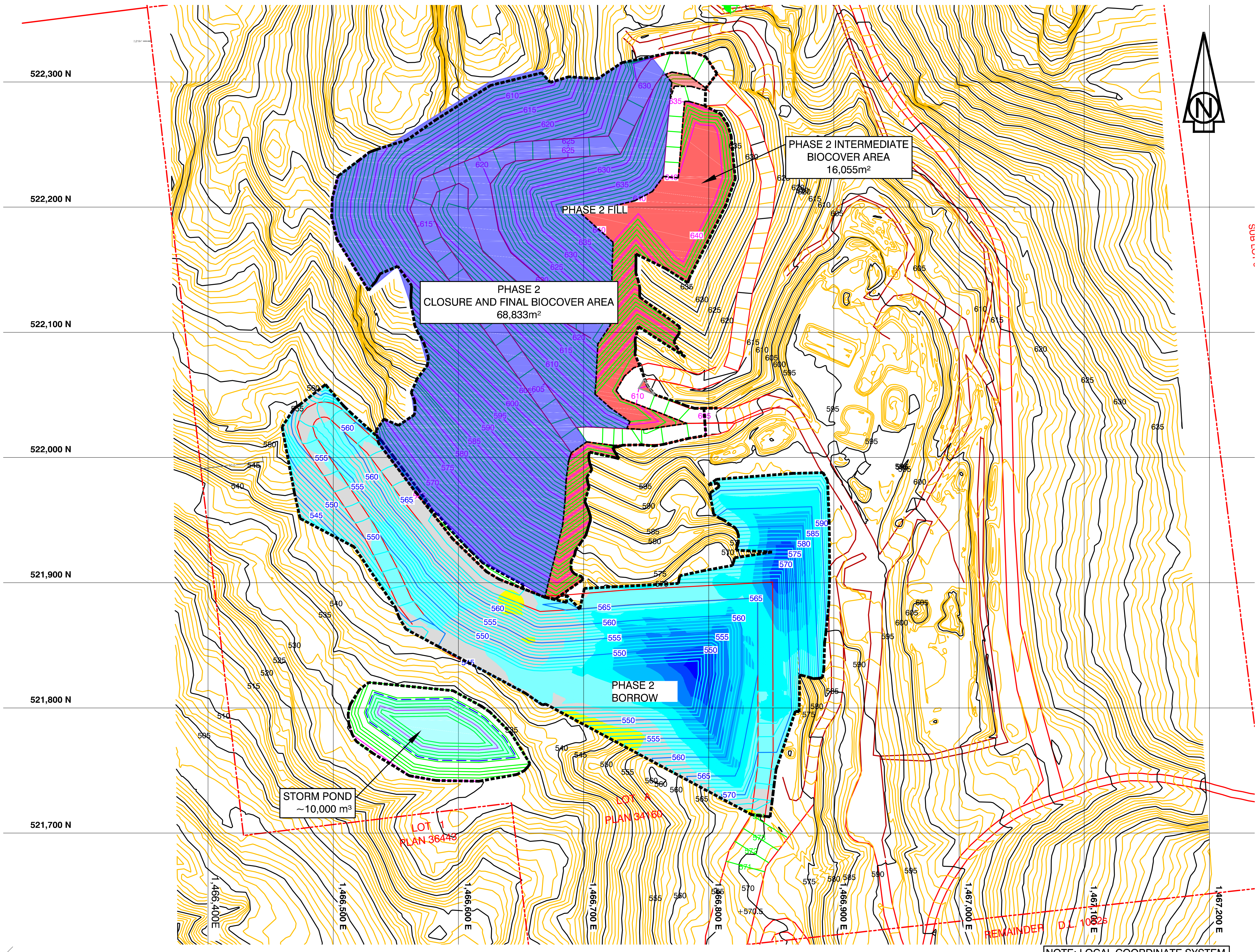
CLIENT:
REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE:
EXISTING NORTH AND PHASE 1 INTERMEDIATE BIOCOVER AREA

SCALE:	DATE:	PROJECT NO:
1:3000	2016/02/10 (yyyy/mm/dd)	PRJ15061

DESIGNED	TS	DRAWING NO:
DRAWN	NL	FIGURE 7-9
CHECKED	TS	



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- Landfill Siting
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- Landfill Closure
- Environmental Monitoring

#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE

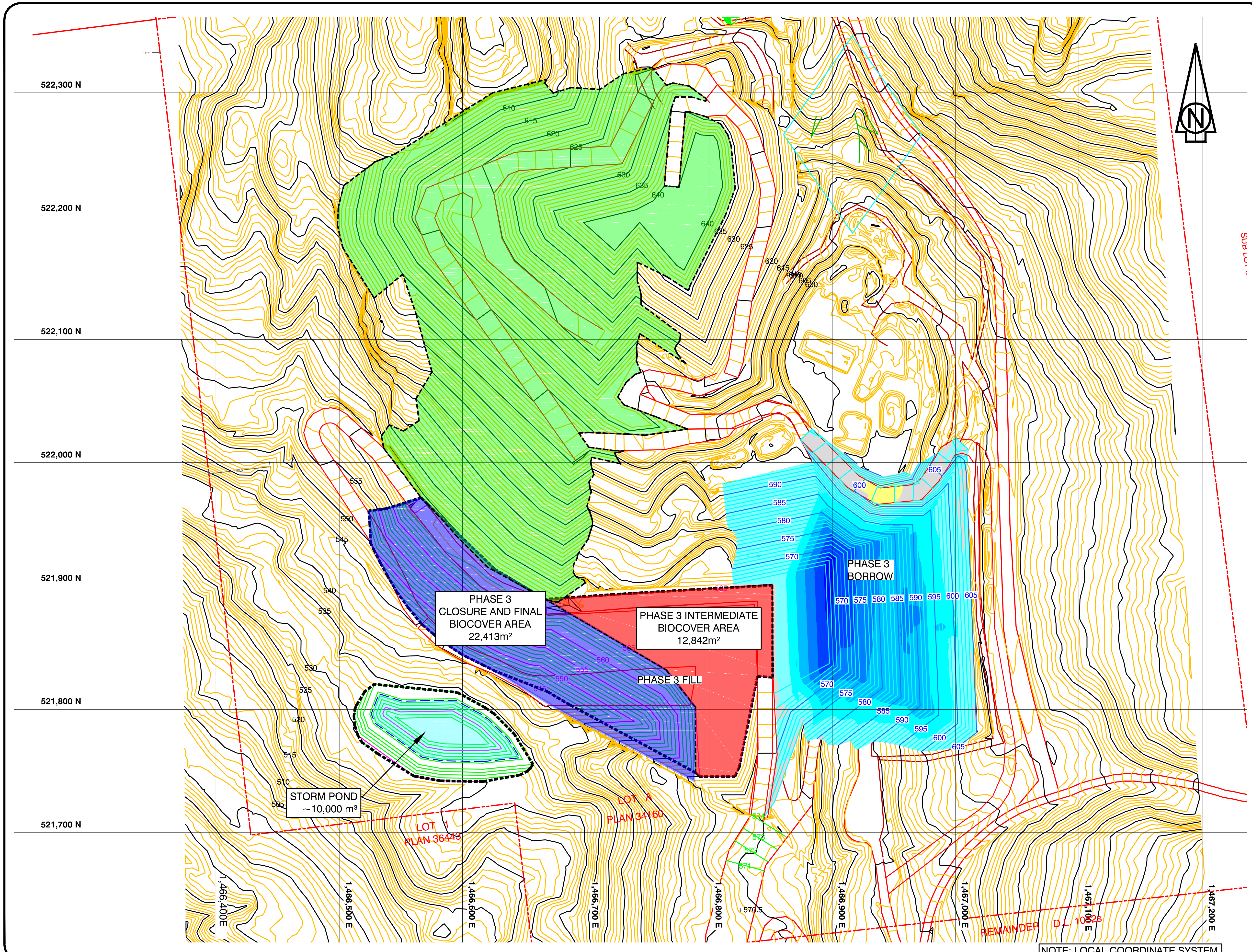
CLIENT:
REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE:
PHASE 2 INTERMEDIATE BIOCOVER AREA AND PHASE 2 CLOSURE AND FINAL BIOCOVER AREA

SCALE:	DATE:	PROJECT NO:
1:3000	2016/03/22 (yyyy/mm/dd)	PRJ15061

		DRAWING NO:
DESIGNED	TS	FIGURE 7-10
DRAWN	NL	
CHECKED	TS	



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Landfill Services Group
- Landfill Siting
- Design & Operations Plans
- Landfill Closure
- Environmental Monitoring

#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:
- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE

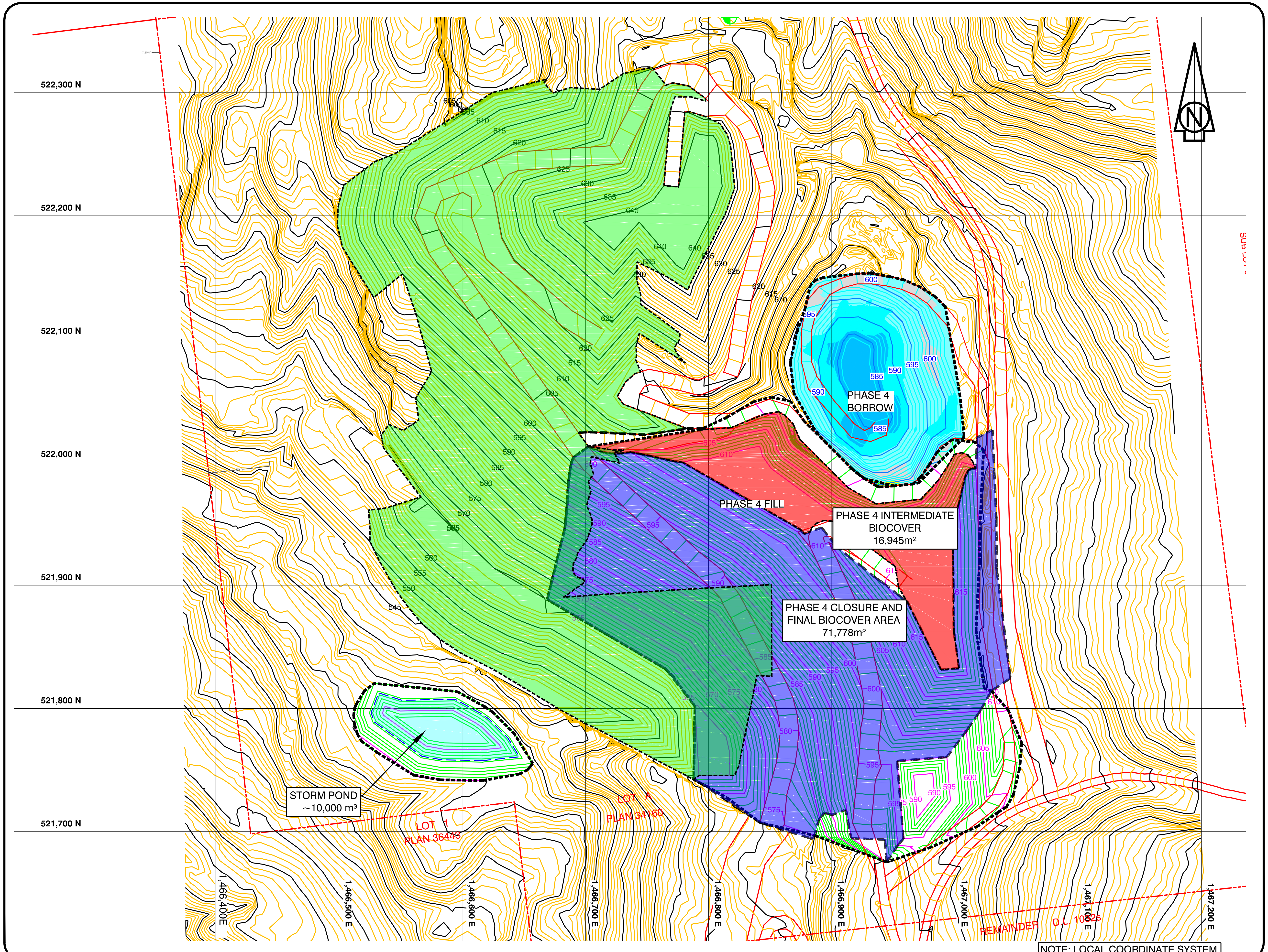
CLIENT: REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT: RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE: PHASE 3 INTERMEDIATE BIOCOVER AREA & PHASE 3 CLOSURE AND FINAL BIOCOVER AREA

SCALE:	DATE:	PROJECT NO:
1:3000	2016/03/22 yyyy/mm/dd	PRJ15061

DESIGNED	TS	DRAWING NO:
DRAWN	NL	FIGURE 7-11
CHECKED	TS	



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Landfill Services Group
- Landfill Siting
- Design & Operations Plans
- Landfill Closure
- Environmental Monitoring

#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

5m EXISTING CONTOUR	
1m EXISTING CONTOUR	
5m DESIGN CONTOUR	
1m DESIGN CONTOUR	
ROAD	
PROPERTY LINE	

CLIENT: REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT: RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE: PHASE 4 INTERMEDIATE BIOCOVER AREA AND PHASE 4 CLOSURE AND FINAL BIOCOVER AREA

SCALE:	DATE:	PROJECT NO:
1:3000	2016/03/22 yyyy/mm/dd	PRJ15061

DESIGNED	TS	DRAWING NO:
DRAWN	NL	FIGURE 7-12
CHECKED	TS	

8. MATERIALS MANAGEMENT

Landfills require a very large amount of construction material during their lifespan. Typically, 25% to 50% of air space in most landfills is consumed by mineral soil and drainage aggregates. These materials are used for daily and intermediate (operational) cover, roads, basal liners and leachate collection systems, gas collection systems and drainage, barrier and top soil layers within the final cover veneer.

Efficient operation of a landfill such as the CMLF, requires that the material acquisition be well planned so that construction materials are available when required.

The following sections present the materials management plan for the CMLF, including the material requirements in each phase of the landfill construction.

8.1 Material Availability

MSW will continue to be placed on top of the existing landfill footprint at the CMLF. This existing waste footprint covers the north and northwest portion of the property. As such, the development of the onsite borrow pit will be in the southwest (Phase 2) southeast (Phase 3) and eastern (Phase 4) portion of the site.

The materials management strategy presented in this chapter assumes that the majority of daily and intermediate cover requirements will continue to be sourced from the onsite borrow pits as currently practiced. This is also assumed for the possible aggregate requirements for roads, ditches and drainage layers.

To provide soil for daily operations, the internal access road construction and final closure, we envision developing three borrow areas within the lateral expansion footprint. Borrow areas have been designed to maximize the available airspace on the current landfill footprint (fenced perimeter).

Table 8-1 below outlines the approximate volume of onsite soil available from the three borrow areas. The borrow areas designed will provide approximately 1,498,200 m^3 of soil throughout the lifespan of the site.

Table 8-1 Summary of Soil Available in Borrow Pits

Borrow Pit	Volume of Borrow Pits (m^3)	Cumulative Volume of Borrow Pits (m^3)
Phase 2 Borrow Area	264,600	264,600
Phase 3 Borrow Area	304,600	569,200
Phase 4 Borrow Area	929,000	1,498,200

Based on current operational practices at the CMLF, all soil used for operational cover is sourced onsite. With this practice in mind, the three onsite borrow areas identified will be mined out prior to filling in those areas and stockpiled for closure system construction. SHA envisions this material to be used for daily and intermediate cover and operational purposes as well as processing the onsite granular material for basal liner expansion material requirements.

During Phase 2 operations, recycling stockpiles will be moved to the current CoP biosolids compost area which has been proposed to be upgraded after relocation of the facility. During Phase 4 recycling stockpiles will be relocated to suitable locations at that stage.

8.2 Material Requirements

Table 8-2 and 8-3 show the granular materials that will be required throughout the life of the landfill for Scenario 1 (Table 8-2) and Scenario 2 (Table 8-3), as previously described in Section 5.3 (Chapter 5, Lifespan Analysis). Scenario 1 considers a current waste to cover ratio of 3.07:1 throughout the lifespan of the landfill whereas Scenario 2 considers a waste to cover ratio of 4:1 throughout the lifespan of the landfill. Both scenarios use a population growth rate of 1.0% per year, compacted waste density of 0.8 tonnes/m^3, waste generation rate of 1.14 tonnes/person/year and a diversion rate of 73% in 2019 until closure.

The granular materials include intermediate cover, silt, sand, fine and coarse gravel for the expansion cells, fine and coarse gravel for roads, rip rap for ditching, biocover and crushed glass for the interim biocover and LFG diffusion layer, and crushed glass, clay and biocover for closure. Table 8-2 and 8-3 extend the lifespan analysis tables presented in Chapter 5. The remaining columns show the materials categorized into capital projects, final closure access roads (on the landfill as during progressive closure), operational materials, expansion requirements and closure requirements. The drainage gravels for leachate sumps and collection make up a very small overall volume and have not been considered in this analysis. The purpose of the these tables is to estimate approximately how much material will be utilized in order to establish whether enough material is available at the site and what material will have to be imported. Also, the volumetrics are conducted on a phase-by-phase basis so that the borrow areas planned for each phase are designed to minimize stockpiling of materials. Stockpiling of materials is undesirable because it leads to double and triple handling of materials which increases operational costs and consumes operational areas on the landfill property.

Closure volumes were determined using the layer thickness (discussed in Chapter 10) and the progressive closure areas. The closure requirements consist mainly of a closure system 1.1 m thick, which include a 200 mm crushed glass LFG diffusion layer, a 600 mm compacted clay barrier layer, and a 300mm biocover layer. The volume estimate also includes 650 mm gravel road base and sub-base and rip rap for ditching. This recommended cover system is presented as a graphic in Figure 10-2b, in Chapter 10. Table 8-4 indicates the progressive closure dates for each phase under the two development scenarios. The first closure to take place will be the Phase 1 Closure in 2020 for Scenario 1 and 2021 for Scenario 2.

The first expansion liner system to be constructed will be in Phase 3. Phase 3 base re-grading and leachate collection should be constructed in 2031 for Scenario 1 and 2032 for Scenario 2 as it must be ready for placement of waste in Phase 3, which must commence following Phase 2 reaching maximum capacity.

A summary of the Progressive Closure / Phase Capacity Completion dates are listed below:

Table 8-4 Completion Dates for Individual Phases for Scenarios 1 & 2

Scenario 1 – 3.07:1 Waste to Cover Ratio

Progressive Closure / Phase Capacity Completion Dates
2020 Phase 1 Fill Closure
2032 Phase 2 Fill Closure
2035 Phase 3 Fill Closure
2067 Phase 4 Fill Closure
2104 Phase 5 Fill Closure

Scenario 2 – 4:1 Waste to Cover Ratio

Progressive Closure / Phase Capacity Completion Dates
2021 Phase 1 Fill Closure
2033 Phase 2 Fill Closure
2037 Phase 3 Fill Closure
2069 Phase 4 Fill Closure
2107 Phase 5 Fill Closure

A summary of the total material requirements for Scenario 1 and Scenario 2 are listed below in Table 8-5. Detailed material requirements for Scenario 1 and Scenario 2 can also be found in Table 8-2 and 8-3. It should be noted that the material estimates are appropriate only for initial planning purposes because actual volumes may well depend on a number of complex factors, including the waste to cover ratio actually achieved, the layer thickness of the environmental control systems established during detailed design and the swell factors that develop as the soil in the borrow area is excavated.

Table 8-5 Material Requirements by Development Scenario

Materials	Scenario 1 (m3)	Scenario 2 (m3)
Sand for Expansion Cells	27,500	27,500
25-150 mm Crush Drainage Layer for Expansion Cells	41,250	41,250
5-25 mm Crush Filter Layer for Expansion Cells	20,625	20,625
Road Base & Sub-Base Gravel, Rip Rap for Downchutes and Ditching (For Closure and Capital Works)	18,794	18,794
Low Permeability Soil for Capping	162,389	162,389
Intermediate / Daily Cover	917,816	740,084
Crushed Glass Gas Diffusion Layer for Closure	54,130	54,130
Biocover for Closure	81,194	81,194
Intermediate Biocover	46,676	46,676
Intermediate Crushed Glass Gas Diffusion Layer	31,118	31,118

8.3 Material Balance

In total, 1,442,742 m^3 of material will be required to be sourced from onsite borrow pits and/or brought to the site during the lifespan of the landfill for Scenario-1 and 1,265,010 m^3 for Scenario-2. For Phase 1, a total of 90,595 m^3 of material for Scenario 1 and 84,265 m^3 of material for Scenario 2 will be needed to complete this phase. This volume also includes the operational soil used in the Phase 1 fill area until it has reached capacity as well as the Phase 1 interim biocover and crushed glass LFG diffusion layer.

Based on previous experience, with the use of the RIG ADC at the CMLF, SHA believes that a waste to cover ratio of 4:1 is achievable. As shown above, the total amount of material used as general intermediate / daily cover is approximately 917,816 m^3 for Scenario 1 and 740,084 m^3 for Scenario 2, a difference of 177,732 m^3. This intermediate/daily cover material will be sourced from the onsite borrow areas. With 1,498,200 m^3 of material being extracted from the three onsite borrow areas, and only 917,816 m^3 of material to be used for intermediate/daily cover until closure based on Scenario 1, a surplus of 580,384 m^3 of material will remain for operational purposes and to be used in processing granular materials for required layers in the expansion liner system for Phases 3 to 5. For Scenario 2, these quantities are 740,084 m^3 and 1,265,010 m^3 respectively.

Table 8-2 Materials Management (Scenario-1 Existing Waste to Cover Ratio)

Year	Phase Ends	Access Roads (Closure)		Basal Liner System						Closure								
		Road Base	Ditching RipRap	Silt (300 mm)	Sand (200 mm)	25-150 Crush Drainage Layer (300 mm)	5-25 mm Crush Filter Layer (150 mm)	Intermediate Biocover (300 mm)	Intermediate Glass Gas Diffusion Layer (200 mm)	Crushed Glass (200 mm)	Clay (600 mm)	Biocover (300 mm)	Cover Material Borrowed Daily and Intermediate	Cumulative Borrowed Material Daily and Intermediate	All Materials	Air Space Used All Materials	Cumulative Airspace Used All Materials	
		m^3	m^3	m^3	m^3	m^3	m^3	m^3		m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	
2014																		
2015													9,788	9,788	9,788	9,788	9,788	for Phase 1
2016													9,886	19,673	9,886	9,886	19,673	
2017								24,854	16,569				8,754	28,427	50,177	50,177	69,850	
2018													7,647	36,074	7,647	7,647	77,497	
2019					-	-	-						6,517	42,591	6,517	6,517	84,014	
2020	**Phase 1 Ends/Phase 2 Starts**	-	-							-	-	-	6,582	49,172	6,582	6,582	90,595	
2021								8,070	5,380				6,647	55,820	20,097	20,097	110,693	
2022													6,714	62,534	6,714	6,714	117,407	
2023													6,781	69,315	6,781	6,781	124,188	
2024													6,849	76,164	6,849	6,849	131,037	
2025													6,917	83,081	6,917	6,917	137,954	
2026													6,987	90,068	6,987	6,987	144,941	
2027													7,056	97,124	7,056	7,056	151,997	
2028													7,127	104,251	7,127	7,127	159,124	
2029													7,198	111,450	7,198	7,198	166,323	
2030													7,270	118,720	7,270	7,270	173,593	
2031				11250	7500	11250	5625						7,343	126,063	42,968	42,968	216,561	
2032	**Phase 2 Ends/Phase 3 Starts**	4,531	1,046							12,598	37,794	18,897	7,416	133,479	82,281	82,281	298,842	
2033								4,817	3,211				7,491	140,970	15,518	15,518	314,360	
2034				13,950	9,300	13,950	6,975						7,565	148,535	51,740	51,740	366,101	
2035	**Phase 3 Ends/Phase 4 Starts**	-	525							6,823	20,469	10,235	7,641	156,176	45,693	45,693	411,793	
2036								3,853	2,568				7,718	163,894	14,139	14,139	425,932	
2037													7,795	171,689	7,795	7,795	433,727	
2038													7,873	179,561	7,873	7,873	441,599	
2039													7,951	187,513	7,951	7,951	449,551	
2040													8,031	195,544	8,031	8,031	457,582	
2041													8,111	203,655	8,111	8,111	465,693	
2042													8,192	211,847	8,192	8,192	473,885	
2043													8,274	220,121	8,274	8,274	482,159	
2044													8,357	228,478	8,357	8,357	490,516	
2045													8,441	236,919	8,441	8,441	498,957	
2046													8,525	245,444	8,525	8,525	507,482	
2047													8,610	254,054	8,610	8,610	516,092	
2048													8,696	262,750	8,696	8,696	524,788	
2049													8,783	271,534	8,783	8,783	533,572	
2050													8,871	280,405	8,871	8,871	542,443	
2051													8,960	289,365	8,960	8,960	551,403	
2052													9,049	298,414	9,049	9,049	560,452	
2053													9,140	307,554	9,140	9,140	569,592	
2054													9,231	316,785	9,231	9,231	578,823	
2055													9,324	326,109	9,324	9,324	588,147	
2056													9,417	335,526	9,417	9,417	597,564	
2057													9,511	345,037	9,511	9,511	607,075	
2058													9,606	354,643	9,606	9,606	616,681	
2059													9,702	364,345	9,702	9,702	626,383	
2060													9,799	374,144	9,799	9,799	636,182	
2061													9,897	384,041	9,897	9,897	646,079	
2062													9,996	394,038	9,996	9,996	656,076	
2063													10,096	404,134	10,096	10,096	666,172	
2064													10,197	414,331	10,197	10,197	676,369	
2065													10,299	424,630	10,299	10,299	686,668	
2066				16,050	10,700	16,050	8,025						10,402	435,032	61,227	61,227	747,895	
2067	**Phase 4 Ends/Phase 5 Starts**	5,369	1,529							15,174	45,521	22,760	10,506	445,538	100,858	100,858	848,753	
2068								5,084	3,389				10,611	456,149	19,084	19,084	867,837	
2069													10,717	466,867	10,717	10,717	878,554	
2070													10,824	477,691	10,824	10,824	889,379	
2071													10,933	488,624	10,933	10,933	900,312	
2072													11,042	499,666	11,042	11,042	911,354	
2073													11,152	510,818	11,152	11,152	922,506	
2074													11,264	522,082	11,264	11,264	933,770	
2075													11,377	533,459	11,377	11,377	945,147	
2076													11,490	544,949	11,490	11,490	956,637	
2077													11,605	556,554	11,605	11,605	968,242	
2078													11,721	568,276	11,721	11,721	979,963	
2079													11,839	580,114	11,839	11,839	991,802	
2080													11,957	592,071	11,957	11,957	1,003,759	
2081													12,076	604,148	12,076	12,076	1,015,835	
2082													12,197	616,345	12,197	12,197	1,028,033	
2083													12,319	628,664	12,319	12,319	1,040,352	
2084													12,442	641,106	12,442	12,442	1,052,794	
2085													12,567	653,673	12,567	12,567	1,065,361	
2086													12,693	666,366	12,693	12,693	1,078,054	
2087													12,819	679,185	12,819	12,819	1,090,873	
2088													12,948	692,133	12,948	12,948	1,103,821	
2089													13,077	705,210	13,077	13,077	1,116,898	
2090													13,208	718,418	13,208	13,208	1,130,106	
2091													13,340	731,758	13,340	13,340	1,143,446	
2092													13,473	745,231	13,473	13,473	1,156,919	
2093													13,608	758,839	13,608	13,608	1,170,527	
2094													13,744	772,583	13,744	13,744	1,184,271	
2095													13,882	786,465	13,882	13,882	1,198,153	
2096													14,020	800,485	14,020	14,020	1,212,173	
2097													14,161	814,646	14,161	14,161	1,226,334	
2098													14,302	828,948	14,302	14,302	1,240,636	
2099													14,445	843,394	14,445	14,445	1,255,081	
2100													14,590	857,983	14,590	14,590	1,269,671	
2101													14,736	872,719	14,736	14,736	1,284,407	
2102													14,883	887,602	14,883	14,883	1,299,290	
2103													15,032	902,634	15,032	15,032	1,314,321	
2104	**Final Closure**	4,540	1,256							19,535	58,605	29,303	15,182	917,816	128,420	128,420	1,442,742	
		14,440	4,355	41,250	27,500	41,250	20,625	46,676	31,118	54,130	162,389	81,194	917,816			1,442,742		

Assumptions:

Compacted Waste De	0.8	tonnes/m^3
Waste Generation Ra	1.14	tonnes/year/person
Waste Diversion Rate	58%	
Waste Diversion Rate	63%	
Waste Diversion Rate	68%	
Waste Diversion Rate	73.0%	
Settlement	10%	by volume
Waste to Cover Ratio	3.07	vol/vol

Phase End / Start

Final Closure

Table 8-3 Materials Management (Scenario 2 - Future Target Waste to Cover Ratio)

Year	Phase Ends	Access Roads (Closure)		Basal Liner Sytem				Closure										
		Road Base	Ditching RipRap	Silt (300 mm)	Sand (200 mm)	25-150 Crush Drainage Layer (300 mm)	5-25 mm Crush Filter Layer (150 mm)	Intermediate Biocover (300 mm)	Intermediate Glass Gas Diffusion Layer (200 mm)	Crushed Glass (200 mm)	Clay (600 mm)	Biocover (300 mm)	Cover Material Borrowed Dialy and Intermediate	Cumulative Borrowed Material Daily and Intermediate	All Materials	Air Space Used All Materials	Cumulative Airspace Used All Materials	
		m^3	m^3	m^3	m^3	m^3	m^3	m^3		m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	
2014																		
2015													7,512	7,512	7,512	7,512	7,512	for Phase 1
2016													7,587	15,099	7,587	7,587	15,099	
2017								24,854	16,569				6,719	21,818	48,142	48,142	63,241	#REF! #REF!
2018													5,869	27,687	5,869	5,869	69,110	
2019													5,001	32,688	5,001	5,001	74,111	
2020					-	-	-						5,051	37,740	5,051	5,051	79,163	
2021	**Phase 1 Ends/Phase 2 Starts**	-	-							-	-	-	5,102	42,842	5,102	5,102	84,265	
2022								8,070	5,380				5,153	47,995	18,603	18,603	102,868	
2023													5,205	53,199	5,205	5,205	108,072	
2024													5,257	58,456	5,257	5,257	113,329	
2025													5,309	63,765	5,309	5,309	118,638	
2026													5,362	69,127	5,362	5,362	124,000	
2027													5,416	74,543	5,416	5,416	129,416	
2028													5,470	80,013	5,470	5,470	134,886	
2029													5,525	85,538	5,525	5,525	140,411	
2030													5,580	91,117	5,580	5,580	145,990	
2031													5,636	96,753	5,636	5,636	151,626	
2032				11250	7500	11250	5625						5,692	102,445	41,317	41,317	192,943	
2033	**Phase 2 Ends/Phase 3 Starts**	4,531	1,046							12,598	37,794	18,897	5,749	108,194	80,614	80,614	273,557	
2034								4,817	3,211				5,806	114,001	13,834	13,834	287,391	
2035													5,865	119,865	5,865	5,865	293,256	
2036				13,950	9,300	13,950	6,975						5,923	125,789	50,098	50,098	343,354	
2037	**Phase 3 Ends/Phase 4 Starts**	-	525							6,823	20,469	10,235	5,982	131,771	44,034	44,034	387,388	
2038								3,853	2,568				6,042	137,813	12,463	12,463	399,851	
2039													6,103	143,916	6,103	6,103	405,954	
2040													6,164	150,080	6,164	6,164	412,118	
2041													6,225	156,305	6,225	6,225	418,343	
2042													6,288	162,593	6,288	6,288	424,631	
2043													6,350	168,943	6,350	6,350	430,981	
2044													6,414	175,357	6,414	6,414	437,395	
2045													6,478	181,835	6,478	6,478	443,873	
2046													6,543	188,378	6,543	6,543	450,416	
2047													6,608	194,986	6,608	6,608	457,024	
2048													6,674	201,661	6,674	6,674	463,699	
2049													6,741	208,402	6,741	6,741	470,440	
2050													6,809	215,211	6,809	6,809	477,249	
2051													6,877	222,087	6,877	6,877	484,125	
2052													6,945	229,033	6,945	6,945	491,071	
2053													7,015	236,048	7,015	7,015	498,086	
2054													7,085	243,133	7,085	7,085	505,171	
2055													7,156	250,289	7,156	7,156	512,327	
2056													7,227	257,516	7,227	7,227	519,554	
2057													7,300	264,816	7,300	7,300	526,854	
2058													7,373	272,188	7,373	7,373	534,226	
2059													7,446	279,635	7,446	7,446	541,673	
2060													7,521	287,156	7,521	7,521	549,194	
2061													7,596	294,752	7,596	7,596	556,790	
2062													7,672	302,424	7,672	7,672	564,462	
2063													7,749	310,173	7,749	7,749	572,211	
2064													7,826	317,999	7,826	7,826	580,037	
2065													7,905	325,904	7,905	7,905	587,942	
2066													7,984	333,887	7,984	7,984	595,925	
2067													8,063	341,951	8,063	8,063	603,989	
2068				16,050	10,700	16,050	8,025						8,144	350,095	58,969	58,969	662,958	
2069	**Phase 4 Ends/Phase 5 Starts**	5,369	1,529							15,174	45,521	22,760	8,226	358,320	98,578	98,578	761,535	
2070								5,084	3,389				8,308	366,628	16,780	16,780	778,316	
2071													8,391	375,019	8,391	8,391	786,707	
2072													8,475	383,493	8,475	8,475	795,181	
2073													8,559	392,053	8,559	8,559	803,741	
2074													8,645	400,698	8,645	8,645	812,386	
2075													8,732	409,430	8,732	8,732	821,117	
2076													8,819	418,248	8,819	8,819	829,936	
2077													8,907	427,155	8,907	8,907	838,843	
2078													8,996	436,152	8,996	8,996	847,839	
2079													9,086	445,238	9,086	9,086	856,925	
2080													9,177	454,415	9,177	9,177	866,102	
2081													9,269	463,683	9,269	9,269	875,371	
2082													9,361	473,045	9,361	9,361	884,732	
2083													9,455	482,500	9,455	9,455	894,187	
2084													9,550	492,049	9,550	9,550	903,737	
2085													9,645	501,694	9,645	9,645	913,382	
2086													9,741	511,436	9,741	9,741	923,124	
2087													9,839	521,275	9,839	9,839	932,962	
2088													9,937	531,212	9,937	9,937	942,900	
2089													10,037	541,249	10,037	10,037	952,936	
2090													10,137	551,386	10,137	10,137	963,074	
2091													10,238	561,624	10,238	10,238	973,312	
2092													10,341	571,965	10,341	10,341	983,653	
2093													10,444	582,409	10,444	10,444	994,097	
2094													10,549	592,958	10,549	10,549	1,004,646	
2095													10,654	603,612	10,654	10,654	1,015,300	
2096													10,761	614,373	10,761	10,761	1,026,060	
2097													10,868	625,241	10,868	10,868	1,036,929	
2098													10,977	636,218	10,977	10,977	1,047,906	
2099													11,087	647,305	11,087	11,087	1,058,992	
2100													11,198	658,502	11,198	11,198	1,070,190	
2101													11,310	669,812	11,310	11,310	1,081,500	
2102													11,423	681,234	11,423	11,423	1,092,922	
2103													11,537	692,771	11,537	11,537	1,104,459	
2104													11,652	704,424	11,652	11,652	1,116,111	
2105													11,769	716,192	11,769	11,769	1,127,880	
2106													11,886	728,079	11,886	11,886	1,139,767	
2107	**Final Closure**	**4,540**	**1,256**							**19,535**	**58,605**	**29,303**	**12,005**	**740,084**	**125,244**	**125,244**	**1,265,010**	
		14,440	4,355	41,250	27,500	41,250	20,625	46,676	31,118	54,130	162,389	81,194	740,084			1,265,010		

Assumptions:

Compacted Waste De	0.8	tonnes/m^3
Waste Generation Rat	1.14	tonnes/year/person
Waste Diversion Rate	58%	
Waste Diversion Rate	63%	
Waste Diversion Rate	68%	
Waste Diversion Rate	73.0%	
Settlement	10%	by volume
Waste to Cover Ratio	4	vol/vol

Phase End / Start

Final Closure

9. OPERATIONS PLAN

The following sections provide guidelines for operation of the CMLF. These include guidelines for soil usage, waste acceptance policies, special waste handling, nuisance management, wildlife management, operation and compaction at the active face, protection of base liners, emergency response planning, site safety planning, landfill gas and leachate management planning, surface water management, controlled burning, liquid waste restrictions, signage and control of fire, dust, litter and vectors.

9.1 Topsoil and Subsoil Salvage and Storage

During the construction, development and operation of the landfill, the person responsible shall separately recover and stockpile all topsoil and subsoil such that all topsoil and subsoil stockpiles:

- shall be constructed in a manner that allows for maximum recovery of the topsoil and subsoil;
- shall be contoured, stabilized and seeded to protect against soil loss by erosion; and
- shall only be used for operations and reclamation at the landfill site.

All incoming soil materials are to be set aside for operational use in landfill daily and intermediate cover requirements. Currently, the RDOS is using a combination of incoming soil and borrow soil for operational and intermediate cover as well as erosion control and access road resurfacing. Large boulders and oversized aggregate material from the borrow area should be set aside and stockpiled for later use as rip rap and energy dissipation in surface water control systems.

9.2 Waste Acceptance Policies and Procedures and Special Wastes

As per the Operating Certificate (OC-15274) for the CMLF, disposal of the following is not permitted at the site:

- hazardous waste;
- bulk liquid and semi-solid waste;
- domestic wastewater;
- explosives;
- hog fuel, log yard debris and chipped wood waste (the reuse of these materials for temporary roads, dust control, or a component of alternative daily cover is permitted);
- radioactive waste;
- biomedical waste;
- recyclable material (automobiles, white goods, other large metallic objects, and tires);
- dead animals and slaughter house, fish hatchery, and farming wastes or cannery wastes and by-products.

Special wastes such as asbestos wastes can be accepted at the site in accordance with Section 40 of the Hazardous Waste Regulation under the *Environmental Management Act*. SHA recommends that burial of asbestos containing waste be buried in separate cell and its location tracked with GPS coordinates and elevations.

Composting of yard waste must be in accordance with the Organic Matter Recycling Regulation under the *Environmental Management Act*.

As per Section 1.1.4 of the OC the burial of dead animals received from Conservation Officers, Road Maintenance Companies, SPCA (buried in the controlled waste cell) and the Veterinary Companies (buried in the controlled waste cell) is authorized at the CML.

All hydrocarbon-contaminated soils shall be disposed of in layers less than 0.3 m and must be deposited a minimum of 1.2 m above the seasonal high groundwater level and a minimum of 2.0 m below the final grade of the landfill. This will prevent the impact on groundwater and future vegetation at the CMLF.

9.3 Wildlife Management

Wildlife does not pose a significant threat for disease transmission unless animals come into close contact with humans, sharing the same spaces as the operators and users of the landfill. Serious problems can develop if bears are allowed to use the landfill as a source of food. Improperly managed garbage has been cited as the greatest source of human-bear conflict in British Columbia and proper management of garbage as the most important prevention. Conservation Officers in B.C. have to kill approximately 800 black bears and 50 grizzly bears every year. Relocating bears that frequent landfills usually does not work as bears tend to find another easy source of food or they do not survive in the new location.

The resident deer and elk populations at the landfill have become a problem recently as they pass through the site and graze on the grassy slopes, stockpiled yard waste and composted materials. Electric fencing at the site does not deter or keep deer and elk out and there may be a necessity of upgrading the sites perimeter fencing to a taller wildlife fence later on when the final outside slopes are completed and have received the proposed biocover layer. In addition, deer and elk have also affected upslope drainage ditches and infrastructure as they track through the ditches and graze the upper slopes, sloughing loose material into the ditches blocking flow paths, as outlined Photo 9-1 below.

Photo 9-1: Shows Wildlife Trails from the Upslope Area, Through Surface Water Ditches, Creating Flow Blockages

All wildlife should be restricted from entering the landfill site. As per the OC, an electrical perimeter fence (or approved alternative) must be installed that is kept in good working order, free of windblown litter which may ground the system, free of grass and weeds which when left to grow may also ground the fence. Photo 9-2 below shows the electric fence at the CMLF.

Photo 9-2: Electric Fence at the Campbell Mountain Landfill

As mentioned above, upgrades to a wildlife perimeter fence may be required to keep out the resident elk and deer population.

9.3.1 Vector and Bird Control

Vectors are defined in the Landfill Criteria as any insect or animal that is capable of transmitting a pathogen from one organism to another. There are two main concerns regarding the presence of vectors at landfills: 1) ensuring that landfill workers are adequately protected from potential disease transmission and 2) preventing the landfill from acting as a source for vectors to transmit diseases to off-site areas. Both of these concerns can largely be dealt with through the control of vector access and numbers.

9.3.2 Bird Control Measures

The objectives of a bird control program must be considered carefully, prior to the development and implementation of the program. If the bird control measures are designed to disturb feeding birds, two main strategies can be employed. One type involves the strategic placement of physical barriers to prevent birds from flocking in areas where they are problematic. The second type of control measures frightens birds away by using sound or movement. At problem sites, a variety of active and passive bird control measures are used to prevent birds from setting down and flocking.

Placing passive physical barriers usually involves stringing a barrier system from a series of interconnected poles that range from 5 to 25 m in height. The most commonly used barrier systems include large polyester nets, similar to those used at driving ranges and baseball diamonds, and heavy-duty monofilament lines designed to disrupt flight paths. Birds may learn to avoid the netting or wires, reducing their effectiveness.

Active “scare away” tactics may involve sound created from pyrotechnical devices, such as propane - fired sound cannons, sirens, bird bangers, screamers or electronic recordings such as bird distress or simulated predator calls. Other common, active “scare away” measures include the use of bird patrols or the use of raptor handlers and trained predators (termed austringers). Passive scare away measures include large, bright “evil eye” balloons, strings of reflective tape or plastic models of raptor species such as owls and hawks.

Photo 9-3: Bird Control at the Hartland Landfill, BC

A well-maintained site with prompt placement of cover material will also help to avoid bird-related vector problems. Putrescible waste should not be exposed at the end of the working day. It will also be important to ensure that all waste containers stored at the site during the week are kept closed and effectively trapped.

The RDOS currently uses starling control capture cages, however, should additional bird control become necessary at CMLF, further work should be undertaken to determine the best method for controlling the bird population. Studies have been undertaken to assess the effectiveness of various methods at controlling different types of birds. Several Cities and Regional Districts have specific experience with bird control, such as the use of hawks at the Nanaimo Regional Landfill and Salmon Arm Landfill, also the system of overhead wires used at the Hartland Landfill in Victoria. These sites could be consulted during the development of a bird control program at the CMLF site should bird activities result in a nuisance or pose a threat to safe air-traffic.

9.3.3 Flies

Improper handling of municipal solid waste will allow flies to breed and multiply, especially during summer months. However, fly populations can be controlled through the rapid burial of waste and the effective use of daily/intermediate cover or alternative daily cover that prevents larval emergence from the refuse. In short, the best defence against flies is adopting good operational and housekeeping practices.

In addition, standing water at the landfill should be avoided to minimize the potential for mosquitoes to breed at the site. This should be controlled through proper surface water management, in particular by ensuring that active and frequently used areas of the landfill are checked for standing water and properly sloped to shed water.

9.3.4 Rodents

Typically, rodents pose a significant health risk only if population densities at the site become high or if rodents begin to frequent equipment or buildings, thereby increasing the potential for human contact. Vegetative ground cover such as tall grass and nesting areas, such as piles of wood and metal, should be avoided. All on-site structures, storage areas and the seat and cab of any heavy equipment used on site should be routinely checked for droppings. If droppings are found, the area should be cleaned and disinfected. An attempt should be made to determine how the rodents are entering the area, and if possible, the entry way should be blocked. If rodents are observed, professional assistance should be obtained and baiting programs should be used. Bait with low secondary toxicity should be placed in the appropriate areas. The bait is typically placed in bait boxes to prevent non-target animals from accessing it. Bait boxes should be checked daily until the rodents are no longer taking it.

9.4 Active Face Operation and Compaction

Currently at the CMLF, waste is filled using the strip method technique where an active face is set up with approximate dimensions of 15m x 25m. Waste is dumped onto the active face area and spread and compacted in lifts. Waste is compacted to a height of approximately 1.5m or whatever height is reached by the waste received over a 3-4 day period, in which the R.I.G. system will be used to cover the active face on a daily basis. Cover soil is placed over the compacted waste in a 150mm lift on a bi-weekly basis.

The recommended active face width, as discussed in Chapter 6, is approximately 19.5 m wide. This dimension is based on the use of the Revelstoke Iron Grizzly (RIG) alternate daily cover system. Typically for small and medium landfills, the smaller the active face, the more efficiently cover materials are used.

The landfill operator should be familiar with all materials that are accepted and banned from the landfill and should inspect the waste for any suspicious materials as it is unloaded and spread out. Any loads that cause concern should be isolated and cordoned off with flagging tape. Drivers should be identified and questioned as to the nature of the suspicious items and the CMLF supervisor should be alerted prior to taking any action.

The recommended approach to filling - the strip method of development - is discussed in Chapter 6. Waste should be spread across the active face using either a push-up or a push-down method. The push-up method will occur when waste is placed at the toe of the active face. This is the preferable method as it results in better compaction and gives the contractor better control over the tipping face. However, at times it may be necessary to dump waste on top of the active lift and the push-down method will have to be employed.

9.5 Waste Compaction

Waste compaction involves using specialized heavy equipment to crush and compress waste during disposal. This process not only conserves airspace and allows for easy placement of the RIG but also helps to reduce issues associated with litter, odours, fires and vectors.

At the active face, waste should be spread in layers no greater than 0.6 m thick. The waste should then be compacted. As layers become thicker than 0.6 m, the maximum compaction that can be achieved drops off sharply and airspace is wasted. SHA recommends that the landfill operator make the first crushing pass over the waste driving forward, so that the equipment blade will protect the driver in the event of an explosive container hidden in the waste, such as a propane bottle, is detonated.

The Solid Waste Association of North America (SWANA) recommends that waste be compacted by making three to five passes over each waste layer (one pass means a single pass in one direction). Anecdotal information from other operations indicates that more than five passes are required to achieve adequate densities in the range of 0.85 tonnes/m^3. Since waste compaction is dependent on so many factors, it will inevitably depend on the experience of the landfill operator to judge when adequate compaction has been achieved. However, the general principles that should be followed include making sure that waste layers are not too thick prior to compaction (no greater than 0.6 m) and that the slope of the active face is not too steep (recommended 4H:1V and no steeper than 3H:1V).

Photo 9-4: Active Face at Campbell Mountain Landfill on December 1st, 2015

Generally bulldozers cost one third of the price of large compactors. On the other hand, large compactors generate twice as much as revenue on a per m^3 basis as the smaller compactors. If the air space is limited or tipping fee is high (e.g. > $75/tonne), the use of a large compactor is justified. The CMLF currently uses a CAT 826 C steel-wheeled compactor to compact its waste and it is estimated that a compaction density close to 0.80-0.85 tonnes/m^3 is achieved.

We recommend that topographic surveys of the site be completed at least once per year to confirm the compaction level achieved by the contractor and to assess the volumetric filling rate for the site. These figures should then be used to update the lifespan of the site on an annual basis and included in the landfill's annual report.

9.6 Daily/ Intermediate Cover

The Landfill Criteria requires that a 0.15 m soil layer or functional equivalent material must be placed over all exposed solid waste at the end of each working day, and that 0.3 m of soil or functional equivalent material must be placed over all areas that will not receive waste for 30 days or more.
The purposes of the daily and intermediate cover are as follows:

- Prevent wind-blown litter,
- Promote surface water drainage,
- Prevent release of odours from landfill,
- Minimize presence of disease vectors, which include flies, mosquitoes, rodents, etc.,
- Prevent larger animals (birds, bears) from scavenging,
- Act as a firebreak between landfill cells,
- Control fire ignition/spread,
- Cover hazardous substances, and
- Improve site aesthetics.

9.7 Alternate Daily Cover

Alternate daily covers (ADC) are adopted to achieve the functional objectives of daily cover without consuming a large amount of air space. A wide range of alternate daily cover systems have been developed over the years. Some achieve a greater number of functional objectives than others. ADC systems generally include the following basic types:

- Rigid steel plate systems (e.g. Revelstoke Iron Grizzly) - Currently Being Used
- Pull on reusable tarp systems
- Roll out reusable tarp systems (e.g. Tarp-O-Matic)
- Spray-on cover systems (e.g. Con-Cover)
- Roll-out plastic film (e.g. Enviro-Cover)

Of these systems, only the rigid steel plate system meets all of the functional objectives typically attained by soil cover. For this reason, steel plate ADC systems are recommended as the preferred ADC systems for landfill sites that can operate effectively on active face widths of less than 20 m. Photo 9-5 shows the Revelstoke Iron Grizzly (RIG) ADC system being deployed.


Photo 9-5: RIG ADC System at Revelstoke Landfill in B.C.

9.8 Controlled Burning

Controlled burning of waste products can be very toxic and pose a serious health risk if mishandled. The Operational Certificate (OC-15274) of the landfill does not allow open burning of any waste products at the CMLF site.

9.9 Asbestos Disposal

Friable asbestos and materials that have been identified by Work Safe B.C. as potentially containing asbestos including Vermiculite insulation, blown-in insulation and acoustic ceiling tiles, are considered as Hazardous Waste under the B.C. Hazardous Waste Regulation. These materials must be transported in compliance with the Transportation of Dangerous Goods Act and Regulations and disposed of following regulation guidance in the Hazardous Waste Regulation, Part 6. Section 40 and landfill specific Asbestos policies, where those policies are in place. The following provides a brief synopsis of requirements.

The landfill shall be notified in advance that asbestos will be brought to the facility. Commercial loads and public loads exceeding 5kg of asbestos waste shall be transported by a licenced transporter and manifested in advance of shipment.

Waste materials shall be brought to the landfill double bagged in durable plastic bags, bagged in steel drums, and with each bag and drum labelled as Asbestos. Minimum bag thickness of each bag is 0.15 mm or 6 mil.

Asbestos loads should be deposited into a dedicated “Asbestos” trench excavated into garbage removed from the operating active face, or in a controlled waste trench excavated into native soil within the final landfill footprint and in an area where no further excavation for cover soil or leachate collection works is to take place. The trench should be excavated between 2,000 and 4,000 mm deep. Bags and drums of asbestos should be immediately covered with a minimum 500 mm of cover soil.

For cases where dedicated disposal of controlled waste is authorized, the specific on-site locations where the controlled wastes are deposited shall be recorded to 5 m accuracy (e.g. using a hand-held GPS) to allow for location of the material in the future so the materials can be avoided during future works (e.g. drilling or trenching of gas collection wells and horizontals, excavations during a landfill fire).

9.10 Signage

The person responsible for landfill operations shall erect and maintain at the landfill entrance providing, at a minimum, all of the following information:

- The name of the approval or registration holder;
- The landfill class;
- Any waste restrictions; and
- The telephone numbers for: i) the person responsible, ii) the local fire department

Photo 9-6 displays the signage for the CML site.

Photo 9-6: Signage at the Campbell Mountain Landfill

9.11 Access Roads

Internal access roads will be required to maintain access to the working areas of the landfill and to the active face. Access roads to the active face on completed portions of the landfill should be at a maximum grade of 8%. The final contour plan shown on Figure 3-4 shows a network of roads for the completed landfill. The road network will consist of access roads encircling the landfill's footprint at different levels to the top of the completed landfill. There will also be an access road leading directly from the toe of the landfill to the crest, starting at the site entrance / scale facility wrapping around the northwest boundary. As filling progresses, these roads will have to be advanced on the waste to access the active face. SHA has also included internal access roads between each phase of development for access during filling. These roads will be temporary and will be filled in with waste as the site expands vertically and horizontally. Further details regarding main and temporary access road alignments and requirements are outlined for Phase 1 in Chapter 6.

9.12 Litter Control

Wind-blown litter is a nuisance. If it is not controlled, it can affect nearby properties or roads. Excessive litter also reflects the quality of the overall operation at the site. A small amount of litter is common to most landfills, but measures to control wind-blown litter should always be implemented.

Currently, the CMLF does not have litter fencing controls near the active face. Based on the recent site visit by SHA, further measures need to be implemented to minimize the windblown litter scattered around the site as can be seen in Photo 9-7 below. Although the majority of the litter shown below was recently uncovered after the spring snow melt, it shows that litter from the active face is being transported away from operational areas and trapped in ditch lines and against sloped areas.

Photo 9-7: Windblown Litter in Ditch Lines and Depressions Downwind of the Operational Filling Area.

Also, semi permanent litter fences should be installed in the prevailing down wind direction at the crest slope break of the active face. Sturdy litter fencing panels that can easily be relocated should be considered. Litter control fences typically consist of an inexpensive product such as snow fencing or a biaxial geogrid. At most landfills the fencing is no greater than 2 m in height although at problem sites, fencing of 4-5 m high can be used, supported on telephone posts. Temporary fences can also be fabricated from steel posts and chain link fencing or iron grills. Fence alignment, strength and maintenance are important factors to consider in design. Fences should be placed perpendicular to the wind direction. They should be well constructed and cleaned regularly.

Another litter control measure that must be implemented at the site is a regular litter pick-up program. In particular, litter that does escape beyond the fencing needs to be collected on a routine basis. The frequency of such a program will depend upon the severity of the problem, but should be undertaken at least twice per year. This task is important as an aesthetically unpleasing landfill can negatively impact the credibility of the owner and operator in addition to creating public relations issues with the community. Often litter pick-up can be arranged with volunteer community groups such as the Boy Scouts to raise funds for their activities.

Photo 9-8: Portable Litter Control Fence at Chetwynd Landfill, BC. Note the Lifting Cables on the Top Cross Member for Ease of Deployment and Transport by an Excavator.

9.13 Dust Control

Dust is a common problem at most landfill sites as a result of hauling and handling waste and borrow material, and from vehicle traffic over unpaved access roads. It is expected that dust mitigation will be required at the landfill, especially during construction operations to expand the landfill. Dust control techniques, such as watering down road surfaces, paving final roads, posting and enforcing reasonable on-site speed limits, and vegetation programs, can be used as required. When watering road surfaces, water application should be kept light to avoid slippery or erosive conditions, and to minimize the production of leachate. If necessary, dust palliatives, which have the ability to reduce dust by absorbing moisture, may be used to control dust within the active landfill area. The commonly used dust palliatives include magnesium chloride, calcium chloride or other similar hydrating chemicals. However the best solution for dust control is to pave or surface all long term access roads with pavement grindings.

Currently, the RDOS uses calcium chloride to mitigate dust issues on roads and recently covered areas of the site.

9.14 Odour and Noise Control

Odours from waste come from putrescible waste entering the site or old buried waste. Waste entering the site should not sit exposed for an extended length of time, and should be placed, compacted and covered as quickly as possible. As the site is well contained and located away from the city, odours from waste do not seem to be a problem at the CMLF. If odour does become a concern, the best method for controlling the odours from buried waste will be to adequately cover it. If LFG is properly managed and/or a biocover is used, these measures will also reduce odour issues as they lessen fugitive emissions.

The largest odour concern historically and currently at the CMLF is due to the biosolids composting operation run by the CoP. This operation and location is currently under review and the RDOS and CoP will be implementing a long term strategy to mitigate the issue.

Noise issues are not considered problematic at the site as it is located far from most neighbours. If any complaints are received they should be promptly addressed. Noise at landfills tends to originate from operational machinery such as bulldozers and compactors. Noise reduction plans should be implemented during construction of closure and expansion systems.

9.15 Vehicle Scales

The CMLF currently has a well laid out scale and office that is nicely configured for staff use. The scale acts as control point for site access. It is located in the south-east corner of the property as shown in Figure 3-1 and Photo 9-9 below. This scale is operational from 8:30am to 4:45pm Monday through Sunday from March to November and 8:30am to 4:45pm Monday to Saturday from December to February, the landfill is closed on Sundays from December to February, all Statutory Holidays and Boxing Day.

The current location of the scale, office and associated buildings cannot be maintained at this location throughout the progressive expansion and closure at the CMLF. The scale will be required to be relocated further south during Phase 3 filling and borrowing which is predicted to occur during 2032 as per Lifespan Analysis - Scenario 1.

Photo 9-9: Entrance to the Landfill and Scale Facility

9.16 Recycle Facilities and Other Designated Areas

Photo 9-10 shows the existing recycling area near the entrance before the scale and Photo 9-11 shows the existing transfer bays. The existing recycling facility will continue until Phase 3 filling has started. At that time a new location for the recycling facility will be selected based on the available space.

Photo 9-11: Recycle Facility near the Entrance

Photo 9-12: Transfer Bay near the Entrance

The materials that are diverted from the landfill and managed in the recycling area have been listed in Section 5.2 of Chapter 5. Other materials maintained at the site include:

- sand quarry
- wood chipping
- yard waste
- wood waste
- propane tanks
- tires
- lead acid batteries
- white goods
- electronic waste
- scrap metal
- house hold hazardous waste

Yard and garden grind feedstock is stored at the site which is later diverted to the City of Penticton Bio-Solids Composting facility. The product of this process is then sold at the site.

The RDOS has a separate shed for the gypsum wallboard recycling as shown in Photo 9-13

Photo 9-13: Gypsum Recycling Shed

9.17 Supervision

SHA recommends that the person in charge of the CMLF ensures that a fulltime, trained operator is present at this landfill during operating hours. The gates are to be locked to prevent unauthorized access during non-operating hours. The operator is to be familiar with the approval, inspection records, the authorized Operational and Closure Plan and all annual reports.

9.18 Scavenging

To prevent the spread of disease, scavenging of waste is to be prevented. The salvaging of wastes should continue to be encouraged. This could be facilitated by providing additional areas and facilities for separation of recyclable or reusable materials such as organics.

9.19 Operation of Environmental Control Systems

Regular maintenance of the environmental control systems such as storm water collection ditches, storm water pond, leachate collection system maintenance, LFG infrastructure and maintenance of monitoring network, is the key to successful operation of the landfill. More details have been provided in Chapter 7.

9.20 Wood waste Management

Wood waste collection at the CMLF are of two types: clean dry dimensional lumber and yard and garden waste. Wood waste is collected mainly following two streams:

1. Residential
2. Commercial

Commercial streams are inspected while residential streams are spot checked by a spotter. Currently, the clean wood is chipped and used for dust control, composting, and animal bedding. Part of the wood waste also goes to the co-gen facility at the City of Kelowna. The RDOS disposes of the wood waste in various uses. Some of the wood waste is taken by Glenmore Landfill for their yard waste composting operation.

10. FINAL COVER DESIGN

10.1 Introduction

A key goal of a site specific Closure Plan for CMLF is to identify the most effective type of final cover system for the landfill under consideration. Four basic types of cover systems are generally used for landfill closure:

1) clay cover,
2) geosynthetic cover,
3) composite cover, and
4) evaporative cover.

This chapter explores the potential effectiveness of each of these cover systems, identifies the best barrier layer option and then fine tunes the design in terms of identifying the optimum barrier layer thickness, drainage layer media and top soil thickness. In short, the objective of this Closure Plan chapter is to provide a detailed guide for construction of an effective closure system at the CMLF.

10.2 Closure Objectives

The purpose of final closure of any landfill is to put in place the necessary environmental control systems to effectively manage leachate, landfill gas and settlement. A well-designed closure system should provide the following benefits:

- Isolation of refuse, preventing direct contact with humans and vectors.
- Minimization of infiltration and leachate production through diversion and run-off.
- Prevention of leachate breakouts at landfill toe and on side slopes.
- Protection of the cover from erosion through maintenance of a sustainable vegetative community.

The final cover design developed in this chapter has been designed to meet all of the MoE closure objectives. It is designed:

- To minimize the risk to the receiving environment by minimizing percolation of water into the landfill.
- To develop a top soil horizon on the landfill surface that will support vegetation.
- To utilize locally available materials as much as possible to keep construction costs low.
- To manage landfill gas in a way that will not cause unacceptable odour impacts.

10.3 Regulatory Requirements

Regulatory requirements for landfill closure have been specified in the MoE Landfill Criteria and Operational Certificate 15274. The key requirements that dictate design of the final cover system are summarized below:

- The final cover barrier layer shall consist of a minimum of 1,000 mm of low permeability ($<1x10^{-5}$ cm/s) compacted soil (or equivalent) cap as per the 1993 Criteria. As per the new Criteria, the final cover shall consist of a minimum of 0.6 metre of low permeability ($<1x10^{-5}$ cm/s for landfill sites located in arid regions and $<1x10^{-7}$ cm/s for landfill sites located in non-arid regions) compacted (or equivalent) cap plus a minimum of 0.15 metre of topsoil and suitable vegetative cover;
- The barrier layer shall be protected with a minimum 150 mm thick topsoil layer with approved vegetation established. Final cover shall be sloped at a minimum of 4%, to promote surface water runoff, to a maximum slope of 33%. As per the new criteria, the top plateau shall be a minimum of 10% for soil barrier layer covers, and 4% for geomembrane or composite barrier layer covers;
- Surface water runoff shall be directed into collection systems and disbursed into existing ditches.

10.4 Elements of Final Cover Systems

To achieve the objectives outlined above, a minimum cover system comprising of a topsoil horizon and barrier layer is required by the MoE. Additional layers including a drainage layer on top of the barrier system and a gas collection layer under the barrier layer may also be required to achieve the objectives at specific sites.

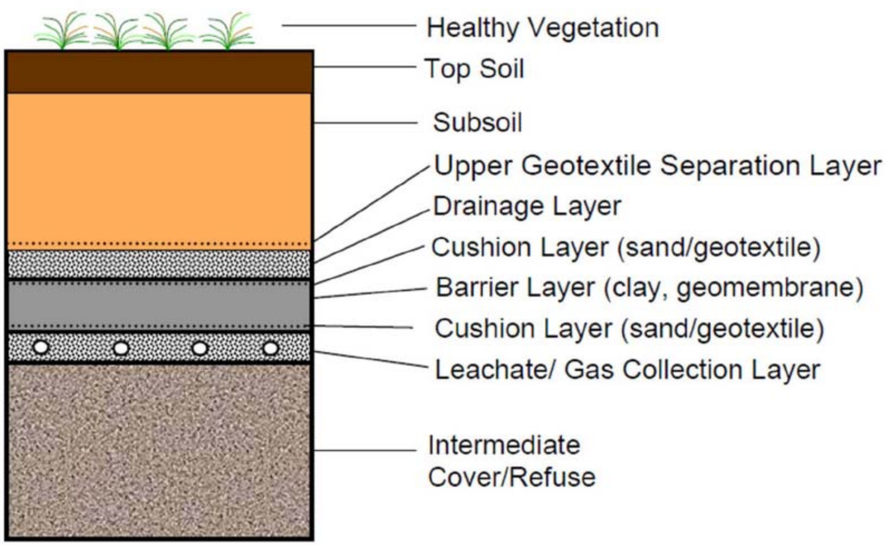


Figure 10-1: Elements of Final Cover System

Figure 10-1 provides a schematic illustration of a generic final cover veneer. As shown in Figure 10-1, depending on the particle size gradation of the various layers, it may also be necessary to introduce geotextile separation / cushion layers at key interfaces to prevent migration of topsoil or clay into the various drainage layers. Healthy vegetation is also a key element of final closure. In the discussion below, layers are presented in a bottom to top order.

10.1.1 Gas / Leachate Collection Layer

The purpose of a gas/leachate collection layer is to provide a high permeability pathway for leachate generated from break-outs to migrate to the landfill toe and for landfill gas to travel laterally beneath the cover system to the closest collection point. Leachate breakouts may be experienced on the landfill side slopes. To prevent head build-up as a result of these breakouts, the gas/leachate drainage layer must attain a permeability of $1x10^{-2}$ cm/s or better. Based on the available information, leachate breakouts are not expected to be a problem at the CMLF. However, for uniform diffusion of gas a Gas/Leachate collection layer is recommended at this site. This will create an opportunity to utilize recycled crushed glass from the region.

10.1.2 Barrier Layer

A low permeability soil or geosynthetic layer forms the backbone of an effective cover system. In British Columbia, a 600 to 1,000 mm layer of low permeability soil has typically been used in constructing a landfill cap (e.g. Port Mann, Bailey, Premier St., Hope, Fernie). As a second closure option geosynthetic barrier layers are being introduced at landfill sites where low permeability soil is not readily available. A third option is a composite liner, consisting of both low permeability soil and geosynthetic barrier components. In the case of a composite liner, a fine-grained soil layer (e.g. clay or silt) is typically used as a cushion layer on top of which the primary geomembrane liner is deployed. There is also a fourth option, which is an evapotranspirative barrier system, consisting of an earthen barrier layer and a vegetative layer.

Compacted Soil Barriers: In British Columbia, the minimum regulatory requirement for a final cover system is a 1,000 mm thick compacted soil barrier with a hydraulic conductivity of $1x10^{-5}$ cm/s as per the 1993 Criteria. As per the new criteria, the minimum final cover is to consist of a 0.6 m thick compacted barrier layer, providing a maximum hydraulic conductivity of 1×10^{-5} cm/sec for the landfill sites located in arid/semi-arid regions and 1×10^{-7} for the landfill sites located in non-arid. Based on our experience, to achieve a high level of diversion efficiency (e.g. 70% or better), the compacted soil barrier should attain an in-situ hydraulic conductivity of $1x10^{-6}$ cm/s or less. To achieve this low level of permeability, soils must contain a significant percentage of clay-sized particles.

Natural low permeability soil cover systems have the following advantages over geosynthetic cover systems:

- Low permeability soil covers have been used widely in British Columbia and are accepted by MoE as an effective means of landfill closure,
- A natural soil cover system may provide the lowest overall cost solution through the use of inexpensive, locally available materials,
- A natural cover system will allow infiltration of small quantities of water into the refuse, thereby increasing the rate of stabilization of the refuse as well as increasing the production of landfill gas,
- Use of synthetic materials may increase long term post-closure maintenance costs because it will be important to regularly mow the cover to protect the underlying membrane from root

penetration by certain tree and brush species, except in areas protected by a thick subsoil (e.g. tree islands).

- Soil cover systems have self-healing properties, whereby clays swell to reseal penetrations and/or cracks, and
- Soil may provide better performance in the very long term (e.g. > 100 years) in the event geomembranes deteriorate over time.

If low permeability soil is locally available along with the required quantity and active LFG collection system is not be implemented, this option would be preferred for the CMLF.

Geomembrane Barriers: A number of geosynthetic membrane products have been used successfully for landfill closure applications, including polyvinyl chloride (PVC), high density polyethylene (HDPE), very low density polyethylene (VLDPE), linear low density polyethylene (LLDPE), polypropylene and geosynthetic clay liners (GCL's). Of these options, PVC geomembranes have been installed in more than 80% of projects completed in North America prior to 2000; however, LLDPE membranes have become popular recently on steep slope applications because the textured LLDPE product has a more aggressive texture and higher friction angle compared to PVC. Geomembrane caps have become prevalent in the U.S. where Subtitle D regulations require the final cover barrier layer to be less pervious than the bottom liner in order to prevent development of the bathtub effect. In British Columbia, PVC geomembrane caps have been successfully installed by SHA at Hartland Landfill in Victoria, Cedar Road Landfill in Nanaimo and the Iona Grit Landfill in Richmond. LLDPE caps have been successfully installed by SHA at landfills in Prince George, Nanaimo, Salmon Arm, Fernie, Creston and at the Vancouver Landfill.

Advantages of geomembrane barriers include:

- Less susceptibility to settlement induced stress cracking;
- No susceptibility to desiccation;
- Superior containment of landfill gas;
- Lower consumption of air space; and
- Reduced leachate generation.

Disadvantages of geomembranes include:

- Lower interface friction resistance than clay (without texture or sand friction layer);
- Skilled labour and more stringent QA/QC is required to achieve a reliable barrier;
- Reliability of membranes in very long term (>100 years) not clearly defined;
- Membrane needs to be deployed on smooth, well compacted ground;
- Synthetic covers can be more susceptible to damage from inappropriate end uses, potentially limiting end use options;
- Overlying drainage and top soil layers must be placed with care;
- Reduced infiltration will slow the rate of decomposition of the garbage, thereby increasing the contaminating lifespan of the landfill;

- Capital costs typically higher than those experienced with soil barriers, if soil material is available on site.

The geomembrane option will be selected if an active LFG collection needs to be installed. If a membrane cap is selected we would recommend a 40 mil LLDPE geomembrane. This material will provide an adequate barrier layer for the relatively small progressive closure areas of the landfill.

Alternately, local silt and clay resources could be utilized to engineer an evaporative cover system.

Composite Barrier Systems: Composite systems are comprised of two barrier layers in intimate contact. The most common composite design is to deploy a geosynthetic membrane on top of a compacted clay liner of reduced thickness (e.g. 300 to 500 mm). The primary advantage of composite lining systems is that they provide a higher level of leak protection and greater security in the very long term. Composite barrier systems are frequently specified for hazardous waste containment facilities. As a fine-grained cushion layer (or geotextile) is required beneath the primary liner in any case, 300 mm thick secondary liners have been adopted in the closure of many B.C. MSW landfills as well.

Given the low environmental impacts observed to date, a composite barrier is not deemed necessary at this site at this stage. However, this should be finalized during detail design.

Evapotranspirative Barrier Systems: Recent investigation in the last 10 to 15 years on alternative earthern covers has suggested that the standard prescriptive cover, consisting of a barrier layer and a vegetated surface, may not be the best choice in specific areas of North America that have a dry climate. Two types of alternative earthen covers have been investigated in recent years and both apply the principle of water storage rather than water resistance, a capillary barrier system and a monolithic barrier system. These types of systems may be appropriate in arid or semi-arid areas where the potential evapotranspiration is greater than precipitation and where there is relatively little snowfall.

The capillary type system consists of a fine-grained soil placed over a coarse grained soil, much like a clay barrier layer over a gas / leachate collection layer. However, clay is typically not the major component in the barrier layer, rather it is a combination of clay, silt, sand and /or loam. The capillary barrier system is based on the idea that flow is restricted across the barrier between the fine-grained soil and the underlying coarse-grained soil in unsaturated conditions. This allows moisture to be stored in the fine-grained soil, which is then taken out of the water balance by evaporation and transpiration by plants. Studies have shown that this type of system performs better than the conventional systems in the right conditions.

The monolithic type barrier consists of a thick layer of fine-grained soil with exceptional storage capacity when unsaturated. These soils also have a low saturated hydraulic conductivity, compared to coarse-grained soils, so that infiltration during rain and snowfall is limited. The monolithic type system also takes advantage of evaporation and transpiration, and therefore these kinds of systems are also called evapotranspirative cover systems.

The primary advantages of this type of barrier is that the soils may be more readily available than clay, that the system will perform better than the standard clay barrier and there is less risk of cracking and desiccation that is associated with a clay system.

10.1.3 Drainage / Cushion Layer

The purpose of a drainage layer on top of the barrier is to quickly convey water passing through the topsoil horizon down slope to the landfill toe or mid-slope groundwater interceptor ditch. Without an effective drainage layer, the topsoil could become saturated during heavy rainfall events. This condition could lead to excessive head build-up on the barrier layer and can lead to erosion and slumping problems on side slopes and increased infiltration over the landfill crest. Use of a high permeability topsoil medium could be considered, however, in our opinion, a high permeability topsoil layer would not achieve the same performance as a gravel drainage layer and would likely become saturated and unstable during extreme precipitation events.

HELP modelling results presented in Section 10.4 indicates that a drainage layer can be avoided at CMLF.

10.1.4 Topsoil Layer

A layer of organic topsoil is essential to ensure a healthy and sustainable vegetative community on top of the final cover system. The minimum requirement is for a 150 mm thick layer of topsoil. In most final cover designs SHA recommends a thicker layer (300 mm) of topsoil to provide sufficient moisture retention in the soil during periods of drought, thereby preventing plant mortality, and to reduce the risk of root penetration into the underlying barrier layer.

10.1.5 Subsoil Layer

The primary function of a subsoil layer is to provide a deep soil horizon in which roots can establish. This layer is important when considering planting of shrubs and trees with deep, penetrating root systems. Without such a protective layer, the roots could penetrate the underlying barrier systems. As per the new criteria, a subsoil layer is recommended if geomembrane cover system is installed.

10.4 HELP Modelling of Closure Options

A range of final cover system options were considered in this study to explore the most suitable final cover system at the CMLF site. To investigate these aspects of cover performance, various model scenarios were constructed and analyzed with HELP (Schroeder, et. al., 1994). Table 10-1 shows the HELP modeling profiles and input details for different scenarios. The results of the modeling are presented in Table 10-2.

All of the scenarios used the same geologic profile representative of average conditions at the site. It was estimated that the typical refuse thickness at the CMLF site will be 30.0 m when the site will be fully developed as per the filling plan mentioned in Chapter 6. The average hydraulic conductivity, K, for the refuse was estimated to be $5x10^{-4}$ cm/s based on our previous experience.

For this project, all the cover option profiles were assessed using a 50 year simulation based on climate patterns from the Penticton Airport Station. These climate values were corrected to reflect the temperature and precipitation experienced at the landfill site and its surrounding areas. The average monthly precipitation rate and temperature based on the Environment Canada Climatic Normal Data (1981 to 2010) were input into the model. The average annual precipitation created by the HELP model was 345.05 mm; however the actual average recorded on site is a bit higher at 346 mm/yr. This difference is due to the artificial parameters that the HELP model uses to simulate the weather.

In the simulations three different cover system designs, as described in Table 10-1, were utilized.

Option 1 (600 mm Clay Barrier with 150 mm Topsoil - MOE), which is also the cover system required as per the MoE Criteria, involves a 150 mm top soil horizon (k= $4x10^{-4}$ cm/s), and a 600 mm Clay Barrier Layer (k= $1x10^{-5}$ cm/s).

Option 2 (1000 mm Clay Barrier with 300 mm Topsoil) involves a 300 mm top soil horizon (k= $4x10^{-4}$ cm/s), a 1000 mm Clay Barrier Layer (k= $1x10^{-5}$ cm/s).

Option 3 (600 mm Low Permeability Soil Barrier with 300 mm Topsoil Layer) involves a 300 mm top soil horizon (k= $4x10^{-4}$ cm/s), with a 200 mm Crushed Glass LFG/Leachate Collection Layer and a 600 mm Clay Barrier Layer (k= $1x10^{-5}$ cm/s).

Option 4 (600 mm Clay Barrier with 300 mm Topsoil Layer and 200 mm Gravel Drainage Layer) involves a 300 mm top soil horizon (k= $4x10^{-4}$ cm/s), and a 600 mm Clay Barrier Layer (k= $1x10^{-5}$ cm/s) with a 200 mm Gravel Drainage Layer (k= $1x10^{-1}$ cm/s) and a 200 mm Crushed Glass LFG/Leachate Collection Layer.

Option 5 (Geomembrane with a 300 mm Topsoil Layer and a gas/leachate collection layer) involves a 300 mm top soil horizon (k= $4x10^{-4}$ cm/s), an LLDPE geomembrane as barrier (k= $2x10^{-13}$ cm/s) and a 200 mm Crushed Glass LFG/Leachate Collection Layer.

Option 6 (Geomembrane with a 300 mm Topsoil Layer and a gas/leachate collection layer and drainage layer) involves a 300 mm top soil horizon (k= $1x10^{-1}$ cm/s), an LLDPE geomembrane as barrier (k= $2x10^{-13}$ cm/s), a 200 mm gravel drainage layer (k= $4x10^{-4}$ cm/s) and a 200 mm Crushed Glass LFG/Leachate Collection Layer.
Each option was simulated for crest (4%) and side slopes (33%). Since leachate generation on the crest (4%) would be critical, and was found to be slightly higher, the results for the crest options are discussed in detail below:

Existing Condition: Each of the cover designs were compared to the existing condition scenario. This scenario has a 300 mm thick intermediate cover with a k value of $4x10^{-4}$ cm/s. This scenario indicates a leachate percolation rate of 37.5 mm/yr.

Option 1- 600 mm Clay Barrier with a 150 mm Topsoil Layer: This option is, in fact, the MOE recommended option as per the Criteria. As mentioned in Table 10-2, the runoff, evapotranspiration and change in water storage were found to be 24.45 mm/yr, 281.51 mm/yr and 1.62 mm/yr respectively for the open condition. Leachate production prior to closure was found to be 37.47 mm/yr. After closure with the clay barrier, run-off was found to be increased to 27.76 mm/yr, while evapotranspiration was found to decrease to 276.38 mm/yr. The change in water storage slightly increased to 1.78 mm/yr. Leachate production was found to increase slightly to 39.14 mm/yr.

Option 2 – 1000 mm Clay Barrier with a 300 mm Topsoil: This option is the same as Option 1 with a thicker barrier layer and topsoil. As mentioned in Table 10-2, the runoff and evapotranspiration were found to be 20.26 mm/yr, 299.1 mm/yr and change in water storage was found to be 1.56 mm/yr, after closure with this option. Leachate production was found to be 24.13 mm/yr for the closed condition under this option.

Option 3 - 600 mm Low Permeability Soil with a 300 mm Topsoil and a Gas Collection Layer: This option is the same as Option 2 with a gas collection layer. As indicated in Table 10-2, the runoff and evapotranspiration were found to be 20.24 mm/yr, 298.85 mm/yr and change in water storage was found to be 1.76 mm/yr, after closure with this option. Leachate production was found to be 24.2 mm/yr for the closed condition under this option.

Option 4 - 600 mm Clay Barrier with a 300 mm Topsoil Layer, a Drainage Layer and a Gas Collection Layer: This option the same as Option 3 with a drainage layer. As mentioned in Table 10-2, the runoff and evapotranspiration were found to be 15.49 mm/yr, 297.49 mm/yr and change in water storage was found to be 1.72 mm/yr, after closure with this option. Lateral drainage at the top drainage layer was found to be very minimal at 23.12 mmm/yr. Leachate production was found to be 7.23 mm/yr for the closed condition under this option.

Option 5 - Geomembrane with a 300 mm Topsoil Layer, a Gas Collection Layer and a Drainage Layer: As mentioned in Table 10-2, the runoff, evapotranspiration and change in water storage were found to be 15.67 mm/yr, 323.44 mm/yr and 1.85 mm/yr respectively after closure with this option. Leachate production was found to be 4.08 mm/yr for the closed condition under this option.

Option 6 - Geomembrane with a 300 mm Topsoil Layer and a Gas Collection Layer: As indicated in Table 10-2, the runoff, evapotranspiration and change in water storage were found to be 15.49 mm/yr, 297.4 mm/yr and -0.51 mm/yr respectively after closure with this option. Lateral drainage at the top drainage layer was found to be 32.66 mmm/yr. Leachate production decreased to 0.004 mm/yr for the closed condition under this option.

10.5 Recommended Cover Design for Final Consideration

Based on the results of this analysis SHA concludes that the most effective cover system that will minimize leachate production long term can be realized with an LLDPE geomembrane cover system involving a 300 mm topsoil layer with hydraulic conductivity of $4x10^{-4}$ cm/s, a 300 mm drainage layer with hydraulic conductivity of $1x10^{-1}$ cm/s and a 40 mil LLDPE Geomembrane Barrier Layer and a 200 mm Crushed Glass Gas Collection Layer. Figure 10-1 shows a typical cover system detail and Figure 10-2a shows the recommended cover design.

Alternatively, a 600 mm compacted low permeability soil cap with a 300 mm topsoil/biocover layer and a 200 mm gas collection layer could be used provided a local source with adequate amount of low permeability soil in reserve can be secured. Figure 10-2b illustrates the low permeability soil/evaporative cover concept. SHA recommends a low permeability soil cap at CMLF as we believe that the application this cover system will function as an evaporative cover system and the biocover would reduce the emissions of LFG gas from the landfill that would be diffused through the gas collection layer beneath the biocover layer. This cover system will also be the cheaper option.

The cover systems described above may be subject to some changes based on the results from investigations and HELP modeling to be completed as part of the detailed design process.

10.6 Surface Water Ditching and Erosion Protection

Surface water management has been discussed in Section 7.2. The mid slope ditches will be triangular in shape to minimize the wetted perimeter and to minimize the infiltration. Figure 7-5 previously showed a conceptual design for surface water ditching.

Slopes that are covered with intermediate cover without any vegetation are expected to lose an average of almost 1.1 cm of soil per year. Under these conditions, soil loss will increase further down the slope as surface run off increases in velocity. The end result will be similar to the situation illustrated in Photograph 10-2 below.

Once final cover is constructed, the slopes should experience an average annual soil loss of around 0.079 cm per year providing a fair stand of grass vegetation is established. This represents a stable situation where erosion damage is controlled.

During final cover construction, the RDOS may wish to protect the topsoil with a biodegradable erosion control mat while the grass cover is becoming established or a highly productive fabricated growing media can be placed on the slopes to quickly establish a vegetative cover.

Photo 10-2: Erosion of Final Cover System – Hartland Landfill, BC

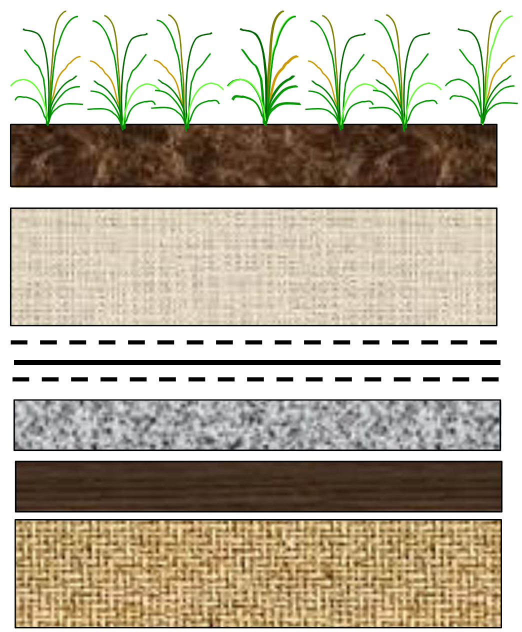
10.7 Progressive Closure

Progressive closure will be necessary to keep leachate generation to a minimum. Essentially, progressive closure involves filling upwards to final grades quickly, rather than spreading waste out horizontally, and then constructing final closure over completed sections of the landfill progressively. This approach has advantages as closure costs can be spread out over the life of the landfill, closed "green" areas can provide screening for operations and most importantly, leachate production will be reduced by capping waste sooner rather than later.

Figure 10-3 provides a progressive closure plan for the site for the CMLF. Included in the plan are the sequential closure phases. Closure of the areas shown should occur within 1 year of the completion of each phase.

10.8 Post Closure Maintenance and Monitoring

At the end of the operational life of the landfill, a closure monitoring program will be implemented. Consequently, all monitoring data collected up to that point will form an essential part of the data set needed to demonstrate closure conditions. A closure report will need to be prepared to support the application to surrender the permit and to demonstrate that waste stabilization has been achieved. Following the closure report, a post-closure monitoring plan will need to be put in place. Selective indicator parameters will continue to be monitored at a reduced frequency to ensure that there is no health risk from the residual impacts. However, these parameters will likely be measured at a lesser frequency than that planned for the other monitoring programs. As per BC MoE Requirements mentioned in the new Criteria, the post-closure monitoring program will continue for a minimum of 30 years after closure. The closure and post-closure monitoring program should include all of the parameters monitored during the routine/regulatory assessment monitoring.



GOOD STAND OF GRASS

300 mm TOPSOIL/BIOCOVER LAYER (4 x 10^{-4} cm/s)

300 mm GRAVEL DRAINAGE LAYER (1 x 10^{-1} cm/s)

CUSHION GEOTEXTILE – HEAVYWEIGHT

40mil LLDPE GEOMEMBRANE BARRIER LAYER (2 x 10^{-13} cm/s)

SEPARATION GEOTEXTILE - HEAVYWEIGHT

200 mm CRUSHED GLASS GAS COLLECTION LAYER (5 x 10^{-3}cm/s)

300 mm INTERMEDIATE COVER LAYER (1 x 10^{-4} cm/s)

MSW WASTE (5 x 10^{-4} cm/s)

SPERLING HANSEN ASSOCIATES	CLIENT: Regional District of Okanagan-Similkameen	PROJECT: **CAMPBELL MOUNTAIN LANDFILL DESIGN, OPERATIONS & CLOSURE PLAN**	TITLE: **Recommended Cover System Geomembrane Option**	SCALE: NTS; DATE: 2016/04/13 (yyyy/mm/dd); PROJECT NO: PRJ1 5061; DESIGNED: IB; DRAWN: MG; CHECKED: TS; DRAWING NO: **Figure 10-2a**

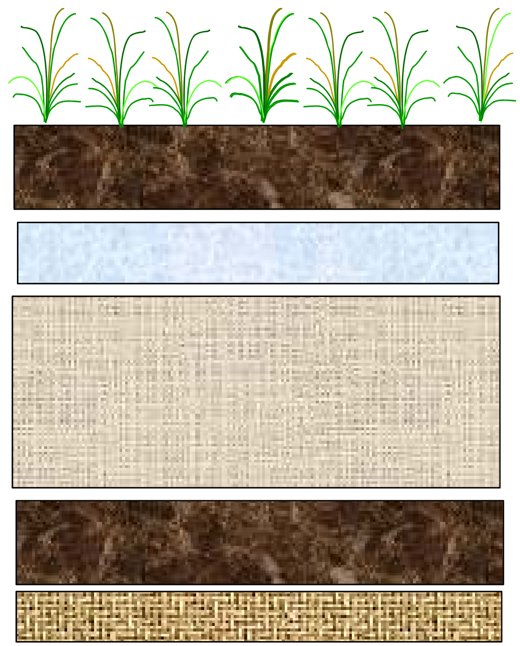
Sperling Hansen Associates

CLIENT: Regional District of Okanagan-Similkameen

PROJECT: **CAMPBELL MOUNTAIN LANDFILL DESIGN, OPERATIONS & CLOSURE PLAN**

TITLE: **Recommend Cover System Clay Option**

SCALE:	DATE:	PROJECT NO:
NTS	2016/04/13 (yyyy/mm/dd)	PRJ1 5061
DESIGNED	IB	DRAWING NO:
DRAWN	MG	**Table 10-2b**
CHECKED	TS	



SPERLING HANSEN ASSOCIATES

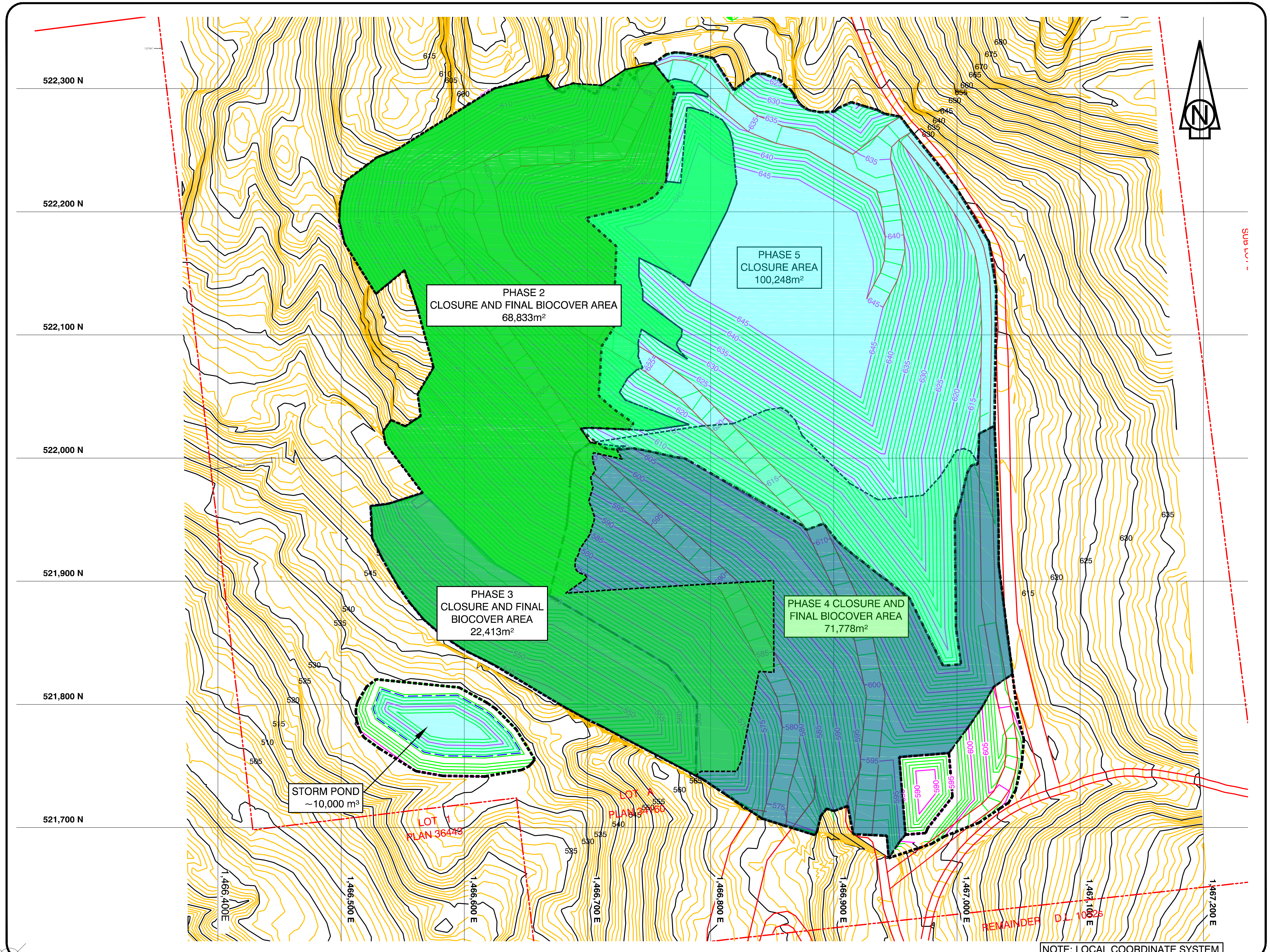
CLIENT:
Regional District of Okanagan-Similkameen

PROJECT:
CAMPBELL MOUNTAIN LANDFILL DESIGN, OPERATIONS & CLOSURE PLAN

TITLE:
RECOMMENDED FINAL COVER SYSTEM (Low Permeable Clay)

SCALE:	DATE:	PROJECT NO:
NTS	2016/04/13 (yyyy/mm/dd)	PRJ15061

DESIGNED	IB	DRAWING NO:
DRAWN	MG	**FIGURE 10-2b**
CHECKED	TS	



SPERLING
HANSEN
ASSOCIATES

Landfill Services Group
- Landfill Siting
- Design & Operations Plans
- Landfill Closure
- Environmental Monitoring

#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE

CLIENT:
REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE:
PROGRESSIVE CLOSURE PLAN

SCALE:	DATE:	PROJECT NO:
1:3000	2016/04/29 yyyy/mm/dd	PRJ15061

DESIGNED	TS	DRAWING NO:
DRAWN	NL	FIGURE 10-3
CHECKED	TS	

Table 10-1 HELP MODEL PROFILE AND SCENARIOS

Layers	Vegetation	Open	Closed					
		Option 0 Existing	**Option 1-Clay Barrier- 150 mm topsoil-MOE)**	**Option 2-1000 mm Clay Barrier with 300 mm topsoil)**	**Option 3-600 mm Low Permeability Barrier- SHA Rec 300 mm topsoil-with Gas Collection Layer)**	**Option 4-600 mm Clay Barrier- SHA Rec 300 mm topsoil-with Gravel Drainage and Gas Collection Layer)**	**Option 5-Geomembrane Barrier- SHA Rec 300 mm topsoil-with Drainage and and Gas Collection Layer)**	**Option 6-Geomembrane Barrier- SHA Rec 300 mm topsoil-without Drainage Layer)**
		Poor Stand of Grass	Good Stand of Grass	Good Stand of Grass	Good Stand of Grass	Good Stand of Grass	Good Stand of Grass	Good Stand of Grass
		Evaporative Zone Depth = 25cm	Evaporative Zone Depth= 51 cm	Evaporative Zone Depth= 51 cm	Evaporative Zone Depth= 51 cm	Evaporative Zone Depth= 51 cm	Evaporative Zone Depth= 51 cm	Evaporative Zone Depth= 51 cm
Layer 1	Material	Intermediate Cover	Topsoil/Biocover	Topsoil/Biocover	Topsoil/Biocover	Topsoil/Biocover	Topsoil/Biocover	Topsoil/Biocover
	Function	Vertical Percolation Layer	Vertical Percolation Layer	Vertical Percolation Layer	Vertical Percolation Layer	Vertical Percolation Layer	Vertical Percolation Layer	Vertical Percolation Layer
	Thickness (mm)	300	150	300	300	300	300	300
	K Value (cm/s)	4x10^{-4}	4x10^{-4}	4x10^{-4}	4x10^{-4}	4x10^{-4}	4x10^{-4}	4x10^{-4}
Layer 2	Material	Refuse	Clay	Clay	Crushed Glass Gas Collection Layer	Gravel	Gravel	Gravel
	Function	Vertical Percolation Layer	Barrier Layer	Barrier Layer	Laterla Drainage Layer	Lateral Drainage Layer	Laterla Drainage Layer	Laterla Drainage Layer
	Thickness (mm)	30000	600	1000	200	200	200	200
	K Value (cm/s)	5x10^{-4}	1x10^{-5}	1x10^{-5}	5x10^{-3}	1x10^{-1}	1x10^{-1}	1x10^{-1}
Layer 3	Material	Native Sand	Intermediate Cover	Crushed Glass Gas Collection Layer	Clay	Clay	Geomembrane	Geomembrane
	Function	Lateral Drainage Layer	Vertical Percolation Layer	Laterla Drainage Layer	Barrier Layer	Barrier Layer	Barrier Layer	Barrier Layer
	Thickness (mm)	2000	300	200	600	600	40 mil	40 mil
	K Value (cm/s)	1x10-^{2}	5x10^{-4}	5x10^{-3}	1x10^{-5}	1x10^{-5}	1x10^{-5}	1x10^{-5}
Layer 4	Material		Refuse	Intermediate Cover	Intermediate Cover	Crushed Glass Gas Collection Layer	Crushed Glass Gas Collection Layer	Crushed Glass Gas Collection Layer
	Function		Vertical Percolation Layer	Vertical Percolation Layer	Vertical Percolation Layer	Laterla Drainage Layer	Laterla Drainage Layer	Laterla Drainage Layer
	Thickness (mm)		30000	300	300	200	200	200
	K Value (cm/s)		5x10^{-4}	5x10^{-4}	5x10^{-4}	5x10^{-3}	5x10^{-3}	5x10^{-3}
Layer 5	Material		Native Sand	Refuse	Refuse	Intermediate Cover	Intermediate Cover	Intermediate Cover
	Function		Lateral Drainage Layer	Vertical Percolation Layer	Vertical Percolation Layer	Vertical Percolation Layer	Vertical Percolation Layer	Vertical Percolation Layer
	Thickness (mm)		2000	30000	30000	300	300	300
	K Value (cm/s)		1x10-^{2}	5x10^{-4}	5x10^{-4}	5x10^{-4}	5x10^{-4}	5x10^{-4}
Layer 6	Material			Native Sand	Native Sand	Refuse	Refuse	Refuse
	Function			Lateral Drainage Layer	Lateral Drainage Layer	Vertical Percolation Layer	Vertical Percolation Layer	Vertical Percolation Layer
	Thickness (mm)			2000	2000	30000	30000	30000
	K Value (cm/s)			1x10-^{2}	1x10-^{2}	5x10^{-4}	5x10^{-4}	5x10^{-4}
Layer 7	Material					Native Sand	Native Sand	Native Sand
	Function					Lateral Drainage Layer	Lateral Drainage Layer	Lateral Drainage Layer
	Thickness (mm)					2000	2000	2000
	K Value (cm/s)					1x10-^{2}	1x10-^{2}	1x10-^{2}
Layer 8	Material							
	Function							
	Thickness (mm)							
	K Value (cm/s)							

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Table 10-2 HELP MODEL RESULTS

Scenarios	Scenario Modelled	Evapotranspiration (mm/yr)	Evapotranspiration as % of P	Runoff (mm/yr)	Runoff as % of P	Percoaltion to leachate (mm/yr)	Percolation to Leachate % of P	Lateral Drainage (mm/yr)	Lateral Drainage % of P	Change in water storgae (mm/yr)	Change in water storgae as % of P	Leakage through Refuse Layer	Leakage through Refuse Layer as % of P	Leachate Produced (mm/yr)	Leachate Produced as % of P	Precipitation (mm/yr)
I.D	4% Slope															
Option 0	Open-Existing	281.5	81.6%	24.45	7.1%	37.48	11.9%	N/A	N/A	1.62	0.5%	37.47	10.9%	37.47	10.9%	345.05
Option 1	Closed- 150 mm Topsoil MOE	276.4	80.1%	27.76	8.0%	41.20	7.6%	N/A	N/A	1.78	0.5%	39.14	11.3%	39.14	11.3%	345.06
Option 2	Closed- with 300 mm topsoil/Biocover with 1000 mm Clay	299.1	86.7%	20.26	5.9%	26.25	7.7%	N/A	N/A	1.56	0.5%	24.13	7.0%	24.13	7.0%	345.05
Option 3	Closed- SHA Rec 300 mm Topsoil/Biocover and 600 mm Clay Barrier with Gas Collection Layer	298.9	86.6%	20.24	5.9%	26.52	2.8%	N/A	N/A	1.76	0.5%	24.2	7.0%	24.2	7.0%	345.05
Option 4	Closed- 300 mm Topsoil/Biocover with 600 mm Clay and Drainage Layer	297.5	86.2%	15.49	4.5%	9.65	0.1%	23.12	6.7%	1.72	0.5%	7.23	2.1%	7.23	2.1%	345.05
Option 5	Closed-300 mm Topsoil/Biocover with 40 mil Geomembrane and Drainage Layer	297.4	86.2%	15.49	4.5%	0.195	0.1%	32.66	9.5%	-0.51	-0.1%	0.003	0.0%	0.003	0.0%	345.04
Option 6	Closed- 300 mm Topsoil/Biocover with 40 mil Geomembrane and without Drainage Layer	297.4	86.2%	15.49	4.5%	0.195	0.0%	32.66	9.5%	-0.51	-0.1%	0.002	0.0%	0.002	0.0%	345.04

11. ENVIRONMENTAL MONITORING

11.1 Existing Monitoring Wells

Currently there are eleven groundwater monitoring wells at the CMLF as shown in Figure 2-7, nine of which were monitored in 2015. There is also one offsite residential well (DW1655) and one off-site monitoring well (MW15-01) that were monitored in 2015.

Five monitoring wells (BH-101, -102, -103, 104, & -105) were installed in 1994, four monitoring wells (BH2000-1, -2, -3, & -4) were installed in 2000, and six monitoring wells (BH04-01, -02, -03, -04, -05, & -06) were installed in 2004. Since then static levels have been taken at monitoring wells BH04-05, and -06 and monitoring well BH04-01 has unreliable readings as there is a smaller half inch PVC pipe installed within the 2 inch well. Monitoring well MW15-1 is located on the Lank property, approximately 500 m downgradient of the landfill toe, and was installed as part of an off-site leachate migration assessment that Western Water Associates Ltd. is currently undertaking.

During the 2015 monitoring period, two of the wells (BH-102 and BH-2000-1) were dry and were unable to be sampled which has proven to be similar in the past. From the nine wells that were sampled onsite during 2015, the depth of water levels ranged from 7.3 m below ground surface in BH-101 to 23.0 m below ground surface in BH04-4.

11.2 Ground Water Monitoring

To determine whether the landfill is having an impact on the underlying water table, it will be necessary to monitor the existing wells.

The monitoring program should include:

- Pumping each well at a low-flow rate using a Waterra Hydro-Lift until field measurements (conductivity, temperature and pH) have stabilized
- A measurement of static water levels in all wells to accurately determine the direction of groundwater flow. These measurements will also help to determine whether there are seasonal fluctuations in groundwater levels. The depth to the water table and the total depth of each well will also be used to determine the thickness of the water column within each standpipe.
- A measurement of flow rate in all wells.
- Collection of representative samples. Samples should be collected in dedicated bottles*, field filtered, preserved and kept on ice (stored at a temperature of approximately 4° C).

  (* Dedicated bottles means that the sample should be collected in bottles that have been cleaned and prepared with preservatives according to specifications set by the laboratory.)
- Submission of samples for laboratory analysis as soon as feasible after collection. Some parameters a holding time have as short as 48 hours so quick delivery to the lab is crucial for

reliable results. Proposed sampling parameters and a schedule for monitoring is presented in Table 11-1 found below.

- Collection and submission of at least one randomly selected duplicate sample, per sampling event, as a quality control/quality assurance measure, in order to check analytical reliability. A full discussion of QA/QC is presented in Section 11.4.
- During each monitoring event the following should be recorded:
  - Water Level;
  - Purging Information; and
  - Field Measurements (Electrical Conductivity, Dissolved Oxygen, Oxidation and Reduction Potential (ORP), pH, and Temperature).
- The majority of the existing wells will be decommissioned when the different phases of the landfill are implemented over the years and will have to be replaced.

If pumping wells will be installed as a means of controlling offsite migration of leachate, then they can be incorporated as downgradient monitoring wells and should be sampled and analyzed for the same parameters as the normal monitoring wells. In order to assess the effectiveness of the pumping wells, it is recommended that additional monitoring wells be installed downgradient of the pumping wells. The exact number of wells and their locations will be determined once the system of pumping wells have been implemented.

As part of the 2015 annual report, Western Water Associates Ltd. (Western, 2016) completed a statistical analysis of the water quality data collected to date, and concluded that a sampling frequency of three times per year would provide as much information as a sampling program based on quarterly sampling. SHA concur with this statement, and therefore recommend that future sampling be completed three times per year rather than on a quarterly basis.

Table 11-1 Groundwater Monitoring Program

GROUNDWATER MONITORING	
Monitoring Locations	Existing wells (BH04-02, BH04-04, BH-101, BH-102, BH-103, BH-104, BH-105, BH2000-1, BH2000-2, BH2000-3, BH2000-4, DW1655, and MW15-1)
Sampling Frequency	Three times per year
Analyses	
Field Measurements	Three times per year - pH, conductivity, temperature, Total Dissolved Solids (TDS), Oxidation and Reduction Potential (ORP), Dissolved Oxygen (DO), Turbidity
Alkalinity	Three times per year
Dissolved Anions	Three times per year - Chloride, fluoride, sulphate, bromide
Nutrients	Three times per year - Ammonia, nitrate, nitrite
Dissolved Metals	Three times per year - ICP/MS Scan for trace heavy metals.
Organic Parameters	Three times per year - COD
PAH and Volatiles	Annually - It is our experience that although many landfills test for them routinely, PAH's and VOC's are seldom found in leachate samples in B.C. landfills. We recommend that testing for these parameters should be conducted once per year and only in the wells that show strongest impact by landfill leachate. If hits are detected, then the sampling program should be expanded to include selected monitoring wells.
Duplicates	One duplicate sample should be submitted per sampling event
Reporting	Annual monitoring report to B.C. MoE.

The analytical results should be interpreted using the most suitable water quality criteria. At present, these are the *"Guidelines for Canadian Drinking Water Quality"* (GCWQ), and BC Contaminated Sites Regulation for protection of: aquatic life (CSR-AW), drinking water (CSR-DW), irrigation water (CSR-IW), and livestock (CSR-LW).

BC MoE guidelines for protection of aquatic life *"British Columbia Approved Water Quality Guidelines Criteria: 2016 Edition"* (updated March 2016) is primarily applicable to surface water, but applies to groundwater within ten meters from streams that the groundwater discharges to. Where concentrations for specific parameters have not been approved by the MoE, a second publication entitled *"A Compendium of Working Water Quality Guidelines for British Columbia: 2015 Edition"* (updated August 2015) should be used. This publication presents benchmark (working) guidelines that have not yet been approved by the Ministry.

11.3 Surface Water Monitoring

A new off-site surface water monitoring location, Lank Springs, was sampled in October and November 2015. The results were compared to BC Water Quality Guidelines for Protection of: Aquatic Life, Livestock and Irrigation. Exceedances were found in the following parameters; uranium, chloride, pH, total dissolved solids, fluoride, and magnesium. The other surface water body in proximity to the landfill (Randolph Springs) is located on private property and has recently become accessible to the RDOS in 2016. Randolph Springs should be included in the 2016 sampling events.

11.4 Leachate Monitoring

As was mentioned in Chapter 7, the landfill leachate collected from the future lined areas, as well as from the pumping wells will be discharged into a leachate collection pond on the south side of the landfill as seen in Figure 7-2. From here, the leachate will be pumped up to one of the two proposed phytoremediation areas for treatment. It is recommended that the leachate in the collection pond be monitored for both quantity and quality as per Table 11-2. The proposed monitoring program consists of monitoring the total volume of leachate being pumped from the pond to the phytoremediation area by tracking the hours the discharge pump is being operated.

With the dry climate in the area, it is anticipated that the majority of the leachate in the pond will evaporate, leaving relatively small quantities needing treatment. Since the phytoremediation area will consist of a poplar plantation, it will be important to regularly monitor the salinity and/or the conductivity of the leachate prior to it being discharge to the plantation as high salinity can be de detrimental to the health of the poplar trees.

Table 11-2 Leachate Monitoring Program

LEACHATE MONITORING	
Monitoring Locations	South Leachate Collection Pond (SW-1)
Sampling Frequency	Monthly – Field Parameters (Conductivity, pH, Temperature) Quarterly – Leachate Sampling
Analyses	
Leachate Parameters	Quarterly - pH, Conductivity, Temp, TSS, Ammonia (total), TKN, Alkalinity, Chloride, Sodium, Sulphate, Sulphide, Total and Dissolved Metals, COD, BOD, Dissolved Oxygen (DO),
	Annually - PAH
Leachate Levels	Weekly measurements
Volume of Leachate removed	As removed (volumes tracked by hour-meter on discharge pump)
Duplicates	Not required
Reporting	Annual monitoring report to the MoE.

11.5 Quality Assurance/Quality Control

SHA recommends that the RDOS incorporate a quality assurance/quality control (QA/QC) program into the monitoring program. A QA/QC program is a system of procedures, checks, audits and corrective actions that will assist in ensuring that the data generated at the laboratory is of the highest achievable quality. This is of prime importance, as the monitoring data will form the basis for all of the conclusions regarding the impact of the landfill on the surrounding environment. As a first step in the QA/QC program, we recommend that the RDOS submit all samples to an analytical laboratory that is certified by the Canadian Association of Environmental Laboratories.

The primary purpose of the QA/QC program is not to check up on the environmental laboratory conducting the analyses, but to demonstrate the reproducibility of the analytical data. Reproducibility demonstrates that the data is of high quality and that, in turn, the conclusions drawn from the data have an associated high level of confidence.

There are two main types of laboratory QA/QC samples – internal and external. Internal QA/QC refers to the routine procedures that laboratories perform, on a daily or a "batch" basis, in order to ensure that nothing inside the laboratory is influencing the analytical results. External QA/QC refers to blind QC samples submitted to the laboratory to determine whether the sampling methodology contaminated the samples, to determine the laboratory analytical precision and accuracy and to assess sampling variability.

11.5.1 Internal QA/QC

As discussed, internal QA/QC consists of routine checks and procedures that are undertaken by the laboratory on a daily or batch basis. Internal QC includes (but is not limited to):

- Standard methods for cleaning sample bottles, utensils and analytical equipment;
- Storage, handling and quality of internal QC samples;
- Sample storage procedures;
- Sample documentation (e.g. analytical technician, analytical technique, control charts and other information);
- Storage, handling and quality of cleaning agents, reagents, acids, distilled or deionized water;
- QA/QC training for and certification of staff.

Laboratories that are certified by the Canadian Association of Environmental Laboratories also undergo a bi-annual audit to ensure that the standard operating procedures meet the minimum standards and that all the technical staff is certified.

11.5.2 External QA/QC

External QA/QC involves submitting blind QC samples as part of a sampling suite. The blind samples usually consist of a combination of blank, duplicate, reference and spike samples. Each type of external QC sample is discussed below.

11.5.2.1 Blank Samples

Blank samples are used to determine whether any systematic sampling contamination is affecting the samples. Blanks typically consist of commercially available de-ionized or distilled water that is taken with the field staff during a sampling event. The blanks are treated identically to all other samples, by being poured into a sample bottle, by undergoing any routine filtration or acidification in the field and by being submitted to the laboratory as a discrete sample.

11.5.2.2 Field Duplicates

Duplicate samples are used to determine the analytical precision of the laboratory and to assess sample variability. Field duplicates, as their name implies, are two samples collected from the same sampling point. The sample is duplicated by either collecting the samples sequentially, or by collecting one large sample, which is subsequently split into two sub-samples. The samples are submitted separately.

11.5.2.3 Reference Samples

Reference samples are used to determine a laboratory's analytical accuracy. Reference samples are commercially available samples with a known composition. These samples are submitted to the laboratory and the results checked against the "ingredient list" once analysis is complete.

11.5.2.4 Spike Samples

Spike samples, like reference samples, are used to determine the analytical accuracy of a laboratory. They differ from reference samples by containing only one or two dissolved parameters of known concentration, rather than a full suite of parameters. Spiked samples are typically used for VOCs, hydrocarbons or other organic parameters, as opposed to inorganic parameters.

QA/QC samples typically constitute 10-20% of each sampling suite submitted to a laboratory. For example, a suite of twenty samples may contain seventeen "real" samples, one duplicate, one blank and one reference. The duplicate, blank and reference samples are submitted under "dummy" numbers that match the rest of the sampling suite. The duplicate sample should be collected from a different, randomly chosen location during each monitoring event.

11.5.3 Data Acceptance Criteria

As part of the QA/QC program, data acceptance criteria are used to assess whether the analytical results being generated by the laboratory are within acceptable bounds. Data that falls outside the acceptable bounds will require further assessment in order to determine the reasons behind the data variability. Table 11-4 lists typical acceptance criteria for the main parameter of interest in groundwater and leachate samples.

Table 11-4. QA/QC Acceptance Criteria

Parameter	Blank	Duplicate	Reference/Spike
Inorganic	No positive detection	25% Variance allowed.	< 2 standard deviations
VOC's	No positive detection	30% Variance allowed	30% Variance allowed
PAH	No positive detection	30% Variance allowed	30% Variance allowed

A common method of identifying data that are outside acceptable limits is through "flagging". Flagging can be performed electronically by comparing the data that is returned by the analytical laboratory to the data acceptance criteria. Flagged data should be brought to the attention of laboratory staff for clarification.

For the CMLF we recommend the following QA/QC program be adopted:

- One duplicate groundwater sample should be collected from one of the downgradient wells every sampling round.
- One duplicate background groundwater sample should be collected annually.
- The data acceptance criteria in Table 11-4 should be adopted.

Western Water is developing a QA/QC program for the RDOS for CMLF. Once their program is developed SHA's recommended program can be modified in light of their program or the RDOS may choose to follow the program developed by Western Water.

11.6 QA/QC-Protocols

A rigorous QA/QC protocol is being developed by Western Water Associates Ltd for the RDOS. The QA/QC protocol includes the procedures for: sampling, calibration of field instruments, chain of custody reports and the use of blank, reference and duplicate samples. The protocol should also specify the QA/QC procedures that the selected laboratory will use.

11.7 Landfill Gas Monitoring

Offsite lateral migration of LFG from the CMLF is currently being monitored in a number of gas migration monitoring probes along the northern perimeter of the site. The probes currently being monitored are: GP-1, -2, -3, -14, -15, 16, -17 and -18, of which gas probes GP-1, -2, -17 and -18 are nested with two or three probes set at different depths at each monitoring location. In addition to the above mentioned monitoring probes, gas composition is also being monitored in eight monitoring probes (GP98-1 to -8) in the area referred to as the North Ravine. These probes are being monitored primarily for presence of carbon monoxide since the area at the North Ravine had a subsurface fire back in 1998, and follow up monitoring is done as a precautionary measure. Gas composition is also being monitored in an old gas extraction well located at the centre of the landfill. A total of six monitoring probes were installed along the south side of the site, of which five are still functioning (GP-5 to GP-9), but are currently not being monitored. The locations of the existing gas monitoring locations are shown in Figure 2-7.

The data from the existing monitoring probes show no signs that landfill gas is migration beyond the property line at the probe locations. SHA is of the opinion that lateral migration is currently not a big concern, but could become a problem as the landfill expands, or if development occurs on neighbouring properties within the 300 m buffer zone.

It is recommended that the probes on the south side (GP-5 to -9) be added to the existing monitoring program for as long as they are in place. Long term, some of these probes will be destroyed when landfill operations start in this area. In addition to monitoring the gas composition in these probes, it is recommended that a site investigation be completed once landfilling in the southern portion of the site commences. This assessment should include identification of possible pathways for lateral migration and soil gas sampling with borehole punch probes along the proposed southern waste footprint. In addition to assessing potential pathways for landfill gas migration, a strategy for replacing probes as they become demolished by landfill development should be developed. Figure 11-1 shows locations of the existing wells that most likely will be intact after the site is fully developed and suggested locations for future landfill gas migration monitoring probes.

This monitoring program should also include monitoring for landfill gases in any buildings constructed at the site along with an annual walkover of the site with a portable gas detector for potential landfill gas migration through the soil. Alarm system for explosive gases should be installed in all permanent structures at the landfill.

11.8 Post Closure Monitoring Locations

SHA's proposed post closure monitoring locations are shown on Figure 11-1. As was mentioned earlier, some of the existing monitoring locations lie outside of the landfill expansion footprint and can be maintained long term, while some will have to be replaced. It is anticipated that monitoring well BH-105 will remain intact and can continue to be used to provide background information. Additional groundwater or vapour wells could be installed around the perimeter as needed in the long-term. Precautions should be taken by operators and contractors to clearly identify existing monitoring wells. SHA suggests protecting existing wells from vehicle traffic with no-post barriers. In addition, post-closure surface water sampling should be conducted at the future storm water pond and leachate sampling should be conducted at the future leachate pond located in the south east portion of the site.

11.9 Annual Inspection

SHA recommends that, during operations an annual inspection and an annual landfill survey be conducted. The annual inspection should include a geotechnical inspection conducted shortly after the snow has melted for the year. A geotechnical inspection and landfill settlement monitoring will also be required (by the Landfill Criteria) annually during post-closure.

For the geotechnical inspection, Regional District staff should inspect the active and inactive areas of the landfill footprint, check the cover for potential problems arising from cracking, erosion (especially during snow melt) or slumping and determine the state of any infrastructure that does not receive regular inspection or maintenance. If significant geotechnical problems are discovered, then a qualified geotechnical engineer should be retained to mitigate the problems.

A survey of the active area every year is also recommended. The mapping will be useful in settlement monitoring and volume calculations. The volume calculations will help reassess lifespan estimates and schedule capital costs. Accurate surveys will also provide information to determine the rate of waste settlement. Our experience at other facilities in the province indicates that landfill waste settles an average of 10% to 15% per year. The waste at the CMLF site may undergo a similar degree of settlement, depending on the degree of compaction at the time of placement. The results of the surveys should be included in the reports submitted to MoE.

Additional inspections should be conducted on a regular basis to detect cover erosion, ditch clogging and blow-outs, sediment accumulation, leachate break-outs and seeps. In addition, the annual operating strategy should be planned for next year's operations. As discussed in Section 11-7, a site walkover with a portable gas detector should be conducted to monitor for any potential landfill gas migration through the soil.

11.10 Annual Report

According to Section 7.17 of the B.C. MoE Landfill Criteria, annual Operating and Monitoring Reports are to be submitted to the Regional Manager of the local B.C. Environment Pollution Prevention Branch. The reports are to contain:

- A total volume or tonnage of waste discharged per year;
- An approved design volume;
- The remaining site lifespan and capacity;
- The operational plan for the next year;
- The operation and maintenance expenditures;
- The leachate, water quality and landfill gas monitoring data and interpretations;
- The volume of leachate collected, treated and disposed (if applicable);
- Any changes from the approved reports, plan and specifications;
- An updated contingency plan, noting any amendments made in the preceding year;
- The volume of landfill gas collected and disposed (if applicable);
- A review of the closure plan and its associated cost estimate.

All of the monitoring data should be compiled once a year into a comprehensive Annual Monitoring Report. The data should be reviewed and interpreted by a qualified professional prior to its inclusion in the annual report. This review should look at the current data on its own, as well as in an historical context. Annual reporting is a requirement of the Landfill Criteria and is a useful way to ensure that all the necessary monitoring is being completed.

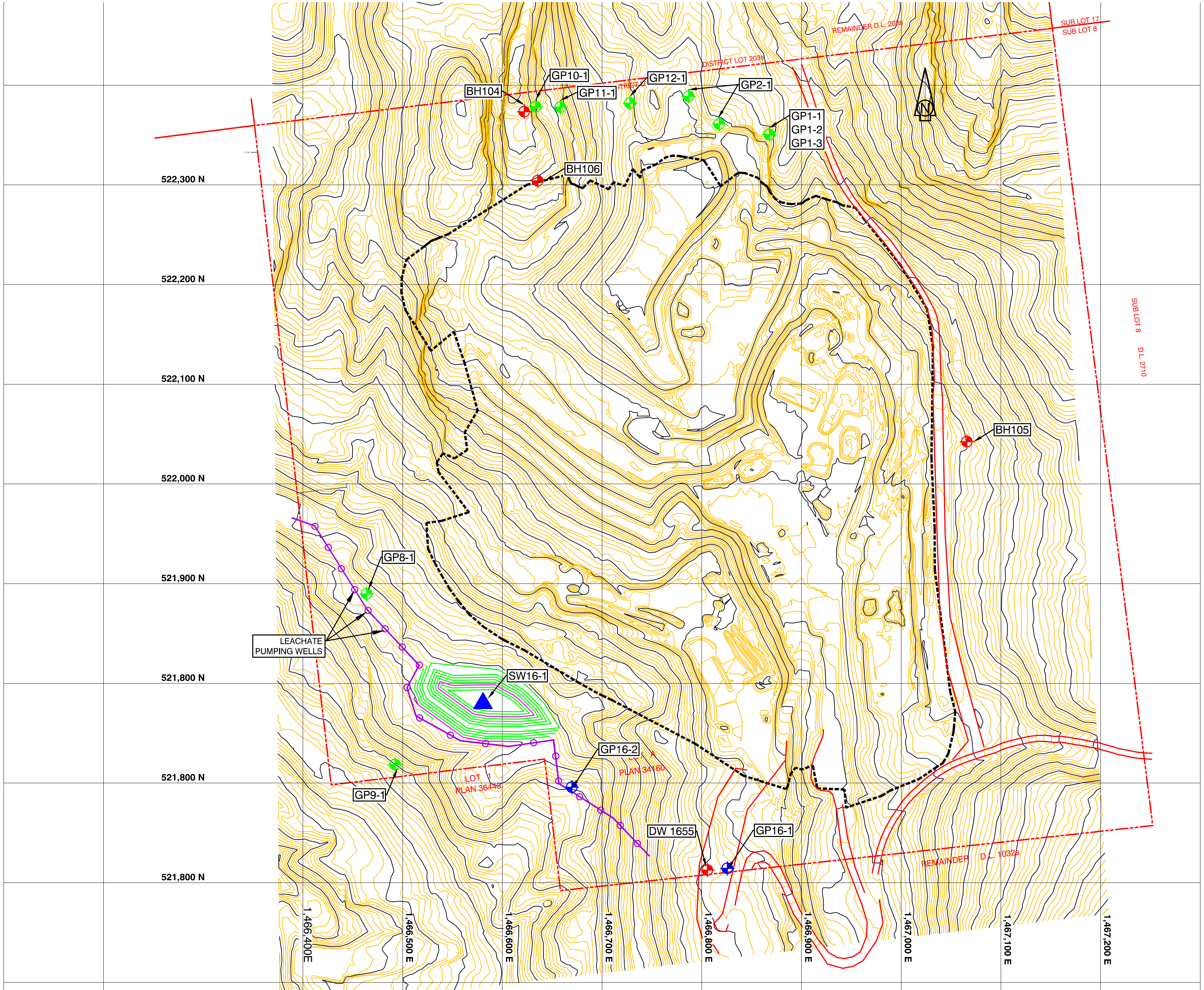
11.11 Data Management

As discussed above, the RDOS will rapidly accumulate data during the lifespan of the landfill. Thus, we recommend that the RDOS initiate the use of a data management system. Commercially available software such as Eqwin, Esims, dBase and SiteFx and others, can be used for the storage and handling of environmental data. The data will need to be reviewed and audited internally prior to its inclusion into the database. The use of a database will allow for the rapid and efficient storage, retrieval, manipulation and presentation of the water quality data the RDOS has accumulated. An added advantage of a computerized database is that water quality data can be downloaded digitally directly from the analytical laboratory to the RDOS.

11.12 Geotechnical Monitoring

The geotechnical monitoring should include:

- Three times per year monitoring of groundwater levels in monitoring wells
- Annual stability surveys of benchmarks and proposed settlement hubs



NOTE: LOCAL COORDINATE SYSTEM

SPERLING HANSEN ASSOCIATES

Landfill Services Group
- Landfill Siting
- Design & Operations Plans
- Landfill Closure
- Environmental Monitoring

#8 - 1225 East Keith Road
North Vancouver, B.C. V7J 1J3
Phone: (604) 986-7723
Fax: (604) 986-7734

LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- 5m DESIGN CONTOUR
- 1m DESIGN CONTOUR
- ROAD
- PROPERTY LINE
- EXISTING MONITORING WELLS
- EXISTING GAS MONITORING PROBES
- PROPOSED GAS MONITORING PROBES
- SURFACE WATER MONITORING LOCATION

CLIENT:
REGIONAL DISTRICT OF OKANAGAN-SIMILKAMEEN

PROJECT:
RDOS CAMPBELL MOUNTAIN LANDFILL DESIGN OPERATIONS AND CLOSURE PLAN

TITLE:
POST CLOSURE MONITORING LOCATIONS

SCALE:	DATE:	PROJECT NO:
1:4000	2016/06/01 (yyyy/mm/dd)	PRJ15061

DESIGNED	DK	DRAWING NO:
DRAWN	NL	FIGURE 11-1
CHECKED	TS	

12. COST ANALYSIS

12.1 Introduction

SHA conducted a detailed cost analysis for developing, operating and closing the CMLF. Cost estimates were made for construction works, closure of each phase, annual operation, and post closure. A particular objective of the analysis was to determine whether it would be advantageous for the RDOS to implement a more costly geomembrane final cover system or a low permeability soil/evaporative cover system with biocover coupled with organic diversion. The analyses are included in Tables 12-1 to 12-19. The tables show the capital cost for development of each phase, annual operating costs, closure costs for each phase, estimated annual post closure costs and a cash flow analyses that provide summary of the findings with costs projected into the future.

12.2 Capital Costs

In this economic analysis SHA considers both the costs of an intermediate biocover application for the low permeability soil/evaporative cover option and the cost of an active landfill gas collection system for the geomembrane cover option. The main capital costs for developing the landfill is based on the consideration of managing leachate onsite through phytoremediation with hybrid poplar plantations, constructing basal liners for all new expansion phases and the application of either a biocover and low permeability soil/evaporative cap closure system or a geomembrane closure system with an active landfill gas collection system. Proposed Capital Cost expenditures based on a low permeability soil/evaporative cover system are outlined below:

- Engineering Structures $ 350,00
- Intermediate Biocover Layer $ 3,889,700
- Surface Water & Leachate Ponds $ 310,000
- Expansion Phases and Leachate Collection $ 5,898,675
- Environmental Monitoring $ 100,000
- Phytoremediation & Leachate Treatment $ 1,060,000

The total capital cost using a low permeability soil/evaporative cover system is approximated at $11,608,375 which is spread over the five proposed phases as the landfill develops, as presented in Table 12-1a Capital Costs for Low permeability soil/evaporative Cover Option. In addition, a 20% engineering fees and a 15% contingency fee are budgeted, resulting in a total capital cost of $16,019,558.

Proposed Capital Cost expenditures based on a geomembrane cover system including an active LFG collection system are outlined below:

- Engineering Structures $ 350,000
- Surface Water & Leachate Ponds $ 310,000
- Expansion Phases and Leachate Collection $ 5,898,675
- Active LFG Management System $ 14,146,436
- Environmental Monitoring $ 100,000

- Phytoremediation & Leachate Treatment $ 1,060,000

The total capital cost using a geomembrane cover system is approximated at $21,865,111 which is spread over the five proposed phases as the landfill develops, as presented in Table 12-1b Capital Costs for Geomembrane Cover Option. In addition, a 20% engineering fees and a 15% contingency fee are budgeted, resulting in a total capital cost of $30,173,853.

12.3 Annual Operating Costs

Annual operating costs are shown on Table 12-2. These are based on typical costs at landfills engineered by SHA with actual costs included for the landfill contractor, scale shack operations, equipment maintenance and power to the site. These costs were provided in detail by the RDOS based on 2014 and 2015 actual costs. A summary of the annual operating costs is below:

- Materials and Equipment $ 1,500
- General Administration $ 626,800
- Landfill Operations and Maintenance $ 1,373,000
- Environmental Monitoring $ 12,000
- Annual Reporting $ 25,000
- Operating Contingency (10%) $ 203,830

The total actual annual operating cost (General Administration and Operations) for the site for 2015 provided by the RDOS is estimated at $2,242,130 excluding Transfer to Capital and Transfer to Reserve. Including a 10% contingency, a unit cost of $93.27/tonne of waste was calculated based on the costs outlined in Table 12-2 for the estimated 2015 waste disposal tonnages (24,038 tonnes/year) received at the CMLF. This unit cost was used in the cash flow analyses (Table 12-15 to 12-18) to project future operating costs.

12.4 Closure Costs

In this economic analysis SHA considers both the costs of Low permeability soil/evaporative Cover and Geomembrane Cover, and explores the resulting impacts on cash flow for both options. Low permeability soil/evaporative cover (including final biocover and progressive intermediate biocover) is shown to be about $11.82 million cheaper than geomembrane cover (including LFG collection, extraction and treatment system). Table 12-3 shows a conceptual cost estimate using average costs for a geomembrane cover system with final biocover and an active LFG system versus a low permeability soil/evaporative cap system with intermediate and final biocover.

The estimated costs of closure for the Low permeability soil/evaporative Cover Option are shown in Table 12-4, 12-5, 12-6 and 12-7 for Phase 2, Phase 3, Phase 4 and Phase 5 respectively. Phase 1 will not receive final cover. The estimated closure costs for Phases 2, 3, 4, 5, and 6 are $2,376,508, $706,674, $2,633,979 and $3,363,560 respectively. The final closure unit costs are $34.53/m^2 for Phase 2, $31.53/m^2 for Phase 3, $36.70/m^2 for Phase 4 and $33.55/m^2 for Phase 5 respectively. The total cost of closure of CMLF with a **low permeability soil/evaporative cover system is $9,080,721** with an average unit cost of $34.08/m^2 of closure area. Please note the average unit price costs of closure are based on Phase 2, 3, 4 and 5 as Phase 1 will not receive final closure.

The estimated costs of closure for Geomembrane Cover Option are shown in Table 12-8, 12-9, 12-10 and 12-11 for Phase 2, Phase 3, Phase 4 and Phase 5 respectively, given Phase 1 will not receive final cover. The estimated closure costs for Phases 2, 3, 4 and 5 are $3,161,205, $962,182, $3,447,028 and $4,911,798 respectively. The final closure unit costs are $45.93/m^2 for Phase 2, $42.93/m^2 for Phase 3, $48.02/m^2 for Phase 4 and $44.54/m^2 for Phase 5 respectively. The total cost of closure of CMLF with a **geomembrane closure system is $12,482,213** with an average unit cost of $45.36/m^2 of closure area. Please note the average unit price costs of closure are based on Phase 2, 3, 4 and 5 as Phase 1 will not receive final closure.

As comparison of closure costs are outlined below based on the two closure options outlined above (Low permeability soil/evaporative Cap vs. Geomembrane Cap).

Table 12-12 Cost Comparison for Closure Option (Low permeability soil/evaporative Cap vs. Geomembrane)

	Clay Cap		Geomembrane Cap	
Phases	**Closure Cost ($)**	**S/m^2**	**Closure Cost ($)**	**S/m^2**
Phase 1	$ -	$ -	$ -	$ -
Phase 2	$ 2,376,508.00	$ 34.53	$ 3,161,205.00	$ 45.93
Phase 3	$ 706,674.00	$ 31.53	$ 962,182.00	$ 42.93
Phase 4	$ 2,633,979.00	$ 36.70	$ 3,447,028.00	$ 48.02
Phase 5	$ 3,363,560.00	$ 33.55	$ 4,911,798.00	$ 44.54
Total	$ 9,080,721.00		$ 12,482,213.00	
Avg (Ph 2 -5)		$ 34.08		$ 45.36

As can be seen in Table 12-12 above, the total cost of a geomembrane cover system (not including LFG collection, extraction and treatment) versus a low permeability soil/evaporative cover system (not including progressive intermediate biocover) is approximately $3,401,492 more expensive. Both cover systems include a final biocover layer.

Table 12-13 shows a summary of capital costs for closure of a number of landfills throughout British Columbia engineered by SHA. These are projects in which SHA have been directly involved in design, project management and construction inspection. Starting on the left of the table and moving to the right are the landfill name, the year in which the project occurred, the approximate area of closure in hectares, indication of whether some type of gas collection or venting system was installed, whether a toe berm was installed, the total construction cost and the unit cost per square meter. The purpose of the table is to show the range of total and unit costs for closure and to compare the costs of the different types of capping systems.

Table 12-13 Actual Landfill Closure Construction Costs Engineered by SHA

Landfill	Year	Area (ha)	Cap Type	Gas	Toe Berm	Cost	Unit Cost /m^2
Hartland South Face	1995	2.5	PVC/Clay	Yes	Yes	$1,044,909	$41.80
Hartland North Face	1996	5.2	PVC/Clay	Yes	Yes	$1,845,071	$35.48
Savona	1996	0.6	Sand	No	No	$46,317	$7.72
Knockholt	1997	0.2	Clay	No	Yes	$196,874	$82.03
Campbell Mountain	1998	0.6	Clay	No	Yes	$172,831	$27.88
Hope	1998	0.5	Clay	No	Yes	$234,877	$51.06
Nanaimo	1999	0.7	PVC/Clay	Yes	Yes	$304,072	$46.42
Nanaimo	2000	0.5	PVC/Clay	Yes	Yes	$360,463	$80.10
Iona	2000	0.9	LLDPE/Clay	No	No	$180,108	$19.37
Logan Lake	2000	2.5	Clay	No	No	$238,750	$9.55
Nanaimo	2001	0.8	PVC	No	Yes	$286,878	$35.86
Prince George	2002	5.3	LLDPE/Clay	Yes	Yes	$1,643,971	$31.02
Teck Cominco Trail	2002	4.8	LLDPE/GCL	No	Yes	$1,903,747	$39.83
Minnie's Pit	2003	1.8	LLDPE/Clay	Yes	Yes	$1,067,774	$59.32
Hartland West Face	2004	2.9	LLDPE	No	Yes	$870,970	$30.03
Skimikin	2005	3.4	LLDPE	Yes	Yes	$1,508,441	$44.37
Nanaimo	2007	1.8	Clay	Yes	No	$588,047	$32.85
Fernie	2009	13.0	6.5 ha LLDPE/ 6.5 ha Clay	Yes	No	$3,500,000	$26.92
Gibraltar Phase 1	2009	0.8	Agru Super Grip Net	No	No	$384,901	$47.40
Islands Landfill Phase 1	2010	1.3	Agru Super Grip Net	No	Yes	$1,200,366	$89.58
Vancouver	2009-2010	14.4	LLDPE/Clay	Yes	Yes	$11,835,750	$82.19
Gibraltar Phase 2	2010	0.8	Agru Super Grip Net	No	No	$409,727	$52.13
Salmon Arm Landfill	2010	3.7	Agru Super Grip Net	Yes	No	$1,037,300	$27.81
Creston Landfill	2011	1.4	LLDPE	Yes	Yes	$786,269	$56.45
SFPR Delta Shake and Shingle	2011	9.6	LLDPE	Yes	No	$7,513,109	$78.26
SFPR Beta Landfill	2011	8.9	LLDPE	Yes	No	$6,964,114	$77.90
SFPR 688147 B.C. Ltd Landfi	2011	3.2	LLDPE	Yes	No	$1,584,660	$49.52
Alpha North	2011	11.1	Clay	Yes	No	$1,457,243	$13.19
Alpha South	2011	5.0	Clay	No	No	$450,000	$9.09
Delta Shake and Shingle	2012	8.5	LLDPE	Yes	No	$4,584,957	$53.94
Vancouver Phase 2	2012-13	19.2	LLDPE	Yes	Yes	$14,700,000	$76.56
Vancouver Phase 3	2013	9.5	LLDPE	No	Yes	$6,966,064	$73.17
Hope Landfill	2013	3.1	LLDPE	Yes	Yes	$2,500,000	$80.65
Average:		**148.4**	**LLDPE/Clay**			**$78,368,561**	**$52.80**

The total costs range from $46,300 for a small closure construction at the Savona Landfill in 1996 to $14,700,000 for a 19.2 hectare closure at the Vancouver Landfill in 2012-2013. Unit costs per square metre range from $7.70/m^2 to $89.58/m^2. The cost of construction generally depends on the type of cap (membrane vs. low permeability soil/evaporative cover only), gas collection or venting, and whether some type of toe berm is constructed. Generally, low permeability soil/evaporative caps are less expensive than a membrane cap or a composite cap with a membrane and low permeability soil/evaporative.

As mentioned before, the estimated total closure cost for all the phases at CMLF with a low permeability soil/evaporative cover system is \$9,080,721 with an average unit cost of \$34.08/m^2 of closure area. This is below the average closure cost for BC landfills. It should be noted that SHA's estimate of closure costs for the CMLF is based on the availability of suitable low permeability material being available onsite. If this is not the case, the costs for closure would increase, dependant on where suitable material is available. If low permeability soil is not available onsite the estimated total closure cost for all phases at CMLF with a low permeability soil/evaporative cover system will be \$11,924,058 with an average cost of \$44.88/m^2

The total cost of closure of CML with a geomembrane closure system is projected at \$12,482,213 with an average unit cost of \$45.36/m^2 of closure area, which is also below the average unit cost in Table 12-13 and below the typical range of unit costs experienced for recent geomembrane landfill closures. However, this average unit cost does not include the cost of the active LFG system.

Including the cost of the active LFG system, the geomembrane cover system will still be \$14,704,591 higher than the low permeability soil/evaporative cover system and \$10,814,891 higher than the low permeability soil/evaporative cover system including progressive intermediate biocover if low permeability soil is not available onsite.

12.5 Post Closure Costs

Post closure costs, shown on Table 12-14, consist of environmental controls, maintenance, monitoring and reporting and administration (local staff). The total estimated cost of post closure is \$163,065 per year with a per unit cost of \$0.60 /m^2, based on an estimated total closure area of 270,648m^2.

12.6 Leachate Management Costs

Our cost analysis also includes an estimate for onsite management of leachate. SHA has proposed that leachate will be collected via a series of downgradient pumping wells as well as from what is collected on the Phase 2, 3, 4 and 5 expansion basal liner systems. Leachate collected through both systems will be stored in the southwest leachate / surface water pond and treated through active aeration, evaporation and phytoremediation through uptake from Hybrid Poplar plantations planned on the final contours of Phase 2 and on the uplands area east of Spiller Rd.

As outlined in Table 12-1a and Table 12-1b Capital Costs, below is a summary of the cost estimated for leachate management (not including Expansion Lining and Collection Piping) onsite at CMLF:

- Leachate Pumping Wells Installation \$ 380,000
- Aeration Controls and Power at South Pond \$ 80,000
- Phytoremediation Area (1 & 2) Development \$ 600,000
- Leachate Pumping System \$ 50,000
- Power for Leachate Treatment System \$ 30,000

It should be noted that the cost of lining / paving the existing CoP biosolids composting area, as mentioned in Table 12-1a and 12-16, could be included in these costs as SHA feels the existing run-off and infiltration from operations is affecting water quality at the site. SHA has estimated a cost of approximately $100,000 to upgrade the facility with an impervious working deck and run-off collection and storage.

12.7 Cash Flow Analysis

SHA relies on a comprehensive lifecycle cash flow model to provide the breakeven all-in cost for each landfill facility. The breakeven cost is the best measure of long term costs of landfill facilities that can be used to set appropriate tipping fees, of course once all other aspects of the waste management system are taken into account as well.

From an economic perspective, the best landfill design, development and closure strategy is one that results in the lowest break-even lifecycle cost. This chapter explores the following options:

The cash flow analyses for the low permeability soil/evaporative cover option are shown on Table 12-15 for Waste Generation Scenario 1 (3.07 W/C ratio) and on Table 12-16 for Scenario 2 (4 W/C ratio). The cash flow analyses for the geomembrane cover option are shown on Table 12-17 for Scenario 1 and on Table 12-18 for Scenario 2.

In each case, the cash flow analysis achieves cumulative net revenue of $0 by the time the 30 year post closure monitoring period has ended.

In each case the cash flow table provides a summary of all cost estimations shown in the year that each cost is expected to occur based on the lifespan analysis. The phased closures are highlighted and the associated closure costs for each phase are shown in the year in which they occur. Annual operating costs are shown for each year of landfill operation, until final closure year. The total cost for landfill operation is the summation of the capital costs, annual operating costs, closure costs and post closure costs. Totals for each cost category over the life of the landfill are shown at the bottom of the table. Total revenue is the summation of tipping revenue from waste and reserve currently available and is set aside annually to the closure reserve fund. Total revenue has been calculated using a theoretical “break-even” tipping rate for both low permeability soil/evaporative cover and geomembrane cover options for Scenario 1 and Scenario 2. The break-even tipping rate may be described as the per tonne charge required to fund the landfill until after the post closure period ends in 2134 for Scenario 1 and 2137 for Scenario 2. The break-even tipping fees for low permeability soil/evaporative cover option were found to be $98.82 and $98.16 for Scenario 1 and Scenario 2 respectively. The break-even tipping fees for geomembrane cover option were found to be $109.81 and $108.80 for Scenario 1 and Scenario 2 respectively. Currently, the tipping fees at CMLF are charged at $95/tonne and $500/tonne for MSW and DRC waste, respectively. The tipping fee for DRC waste at the CML is high as the RDOS wants to encourage the public to dispose of it at OK Falls Landfill.

In conclusion, SHA’s analysis reveals that, in the long term, the low permeability soil/evaporative cover would result in a significant cost savings of approximately $17.5 million as a result of much reduced landfill gas extraction costs assuming that low permeability soil is available onsite.

In summary, for low permeability soil/evaporative cover option Scenario 1, during the landfill life until 2104 and 30 years after closure, $16,019,558 (7% of tipping fees) would be spent on capital infrastructure, $9,080,721 (4% of tipping fees) would be spent on closure, $206,772,960 (84% of the revenue from tipping fees) would be spent on annual operations, $4,891,944 (2% of the revenue from tipping fees) would be spent on post closure care and $8,544,654 (3% of the revenue from tipping fees) would be earned from interest. The break even tipping fee for this scenario is projected at $98.82 per tonne.

For low permeability soil/evaporative cover option Scenario 2, during the landfill life until 2107 and 30 years after closure, $16,019,558 (6% of tipping fees) would be spent on capital infrastructure, $9,080,721 (4% of tipping fees) would be spent on closure, $217,311,279 (85% of the revenue from tipping fees) would be spent on annual operations, $4,891,944 (2% of the revenue from tipping fees) would be spent on post closure care and $8,430,610 (3% of the revenue from tipping fees) would be earned from interest. The break-even tipping fee for this scenario is projected at $98.16 per tonne.

For geomembrane cover option Scenario 1, during the landfill life until 2104 and 30 years after closure, $30,173,853 (11% of tipping fees) would be spent on capital infrastructure, $12,482,213 (5% of tipping fees) would be spent on closure, $206,772,960 (77% of the revenue from tipping fees) would be spent on annual operations, $4,891,944 (2% of the revenue from tipping fees) would be spent on post closure care and $15,774,729 (6% of the revenue from tipping fees) would be earned from interest. The break-even tipping fee for this scenario is projected at $109.81 per tonne.

For geomembrane cover option Scenario 2, during the landfill life until 2107 and 30 years after closure, $30,173,853 (11% of tipping fees) would be spent on capital infrastructure, $12,482,213 (4% of tipping fees) would be spent on closure, $217,311,279 (77% of the revenue from tipping fees) would be spent on annual operations, $4,891,944 (2% of the revenue from tipping fees) would be spent on post closure care and $16,134,013 (6% of the revenue from tipping fees) would be earned from interest. The break-even tipping fee for this scenario is projected at $108.80 per tonne.

In consideration of these results, SHA recommends that the RDOS continue to focus on efficient waste operations to increase the waste to cover ratio from 3.07:1 to 4:1 and that the RDOS give careful consideration to adopting a low permeability soil/evaporative closure system with biocover as it is expected to reduce overall landfill costs by some $17.5 million dollars.

SHA notes that the aforementioned break-even tipping fees are for waste only and the costs used in the analysis are 2016 costs.

Table 12-1a Campbell Mountain Landfill Capital Costs for Clay Cover Option

Item	Quantity	Units	Unit Cost ($)	Sub-Cost ($)	Total Cost ($)	Comments	2017 Construction Costs Start-up Cost ($)	Phase 1 ($)	Phase 2 ($)	Phase 3 ($)	Phase 4 ($)	Phase 5 ($)		
Engineering Structures					**$350,000**		**$100,000**	**$0**	**$0**	**$250,000**	**$0**	**$0**	$350,000	
CoP Biosolids Composting Area Lining SW Capture Upgrades	1	unit	$100,000	$100,000			$100,000							
Scale and Scale House Relocation	1	unit	$250,000	$250,000						$250,000				
Intermediate Biocover					**$2,644,996**		**$0**	**$1,408,382**	**$457,300**	**$272,935**	**$218,314**	**$288,065**	$2,644,996	
Phase 1	82,846	m^2	$17.00	$1,408,382				$1,408,382						
Phase 2	26,900	m^2	$17.00	$457,300					$457,300					
Phase 3	16,055	m^2	$17.00	$272,935						$272,935				
Phase 4	12,842	m^2	$17.00	$218,314							$218,314			
Phase 5	16,945	m^2	$17.00	$288,065								$288,065		
Intermediate Crushed Glass LFG Diffusion Layer					**$1,244,704**		**$0**	**$662,768**	**$215,200**	**$128,440**	**$102,736**	**$135,560**	$1,244,704	
Phase 1	82,846	m^2	$8.00	$662,768				$662,768						
Phase 2	26,900	m^2	$8.00	$215,200					$215,200					
Phase 3	16,055	m^2	$8.00	$128,440						$128,440				
Phase 4	12,842	m^2	$8.00	$102,736							$102,736			
Phase 5	16,945	m^2	$8.00	$135,560								$135,560		
Surface Water Pond Construction (2x Ponds)					**$310,000**			**$205,000**	**$0**	**$0**	**$105,000**	**$0**	$310,000	
Excavation and Construction of Ponds	15,000	m^3	$8.0	$120,000				$80,000			$40,000			
Geomembrane Liner (60 mil) and Secondary Containment	12,000	m^2	$15.0	$180,000				$120,000			$60,000			
Spillway Control	2	LS	$5,000.0	$10,000				$5,000			$5,000			
Expansion Liner System and Leachate Collection System					**$5,898,675**		**$380,000**	**$0**	**$1,500,225**	**$1,855,575**	**$2,162,875**	**$0**	$5,898,675	
Subgrade Preparation	137,500	m^2	$2.00	$275,000										
Compacted Silt - 300 mm	41,250	m^3	$8.00	$330,000										
GCL	137,500	m^2	$10.00	$1,375,000										
HDPE membrane, textured (60 mm)	137,500	m^2	$9.00	$1,237,500										
Sand cushion layer - 150 mm thick	20,625	m^3	$25.00	$515,625										
Geotextile seperator - Medium weight	137,500	m^2	$2.00	$275,000										
Coarse rock drainage layer - 300 mm	41,250	m^3	$20.00	$825,000										
Graded sand and gravel filter - 150 mm	20,625	m^3	$20.00	$412,500										
Leachate Collection-inc. collector, clean, pipe surround	1,487	m	$150.00	$223,050										
Leachate Header	500	m	$100.0	$50,000										
Leachate Pumping Wells Installation	19	units	$20,000.0	$380,000			$380,000							
Environmental Monitoring					**$100,000**		**$0**	**$20,000**	**$20,000**	**$20,000**	**$20,000**	**$20,000**	$100,000	
Landfill Gas Probes	10	units	$2,500.0	$25,000				$5,000	$5,000	$5,000	$5,000	$5,000		
Groundwater monitoring well	10	units	$7,500.0	$75,000				$15,000	$15,000	$15,000	$15,000	$15,000		
Phytoremediation Area and Aeration Treatment System					**$1,060,000**		**$0**	**$380,000**	**$80,000**	**$300,000**	**$0**	**$300,000**	$1,060,000	
Aeration Controls for South Pond	1	units	$80,000.0	$80,000					$80,000					
Phytoremediation Area and Irrigation System - 1	1	units	$300,000.0	$300,000				$300,000						
Phytoremediation Area and Irrigation System - 2	1	units	$300,000.0	$300,000						$300,000				
Phytoremediation Area and Irrigation System -3	1	units	$300,000.0	$300,000								$300,000		
Leachate Pumping System	1	units	$50,000.0	$50,000				$50,000						
Power for Leachate Treatment	1	LS	$30,000.0	$30,000				$30,000						Check
SUBTOTAL					**$11,608,375**		**$480,000**	**$2,676,150**	**$2,272,725**	**$2,826,950**	**$2,608,925**	**$743,625**	$11,608,375	$11,608,375
Engineering					**$2,321,675**	`	**$96,000**	**$535,230**	**$454,545**	**$565,390**	**$521,785**	**$148,725**	$2,321,675	
Estimate at 20% of Capital Projects				$2,321,675										
SUBTOTAL					**$13,930,050**		**$576,000**	**$3,211,380**	**$2,727,270**	**$3,392,340**	**$3,130,710**	**$892,350**	$13,930,050	
Contingency 15%					$2,089,508		$86,400	$481,707	$409,091	$508,851	$469,607	$133,853	$2,089,508	
TOTAL					**$16,019,558**		**$662,400**	**$3,693,087**	**$3,136,361**	**$3,901,191**	**$3,600,317**	**$1,026,203**	$16,019,558	

Table 12-1b Campbell Mountain Landfill Capital Costs for Geomembrane Option

Item	Quantity	Units	Unit Cost ($)	Sub-Cost ($)	Total Cost ($)	Comments	Start-up Cost ($)	Phase 1 ($)	Phase 2 ($)	Phase 3 ($)	Phase 4 ($)	Phase 5 ($)		
							2017 Construction Costs							
Engineering Structures					**$350,000**		**$100,000**	**$0**	**$0**	**$250,000**	**$0**	**$0**	$350,000	
CoP Biosolids Composting Area Lining SW Capture Upgrades	1	unit	$100,000	$100,000			$100,000							
Scale and Scale House Relocation	1	unit	$250,000	$250,000						$250,000				
Intermediate Biocover					**$0**		**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	$0	
Phase 1	0	m^2	$17.00	$0				$0						
Phase 2	0	m^2	$17.00	$0					$0					
Phase 3	0	m^2	$17.00	$0						$0				
Phase 4	0	m^2	$17.00	$0							$0			
Phase 5	0	m^2	$17.00	$0								$0		
Intermediate Crushed Glass LFG Diffusion Layer					**$0**		**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	$0	
Phase 1	0	m^2	$8.00	$0				$0						
Phase 2	0	m^2	$8.00	$0					$0					
Phase 3	0	m^2	$8.00	$0						$0				
Phase 4	0	m^2	$8.00	$0							$0			
Phase 5	0	m^2	$8.00	$0								$0		
Surface Water Pond Construction (2x Ponds)					**$310,000**			**$205,000**	**$0**	**$0**	**$105,000**	**$0**	$310,000	
Excavation and Construction of Ponds	15,000	m^3	$8.0	$120,000				$80,000			$40,000			
Geomembrane Liner (60 mil) and Secondary Containment	12,000	m^2	$15.0	$180,000				$120,000			$60,000			
Spillway Control	2	LS	$5,000.0	$10,000				$5,000			$5,000			
Expansion Liner System and Leachate Collection System					**$5,898,675**		**$380,000**	**$0**	**$1,500,225**	**$1,855,575**	**$2,162,875**	**$0**	$5,898,675	
Subgrade Preparation	137,500	m^2	$2.00	$275,000										
Compacted Silt - 300 mm	41,250	m^3	$8.00	$330,000										
GCL	137,500	m^2	$10.00	$1,375,000										
HDPE membrane, textured (60 mm)	137,500	m^2	$9.00	$1,237,500										
Sand cushion layer - 150 mm thick	20,625	m^3	$25.00	$515,625										
Geotextile seperator - Medium weight	137,500	m^2	$2.00	$275,000										
Coarse rock drainage layer - 300 mm	41,250	m^3	$20.00	$825,000										
Graded sand and gravel filter - 150 mm	20,625	m^3	$20.00	$412,500										
Leachate Collection-inc. collector, clean, pipe surround	1,487	m	$150.00	$223,050										
Leachate Header	500	m	$100.0	$50,000										
Leachate Pumping Wells Installation	19	units	$20,000.0	$380,000			$380,000							
Active LFG Managemnt System					**$14,146,436**		**$0**	**$5,769,108**	**$560,000**	**$1,427,564**	**$2,782,820**	**$3,606,944**	$14,146,436	
Phase 1	1	LS	$5,769,108.0	$5,769,108				$5,769,108						
Phase 2	1	LS	$560,000.0	$560,000					$560,000					
Phase 3	1	LS	$1,427,564.0	$1,427,564						$1,427,564				
Phase 4	1	LS	$2,782,820.0	$2,782,820							$2,782,820			
Phase 5	1	LS	$3,606,944.0	$3,606,944								**$3,606,944**		
Environmental Monitoring					**$100,000**		**$0**	**$20,000**	**$20,000**	**$20,000**	**$20,000**	**$20,000**	$100,000	
Landfill Gas Probes	10	units	$2,500.0	$25,000				$5,000	$5,000	$5,000	$5,000	$5,000		
Groundwater monitoring well	10	units	$7,500.0	$75,000				$15,000	$15,000	$15,000	$15,000	$15,000		
Phytoremediation Area and Aeration Treatment System					**$1,060,000**		**$0**	**$380,000**	**$80,000**	**$300,000**	**$0**	**$300,000**	$1,060,000	
Aeration Controls for South Pond	1	units	$80,000.0	$80,000					$80,000					
Phytoremediation Area and Irrigation System - 1	1	units	$300,000.0	$300,000				$300,000						
Phytoremediation Area and Irrigation System - 2	1	units	$300,000.0	$300,000						$300,000				
Phytoremediation Area and Irrigation System - 2	1	units	$300,000.0	$300,000								$300,000		
Leachate Pumping System	1	units	$50,000.0	$50,000				$50,000						
Power for Leachate Treatment	1	LS	$30,000.0	$30,000				$30,000						Check
SUBTOTAL					**$21,865,111**		**$480,000**	**$6,374,108**	**$2,160,225**	**$3,853,139**	**$5,070,695**	**$3,926,944**	$21,865,111	$21,865,111
Engineering					**$4,373,022**	`	**$96,000**	**$1,274,822**	**$432,045**	**$770,628**	**$1,014,139**	**$785,389**	$4,373,022	
Estimate at 20% of Capital Projects				$4,373,022										
SUBTOTAL					**$26,238,133**		**$576,000**	**$7,648,930**	**$2,592,270**	**$4,623,767**	**$6,084,834**	**$4,712,333**	$26,238,133	
Contingency 15%					$3,935,720		$86,400	$1,147,339	$388,841	$693,565	$912,725	$706,850	$3,935,720	
TOTAL					**$30,173,853**		**$662,400**	**$8,796,269**	**$2,981,111**	**$5,317,332**	**$6,997,559**	**$5,419,183**	$30,173,853	

Note: Active LFG Management System Costs for Geomembrane Option is also presented on Table 12-3

Table 12-3. Campbell Mountain LFG System Conceptual Cost Estimate for Active System with Geomemberane Cover Plus Biocover and Intermediate Biocover with Clay Cap and Biocover

Progressive Active LFG Collection System As per The BC MOE LFG Regulation

		Phase 1 Ongoing	Phase 2 Ongoing	Phase 2 Closure	Phase 3 Ongoing	Phase 3 Closure	Phase 4 Ongoing	Phase 4 Closure	Phase 5 Ongoing	Phase 5 Closure	TOTAL
	LFG Collection system Area (m²)	82,846	20,000			22,413		70,815		100,248	
1	LFG/ Condensate Collection System	$ 2,319,688	$ 560,000	$ -	$ -	$ 627,564	$ -	$ 1,982,820	$ -	$ 2,806,944	$ 8,297,016
2	Blower/ Flare Skid (Supply and Install)	$ 800,000	$ -		$ -	$ 800,000	$ -	$ 800,000	$ -	$ 800,000	$ 3,200,000
		$ 5,769,108	$ 560,000	$ -	$ -	$ 1,427,564	$ -	$ 2,782,820	$ -	$ 3,606,944	$ 11,497,016
	Final Closure Area (m²)			68,833		22,413		71,778		100,248	
3	Geomembrane Cap + Biocover	$ -	$ -	$ 3,121,937	$ -	$ 1,016,547	$ -	$ 3,255,509	$ -	$ 4,546,772	$ 11,940,765
	Grand Total	$ 3,119,688	$ 560,000	$ 3,121,937	$ -	$ 2,444,111	$ -	$ 6,038,329	$ -	$ 8,153,716	$ 23,437,781

Progressive BioCover System Installation with Clay Cap at Final Elevations

		Existing North Slope Biocover	Phase 1 Intermediate Biocover	Phase 2 Closure and Final Biocover	Phase 2 Intermediate Biocover	Phase 3 Closure and Final Biocover	Phase 3 Intermediate Biocover	Phase 4 Closure and Final Biocover	Phase 4 Intermediate Biocover	Phase 5 Closure and Final Biocover	TOTAL
	Biocover Area (m²)	82,846	26,900		16,055		12,842		16,945		
1	Intermediate Biocover	$ 1,408,382	$ 457,300	$ -	$ 272,935	$ -	$ 218,314	$ -	$ 288,065	$ -	$ 2,644,996
	Final Closure Area (m²)			68,833		22,413		71,778		100,248	
2	Clay Cap + Biocover	$ -	$ -	$ 2,345,552	$ -	$ 763,745	$ -	$ 2,445,906	$ -	$ 3,416,049	$ 8,971,251
	Grand Total	$ 380,000	$ -	$ 92,500	$ -	$ -	$ -	$ -	$ -	$ -	$ 11,616,247

*Cost Estimates DO NOT include inflation

LFG Collection System:	$ 28	$/m²	
Geomembrane plus Biocover:	$ 45	$/m²	Average of Phase 2,3,4 and 5 Closure Costs
Biocover:	$ 17	$/m²	
Clay Cap + Biocover:	$ 34	$/m²	Average of Phase 2,3,4 and 5 Closure Costs

TABLE 12-2
Annual Operating Costs

Item	Quantity	Units	Unit Cost ($)	Sub-Cost ($)	Total Cost ($)	Comments
Materials and Equipment					**$1,500**	
Electric Fencing	1	LS	$1,500	$1,500		
General Administration					**$626,800**	
Salaries & Wages	1	LS	$380,000	$380,000		
Supplies	1	LS	$200	$200		
Legal Fees	1	LS	$1,000	$1,000		
Administration	1	LS	$62,000	$62,000		
Travel	1	LS	$25,000	$25,000		
Utilities	1	LS	$20,000	$20,000		
Advertising	1	LS	$8,000	$8,000		
Engineering	1	LS	$80,000	$80,000		
Lease	1	LS	$20,000	$20,000		
Insurance	1	LS	$30,600	$30,600		
Transfer to Capital	1	LS	-	-		$250,000 per year based on 2015 Annual Report
Transfer to Reserve	1	LS	-	-		
Landfill Operations and Maintenance					**$1,373,000**	
Landfill Operations (Wood Chipping, Gypsum Recy	1	annual	$660,000	$660,000		
Contract Services	1	annual	$685,000	$685,000		
Education and Training	1	annual	$6,000	$6,000		
Environmental Control	1	annual	$12,000	$12,000		
Depreciation	1	annual	$10,000	$10,000		
Environmental Monitoring					**$12,000**	
Envrionmental Monitoring	1	LS	$12,000	$12,000		
Annual Reporting					**$25,000**	
Topographic survey	1	per site	$10,000	$10,000		complete survey of active areas every year.
Operations records review	1	per site	$5,000	$5,000		review and interpret annual weigh scale records
Environmental monitoring review	1	per site	$10,000	$10,000		review of water quality, gas and geotechnical data, annual report.
Subtotal of Operating Costs					**$2,038,300**	
Operating Contingency						
Contingency @ 10% of Costs					**$203,830**	
TOTAL					**$2,242,130**	
				Unit Cost (per tonne of waste) =	**$93.27**	

TABLE 12-4 Preliminary Closure Costs for Phase 2
Low Permeability Soil/Evaporative Cover Option

Item	Quantity	Units	Unit Cost ($)	Sub-Cost ($)	Total Cost ($)	Comments
CLOSURE COSTS						
Approximate Phase 2 Closure Area =	68,833	m^2				
Site Preparation					**$103,250**	Prepare area for final closure
Site grading, smoothing and picking	68,833	m^2	$0.75	$51,625		
Proof rolling	68,833	m^2	$0.75	$51,625		
Cover System					**$1,562,509**	
600 mm Clay for Barrier Layer	41,300	m^2	$25.00	$1,032,495		Assuming Onsite Clay is available
200 mm Crushed Glass Gas Diffusion Layer	13,767	m^3	$8.00	$110,133		
300 mm Biocover Layer	20,650	m^3	$17.00	$351,048		
Hydroseeding	68,833	m^2	$1.00	$68,833		
Surface Water Management					**$88,140**	
Ditches	697	m	$120	$83,640		
Culverts	30	m	$150	$4,500		600 mm HDPE pipes
Access Roads/ Berms (697 m)					**$226,525**	10 m wide access roads across final slope
granular sub-base	3,485	m^3	$50	$174,250		Sub-base depth of 0.6 m
granular road base	1,046	m^3	$50	$52,275		Crushed topping depth of 0.15 m
SUBTOTAL					**$1,980,424**	
Engineering and Contingency					**$396,085**	
Estimate at 20% of Capital Projects						
TOTAL					**$2,376,508**	
Unit Cost (per m^2) =	**$34.53**					

TABLE 12-5 Preliminary Closure Costs for Phase 3
Low Permeability Soil/Evaporative Cover Option

Item	Quantity	Units	Unit Cost ($)	Sub-Cost ($)	Total Cost ($)	Comments
CLOSURE COSTS						
Approximate Phase 3 Closure Area =	22,413	m^2				
Site Preparation					**$33,620**	Prepare area for final closure
Site grading, smoothing and picking	22,413	m^2	$0.75	$16,810		
Proof rolling	22,413	m^2	$0.75	$16,810		
Cover System					**$508,775**	
600 mm Clay for Barrier Layer	13,448	m^2	$25.00	$336,195		Assuming Clay is Onsite
200 mm Crushed Glass Gas Diffusion Layer	4,483	m^3	$8.00	$35,861		
300 mm Biocover Layer	6,724	m^3	$17.00	$114,306		
Hydroseeding	22,413	m^2	$1.00	$22,413		
Surface Water Management					**$46,500**	
Ditches	350	m	$120	$42,000		
Culverts	30	m	$150	$4,500		600 mm HDPE pipes
Access Roads/ Berms					**$0**	10 m wide access roads across final slope
granular sub-base	0	m^3	$50	$0		Sub-base depth of 0.6 m
granular road base	0	m^3	$50	$0		Crushed topping depth of 0.15 m
SUBTOTAL					**$588,895**	
Engineering and Contingency					**$117,779**	
Estimate at 20% of Capital Projects						
TOTAL					**$706,674**	
Unit Cost (per m^2) =	**$31.53**					

TABLE 12-6 Preliminary Closure Costs for Phase 4
Low Permeability Soil/Evaporative Cover Option

Item	Quantity	Units	Unit Cost ($)	Sub-Cost ($)	Total Cost ($)	Comments
CLOSURE COSTS						
Approximate Phase 4 Closure Area =	71,778	m^2				
Site Preparation					**$107,667**	Prepare area for final closure
Site grading, smoothing and picking	71,778	m^2	$0.75	$53,834		
Proof rolling	71,778	m^2	$0.75	$53,834		
Cover System					**$1,629,361**	
600 mm Clay for Barrier Layer	43,067	m^2	$25.00	$1,076,670		Assuming Clay is Onsite
200 mm Crushed Glass Gas Diffusion Layer	14,356	m^3	$8.00	$114,845		
300 mm Biocover Layer	21,533	m^3	$17.00	$366,068		
Hydroseeding	71,778	m^2	$1.00	$71,778		
Surface Water Management					**$126,780**	
Ditches	1,019	m	$120	$122,280		
Culverts	30	m	$150	$4,500		600 mm HDPE pipes
Access Roads/ Berms (1,019 m)					**$331,175**	10 m wide access roads across final slope
granular sub-base	5,095	m^3	$50	$254,750		Sub-base depth of 0.6 m
granular road base	1,529	m^3	$50	$76,425		Crushed topping depth of 0.15 m
SUBTOTAL					**$2,194,983**	
Engineering and Contingency					**$438,997**	
Estimate at 20% of Capital Projects						
TOTAL					**$2,633,979**	
Unit Cost (per m^2) =	**$36.70**					

TABLE 12-7 Preliminary Closure Costs for Phase 5
Low Permeability Soil/Evaporative Cover Option

Item	Quantity	Units	Unit Cost ($)	Sub-Cost ($)	Total Cost ($)	Comments
CLOSURE COSTS						
Approximate Phase 5 Closure Area =	100,248	m^2				
Site Preparation					**$150,372**	Prepare area for final closure
Site grading, smoothing and picking	100,248	m^2	$0.75	$75,186		
Proof rolling	100,248	m^2	$0.75	$75,186		
Cover System					**$2,275,630**	
600 mm Clay for Barrier Layer	60,149	m^2	$25.00	$1,503,720		Assuming Clay is Onsite
200 mm Crushed Glass Gas Diffusion Layer	20,050	m^3	$8.00	$160,397		
300 mm Biocover Layer	30,074	m^3	$17.00	$511,265		
Hydroseeding	100,248	m^2	$1.00	$100,248		
Surface Water Management					**$104,940**	
Ditches	837	m	$120	$100,440		
Culverts	30	m	$150	$4,500		600 mm HDPE pipes
Access Roads/ Berms (837 m)					**$272,025**	10 m wide access roads across final slope
granular sub-base	4,185	m^3	$50	$209,250		Sub-base depth of 0.6 m
granular road base	1,256	m^3	$50	$62,775		Crushed topping depth of 0.15 m
SUBTOTAL					**$2,802,967**	
Engineering and Contingency					**$560,593**	
Estimate at 20% of Capital Projects						
TOTAL					**$3,363,560**	
Unit Cost (per m^2) =	**$33.55**					

TABLE 12-8 Preliminary Closure Costs for Phase 2
Geomembrane Option

Item	Quantity	Units	Unit Cost ($)	Sub-Cost ($)	Total Cost ($)	Comments
CLOSURE COSTS						
Approximate Phase 2 Closure Area =	68,833	m^2				
Site Preparation					**$103,250**	Prepare area for final closure
Site grading, smoothing and picking	68,833	m^2	$0.75	$51,625		
Proof rolling	68,833	m^2	$0.75	$51,625		
Cover System					**$2,216,423**	
200 mm Crushed Glass Gas Diffusion Layer	13,767	m^3	$8.00	$110,133		
12 oz Geotextile	68,833	m^2	$4.50	$309,749		
40 mil LLDPE Geomembrane	68,833	m^2	$8.00	$550,664		
12 oz Geotextile	68,833	m^2	$4.50	$309,749		
300 mm Gravel Drainage Layer	20,650	m^3	$15.00	$309,749		
8 oz Geotextile	68,833	m^2	$3.00	$206,499		
300 mm Biocover Layer	20,650	m^3	$17.00	$351,048		
Hydroseeding	68,833	m^2	$1.00	$68,833		
Surface Water Management					**$88,140**	
Ditches	697	m	$120	$83,640		
Culverts	30	m	$150	$4,500		600 mm HDPE pipe
Access Roads/ Berms (697m)					**$226,525**	10 m wide access roads across final slope
granular sub-base	3,485	m^3	$50	$174,250		Sub-base depth of 0.6 m
granular road base	1,046	m^3	$50	$52,275		Crushed topping depth of 0.15 m
Landfill Gas Management					**$0**	See Table 12-3
SUBTOTAL					**$2,634,337**	
Engineering and Contingency					**$526,867**	
Estimate at 20% of Capital Projects						
TOTAL					**$3,161,205**	
Unit Cost (per m^2) =	**$45.93**					

TABLE 12-9 Preliminary Closure Costs for Phase 3
Geomembrane Option

Item	Quantity	Units	Unit Cost ($)	Sub-Cost ($)	Total Cost ($)	Comments
CLOSURE COSTS						
Approximate Phase 3 Closure Area =	22,413	m^2				
Site Preparation					**$33,620**	Prepare area for final closure
Site grading, smoothing and picking	22,413	m^2	$0.75	$16,810		
Proof rolling	22,413	m^2	$0.75	$16,810		
Cover System					**$721,699**	
200 mm Crushed Glass Gas Diffusion Layer	4,483	m^3	$8.00	$35,861		
12 oz Geotextile	22,413	m^2	$4.50	$100,859		
40 mil LLDPE Geomembrane	22,413	m^2	$8.00	$179,304		
12 oz Geotextile	22,413	m^2	$4.50	$100,859		
300 mm Gravel Drainage Layer	6,724	m^3	$15.00	$100,859		
8 oz Geotextile	22,413	m^2	$3.00	$67,239		
300 mm Biocover Layer	6,724	m^3	$17.00	$114,306		
Hydroseeding	22,413	m^2	$1.00	$22,413		
Surface Water Management					**$46,500**	
Ditches	350	m	$120	$42,000		
Culverts	30	m	$150	$4,500		600 mm HDPE pipe
Access Roads/ Berms					**$0**	10 m wide access roads across final slope
granular sub-base	0	m^3	$50	$0		Sub-base depth of 0.6 m
granular road base	0	m^3	$50	$0		Crushed topping depth of 0.15 m
Landfill Gas Management					**$0**	See Table 12-3
SUBTOTAL					**$801,818**	
Engineering and Contingency					**$160,364**	
Estimate at 20% of Capital Projects						
TOTAL					**$962,182**	
Unit Cost (per m^2) =	**$42.93**					

TABLE 12-10 Preliminary Closure Costs for Phase 4
Geomembrane Option

Item	Quantity	Units	Unit Cost ($)	Sub-Cost ($)	Total Cost ($)	Comments
CLOSURE COSTS						
Approximate Phase 4 Closure Area =	71,778	m^2				
Site Preparation					**$107,667**	Prepare area for final closure
Site grading, smoothing and picking	71,778	m^2	$0.75	$53,834		
Proof rolling	71,778	m^2	$0.75	$53,834		
Cover System					**$2,311,252**	
200 mm Crushed Glass Gas Diffusion Layer	14,356	m^3	$8.00	$114,845		
12 oz Geotextile	71,778	m^2	$4.50	$323,001		
40 mil LLDPE Geomembrane	71,778	m^2	$8.00	$574,224		
12 oz Geotextile	71,778	m^2	$4.50	$323,001		
300 mm Gravel Drainage Layer	21,533	m^3	$15.00	$323,001		
8 oz Geotextile	71,778	m^2	$3.00	$215,334		
300 mm Biocover Layer	21,533	m^3	$17.00	$366,068		
Hydroseeding	71,778	m^2	$1.00	$71,778		
Surface Water Management					**$122,430**	
Ditches	1,019	m	$120	$122,280		
Culverts	1	m	$150	$150		600 mm HDPE pipe
Access Roads/ Berms (1,019 m)					**$331,175**	10 m wide access roads across final slope
granular sub-base	5,095	m^3	$50	$254,750		Sub-base depth of 0.6 m
granular road base	1,529	m^3	$50	$76,425		Crushed topping depth of 0.15 m
Landfill Gas Management					**$0**	See Table 12-3
SUBTOTAL					**$2,872,524**	
Engineering and Contingency					**$574,505**	
Estimate at 20% of Capital Projects						
TOTAL					**$3,447,028**	
Unit Cost (per m^2) =	**$48.02**					

TABLE 12-11 Preliminary Closure Costs for Phase 5
Geomembrane Option

Item	Quantity	Units	Unit Cost ($)	Sub-Cost ($)	Total Cost ($)	Comments
CLOSURE COSTS						
Approximate Phase 5 Closure Area =	110,273	m^2				
Site Preparation					**$165,410**	Prepare area for final closure
Site grading, smoothing and picking	110,273	m^2	$0.75	$82,705		
Proof rolling	110,273	m^2	$0.75	$82,705		
Cover System					**$3,550,791**	
200 mm Crushed Glass Gas Diffusion Layer	22,055	m^3	$8.00	$176,437		
12 oz Geotextile	110,273	m^2	$4.50	$496,229		
40 mil LLDPE Geomembrane	110,273	m^2	$8.00	$882,184		
12 oz Geotextile	110,273	m^2	$4.50	$496,229		
300 mm Gravel Drainage Layer	33,082	m^3	$15.00	$496,229		
8 oz Geotextile	110,273	m^2	$3.00	$330,819		
300 mm Biocover Layer	33,082	m^3	$17.00	$562,392		
Hydroseeding	110,273	m^2	$1.00	$110,273		
Surface Water Management					**$104,940**	
Ditches	837	m	$120	$100,440		
Culverts	30	m	$150	$4,500		600 mm PVC pipe
Access Roads/ Berms (837 m)					**$272,025**	10 m wide access roads across final slope
granular sub-base	4,185	m^3	$50	$209,250		Sub-base depth of 0.6 m
granular road base	1,256	m^3	$50	$62,775		Crushed topping depth of 0.15 m
Landfill Gas Management					**$0**	See Table 12-3
SUBTOTAL					**$4,093,165**	
Engineering and Contingency					**$818,633**	
Estimate at 20% of Capital Projects						
TOTAL					**$4,911,798**	
Unit Cost (per m^2) =	**$44.54**					

Table 12-14
Annual Post Closure Costs

ANNUAL POST CLOSURE COSTS	**Total Area =**	**270,648**	**m²**			
Environmental Controls					**$10,000**	
Power for fence (1500 m)	1	LS	$10,000	$10,000		
Maintenance					**$87,065**	
Cover system maintenance	1	LS	$10,000	$10,000		
Leachate Collection System Maintenance	1	LS	$10,000	$10,000		
Storm Water Ponds and Ditch Maintenance	1	LS	$20,000	$20,000		
Leachate Treatment System Maintenance	1	LS	$20,000	$20,000		
Mowing & Fertilizing	270,648	m^2	$0.10	$27,065		
Monitoring and Reporting					**$46,000**	
Annual Water Quality Monitoring	1	LS	$15,000	$15,000		annual water quality program - sampling completed by Authority personnel
Annual Landfill Gas Monitoring	1	LS	$10,000	$10,000		Landfill Gas Survey and Report once per year
Annual Erosion Control Inspection	1	LS	$5,000	$5,000		annual inspection of erosion, slope stability
Annual Settlement Survey	1	LS	$6,000	$6,000		
Annual Reporting	1	LS	$10,000	$10,000		
Administration					**$20,000**	
Local Staff	1	LS	$20,000	$20,000		
TOTAL					**$163,065**	
Unit Cost (per m^2) =	**$0.60**					

Table 12-15 - Cash Flow using Low Permeability Soil/Evaporative Cover System (Scenario 1 - Existing Waste to Cover Ratio)

Year	Waste Disposal	Cover Volume	Residuals to Landfill	Cumulative Residual to Landfill	Cumulative Tonnage to Landfill	Tipping Fee Revenue	Capital Cost	Phased Closure Cost	Annual Operating Cost	Post Closure Cost	Reserve for Landfill Development	Total Cost	Net Revenue	Cumulative Net Revenue	Interest Cost
	Tonnes	m^3	m^3 (waste+cover)	m^3 (waste+cover)	tonne (waste)	$ / yr	$ / yr	$ / yr	$ / yr	$ / yr	$/yr	$ / yr	$ / yr	$	$ / yr
2014	23,800.47	9,690.75	36,466.28												
2015	24,038.48	9,787.65	36,830.94	18,415	24,038	$2,375,445			$2,242,130		$250,000	$2,242,130	$383,315	$394,815	$11,844
2016	24,278.86	9,885.53	37,199.25	55,615	48,317	$2,399,200			$2,264,551		$250,000	$2,264,551	$384,649	$791,308	$23,739
2017	21,500.02	8,754.08	32,941.61	88,556	69,817	$2,124,600	4,355,487		$2,005,362		$250,000	$6,360,849	($3,986,250)	($3,171,202)	($95,136)
2018	18,780.56	7,646.81	28,774.94	117,331	88,598	$1,855,866			$1,751,711		$250,000	$1,751,711	$354,156	($2,912,183)	($87,365)
2019	16,004.56	6,516.51	24,521.64	141,853	104,602	$1,581,546			$1,492,786		$250,000	$1,492,786	$338,760	($2,660,788)	($79,824)
2020	**16,164.61**	**6,581.68**	**24,766.86**	**166,620**	**120,767**	$1,597,362		$0	$1,507,714		$250,000	$1,507,714	$339,648	($2,400,964)	($72,029)
2021	16,326.25	6,647.50	25,014.53	191,634	137,093	$1,613,335			$1,522,791		$250,000	$1,522,791	$340,544	($2,132,449)	($63,973)
2022	16,489.51	6,713.97	25,264.67	216,899	153,583	$1,629,469			$1,538,019		$250,000	$1,538,019	$341,450	($1,854,973)	($55,649)
2023	16,654.41	6,781.11	25,517.32	242,416	170,237	$1,645,763			$1,553,399		$250,000	$1,553,399	$342,364	($1,568,258)	($47,048)
2024	16,820.95	6,848.92	25,772.49	268,189	187,058	$1,662,221			$1,568,933		$250,000	$1,568,933	$343,288	($1,272,018)	($38,161)
2025	16,989.16	6,917.41	26,030.22	294,219	204,047	$1,678,843			$1,584,623		$250,000	$1,584,623	$344,221	($965,958)	($28,979)
2026	17,159.05	6,986.59	26,290.52	320,510	221,206	$1,695,632			$1,600,469		$250,000	$1,600,469	$345,163	($649,774)	($19,493)
2027	17,330.64	7,056.45	26,553.43	347,063	238,537	$1,712,588			$1,616,473		$250,000	$1,616,473	$346,114	($323,153)	($9,695)
2028	17,503.95	7,127.02	26,818.96	373,882	256,041	$1,729,714			$1,632,638		$250,000	$1,632,638	$347,076	$14,228	$427
2029	17,678.99	7,198.29	27,087.15	400,969	273,720	$1,747,011			$1,648,965		$250,000	$1,648,965	$348,046	$362,701	$10,881
2030	17,855.78	7,270.27	27,358.02	428,327	291,576	$1,764,481			$1,665,454		$250,000	$1,665,454	$349,027	$722,609	$21,678
2031	18,034.34	7,342.97	27,631.60	455,959	309,610	$1,782,126	3,136,361		$1,682,109		$250,000	$4,818,469	($2,786,343)	($2,042,057)	($61,262)
2032	**18,214.68**	**7,416.40**	**27,907.92**	**483,867**	**327,825**	$1,799,947		$2,376,508	$1,698,930		$250,000	$4,075,438	($2,025,491)	($4,128,809)	($123,864)
2033	18,396.83	7,490.57	28,187.00	512,054	346,222	$1,817,947			$1,715,919		$250,000	$1,715,919	$352,027	($3,900,646)	($117,019)
2034	18,580.80	7,565.47	28,468.87	540,522	364,802	$1,836,126	3,901,191		$1,733,078		$250,000	$5,634,269	($3,548,143)	($7,565,809)	($226,974)
2035	**18,766.60**	**7,641.13**	**28,753.56**	**569,276**	**383,569**	$1,854,487		$706,674	$1,750,409		$250,000	$2,457,083	($352,595)	($8,145,379)	($244,361)
2036	18,954.27	7,717.54	29,041.09	598,317	402,523	$1,873,032			$1,767,913		$250,000	$1,767,913	$355,119	($8,034,621)	($241,039)
2037	19,143.81	7,794.71	29,331.50	627,649	421,667	$1,891,762			$1,785,592		$250,000	$1,785,592	$356,170	($7,919,490)	($237,585)
2038	19,335.25	7,872.66	29,624.82	657,273	441,002	$1,910,680			$1,803,448		$250,000	$1,803,448	$357,232	($7,799,843)	($233,995)
2039	19,528.60	7,951.39	29,921.07	687,195	460,531	$1,929,787			$1,821,483		$250,000	$1,821,483	$358,304	($7,675,534)	($230,266)
2040	19,723.89	8,030.90	30,220.28	717,415	480,255	$1,949,085			$1,839,698		$250,000	$1,839,698	$359,387	($7,546,413)	($226,392)
2041	19,921.13	8,111.21	30,522.48	747,937	500,176	$1,968,576			$1,858,095		$250,000	$1,858,095	$360,481	($7,412,324)	($222,370)
2042	20,120.34	8,192.32	30,827.70	778,765	520,296	$1,988,261			$1,876,676		$250,000	$1,876,676	$361,586	($7,273,108)	($218,193)
2043	20,321.54	8,274.24	31,135.98	809,901	540,618	$2,008,144			$1,895,442		$250,000	$1,895,442	$362,702	($7,128,600)	($213,858)
2044	20,524.76	8,356.99	31,447.34	841,348	561,143	$2,028,225			$1,914,397		$250,000	$1,914,397	$363,829	($6,978,629)	($209,359)
2045	20,730.01	8,440.56	31,761.81	873,110	581,873	$2,048,508			$1,933,541		$250,000	$1,933,541	$364,967	($6,823,021)	($204,691)
2046	20,937.31	8,524.96	32,079.43	905,190	602,810	$2,068,993			$1,952,876		$250,000	$1,952,876	$366,117	($6,661,595)	($199,848)
2047	21,146.68	8,610.21	32,400.23	937,590	623,957	$2,089,683			$1,972,405		$250,000	$1,972,405	$367,278	($6,494,165)	($194,825)
2048	21,358.15	8,696.31	32,724.23	970,314	645,315	$2,110,580			$1,992,129		$250,000	$1,992,129	$368,451	($6,320,539)	($189,616)
2049	21,571.73	8,783.28	33,051.47	1,003,365	666,887	$2,131,685			$2,012,050		$250,000	$2,012,050	$369,635	($6,140,520)	($184,216)
2050	21,787.45	8,871.11	33,381.99	1,036,747	688,674	$2,153,002			$2,032,171		$250,000	$2,032,171	$370,831	($5,953,904)	($178,617)
2051	22,005.32	8,959.82	33,715.81	1,070,463	710,679	$2,174,532			$2,052,492		$250,000	$2,052,492	$372,040	($5,760,482)	($172,814)
2052	22,225.37	9,049.42	34,052.96	1,104,516	732,905	$2,196,277			$2,073,017		$250,000	$2,073,017	$373,260	($5,560,036)	($166,801)
2053	22,447.63	9,139.91	34,393.49	1,138,910	755,352	$2,218,240			$2,093,748		$250,000	$2,093,748	$374,493	($5,352,344)	($160,570)
2054	22,672.10	9,231.31	34,737.43	1,173,647	778,024	$2,240,423			$2,114,685		$250,000	$2,114,685	$375,738	($5,137,177)	($154,115)
2055	22,898.82	9,323.63	35,084.80	1,208,732	800,923	$2,262,827			$2,135,832		$250,000	$2,135,832	$376,995	($4,914,297)	($147,429)
2056	23,127.81	9,416.86	35,435.65	1,244,168	824,051	$2,285,455			$2,157,190		$250,000	$2,157,190	$378,265	($4,683,461)	($140,504)
2057	23,359.09	9,511.03	35,790.01	1,279,958	847,410	$2,308,310			$2,178,762		$250,000	$2,178,762	$379,548	($4,444,417)	($133,333)
2058	23,592.68	9,606.14	36,147.91	1,316,106	871,003	$2,331,393			$2,200,550		$250,000	$2,200,550	$380,843	($4,196,907)	($125,907)
2059	23,828.61	9,702.20	36,509.39	1,352,615	894,831	$2,354,707			$2,222,555		$250,000	$2,222,555	$382,152	($3,940,662)	($118,220)
2060	24,066.89	9,799.22	36,874.48	1,389,489	918,898	$2,378,254			$2,244,781		$250,000	$2,244,781	$383,473	($3,675,409)	($110,262)
2061	24,307.56	9,897.22	37,243.23	1,426,733	943,206	$2,402,036			$2,267,229		$250,000	$2,267,229	$384,808	($3,400,864)	($102,026)
2062	24,550.64	9,996.19	37,615.66	1,464,348	967,757	$2,426,057			$2,289,901		$250,000	$2,289,901	$386,156	($3,116,734)	($93,502)
2063	24,796.15	10,096.15	37,991.81	1,502,340	992,553	$2,450,317			$2,312,800		$250,000	$2,312,800	$387,517	($2,822,718)	($84,682)
2064	25,044.11	10,197.11	38,371.73	1,540,712	1,017,597	$2,474,820			$2,335,928		$250,000	$2,335,928	$388,893	($2,518,507)	($75,555)
2065	25,294.55	10,299.08	38,755.45	1,579,467	1,042,891	$2,499,569			$2,359,287		$250,000	$2,359,287	$390,282	($2,203,781)	($66,113)
2066	25,547.49	10,402.07	39,143.00	1,618,610	1,068,439	$2,524,564	3,600,317		$2,382,880		$250,000	$5,983,196	($3,208,632)	($5,478,526)	($164,356)
2067	**25,802.97**	**10,506.09**	**39,534.43**	**1,658,145**	**1,094,242**	$2,549,810		$2,633,979	$2,406,709		$250,000	$5,040,688	($2,240,878)	($7,883,760)	($236,513)
2068	26,061.00	10,611.16	39,929.78	1,698,074	1,120,303	$2,575,308			$2,430,776		$250,000	$2,430,776	$394,532	($7,725,741)	($231,772)
2069	26,321.61	10,717.27	40,329.08	1,738,404	1,146,624	$2,601,061			$2,455,084		$250,000	$2,455,084	$395,978	($7,561,535)	($226,846)
2070	26,584.82	10,824.44	40,732.37	1,779,136	1,173,209	$2,627,072			$2,479,634		$250,000	$2,479,634	$397,437	($7,390,944)	($221,728)
2071	26,850.67	10,932.68	41,139.69	1,820,276	1,200,060	$2,653,342			$2,504,431		$250,000	$2,504,431	$398,912	($7,213,761)	($216,413)
2072	27,119.18	11,042.01	41,551.09	1,861,827	1,227,179	$2,679,876			$2,529,475		$250,000	$2,529,475	$400,401	($7,029,773)	($210,893)
2073	27,390.37	11,152.43	41,966.60	1,903,793	1,254,569	$2,706,675			$2,554,770		$250,000	$2,554,770	$401,905	($6,838,761)	($205,163)
2074	27,664.27	11,263.96	42,386.26	1,946,180	1,282,234	$2,733,741			$2,580,318		$250,000	$2,580,318	$403,424	($6,640,500)	($199,215)
2075	27,940.92	11,376.60	42,810.13	1,988,990	1,310,175	$2,761,079			$2,606,121		$250,000	$2,606,121	$404,958	($6,434,757)	($193,043)
2076	28,220.33	11,490.36	43,238.23	2,032,228	1,338,395	$2,788,690			$2,632,182		$250,000	$2,632,182	$406,508	($6,221,292)	($186,639)
2077	28,502.53	11,605.26	43,670.61	2,075,899	1,366,897	$2,816,577			$2,658,504		$250,000	$2,658,504	$408,073	($5,999,858)	($179,996)
2078	28,787.56	11,721.32	44,107.32	2,120,006	1,395,685	$2,844,742			$2,685,089		$250,000	$2,685,089	$409,654	($5,770,200)	($173,106)
2079	29,075.43	11,838.53	44,548.39	2,164,554	1,424,760	$2,873,190			$2,711,940		$250,000	$2,711,940	$411,250	($5,532,056)	($165,962)
2080	29,366.19	11,956.92	44,993.87	2,209,548	1,454,127	$2,901,922			$2,739,059		$250,000	$2,739,059	$412,863	($5,285,155)	($158,555)
2081	29,659.85	12,076.48	45,443.81	2,254,992	1,483,786	$2,930,941			$2,766,450		$250,000	$2,766,450	$414,491	($5,029,219)	($150,877)
2082	29,956.45	12,197.25	45,898.25	2,300,890	1,513,743	$2,960,250			$2,794,114		$250,000	$2,794,114	$416,136	($4,763,959)	($142,919)
2083	30,256.01	12,319.22	46,357.23	2,347,247	1,543,999	$2,989,853			$2,822,055		$250,000	$2,822,055	$417,797	($4,489,080)	($134,672)
2084	30,558.57	12,442.41	46,820.81	2,394,068	1,574,558	$3,019,751			$2,850,276		$250,000	$2,850,276	$419,475	($4,204,277)	($126,128)
2085	30,864.16	12,566.84	47,289.01	2,441,357	1,605,422	$3,049,949			$2,878,779		$250,000	$2,878,779	$421,170	($3,909,236)	($117,277)
2086	31,172.80	12,692.51	47,761.90	2,489,119	1,636,594	$3,080,448			$2,907,566		$250,000	$2,907,566	$422,882	($3,603,631)	($108,109)
2087	31,484.53	12,819.43	48,239.52	2,537,359	1,668,079	$3,111,253			$2,936,642		$250,000	$2,936,642	$424,611	($3,287,129)	($98,614)
2088	31,799.37	12,947.63	48,721.92	2,586,081	1,699,878	$3,142,365			$2,966,008		$250,000	$2,966,008	$426,357	($2,959,386)	($88,782)
2089	32,117.36	13,077.10	49,209.14	2,635,290	1,731,996	$3,173,789			$2,995,669		$250,000	$2,995,669	$428,120	($2,620,047)	($78,601)
2090	32,438.54	13,207.87	49,701.23	2,684,991	1,764,434	$3,205,527			$3,025,625		$250,000	$3,025,625	$429,902	($2,268,747)	($68,062)
2091	32,762.92	13,339.95	50,198.24	2,735,189	1,797,197	$3,237,582			$3,055,882		$250,000	$3,055,882	$431,701	($1,905,109)	($57,153)
2092	33,090.55	13,473.35	50,700.22	2,785,889	1,830,288	$3,269,958			$3,086,440		$250,000	$3,086,440	$433,518	($1,528,745)	($45,862)
2093	33,421.46	13,608.09	51,207.23	2,837,097	1,863,709	$3,302,657			$3,117,305		$250,000	$3,117,305	$435,353	($1,139,254)	($34,178)
2094	33,755.67	13,744.17	51,719.30	2,888,816	1,897,465	$3,335,684			$3,148,478		$250,000	$3,148,478	$437,206	($736,226)	($22,087)
2095	34,093.23	13,881.61	52,236.49	2,941,052	1,931,558	$3,369,041			$3,179,963		$250,000	$3,179,963	$439,078	($319,234)	($9,577)
2096	34,434.16	14,020.42	52,758.86	2,993,811	1,965,992	$3,402,731			$3,211,762		$250,000	$3,211,762	$440,969	$112,158	$3,365
2097	34,778.50	14,160.63	53,286.44	3,047,098	2,000,771	$3,436,759			$3,243,880		$250,000	$3,243,880	$442,879	$558,402	$16,752
2098	35,126.29	14,302.23	53,819.31	3,100,917	2,035,897	$3,471,126			$3,276,319		$250,000	$3,276,319	$444,808	$1,019,961	$30,599
2099	35,477.55	14,445.26	54,357.50	3,155,275	2,071,375	$3,505,837			$3,309,082		$250,000	$3,309,082	$446,756	$1,497,316	$44,919
2100	35,832.33	14,589.71	54,901.08	3,210,176	2,107,207	$3,540,896			$3,342,173		$250,000	$3,342,173	$448,723	$1,990,959	$59,729
2101	36,190.65	14,735.61	55,450.09	3,265,626	2,143,398	$3,576,305			$3,375,594		$250,000	$3,375,594	$450,710	$2,501,398	$75,042
2102	36,552.56	14,882.96	56,004.59	3,321,630	2,179,950	$3,612,068			$3,409,350		$250,000	$3,409,350	$452,718	$3,029,157	$90,875
2103	36,918.08	15,031.79	56,564.63	3,378,195	2,216,868	$3,648,189	1,026,203		$3,443,444		$250,000	$4,469,646	($571,458)	$2,548,574	$76,457
2104	**37,287.26**	**15,182.11**	**57,130.28**	**3,435,325**	**2,254,155**	**$3,684,670**		$3,363,560			**$250,000**	$3,363,560	$571,110	$3,196,142	$95,884
2105										$163,065		$163,065	($163,065)	$3,128,962	$93,869
2106										$163,065		$163,065	($163,065)	$3,059,766	$91,793
2107										$163,065		$163,065	($163,065)	$2,988,494	$89,655
2108										$163,065		$163,065	($163,065)	$2,915,084	$87,453
2109										$163,065		$163,065	($163,065)	$2,839,471	$85,184
2110										$163,065		$163,065	($163,065)	$2,761,591	$82,848
2111										$163,065		$163,065	($163,065)	$2,681,374	$80,441
2112										$163,065		$163,065	($163,065)	$2,598,750	$77,963
2113										$163,065		$163,065	($163,065)	$2,513,648	$75,409
2114										$163,065		$163,065	($163,065)	$2,425,992	$72,780
2115										$163,065		$163,065	($163,065)	$2,335,707	$70,071
2116										$163,065		$163,065	($163,065)	$2,242,714	$67,281
2117										$163,065		$163,065	($163,065)	$2,146,930	$64,408
2118										$163,065		$163,065	($163,065)	$2,048,274	$61,448
2119										$163,065		$163,065	($163,065)	$1,946,657	$58,400
2120										$163,065		$163,065	($163,065)	$1,841,992	$55,260
2121										$163,065		$163,065	($163,065)	$1,734,187	$52,026
2122										$163,065		$163,065	($163,065)	$1,623,148	$48,694
2123										$163,065		$163,065	($163,065)	$1,508,777	$45,263
2124										$163,065		$163,065	($163,065)	$1,390,976	$41,729
2125										$163,065		$163,065	($163,065)	$1,269,640	$38,089
2126										$163,065		$163,065	($163,065)	$1,144,665	$34,340
2127										$163,065		$163,065	($163,065)	$1,015,940	$30,478
2128										$163,065		$163,065	($163,065)	$883,353	$26,501
2129										$163,065		$163,065	($163,065)	$746,789	$22,404
2130										$163,065		$163,065	($163,065)	$606,128	$18,184
2131										$163,065		$163,065	($163,065)	$461,247	$13,837
2132										$163,065		$163,065	($163,065)	$312,020	$9,361
2133										$163,065		$163,065	($163,065)	$158,315	$4,749
2134										$163,065		$163,065	($163,065)	($0)	($0)
	2,254,155	**917,816**	**3,453,741**	**134,601,654**	**88,932,293**	**222,752,206**	**16,019,558**	**9,080,721**	**206,772,960**	**4,891,944**	**22,500,000**	**236,765,182**			**-$8,544,654**

Breakeven Tipping Fee = $98.82 per tonne of waste

Interest rate = 3.00%
Annual Operating Cost (per tonne of waste) = $93

	Total Cost	$/tonne	Percent of Fee
Total Revenues =	$245,252,206	108.80	100%
Total Landfilling Cost (excluding interest) =	$236,765,182	105.03	97%
Total Capital Cost =	$16,019,558	7.11	7%
Total Closure Cost =	$9,080,721	4.03	4%
Total Operating Expenses =	$206,772,960	91.73	84%
Total Post Operating Cost =	$4,891,944	2.17	2%
Total Interest =	$8,544,654	3.79	3%
Total Landfilling Cost (including interest charges)	$245,309,837	$109	100%

Table 12-16 - Cash Flow using Low Permeability Soil/Evaporative Cover System (Scenario 2 - Future Waste to Cover Ratio)

Year	Waste Disposal	Cover Volume	Residuals to Landfill	Cumulative Residual to Landfill	Cumulative Tonnage to Landfill	Tipping Fee Revenue	Capital Cost	Phased Closure Cost	Annual Operating Cost	Post Closure Cost	Reserve for Landfill Development	Total Cost	Net Revenue	Cumulative Net Revenue	Interest Cost
	Tonnes	m^3	m^3 (waste+cover)	m^3 (waste+cover)	tonne (waste)	$ / yr	$ / yr	$ / yr	$ / yr	$ / yr	$/yr	$ / yr	$ / yr	$	$ / yr
2014	23,800.47	7,437.65	34,213.18												
2015	24,038.48	7,512.02	34,555.31	17,278	24,038	$2,359,655			$2,242,130		$250,000	$2,242,130	$367,525	$378,551	$11,357
2016	24,278.86	7,587.14	34,900.86	52,179	48,317	$2,383,251			$2,264,551		$250,000	$2,264,551	$368,700	$758,607	$22,758
2017	21,500.02	6,718.76	30,906.28	83,085	69,817	$2,110,476	4,355,487		$2,005,362		$250,000	$6,360,849	($4,000,373)	($3,219,007)	($96,570)
2018	18,780.56	5,868.93	26,997.06	110,082	88,598	$1,843,530			$1,751,711		$250,000	$1,751,711	$341,819	($2,973,759)	($89,213)
2019	16,004.56	5,001.42	23,006.55	133,088	104,602	$1,571,033			$1,492,786		$250,000	$1,492,786	$328,247	($2,734,725)	($82,042)
2020	16,164.61	5,051.44	23,236.62	156,325	120,767	$1,586,743			$1,507,714		$250,000	$1,507,714	$329,029	($2,487,737)	($74,632)
2021	**16,326.25**	**5,101.95**	**23,468.99**	**179,794**	**137,093**	$1,602,611			$1,522,791		$250,000	$1,522,791	$329,820	($2,232,550)	($66,976)
2022	16,489.51	5,152.97	23,703.68	203,498	153,583	$1,618,637			$1,538,019		$250,000	$1,538,019	$330,618	($1,968,908)	($59,067)
2023	16,654.41	5,204.50	23,940.71	227,438	170,237	$1,634,823			$1,553,399		$250,000	$1,553,399	$331,424	($1,696,552)	($50,897)
2024	16,820.95	5,256.55	24,180.12	251,619	187,058	$1,651,171			$1,568,933		$250,000	$1,568,933	$332,238	($1,415,210)	($42,456)
2025	16,989.16	5,309.11	24,421.92	276,040	204,047	$1,667,683			$1,584,623		$250,000	$1,584,623	$333,061	($1,124,606)	($33,738)
2026	17,159.05	5,362.20	24,666.14	300,707	221,206	$1,684,360			$1,600,469		$250,000	$1,600,469	$333,891	($824,453)	($24,734)
2027	17,330.64	5,415.83	24,912.80	325,619	238,537	$1,701,204			$1,616,473		$250,000	$1,616,473	$334,730	($514,456)	($15,434)
2028	17,503.95	5,469.98	25,161.93	350,781	256,041	$1,718,216			$1,632,638		$250,000	$1,632,638	$335,577	($194,313)	($5,829)
2029	17,678.99	5,524.68	25,413.55	376,195	273,720	$1,735,398			$1,648,965		$250,000	$1,648,965	$336,433	$136,291	$4,089
2030	17,855.78	5,579.93	25,667.68	401,863	291,576	$1,752,752			$1,665,454		$250,000	$1,665,454	$337,297	$477,677	$14,330
2031	18,034.34	5,635.73	25,924.36	427,787	309,610	$1,770,279			$1,682,109		$250,000	$1,682,109	$338,170	$830,178	$24,905
2032	18,214.68	5,692.09	26,183.61	453,971	327,825	$1,787,982	3,136,361		$1,698,930		$250,000	$4,835,290	($2,797,308)	($1,942,225)	($58,267)
2033	**18,396.83**	**5,749.01**	**26,445.44**	**480,416**	**346,222**	$1,805,862		$2,376,508	$1,715,919		$250,000	$4,092,428	($2,036,566)	($4,037,057)	($121,112)
2034	18,580.80	5,806.50	26,709.90	507,126	364,802	$1,823,920			$1,733,078		$250,000	$1,733,078	$340,842	($3,817,327)	($114,520)
2035	18,766.60	5,864.56	26,976.99	534,103	383,569	$1,842,160			$1,750,409		$250,000	$1,750,409	$341,751	($3,590,096)	($107,703)
2036	18,954.27	5,923.21	27,246.76	561,350	402,523	$1,860,581	3,901,191		$1,767,913		$250,000	$5,669,104	($3,558,523)	($7,256,322)	($217,690)
2037	**19,143.81**	**5,982.44**	**27,519.23**	**588,869**	**421,667**	$1,879,187		$706,674	$1,785,592		$250,000	$2,492,266	($363,079)	($7,837,090)	($235,113)
2038	19,335.25	6,042.27	27,794.42	616,663	441,002	$1,897,979			$1,803,448		$250,000	$1,803,448	$344,531	($7,727,672)	($231,830)
2039	19,528.60	6,102.69	28,072.37	644,736	460,531	$1,916,959			$1,821,483		$250,000	$1,821,483	$345,476	($7,614,027)	($228,421)
2040	19,723.89	6,163.72	28,353.09	673,089	480,255	$1,936,128			$1,839,698		$250,000	$1,839,698	$346,431	($7,496,017)	($224,881)
2041	19,921.13	6,225.35	28,636.62	701,725	500,176	$1,955,490			$1,858,095		$250,000	$1,858,095	$347,395	($7,373,502)	($221,205)
2042	20,120.34	6,287.61	28,922.99	730,648	520,296	$1,975,045			$1,876,676		$250,000	$1,876,676	$348,369	($7,246,338)	($217,390)
2043	20,321.54	6,350.48	29,212.22	759,861	540,618	$1,994,795			$1,895,442		$250,000	$1,895,442	$349,353	($7,114,376)	($213,431)
2044	20,524.76	6,413.99	29,504.34	789,365	561,143	$2,014,743			$1,914,397		$250,000	$1,914,397	$350,346	($6,977,461)	($209,324)
2045	20,730.01	6,478.13	29,799.39	819,164	581,873	$2,034,890			$1,933,541		$250,000	$1,933,541	$351,350	($6,835,435)	($205,063)
2046	20,937.31	6,542.91	30,097.38	849,262	602,810	$2,055,239			$1,952,876		$250,000	$1,952,876	$352,363	($6,688,135)	($200,644)
2047	21,146.68	6,608.34	30,398.35	879,660	623,957	$2,075,792			$1,972,405		$250,000	$1,972,405	$353,387	($6,535,392)	($196,062)
2048	21,358.15	6,674.42	30,702.34	910,362	645,315	$2,096,550			$1,992,129		$250,000	$1,992,129	$354,421	($6,377,033)	($191,311)
2049	21,571.73	6,741.17	31,009.36	941,372	666,887	$2,117,515			$2,012,050		$250,000	$2,012,050	$355,465	($6,212,879)	($186,386)
2050	21,787.45	6,808.58	31,319.45	972,691	688,674	$2,138,690			$2,032,171		$250,000	$2,032,171	$356,520	($6,042,746)	($181,282)
2051	22,005.32	6,876.66	31,632.65	1,004,324	710,679	$2,160,077			$2,052,492		$250,000	$2,052,492	$357,585	($5,866,444)	($175,993)
2052	22,225.37	6,945.43	31,948.97	1,036,273	732,905	$2,181,678			$2,073,017		$250,000	$2,073,017	$358,661	($5,683,777)	($170,513)
2053	22,447.63	7,014.88	32,268.46	1,068,541	755,352	$2,203,495			$2,093,748		$250,000	$2,093,748	$359,747	($5,494,543)	($164,836)
2054	22,672.10	7,085.03	32,591.15	1,101,132	778,024	$2,225,530			$2,114,685		$250,000	$2,114,685	$360,845	($5,298,534)	($158,956)
2055	22,898.82	7,155.88	32,917.06	1,134,049	800,923	$2,247,785			$2,135,832		$250,000	$2,135,832	$361,953	($5,095,537)	($152,866)
2056	23,127.81	7,227.44	33,246.23	1,167,296	824,051	$2,270,263			$2,157,190		$250,000	$2,157,190	$363,073	($4,885,331)	($146,560)
2057	23,359.09	7,299.72	33,578.69	1,200,874	847,410	$2,292,965			$2,178,762		$250,000	$2,178,762	$364,203	($4,667,687)	($140,031)
2058	23,592.68	7,372.71	33,914.48	1,234,789	871,003	$2,315,895			$2,200,550		$250,000	$2,200,550	$365,345	($4,442,373)	($133,271)
2059	23,828.61	7,446.44	34,253.62	1,269,042	894,831	$2,339,054			$2,222,555		$250,000	$2,222,555	$366,499	($4,209,145)	($126,274)
2060	24,066.89	7,520.90	34,596.16	1,303,639	918,898	$2,362,445			$2,244,781		$250,000	$2,244,781	$367,664	($3,967,756)	($119,033)
2061	24,307.56	7,596.11	34,942.12	1,338,581	943,206	$2,386,069			$2,267,229		$250,000	$2,267,229	$368,840	($3,717,948)	($111,538)
2062	24,550.64	7,672.07	35,291.54	1,373,872	967,757	$2,409,930			$2,289,901		$250,000	$2,289,901	$370,029	($3,459,457)	($103,784)
2063	24,796.15	7,748.80	35,644.46	1,409,517	992,553	$2,434,029			$2,312,800		$250,000	$2,312,800	$371,229	($3,192,012)	($95,760)
2064	25,044.11	7,826.28	36,000.90	1,445,518	1,017,597	$2,458,369			$2,335,928		$250,000	$2,335,928	$372,441	($2,915,331)	($87,460)
2065	25,294.55	7,904.55	36,360.91	1,481,879	1,042,891	$2,482,953			$2,359,287		$250,000	$2,359,287	$373,666	($2,629,125)	($78,874)
2066	25,547.49	7,983.59	36,724.52	1,518,603	1,068,439	$2,507,782			$2,382,880		$250,000	$2,382,880	$374,903	($2,333,096)	($69,993)
2067	25,802.97	8,063.43	37,091.77	1,555,695	1,094,242	$2,532,860			$2,406,709		$250,000	$2,406,709	$376,152	($2,026,938)	($60,808)
2068	26,061.00	8,144.06	37,462.68	1,593,158	1,120,303	$2,558,189	3,600,317		$2,430,776		$250,000	$6,031,092	($3,222,903)	($5,310,649)	($159,319)
2069	**26,321.61**	**8,225.50**	**37,837.31**	**1,630,995**	**1,146,624**	$2,583,771		$2,633,979	$2,455,084		$250,000	$5,089,063	($2,255,292)	($7,725,261)	($231,758)
2070	26,584.82	8,307.76	38,215.68	1,669,211	1,173,209	$2,609,609			$2,479,634		$250,000	$2,479,634	$379,974	($7,577,044)	($227,311)
2071	26,850.67	8,390.84	38,597.84	1,707,808	1,200,060	$2,635,705			$2,504,431		$250,000	$2,504,431	$381,274	($7,423,082)	($222,692)
2072	27,119.18	8,474.74	38,983.82	1,746,792	1,227,179	$2,662,062			$2,529,475		$250,000	$2,529,475	$382,587	($7,263,188)	($217,896)
2073	27,390.37	8,559.49	39,373.66	1,786,166	1,254,569	$2,688,682			$2,554,770		$250,000	$2,554,770	$383,912	($7,097,171)	($212,915)
2074	27,664.27	8,645.09	39,767.39	1,825,933	1,282,234	$2,715,569			$2,580,318		$250,000	$2,580,318	$385,252	($6,924,835)	($207,745)
2075	27,940.92	8,731.54	40,165.07	1,866,098	1,310,175	$2,742,725			$2,606,121		$250,000	$2,606,121	$386,604	($6,745,976)	($202,379)
2076	28,220.33	8,818.85	40,566.72	1,906,665	1,338,395	$2,770,152			$2,632,182		$250,000	$2,632,182	$387,970	($6,560,385)	($196,812)
2077	28,502.53	8,907.04	40,972.39	1,947,637	1,366,897	$2,797,854			$2,658,504		$250,000	$2,658,504	$389,350	($6,367,847)	($191,035)
2078	28,787.56	8,996.11	41,382.11	1,989,020	1,395,685	$2,825,832			$2,685,089		$250,000	$2,685,089	$390,743	($6,168,139)	($185,044)
2079	29,075.43	9,086.07	41,795.93	2,030,816	1,424,760	$2,854,090			$2,711,940		$250,000	$2,711,940	$392,151	($5,961,032)	($178,831)
2080	29,366.19	9,176.93	42,213.89	2,073,029	1,454,127	$2,882,631			$2,739,059		$250,000	$2,739,059	$393,572	($5,746,291)	($172,389)
2081	29,659.85	9,268.70	42,636.03	2,115,665	1,483,786	$2,911,458			$2,766,450		$250,000	$2,766,450	$395,008	($5,523,672)	($165,710)
2082	29,956.45	9,361.39	43,062.39	2,158,728	1,513,743	$2,940,572			$2,794,114		$250,000	$2,794,114	$396,458	($5,292,924)	($158,788)
2083	30,256.01	9,455.00	43,493.01	2,202,221	1,543,999	$2,969,978			$2,822,055		$250,000	$2,822,055	$397,923	($5,053,789)	($151,614)
2084	30,558.57	9,549.55	43,927.94	2,246,149	1,574,558	$2,999,678			$2,850,276		$250,000	$2,850,276	$399,402	($4,806,001)	($144,180)
2085	30,864.16	9,645.05	44,367.22	2,290,516	1,605,422	$3,029,674			$2,878,779		$250,000	$2,878,779	$400,896	($4,549,285)	($136,479)
2086	31,172.80	9,741.50	44,810.90	2,335,327	1,636,594	$3,059,971			$2,907,566		$250,000	$2,907,566	$402,405	($4,283,359)	($128,501)
2087	31,484.53	9,838.91	45,259.00	2,380,586	1,668,079	$3,090,571			$2,936,642		$250,000	$2,936,642	$403,929	($4,007,931)	($120,238)
2088	31,799.37	9,937.30	45,711.59	2,426,297	1,699,878	$3,121,477			$2,966,008		$250,000	$2,966,008	$405,468	($3,722,700)	($111,681)
2089	32,117.36	10,036.68	46,168.71	2,472,466	1,731,996	$3,152,691			$2,995,669		$250,000	$2,995,669	$407,023	($3,427,358)	($102,821)
2090	32,438.54	10,137.04	46,630.40	2,519,097	1,764,434	$3,184,218			$3,025,625		$250,000	$3,025,625	$408,593	($3,121,586)	($93,648)
2091	32,762.92	10,238.41	47,096.70	2,566,193	1,797,197	$3,216,060			$3,055,882		$250,000	$3,055,882	$410,179	($2,805,055)	($84,152)
2092	33,090.55	10,340.80	47,567.67	2,613,761	1,830,288	$3,248,221			$3,086,440		$250,000	$3,086,440	$411,781	($2,477,426)	($74,323)
2093	33,421.46	10,444.21	48,043.35	2,661,804	1,863,709	$3,280,703			$3,117,305		$250,000	$3,117,305	$413,399	($2,138,350)	($64,150)
2094	33,755.67	10,548.65	48,523.78	2,710,328	1,897,465	$3,313,510			$3,148,478		$250,000	$3,148,478	$415,033	($1,787,468)	($53,624)
2095	34,093.23	10,654.13	49,009.02	2,759,337	1,931,558	$3,346,645			$3,179,963		$250,000	$3,179,963	$416,683	($1,424,409)	($42,732)
2096	34,434.16	10,760.68	49,499.11	2,808,836	1,965,992	$3,380,112			$3,211,762		$250,000	$3,211,762	$418,350	($1,048,792)	($31,464)
2097	34,778.50	10,868.28	49,994.10	2,858,830	2,000,771	$3,413,913			$3,243,880		$250,000	$3,243,880	$420,033	($660,222)	($19,807)
2098	35,126.29	10,976.97	50,494.04	2,909,324	2,035,897	$3,448,052			$3,276,319		$250,000	$3,276,319	$421,734	($258,295)	($7,749)
2099	35,477.55	11,086.73	50,998.98	2,960,323	2,071,375	$3,482,533			$3,309,082		$250,000	$3,309,082	$423,451	$157,407	$4,722
2100	35,832.33	11,197.60	51,508.97	3,011,832	2,107,207	$3,517,358			$3,342,173		$250,000	$3,342,173	$425,185	$587,314	$17,619
2101	36,190.65	11,309.58	52,024.06	3,063,856	2,143,398	$3,552,532			$3,375,594		$250,000	$3,375,594	$426,937	$1,031,871	$30,956
2102	36,552.56	11,422.67	52,544.30	3,116,401	2,179,950	$3,588,057			$3,409,350		$250,000	$3,409,350	$428,707	$1,491,534	$44,746
2103	36,918.08	11,536.90	53,069.74	3,169,470	2,216,868	$3,623,937			$3,443,444		$250,000	$3,443,444	$430,494	$1,966,774	$59,003
2104	37,287.26	11,652.27	53,600.44	3,223,071	2,254,155	$3,660,177			$3,477,878		$250,000	$3,477,878	$432,299	$2,458,075	$73,742
2105	37,660.14	11,768.79	54,136.44	3,277,207	2,291,816	$3,696,779			$3,512,657		$250,000	$3,512,657	$434,122	$2,965,939	$88,978
2106	38,036.74	11,886.48	54,677.81	3,331,885	2,329,852	$3,733,746	1,026,203		$3,547,784		$250,000	$4,573,986	($590,240)	$2,464,678	$73,940
2107	**38,417.10**	**12,005.35**	**55,224.59**	**3,387,110**	**2,368,269**	**$3,771,084**		$3,363,560			**$250,000**	$3,363,560	$657,524	$3,196,142	$95,884
2108										$163,065		$163,065	($163,065)	$3,128,962	$93,869
2109										$163,065		$163,065	($163,065)	$3,059,766	$91,793
2110										$163,065		$163,065	($163,065)	$2,988,494	$89,655
2111										$163,065		$163,065	($163,065)	$2,915,084	$87,453
2112										$163,065		$163,065	($163,065)	$2,839,471	$85,184
2113										$163,065		$163,065	($163,065)	$2,761,591	$82,848
2114										$163,065		$163,065	($163,065)	$2,681,374	$80,441
2115										$163,065		$163,065	($163,065)	$2,598,750	$77,963
2116										$163,065		$163,065	($163,065)	$2,513,648	$75,409
2117										$163,065		$163,065	($163,065)	$2,425,992	$72,780
2118										$163,065		$163,065	($163,065)	$2,335,707	$70,071
2119										$163,065		$163,065	($163,065)	$2,242,714	$67,281
2120										$163,065		$163,065	($163,065)	$2,146,930	$64,408
2121										$163,065		$163,065	($163,065)	$2,048,274	$61,448
2122										$163,065		$163,065	($163,065)	$1,946,657	$58,400
2123										$163,065		$163,065	($163,065)	$1,841,992	$55,260
2124										$163,065		$163,065	($163,065)	$1,734,187	$52,026
2125										$163,065		$163,065	($163,065)	$1,623,148	$48,694
2126										$163,065		$163,065	($163,065)	$1,508,777	$45,263
2127										$163,065		$163,065	($163,065)	$1,390,976	$41,729
2128										$163,065		$163,065	($163,065)	$1,269,640	$38,089
2129										$163,065		$163,065	($163,065)	$1,144,665	$34,340
2130										$163,065		$163,065	($163,065)	$1,015,940	$30,478
2131										$163,065		$163,065	($163,065)	$883,353	$26,501
2132										$163,065		$163,065	($163,065)	$746,789	$22,404
2133										$163,065		$163,065	($163,065)	$606,128	$18,184
2134										$163,065		$163,065	($163,065)	$461,247	$13,837
2135										$163,065		$163,065	($163,065)	$312,020	$9,361
2136										$163,065		$163,065	($163,065)	$158,315	$4,749
2137										$163,065		$163,065	($163,065)	($0)	($0)
	2,368,269	**740,084**	**3,404,387**	**136,281,384**	**95,922,230**	**232,473,085**	**16,019,558**	**9,080,721**	**217,311,279**	**4,891,944**	**23,250,000**	**247,303,501**			**-$8,430,610**

Breakeven Tipping Fee = **$98.16** **per tonne of waste**

Interest rate = **3.00%**
Annual Operating Cost (per tonn **$93**

	Total Cost	$/tonne	Percent of Fee
Total Revenues =	$255,723,085	107.98	100%
Total Landfilling Cost (excluding interest) =	$247,303,501	104.42	97%
Total Capital Cost =	$16,019,558	6.76	6%
Total Closure Cost =	$9,080,721	3.83	4%
Total Operating Expenses =	$217,311,279	91.76	85%
Total Post Operating Cost =	$4,891,944	2.07	2%
Total Interest =	$8,430,610	3.56	3%
Total Landfilling Cost (including interest charges)	$255,734,111	$108	100%

Table 12-17 - Cash Flow using Geomembrane Cover System (Scenario 1 - Existing Waste to Cover Ratio)

Year	Waste Disposal	Cover Volume	Residuals to Landfill	Cumulative Residual to Landfill	Cumulative Tonnage to Landfil	Tipping Fee Revenue	Capital Cost	Phased Closure Cost	Annual Operating Cost	Post Closure Cost	Reserve for Landfill Development	Total Cost	Net Revenue	Cumulative Net Revenue	Interest Cost
	Tonnes	m^3	m^3 (waste+cover)	m^3 (waste+cover)	tonne (waste)	$ / yr	$ / yr	$ / yr	$ / yr	$ / yr	$/yr	$ / yr	$ / yr	$	$ / yr
2014	23,800.47	9,690.75	36,466.28												
2015	24,038.48	9,787.65	36,830.94	18,415	24,038	$2,639,679			$2,242,130		$250,000	$2,242,130	$647,549	$666,976	$20,009
2016	24,278.86	9,885.53	37,199.25	55,615	48,317	$2,666,076			$2,264,551		$250,000	$2,264,551	$651,525	$1,338,510	$40,155
2017	21,500.02	8,754.08	32,941.61	88,556	69,817	$2,360,930	9,458,669		$2,005,362		$250,000	$11,464,031	($8,853,101)	($7,474,436)	($224,233)
2018	18,780.56	7,646.81	28,774.94	117,331	88,598	$2,062,305			$1,751,711		$250,000	$1,751,711	$560,594	($7,138,076)	($214,142)
2019	16,004.56	6,516.51	24,521.64	141,853	104,602	$1,757,470			$1,492,786		$250,000	$1,492,786	$514,684	($6,837,534)	($205,126)
2020	**16,164.61**	**6,581.68**	**24,766.86**	**166,620**	**120,767**	$1,775,045		$0	$1,507,714		$250,000	$1,507,714	$517,331	($6,525,329)	($195,760)
2021	16,326.25	6,647.50	25,014.53	191,634	137,093	$1,792,795			$1,522,791		$250,000	$1,522,791	$520,004	($6,201,085)	($186,033)
2022	16,489.51	6,713.97	25,264.67	216,899	153,583	$1,810,723			$1,538,019		$250,000	$1,538,019	$522,704	($5,864,413)	($175,932)
2023	16,654.41	6,781.11	25,517.32	242,416	170,237	$1,828,830			$1,553,399		$250,000	$1,553,399	$525,431	($5,514,914)	($165,447)
2024	16,820.95	6,848.92	25,772.49	268,189	187,058	$1,847,119			$1,568,933		$250,000	$1,568,933	$528,186	($5,152,176)	($154,565)
2025	16,989.16	6,917.41	26,030.22	294,219	204,047	$1,865,590			$1,584,623		$250,000	$1,584,623	$530,967	($4,775,774)	($143,273)
2026	17,159.05	6,986.59	26,290.52	320,510	221,206	$1,884,246			$1,600,469		$250,000	$1,600,469	$533,777	($4,385,270)	($131,558)
2027	17,330.64	7,056.45	26,553.43	347,063	238,537	$1,903,088			$1,616,473		$250,000	$1,616,473	$536,615	($3,980,214)	($119,406)
2028	17,503.95	7,127.02	26,818.96	373,882	256,041	$1,922,119			$1,632,638		$250,000	$1,632,638	$539,481	($3,560,139)	($106,804)
2029	17,678.99	7,198.29	27,087.15	400,969	273,720	$1,941,340			$1,648,965		$250,000	$1,648,965	$542,376	($3,124,568)	($93,737)
2030	17,855.78	7,270.27	27,358.02	428,327	291,576	$1,960,754			$1,665,454		$250,000	$1,665,454	$545,300	($2,673,005)	($80,190)
2031	18,034.34	7,342.97	27,631.60	455,959	309,610	$1,980,361	2,981,111		$1,682,109		$250,000	$4,663,219	($2,432,858)	($5,186,053)	($155,582)
2032	**18,214.68**	**7,416.40**	**27,907.92**	**483,867**	**327,825**	$2,000,165		$3,161,205	$1,698,930		$250,000	$4,860,134	($2,609,969)	($7,951,604)	($238,548)
2033	18,396.83	7,490.57	28,187.00	512,054	346,222	$2,020,167			$1,715,919		$250,000	$1,715,919	$554,247	($7,635,905)	($229,077)
2034	18,580.80	7,565.47	28,468.87	540,522	364,802	$2,040,368	5,317,332		$1,733,078		$250,000	$7,050,410	($4,760,042)	($12,625,024)	($378,751)
2035	**18,766.60**	**7,641.13**	**28,753.56**	**569,276**	**383,569**	$2,060,772		$962,182	$1,750,409		$250,000	$2,712,591	($401,819)	($13,405,594)	($402,168)
2036	18,954.27	7,717.54	29,041.09	598,317	402,523	$2,081,380			$1,767,913		$250,000	$1,767,913	$563,466	($13,244,295)	($397,329)
2037	19,143.81	7,794.71	29,331.50	627,649	421,667	$2,102,193			$1,785,592		$250,000	$1,785,592	$566,601	($13,075,023)	($392,251)
2038	19,335.25	7,872.66	29,624.82	657,273	441,002	$2,123,215			$1,803,448		$250,000	$1,803,448	$569,767	($12,897,507)	($386,925)
2039	19,528.60	7,951.39	29,921.07	687,195	460,531	$2,144,448			$1,821,483		$250,000	$1,821,483	$572,965	($12,711,467)	($381,344)
2040	19,723.89	8,030.90	30,220.28	717,415	480,255	$2,165,892			$1,839,698		$250,000	$1,839,698	$576,194	($12,516,617)	($375,499)
2041	19,921.13	8,111.21	30,522.48	747,937	500,176	$2,187,551			$1,858,095		$250,000	$1,858,095	$579,456	($12,312,659)	($369,380)
2042	20,120.34	8,192.32	30,827.70	778,765	520,296	$2,209,426			$1,876,676		$250,000	$1,876,676	$582,751	($12,099,288)	($362,979)
2043	20,321.54	8,274.24	31,135.98	809,901	540,618	$2,231,521			$1,895,442		$250,000	$1,895,442	$586,078	($11,876,188)	($356,286)
2044	20,524.76	8,356.99	31,447.34	841,348	561,143	$2,253,836			$1,914,397		$250,000	$1,914,397	$589,439	($11,643,034)	($349,291)
2045	20,730.01	8,440.56	31,761.81	873,110	581,873	$2,276,374			$1,933,541		$250,000	$1,933,541	$592,834	($11,399,492)	($341,985)
2046	20,937.31	8,524.96	32,079.43	905,190	602,810	$2,299,138			$1,952,876		$250,000	$1,952,876	$596,262	($11,145,215)	($334,356)
2047	21,146.68	8,610.21	32,400.23	937,590	623,957	$2,322,129			$1,972,405		$250,000	$1,972,405	$599,725	($10,879,847)	($326,395)
2048	21,358.15	8,696.31	32,724.23	970,314	645,315	$2,345,351			$1,992,129		$250,000	$1,992,129	$603,222	($10,603,020)	($318,091)
2049	21,571.73	8,783.28	33,051.47	1,003,365	666,887	$2,368,804			$2,012,050		$250,000	$2,012,050	$606,754	($10,314,357)	($309,431)
2050	21,787.45	8,871.11	33,381.99	1,036,747	688,674	$2,392,492			$2,032,171		$250,000	$2,032,171	$610,322	($10,013,466)	($300,404)
2051	22,005.32	8,959.82	33,715.81	1,070,463	710,679	$2,416,417			$2,052,492		$250,000	$2,052,492	$613,925	($9,699,945)	($290,998)
2052	22,225.37	9,049.42	34,052.96	1,104,516	732,905	$2,440,581			$2,073,017		$250,000	$2,073,017	$617,564	($9,373,379)	($281,201)
2053	22,447.63	9,139.91	34,393.49	1,138,910	755,352	$2,464,987			$2,093,748		$250,000	$2,093,748	$621,240	($9,033,341)	($271,000)
2054	22,672.10	9,231.31	34,737.43	1,173,647	778,024	$2,489,637			$2,114,685		$250,000	$2,114,685	$624,952	($8,679,389)	($260,382)
2055	22,898.82	9,323.63	35,084.80	1,208,732	800,923	$2,514,533			$2,135,832		$250,000	$2,135,832	$628,702	($8,311,070)	($249,332)
2056	23,127.81	9,416.86	35,435.65	1,244,168	824,051	$2,539,679			$2,157,190		$250,000	$2,157,190	$632,489	($7,927,913)	($237,837)
2057	23,359.09	9,511.03	35,790.01	1,279,958	847,410	$2,565,076			$2,178,762		$250,000	$2,178,762	$636,313	($7,529,437)	($225,883)
2058	23,592.68	9,606.14	36,147.91	1,316,106	871,003	$2,590,726			$2,200,550		$250,000	$2,200,550	$640,177	($7,115,143)	($213,454)
2059	23,828.61	9,702.20	36,509.39	1,352,615	894,831	$2,616,634			$2,222,555		$250,000	$2,222,555	$644,078	($6,684,519)	($200,536)
2060	24,066.89	9,799.22	36,874.48	1,389,489	918,898	$2,642,800			$2,244,781		$250,000	$2,244,781	$648,019	($6,237,036)	($187,111)
2061	24,307.56	9,897.22	37,243.23	1,426,733	943,206	$2,669,228			$2,267,229		$250,000	$2,267,229	$651,999	($5,772,148)	($173,164)
2062	24,550.64	9,996.19	37,615.66	1,464,348	967,757	$2,695,920			$2,289,901		$250,000	$2,289,901	$656,019	($5,289,293)	($158,679)
2063	24,796.15	10,096.15	37,991.81	1,502,340	992,553	$2,722,879			$2,312,800		$250,000	$2,312,800	$660,080	($4,787,892)	($143,637)
2064	25,044.11	10,197.11	38,371.73	1,540,712	1,017,597	$2,750,108			$2,335,928		$250,000	$2,335,928	$664,180	($4,267,348)	($128,020)
2065	25,294.55	10,299.08	38,755.45	1,579,467	1,042,891	$2,777,609			$2,359,287		$250,000	$2,359,287	$668,322	($3,727,047)	($111,811)
2066	25,547.49	10,402.07	39,143.00	1,618,610	1,068,439	$2,805,385	6,997,559		$2,382,880		$250,000	$9,380,439	($6,325,054)	($10,163,912)	($304,917)
2067	**25,802.97**	**10,506.09**	**39,534.43**	**1,658,145**	**1,094,242**	$2,833,439		$3,447,028	$2,406,709		$250,000	$5,853,737	($2,770,298)	($13,239,127)	($397,174)
2068	26,061.00	10,611.16	39,929.78	1,698,074	1,120,303	$2,861,774			$2,430,776		$250,000	$2,430,776	$680,998	($12,955,303)	($388,659)
2069	26,321.61	10,717.27	40,329.08	1,738,404	1,146,624	$2,890,391			$2,455,084		$250,000	$2,455,084	$685,308	($12,658,655)	($379,760)
2070	26,584.82	10,824.44	40,732.37	1,779,136	1,173,209	$2,919,295			$2,479,634		$250,000	$2,479,634	$689,661	($12,348,754)	($370,463)
2071	26,850.67	10,932.68	41,139.69	1,820,276	1,200,060	$2,948,488			$2,504,431		$250,000	$2,504,431	$694,057	($12,025,159)	($360,755)
2072	27,119.18	11,042.01	41,551.09	1,861,827	1,227,179	$2,977,973			$2,529,475		$250,000	$2,529,475	$698,498	($11,687,416)	($350,622)
2073	27,390.37	11,152.43	41,966.60	1,903,793	1,254,569	$3,007,753			$2,554,770		$250,000	$2,554,770	$702,983	($11,335,055)	($340,052)
2074	27,664.27	11,263.96	42,386.26	1,946,180	1,282,234	$3,037,830			$2,580,318		$250,000	$2,580,318	$707,513	($10,967,594)	($329,028)
2075	27,940.92	11,376.60	42,810.13	1,988,990	1,310,175	$3,068,209			$2,606,121		$250,000	$2,606,121	$712,088	($10,584,534)	($317,536)
2076	28,220.33	11,490.36	43,238.23	2,032,228	1,338,395	$3,098,891			$2,632,182		$250,000	$2,632,182	$716,709	($10,185,361)	($305,561)
2077	28,502.53	11,605.26	43,670.61	2,075,899	1,366,897	$3,129,880			$2,658,504		$250,000	$2,658,504	$721,376	($9,769,546)	($293,086)
2078	28,787.56	11,721.32	44,107.32	2,120,006	1,395,685	$3,161,178			$2,685,089		$250,000	$2,685,089	$726,090	($9,336,543)	($280,096)
2079	29,075.43	11,838.53	44,548.39	2,164,554	1,424,760	$3,192,790			$2,711,940		$250,000	$2,711,940	$730,850	($8,885,789)	($266,574)
2080	29,366.19	11,956.92	44,993.87	2,209,548	1,454,127	$3,224,718			$2,739,059		$250,000	$2,739,059	$735,659	($8,416,704)	($252,501)
2081	29,659.85	12,076.48	45,443.81	2,254,992	1,483,786	$3,256,965			$2,766,450		$250,000	$2,766,450	$740,516	($7,928,689)	($237,861)
2082	29,956.45	12,197.25	45,898.25	2,300,890	1,513,743	$3,289,535			$2,794,114		$250,000	$2,794,114	$745,421	($7,421,129)	($222,634)
2083	30,256.01	12,319.22	46,357.23	2,347,247	1,543,999	$3,322,430			$2,822,055		$250,000	$2,822,055	$750,375	($6,893,388)	($206,802)
2084	30,558.57	12,442.41	46,820.81	2,394,068	1,574,558	$3,355,655			$2,850,276		$250,000	$2,850,276	$755,379	($6,344,811)	($190,344)
2085	30,864.16	12,566.84	47,289.01	2,441,357	1,605,422	$3,389,211			$2,878,779		$250,000	$2,878,779	$760,432	($5,774,723)	($173,242)
2086	31,172.80	12,692.51	47,761.90	2,489,119	1,636,594	$3,423,103			$2,907,566		$250,000	$2,907,566	$765,537	($5,182,428)	($155,473)
2087	31,484.53	12,819.43	48,239.52	2,537,359	1,668,079	$3,457,334			$2,936,642		$250,000	$2,936,642	$770,692	($4,567,208)	($137,016)
2088	31,799.37	12,947.63	48,721.92	2,586,081	1,699,878	$3,491,908			$2,966,008		$250,000	$2,966,008	$775,899	($3,928,325)	($117,850)
2089	32,117.36	13,077.10	49,209.14	2,635,290	1,731,996	$3,526,827			$2,995,669		$250,000	$2,995,669	$781,158	($3,265,017)	($97,951)
2090	32,438.54	13,207.87	49,701.23	2,684,991	1,764,434	$3,562,095			$3,025,625		$250,000	$3,025,625	$786,470	($2,576,498)	($77,295)
2091	32,762.92	13,339.95	50,198.24	2,735,189	1,797,197	$3,597,716			$3,055,882		$250,000	$3,055,882	$791,834	($1,861,958)	($55,859)
2092	33,090.55	13,473.35	50,700.22	2,785,889	1,830,288	$3,633,693			$3,086,440		$250,000	$3,086,440	$797,253	($1,120,564)	($33,617)
2093	33,421.46	13,608.09	51,207.23	2,837,097	1,863,709	$3,670,030			$3,117,305		$250,000	$3,117,305	$802,725	($351,456)	($10,544)
2094	33,755.67	13,744.17	51,719.30	2,888,816	1,897,465	$3,706,730			$3,148,478		$250,000	$3,148,478	$808,252	$446,253	$13,388
2095	34,093.23	13,881.61	52,236.49	2,941,052	1,931,558	$3,743,798			$3,179,963		$250,000	$3,179,963	$813,835	$1,273,475	$38,204
2096	34,434.16	14,020.42	52,758.86	2,993,811	1,965,992	$3,781,236			$3,211,762		$250,000	$3,211,762	$819,473	$2,131,153	$63,935
2097	34,778.50	14,160.63	53,286.44	3,047,098	2,000,771	$3,819,048			$3,243,880		$250,000	$3,243,880	$825,168	$3,020,256	$90,608
2098	35,126.29	14,302.23	53,819.31	3,100,917	2,035,897	$3,857,238			$3,276,319		$250,000	$3,276,319	$830,920	$3,941,783	$118,253
2099	35,477.55	14,445.26	54,357.50	3,155,275	2,071,375	$3,895,811			$3,309,082		$250,000	$3,309,082	$836,729	$4,896,766	$146,903
2100	35,832.33	14,589.71	54,901.08	3,210,176	2,107,207	$3,934,769			$3,342,173		$250,000	$3,342,173	$842,596	$5,886,265	$176,588
2101	36,190.65	14,735.61	55,450.09	3,265,626	2,143,398	$3,974,117			$3,375,594		$250,000	$3,375,594	$848,522	$6,911,375	$207,341
2102	36,552.56	14,882.96	56,004.59	3,321,630	2,179,950	$4,013,858			$3,409,350		$250,000	$3,409,350	$854,507	$7,973,224	$239,197
2103	36,918.08	15,031.79	56,564.63	3,378,195	2,216,868	$4,053,996	5,419,183		$3,443,444		$250,000	$8,862,626	($4,558,630)	$3,653,790	$109,614
2104	**37,287.26**	**15,182.11**	**57,130.28**	**3,435,325**	**2,254,155**	**$4,094,536**		$4,911,798			**$250,000**	$4,911,798	($567,262)	$3,196,142	$95,884
2105										$163,065		$163,065	($163,065)	$3,128,962	$93,869
2106										$163,065		$163,065	($163,065)	$3,059,766	$91,793
2107										$163,065		$163,065	($163,065)	$2,988,494	$89,655
2108										$163,065		$163,065	($163,065)	$2,915,084	$87,453
2109										$163,065		$163,065	($163,065)	$2,839,471	$85,184
2110										$163,065		$163,065	($163,065)	$2,761,591	$82,848
2111										$163,065		$163,065	($163,065)	$2,681,374	$80,441
2112										$163,065		$163,065	($163,065)	$2,598,750	$77,963
2113										$163,065		$163,065	($163,065)	$2,513,648	$75,409
2114										$163,065		$163,065	($163,065)	$2,425,992	$72,780
2115										$163,065		$163,065	($163,065)	$2,335,707	$70,071
2116										$163,065		$163,065	($163,065)	$2,242,714	$67,281
2117										$163,065		$163,065	($163,065)	$2,146,930	$64,408
2118										$163,065		$163,065	($163,065)	$2,048,274	$61,448
2119										$163,065		$163,065	($163,065)	$1,946,657	$58,400
2120										$163,065		$163,065	($163,065)	$1,841,992	$55,260
2121										$163,065		$163,065	($163,065)	$1,734,187	$52,026
2122										$163,065		$163,065	($163,065)	$1,623,148	$48,694
2123										$163,065		$163,065	($163,065)	$1,508,777	$45,263
2124										$163,065		$163,065	($163,065)	$1,390,976	$41,729
2125										$163,065		$163,065	($163,065)	$1,269,640	$38,089
2126										$163,065		$163,065	($163,065)	$1,144,665	$34,340
2127										$163,065		$163,065	($163,065)	$1,015,940	$30,478
2128										$163,065		$163,065	($163,065)	$883,353	$26,501
2129										$163,065		$163,065	($163,065)	$746,789	$22,404
2130										$163,065		$163,065	($163,065)	$606,128	$18,184
2131										$163,065		$163,065	($163,065)	$461,247	$13,837
2132										$163,065		$163,065	($163,065)	$312,020	$9,361
2133										$163,065		$163,065	($163,065)	$158,315	$4,749
2134										$163,065		$163,065	($163,065)	$0	$0
	2,254,155	**917,816**	**3,453,741**	**134,601,654**	**88,932,293**	**247,530,141**	**30,173,853**	**12,482,213**	**206,772,960**	**4,891,944**	**22,500,000**	**254,320,970**			**-$15,774,729**

Breakeven Tipping Fee = **$109.81 per tonne of waste**

Interest rate = **3.00%**

Annual Operating Cost (per tonne of waste) = **$93**

	Total Cost	$/tonne	Percent of Fee
Total Revenues =	$270,030,141	119.79	100%
Total Landfilling Cost (excluding interest) =	$254,320,970	112.82	94%
Total Capital Cost =	$30,173,853	13.39	11%
Total Closure Cost =	$12,482,213	5.54	5%
Total Operating Expenses =	$206,772,960	91.73	77%
Total Post Operating Cost =	$4,891,944	2.17	2%
Total Interest =	$15,774,729	7.00	6%
Total Landfilling Cost (including interest charges)	$270,095,698	$120	100%

Table 12-18 - Cash Flow using Geomembrane Cover System (Scenario 2 - Future Waste to Cover Ratio)

Year	Waste Disposal	Cover Volume	Residuals to Landfill	Cumulative Residual to Landfill	Cumulative Tonnage to Landfill	Tipping Fee Revenue	Capital Cost	Phased Closure Cost	Annual Operating Cost	Post Closure Cost	Reserve for Landfill Development	Total Cost	Net Revenue	Cumulative Net Revenue	Interest Cost
	Tonnes	m^3	m^3 (waste+cover)	m^3 (waste+cover)	tonne (waste)	$ / yr	$ / yr	$ / yr	$ / yr	$ / yr	$/yr	$ / yr	$ / yr	$	$ / yr
2014	23,800.47	7,437.65	34,213.18												
2015	24,038.48	7,512.02	34,555.31	17,278	24,038	$2,615,495			$2,242,130		$250,000	$2,242,130	$623,365	$642,066	$19,262
2016	24,278.86	7,587.14	34,900.86	52,179	48,317	$2,641,650			$2,264,551		$250,000	$2,264,551	$627,099	$1,288,427	$38,653
2017	21,500.02	6,718.76	30,906.28	83,085	69,817	$2,339,300	9,458,669		$2,005,362		$250,000	$11,464,031	($8,874,731)	($7,547,651)	($226,430)
2018	18,780.56	5,868.93	26,997.06	110,082	88,598	$2,043,410			$1,751,711		$250,000	$1,751,711	$541,699	($7,232,381)	($216,971)
2019	16,004.56	5,001.42	23,006.55	133,088	104,602	$1,741,369			$1,492,786		$250,000	$1,492,786	$498,583	($6,950,770)	($208,523)
2020	16,164.61	5,051.44	23,236.62	156,325	120,767	$1,758,782			$1,507,714		$250,000	$1,507,714	$501,068	($6,658,225)	($199,747)
2021	**16,326.25**	**5,101.95**	**23,468.99**	**179,794**	**137,093**	$1,776,370			$1,522,791		$250,000	$1,522,791	$503,579	($6,354,392)	($190,632)
2022	16,489.51	5,152.97	23,703.68	203,498	153,583	$1,794,134			$1,538,019		$250,000	$1,538,019	$506,115	($6,038,909)	($181,167)
2023	16,654.41	5,204.50	23,940.71	227,438	170,237	$1,812,075			$1,553,399		$250,000	$1,553,399	$508,676	($5,711,400)	($171,342)
2024	16,820.95	5,256.55	24,180.12	251,619	187,058	$1,830,196			$1,568,933		$250,000	$1,568,933	$511,263	($5,371,479)	($161,144)
2025	16,989.16	5,309.11	24,421.92	276,040	204,047	$1,848,498			$1,584,623		$250,000	$1,584,623	$513,875	($5,018,748)	($150,562)
2026	17,159.05	5,362.20	24,666.14	300,707	221,206	$1,866,983			$1,600,469		$250,000	$1,600,469	$516,514	($4,652,797)	($139,584)
2027	17,330.64	5,415.83	24,912.80	325,619	238,537	$1,885,653			$1,616,473		$250,000	$1,616,473	$519,179	($4,273,201)	($128,196)
2028	17,503.95	5,469.98	25,161.93	350,781	256,041	$1,904,509			$1,632,638		$250,000	$1,632,638	$521,871	($3,879,526)	($116,386)
2029	17,678.99	5,524.68	25,413.55	376,195	273,720	$1,923,554			$1,648,965		$250,000	$1,648,965	$524,590	($3,471,322)	($104,140)
2030	17,855.78	5,579.93	25,667.68	401,863	291,576	$1,942,790			$1,665,454		$250,000	$1,665,454	$527,336	($3,048,126)	($91,444)
2031	18,034.34	5,635.73	25,924.36	427,787	309,610	$1,962,218			$1,682,109		$250,000	$1,682,109	$530,109	($2,609,461)	($78,284)
2032	18,214.68	5,692.09	26,183.61	453,971	327,825	$1,981,840	2,981,111		$1,698,930		$250,000	$4,680,040	($2,448,200)	($5,135,945)	($154,078)
2033	**18,396.83**	**5,749.01**	**26,445.44**	**480,416**	**346,222**	$2,001,658		$3,161,205	$1,715,919		$250,000	$4,877,124	($2,625,465)	($7,915,488)	($237,465)
2034	18,580.80	5,806.50	26,709.90	507,126	364,802	$2,021,675			$1,733,078		$250,000	$1,733,078	$538,597	($7,614,356)	($228,431)
2035	18,766.60	5,864.56	26,976.99	534,103	383,569	$2,041,892			$1,750,409		$250,000	$1,750,409	$541,483	($7,301,304)	($219,039)
2036	18,954.27	5,923.21	27,246.76	561,350	402,523	$2,062,311	5,317,332		$1,767,913		$250,000	$7,085,245	($4,772,934)	($12,293,278)	($368,798)
2037	**19,143.81**	**5,982.44**	**27,519.23**	**588,869**	**421,667**	$2,082,934		$962,182	$1,785,592		$250,000	$2,747,774	($414,840)	($13,076,916)	($392,307)
2038	19,335.25	6,042.27	27,794.42	616,663	441,002	$2,103,763			$1,803,448		$250,000	$1,803,448	$550,315	($12,918,909)	($387,567)
2039	19,528.60	6,102.69	28,072.37	644,736	460,531	$2,124,801			$1,821,483		$250,000	$1,821,483	$553,318	($12,753,158)	($382,595)
2040	19,723.89	6,163.72	28,353.09	673,089	480,255	$2,146,049			$1,839,698		$250,000	$1,839,698	$556,351	($12,579,402)	($377,382)
2041	19,921.13	6,225.35	28,636.62	701,725	500,176	$2,167,509			$1,858,095		$250,000	$1,858,095	$559,415	($12,397,369)	($371,921)
2042	20,120.34	6,287.61	28,922.99	730,648	520,296	$2,189,184			$1,876,676		$250,000	$1,876,676	$562,509	($12,206,781)	($366,203)
2043	20,321.54	6,350.48	29,212.22	759,861	540,618	$2,211,076			$1,895,442		$250,000	$1,895,442	$565,634	($12,007,351)	($360,221)
2044	20,524.76	6,413.99	29,504.34	789,365	561,143	$2,233,187			$1,914,397		$250,000	$1,914,397	$568,790	($11,798,781)	($353,963)
2045	20,730.01	6,478.13	29,799.39	819,164	581,873	$2,255,519			$1,933,541		$250,000	$1,933,541	$571,978	($11,580,766)	($347,423)
2046	20,937.31	6,542.91	30,097.38	849,262	602,810	$2,278,074			$1,952,876		$250,000	$1,952,876	$575,198	($11,352,991)	($340,590)
2047	21,146.68	6,608.34	30,398.35	879,660	623,957	$2,300,855			$1,972,405		$250,000	$1,972,405	$578,450	($11,115,131)	($333,454)
2048	21,358.15	6,674.42	30,702.34	910,362	645,315	$2,323,863			$1,992,129		$250,000	$1,992,129	$581,734	($10,866,851)	($326,006)
2049	21,571.73	6,741.17	31,009.36	941,372	666,887	$2,347,102			$2,012,050		$250,000	$2,012,050	$585,052	($10,607,804)	($318,234)
2050	21,787.45	6,808.58	31,319.45	972,691	688,674	$2,370,573			$2,032,171		$250,000	$2,032,171	$588,402	($10,337,636)	($310,129)
2051	22,005.32	6,876.66	31,632.65	1,004,324	710,679	$2,394,279			$2,052,492		$250,000	$2,052,492	$591,786	($10,055,979)	($301,679)
2052	22,225.37	6,945.43	31,948.97	1,036,273	732,905	$2,418,222			$2,073,017		$250,000	$2,073,017	$595,204	($9,762,454)	($292,874)
2053	22,447.63	7,014.88	32,268.46	1,068,541	755,352	$2,442,404			$2,093,748		$250,000	$2,093,748	$598,656	($9,456,671)	($283,700)
2054	22,672.10	7,085.03	32,591.15	1,101,132	778,024	$2,466,828			$2,114,685		$250,000	$2,114,685	$602,143	($9,138,229)	($274,147)
2055	22,898.82	7,155.88	32,917.06	1,134,049	800,923	$2,491,496			$2,135,832		$250,000	$2,135,832	$605,664	($8,806,711)	($264,201)
2056	23,127.81	7,227.44	33,246.23	1,167,296	824,051	$2,516,411			$2,157,190		$250,000	$2,157,190	$609,221	($8,461,692)	($253,851)
2057	23,359.09	7,299.72	33,578.69	1,200,874	847,410	$2,541,575			$2,178,762		$250,000	$2,178,762	$612,813	($8,102,729)	($243,082)
2058	23,592.68	7,372.71	33,914.48	1,234,789	871,003	$2,566,991			$2,200,550		$250,000	$2,200,550	$616,441	($7,729,370)	($231,881)
2059	23,828.61	7,446.44	34,253.62	1,269,042	894,831	$2,592,661			$2,222,555		$250,000	$2,222,555	$620,106	($7,341,146)	($220,234)
2060	24,066.89	7,520.90	34,596.16	1,303,639	918,898	$2,618,587			$2,244,781		$250,000	$2,244,781	$623,807	($6,937,573)	($208,127)
2061	24,307.56	7,596.11	34,942.12	1,338,581	943,206	$2,644,773			$2,267,229		$250,000	$2,267,229	$627,545	($6,518,156)	($195,545)
2062	24,550.64	7,672.07	35,291.54	1,373,872	967,757	$2,671,221			$2,289,901		$250,000	$2,289,901	$631,320	($6,082,380)	($182,471)
2063	24,796.15	7,748.80	35,644.46	1,409,517	992,553	$2,697,933			$2,312,800		$250,000	$2,312,800	$635,133	($5,629,718)	($168,892)
2064	25,044.11	7,826.28	36,000.90	1,445,518	1,017,597	$2,724,913			$2,335,928		$250,000	$2,335,928	$638,985	($5,159,625)	($154,789)
2065	25,294.55	7,904.55	36,360.91	1,481,879	1,042,891	$2,752,162			$2,359,287		$250,000	$2,359,287	$642,875	($4,671,539)	($140,146)
2066	25,547.49	7,983.59	36,724.52	1,518,603	1,068,439	$2,779,683			$2,382,880		$250,000	$2,382,880	$646,803	($4,164,882)	($124,946)
2067	25,802.97	8,063.43	37,091.77	1,555,695	1,094,242	$2,807,480			$2,406,709		$250,000	$2,406,709	$650,771	($3,639,057)	($109,172)
2068	26,061.00	8,144.06	37,462.68	1,593,158	1,120,303	$2,835,555	6,997,559		$2,430,776		$250,000	$9,428,335	($6,342,780)	($10,091,009)	($302,730)
2069	**26,321.61**	**8,225.50**	**37,837.31**	**1,630,995**	**1,146,624**	$2,863,910		$3,447,028	$2,455,084		$250,000	$5,902,112	($2,788,201)	($13,181,941)	($395,458)
2070	26,584.82	8,307.76	38,215.68	1,669,211	1,173,209	$2,892,550			$2,479,634		$250,000	$2,479,634	$662,915	($12,914,484)	($387,435)
2071	26,850.67	8,390.84	38,597.84	1,707,808	1,200,060	$2,921,475			$2,504,431		$250,000	$2,504,431	$667,044	($12,634,874)	($379,046)
2072	27,119.18	8,474.74	38,983.82	1,746,792	1,227,179	$2,950,690			$2,529,475		$250,000	$2,529,475	$671,215	($12,342,705)	($370,281)
2073	27,390.37	8,559.49	39,373.66	1,786,166	1,254,569	$2,980,197			$2,554,770		$250,000	$2,554,770	$675,427	($12,037,560)	($361,127)
2074	27,664.27	8,645.09	39,767.39	1,825,933	1,282,234	$3,009,999			$2,580,318		$250,000	$2,580,318	$679,681	($11,719,005)	($351,570)
2075	27,940.92	8,731.54	40,165.07	1,866,098	1,310,175	$3,040,099			$2,606,121		$250,000	$2,606,121	$683,978	($11,386,597)	($341,598)
2076	28,220.33	8,818.85	40,566.72	1,906,665	1,338,395	$3,070,500			$2,632,182		$250,000	$2,632,182	$688,318	($11,039,878)	($331,196)
2077	28,502.53	8,907.04	40,972.39	1,947,637	1,366,897	$3,101,205			$2,658,504		$250,000	$2,658,504	$692,701	($10,678,373)	($320,351)
2078	28,787.56	8,996.11	41,382.11	1,989,020	1,395,685	$3,132,217			$2,685,089		$250,000	$2,685,089	$697,128	($10,301,596)	($309,048)
2079	29,075.43	9,086.07	41,795.93	2,030,816	1,424,760	$3,163,539			$2,711,940		$250,000	$2,711,940	$701,599	($9,909,045)	($297,271)
2080	29,366.19	9,176.93	42,213.89	2,073,029	1,454,127	$3,195,174			$2,739,059		$250,000	$2,739,059	$706,115	($9,500,201)	($285,006)
2081	29,659.85	9,268.70	42,636.03	2,115,665	1,483,786	$3,227,126			$2,766,450		$250,000	$2,766,450	$710,676	($9,074,531)	($272,236)
2082	29,956.45	9,361.39	43,062.39	2,158,728	1,513,743	$3,259,397			$2,794,114		$250,000	$2,794,114	$715,283	($8,631,484)	($258,945)
2083	30,256.01	9,455.00	43,493.01	2,202,221	1,543,999	$3,291,991			$2,822,055		$250,000	$2,822,055	$719,936	($8,170,492)	($245,115)
2084	30,558.57	9,549.55	43,927.94	2,246,149	1,574,558	$3,324,911			$2,850,276		$250,000	$2,850,276	$724,635	($7,690,972)	($230,729)
2085	30,864.16	9,645.05	44,367.22	2,290,516	1,605,422	$3,358,160			$2,878,779		$250,000	$2,878,779	$729,382	($7,192,319)	($215,770)
2086	31,172.80	9,741.50	44,810.90	2,335,327	1,636,594	$3,391,742			$2,907,566		$250,000	$2,907,566	$734,175	($6,673,913)	($200,217)
2087	31,484.53	9,838.91	45,259.00	2,380,586	1,668,079	$3,425,659			$2,936,642		$250,000	$2,936,642	$739,017	($6,135,113)	($184,053)
2088	31,799.37	9,937.30	45,711.59	2,426,297	1,699,878	$3,459,916			$2,966,008		$250,000	$2,966,008	$743,907	($5,575,259)	($167,258)
2089	32,117.36	10,036.68	46,168.71	2,472,466	1,731,996	$3,494,515			$2,995,669		$250,000	$2,995,669	$748,846	($4,993,671)	($149,810)
2090	32,438.54	10,137.04	46,630.40	2,519,097	1,764,434	$3,529,460			$3,025,625		$250,000	$3,025,625	$753,835	($4,389,646)	($131,689)
2091	32,762.92	10,238.41	47,096.70	2,566,193	1,797,197	$3,564,755			$3,055,882		$250,000	$3,055,882	$758,873	($3,762,462)	($112,874)
2092	33,090.55	10,340.80	47,567.67	2,613,761	1,830,288	$3,600,402			$3,086,440		$250,000	$3,086,440	$763,962	($3,111,374)	($93,341)
2093	33,421.46	10,444.21	48,043.35	2,661,804	1,863,709	$3,636,406			$3,117,305		$250,000	$3,117,305	$769,102	($2,435,613)	($73,068)
2094	33,755.67	10,548.65	48,523.78	2,710,328	1,897,465	$3,672,770			$3,148,478		$250,000	$3,148,478	$774,293	($1,734,389)	($52,032)
2095	34,093.23	10,654.13	49,009.02	2,759,337	1,931,558	$3,709,498			$3,179,963		$250,000	$3,179,963	$779,536	($1,006,885)	($30,207)
2096	34,434.16	10,760.68	49,499.11	2,808,836	1,965,992	$3,746,593			$3,211,762		$250,000	$3,211,762	$784,831	($252,261)	($7,568)
2097	34,778.50	10,868.28	49,994.10	2,858,830	2,000,771	$3,784,059			$3,243,880		$250,000	$3,243,880	$790,179	$530,351	$15,911
2098	35,126.29	10,976.97	50,494.04	2,909,324	2,035,897	$3,821,900			$3,276,319		$250,000	$3,276,319	$795,581	$1,341,842	$40,255
2099	35,477.55	11,086.73	50,998.98	2,960,323	2,071,375	$3,860,119			$3,309,082		$250,000	$3,309,082	$801,037	$2,183,134	$65,494
2100	35,832.33	11,197.60	51,508.97	3,011,832	2,107,207	$3,898,720			$3,342,173		$250,000	$3,342,173	$806,547	$3,055,175	$91,655
2101	36,190.65	11,309.58	52,024.06	3,063,856	2,143,398	$3,937,707			$3,375,594		$250,000	$3,375,594	$812,113	$3,958,943	$118,768
2102	36,552.56	11,422.67	52,544.30	3,116,401	2,179,950	$3,977,084			$3,409,350		$250,000	$3,409,350	$817,734	$4,895,446	$146,863
2103	36,918.08	11,536.90	53,069.74	3,169,470	2,216,868	$4,016,855			$3,443,444		$250,000	$3,443,444	$823,411	$5,865,720	$175,972
2104	37,287.26	11,652.27	53,600.44	3,223,071	2,254,155	$4,057,023			$3,477,878		$250,000	$3,477,878	$829,145	$6,870,837	$206,125
2105	37,660.14	11,768.79	54,136.44	3,277,207	2,291,816	$4,097,594			$3,512,657		$250,000	$3,512,657	$834,937	$7,911,899	$237,357
2106	38,036.74	11,886.48	54,677.81	3,331,885	2,329,852	$4,138,570	5,419,183		$3,547,784		$250,000	$8,966,966	($4,578,397)	$3,570,859	$107,126
2107	**38,417.10**	**12,005.35**	**55,224.59**	**3,387,110**	**2,368,269**	**$4,179,955**		$4,911,798			**$250,000**	$4,911,798	($481,843)	$3,196,142	$95,884
2108										$163,065		$163,065	($163,065)	$3,128,962	$93,869
2109										$163,065		$163,065	($163,065)	$3,059,766	$91,793
2110										$163,065		$163,065	($163,065)	$2,988,494	$89,655
2111										$163,065		$163,065	($163,065)	$2,915,084	$87,453
2112										$163,065		$163,065	($163,065)	$2,839,471	$85,184
2113										$163,065		$163,065	($163,065)	$2,761,591	$82,848
2114										$163,065		$163,065	($163,065)	$2,681,374	$80,441
2115										$163,065		$163,065	($163,065)	$2,598,750	$77,963
2116										$163,065		$163,065	($163,065)	$2,513,648	$75,409
2117										$163,065		$163,065	($163,065)	$2,425,992	$72,780
2118										$163,065		$163,065	($163,065)	$2,335,707	$70,071
2119										$163,065		$163,065	($163,065)	$2,242,714	$67,281
2120										$163,065		$163,065	($163,065)	$2,146,930	$64,408
2121										$163,065		$163,065	($163,065)	$2,048,274	$61,448
2122										$163,065		$163,065	($163,065)	$1,946,657	$58,400
2123										$163,065		$163,065	($163,065)	$1,841,992	$55,260
2124										$163,065		$163,065	($163,065)	$1,734,187	$52,026
2125										$163,065		$163,065	($163,065)	$1,623,148	$48,694
2126										$163,065		$163,065	($163,065)	$1,508,777	$45,263
2127										$163,065		$163,065	($163,065)	$1,390,976	$41,729
2128										$163,065		$163,065	($163,065)	$1,269,640	$38,089
2129										$163,065		$163,065	($163,065)	$1,144,665	$34,340
2130										$163,065		$163,065	($163,065)	$1,015,940	$30,478
2131										$163,065		$163,065	($163,065)	$883,353	$26,501
2132										$163,065		$163,065	($163,065)	$746,789	$22,404
2133										$163,065		$163,065	($163,065)	$606,128	$18,184
2134										$163,065		$163,065	($163,065)	$461,247	$13,837
2135										$163,065		$163,065	($163,065)	$312,020	$9,361
2136										$163,065		$163,065	($163,065)	$158,315	$4,749
2137										$163,065		$163,065	($163,065)	($0)	($0)
	2,368,269	**740,084**	**3,404,387**	**136,281,384**	**95,922,230**	**257,678,470**	**30,173,853**	**12,482,213**	**217,311,279**	**4,891,944**	**23,250,000**	**264,859,289**			**-$16,134,013**

Breakeven Tipping Fee = **$108.80 per tonne of waste**

Interest rate = **3.00%**

Annual Operating Cost (per tonne of waste) = **$93**

	Total Cost	$/tonne	Percent of Fee
Total Revenues =	$280,928,470	118.62	100%
Total Landfilling Cost (excluding interest) =	$264,859,289	111.84	94%
Total Capital Cost =	$30,173,853	12.74	11%
Total Closure Cost =	$12,482,213	5.27	4%
Total Operating Expenses =	$217,311,279	91.76	77%
Total Post Operating Cost =	$4,891,944	2.07	2%
Total Interest =	$16,134,013	6.81	6%
Total Landfilling Cost (including interest charges)	$280,993,302	$119	100%

13. FIRE SAFETY AND EMERGENCY RESPONSE PLAN

13.1 Fire Safety Plan

If not controlled, landfill fires can threaten the health of landfill staff and residents in surrounding neighbourhoods, as well as lead to undesirable impacts on the environment in terms of toxic emissions of pollutants to the air and groundwater.

This section presents a Risk Mitigation Plan and Monitoring Program to minimize the risk of a landfill fire during operations at the CMLF, and establishes protocols for quick control and extinguishment of any fire that can develop.

13.1.1 Filling Strategy

The risk of a landfill fire occurring due to spontaneous combustion or surface ignition can be minimized by maintaining the active filling area as small as practical and placing daily cover at the end of each day.

13.1.2 Rapid Attack Crew and Strategy

The first response crew for a landfill fire will be the operational staff on site. A water tanker should be on site at all times in order to immediately suppress any fires. The most effective method for immediate fire suppression is to excavate to the source of the fire and saturate the area with water or bury it with dirt provided the fire is not electrical, hydrocarbon or chemical in nature.

13.1.3 On-Site Policies

The on-site policies for fire risk reduction include:

- Coverage of waste, using adequate cover comprised of inert mineral soil;
- Maintaining adequate soil resources onsite to fight a fire;
- Maintaining sufficient water resources available to fight a fire;
- A smoking ban, especially in refuelling areas and active landfill areas;
- Supply and keep a maintenance log for an adequate amount of fire extinguishers;
- Any onsite alarm systems should be inspected on a monthly basis and tested annually;
- Incoming vehicles should be visually inspected for smoke, steam, or heat;
- Site exits should remain free of obstructions and unlocked;
- Periodic testing of landfill gas monitoring wells for oxygen entry, elevated temperatures and presence of carbon monoxide;
- Good site security to prevent arson; and
- Training for all operational staff to recognize signs of a landfill fire.

13.1.4 Continuous Site Inspections

Continued visual inspection for landfill fire initiation will be conducted by operational staff on site. These indicators will include:

- Open flame
- Smoke
- Steam venting
- Rapid settlement and cracking
- Elevated surface temperatures
- Unusual odours

13.1.5 Action Steps, Reporting and Reclamation in Case of a Fire

During the continuous site inspections, if a landfill fire is suspected Landfill Fire Control Inc. (LFCI), a subsidiary of SHA, should be contacted to investigate. If monitoring indicates that temperature and Carbon Monoxide (CO) levels are above normal then a more detailed investigation will need to be initiated with additional drilling and instrumentation requirements to be determined on a case by case basis. If an investigation is initiated, the mitigation steps will be discussed with the RDOS and the current onsite contractors (currently – SSG Construction Ltd.).

The steps to extinguish a fire, should it occur, are described briefly below and will need to be determined on a site specific situation. If a fire were to occur, a detailed response action plan would need to be completed which would include details on the extinguishment method, health and safety and ultimate reclamation.

13.2 Fire Fighting Resources

13.2.1 Onsite Equipment Resources

In case of a fire emergency, the immediate response will be by the landfill operational staff as they will be on site and working directly with the waste filling. There are numerous pieces of heavy equipment on site to quickly attack a fire. Currently these include:

- 826 C Caterpillar
- CAT 300 Series Excavators
- Rock Truck for Tramming Soil
- Min. 1500 gal. Water Tank Unit
- Year round access to sufficient water source within close proximity to site

13.2.2 Fire Department Resources

The Fire Department that services the area where construction is occurring is the Penticton Fire Department, located at either 250 Nanaimo Avenue West (Station 201- Headquarters) or 285 Dawson Avenue (Station 202), Penticton, B.C. The furthest station is approximately 8 km from the site in the

City of Penticton. The composite department consists of 37 career and 41 auxiliary members able to respond to emergencies 24-hours a day, 7-days a week.

13.2.3 Outside Contractor Resources

Outside contractor resources are generally required on large fires that may require several weeks or more to fully extinguish. On protracted fires RDOS will retain appropriate outside contractors. Outside contractor's resources may be required in the following areas:

- Additional water tankers;
- Additional earth moving equipment;
- Drilling;
- Security;
- Air quality testing;
- Analytical laboratory;
- Occupational health and safety; and
- Catering

13.3 Landfill Fire Alert Levels

Landfill fires can occur in a number of ways, with each type of fire requiring a different level of response and fire fighting strategy. In this plan, there are four basic Alert Categories as outlined below.

Non Refuse Fires: Small fires occurring on landfill property but not actually involving landfilled refuse, compost or stockpiled recyclables.

Small Fires: Small refuse fires that can be contained by on-site resources within 24 hours and fully extinguished within 48 hours. Level 2 fires will typically involve less than 200 cubic meters of burning material.

Medium Fires: Medium size refuse fires or large fires at compost facilities that can be contained in less than one week and that can be fully extinguished in less than two weeks. Typically 200 to 5,000 cubic meters of waste materials are involved.

Large Fires: Large or deep seated landfill fires that require more than two weeks to contain, typically involving more than 5,000 cubic meters of burning refuse.

13.3.1 General Procedures for Small Fires at Active Face

- Follow General Fire Procedures for reporting and evacuation. Call 911.
- Initiate Incident Command Structure Protocols.
- Put on approved half face respirators.
- Stay upwind of the fire.
- Assess toxicity of the smoke. If eyes, throat or lungs become irritated clear area immediately.
- If it can be done safely, remove all vehicles and landfill equipment from the area.

- If it can be done safely, use the landfill equipment to construct a firebreak around the fire using soil from the stockpile.
- If it can be done safely, cover all refuse that is not on fire with 60 cm. of inert soil.
- Never drive a bulldozer or track loader onto burning material.
- If two or more water trucks are being used, try to sequence deliveries in shifts so that at least one water truck is at the fire at all times.
- Do not overuse water. Remember that most landfill fires can be controlled with a relatively small amount of water. In most cases, soil is more effective than water.
- Don't waste time trying to fight a large fire with a fire extinguisher.
- Commence application of water with Class A Foam or F-500 (typically at 0.5%) on the fire in-situ or dig out burning material, and soak or smother once placed on inert soil surface.
- Shut down any methane gas extraction wells within 100 meters of the fire zone.
- Notify the surrounding landowners if there is a chance that the fire could spread beyond the landfill.

13.3.2 General Procedures for Medium Landfill Fires

- Follow General Safety Procedures for reporting and evacuation. Call 911.
- Mobilize Unified Command Team.
- Initiate Incident Command Structure Protocols.
- Assess fire situation.
- Develop fire fighting strategy (water, oxygen control, overhaul, or combination)
- Assess appropriate level of respiratory protection & health and safety issues, ensure all staff wear required level of personal protection.
- Notify regulatory agencies.
- Implement fire-fighting strategy.
- Establish Command Post.
- Implement security protocols, especially sign-in/sign-out.
- Implement financial control protocols.
- Install monitoring equipment to assess progress (gases, temperature).
- Review strategy on a daily basis, adjust as necessary.

13.3.3 General Fire Fighting Procedures for Large Landfill Fires

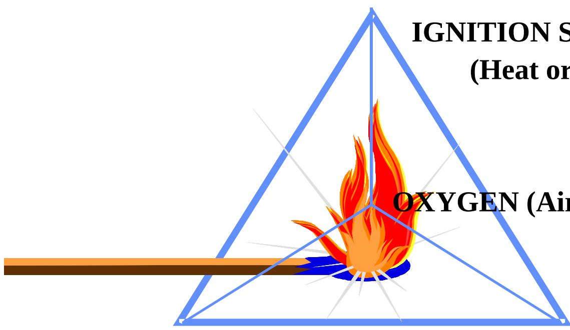
- Follow General Safety Procedures for reporting and evacuation. Call 911.
- Mobilize Incident Command Team.
- Initiate Incident Command Structure Protocols.
- Assess fire situation.
- Establish Command Post.
- Implement security protocols, especially sign-in/sign-out.
- Notify regulatory agencies.
- Initiate public relations program.
- Initiate planning for evacuation of on-site staff and potentially affected residents, if there is potential for air quality hazard.
- Develop fire-fighting strategy (water, oxygen control, overhaul, or combination). Review

strategy with technical staff from Landfill Fire Control Inc.

- Assess appropriate level of respiratory protection & health and safety issues; ensure all staff wear required level of personal protection.
- Implement fire-fighting strategy.
- Implement financial control protocols.
- Install monitoring equipment to assess progress (gases, temperature).
- Review strategy on a daily basis, adjust as necessary.

13.4 Fire Fighting Methods

Four basic ingredients are required for a fire to burn: 1) fuel, 2) an ignition source, 3) sustained heat and 4) sustained chemical reaction these form the fire tetrahedron. To prevent a fire from occurring, or to control a fire that is already burning it is necessary to remove at least one of the four fire tetrahedron ingredients.



Fire prevention focuses on elimination of all potential ignition sources from the landfill, including burning cigarettes, hot loads and conditions that increase the risk of spontaneous combustion. Once a fire starts, the ignition source has been introduced. Therefore, to achieve extinguishment one must remove the heat source, cut off the oxygen supply or interrupt the rapid oxidation reaction.

There are three principal methods of fighting landfill fires:

- Water Extinguishment Method
- Oxygen Suppression Method
- Excavate and Overhaul Method

A fourth method, which involves isolating the fire and allowing it to burn itself out or accelerating combustion, is generally undesirable due to associated air pollution impacts arising from particulate matter and contaminants contained in the smoke. Open combustion of refuse is also contrary to Ministry of Environment regulations and is not permitted at the Campbell Mountain Landfill.

- Selection of the preferred method of fire extinguishment is dependant upon many variables, including but not necessarily limited to size and intensity of the fire;
- Depth of the fire (surface fire versus deep fire);
- Material fuelling the fire (MSW, DLC waste, clean wood waste, etc.);
- Compaction of refuse in place;
- Size of cells in which refuse is contained;
- Thickness and continuity of intermediate cover fire breaks;
- Material used for intermediate cover (clay, sand, inert soil, wood waste);
- Availability of inert cover soil (preferably clay);
- Availability and delivery pressure of water for fire fighting purposes;
- Population density and sensitivity of people down wind of the fire zone;
- Sensitivity of other receptors in the terrestrial and aquatic environment;
- Proximity of sensitive infrastructure (e.g. gas pipelines, utilities, fuel tanks, etc.);
- Risk of the fire spreading off-site; and
- Availability of firefighting resources.

13.5 Post Fire Procedures

After the fire has been extinguished the following procedures should be followed:

- Replace any fire protection equipment that was used or destroyed during the fire;
- Cordon the area affected by the fire until it is safe for re-entry;
- Reclaim any equipment that can be salvaged.

13.6 Emergency Response Plan

A detailed Emergency Response Plan (ERP) should form part of any prudent landfill operation plan. The ERP should address not only the risk of landfill fire, but other emergencies that may arise on site as well.

The purpose of the plan is to identify the responsibilities of the emergency response coordinators, procedures to follow in the event of an emergency and to limit or reduce the risk of injury and / or loss to workers, the environment, and property. The plan should serve as a guideline during emergency response situations, and as a training guide for evacuation drills and emergency planning.

A Site Emergency Action Team will need to be identified and located at the CMLF facility. This team will be authorized and directed to assure the implementation of the Emergency Procedures until the arrival of the Emergence Response Services. The Site Emergency Action Team shall consist of at least two members, one of whom shall be the Supervisor, who is hereby designated as the Emergency Coordinator, and the other of whom shall be designated as the Assistant Emergency Coordinator. The Emergency Coordinator may appoint such additional members of the Site Emergency Action Team, as he or she may deem necessary to assure implementation of the Emergency Procedures.

In the event of an emergency, the Emergency Coordinator shall be contacted. If the Emergency Coordinator is not available, contact the Assistant Emergency Coordinator. The Emergency Coordinator and or the Assistant will command and control all response personnel and equipment necessary to control the emergency.

The Emergency Coordinator will assist all needed response agencies. Employees will be directed by the Emergency Coordinator to assist in procedures for any response agency.

In the event the Emergency Procedures must be implemented, the incident shall be reported immediately to Director of Environmental Services, at home if necessary. Appropriate Management Personnel will report to the site and help co-ordinate activities.

During the post event period, an Accident Investigation must be prepared summarizing the events, actions taken and resulting effect. This report is to be forwarded to the Director of Environmental Services by the end of the next working day. If a spill occurs, then an environmental spill report must be completed.

Areas that the site Specific Emergency Reponses Plan should address are:

- Site Emergency Action Team-Roles and Responsibilities
- Evacuation Summary
- Medical Emergencies
- Fire Evacuation Guidelines
- Fire Prevention
- Landfill Fire
- Equipment Fires
- Post Fire Activities Unknown Cloud
- Missing Person Procedures
- Emergency First Aid Procedures
- List of Active First Aiders
- Earthquake Procedures
- Bomb Threat Response
- Emergency Response Forms
- Emergency Spill Response Plan
- Emergency Contact Numbers
- Evacuation Drills

14 LIMITATIONS

This report has been prepared by Sperling Hansen Associates (SHA) on behalf of the Regional District of Okanagan-Similkameen in accordance with generally accepted engineering practices to a level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions in British Columbia, subject to the time limits and financial and physical constraints applicable to the services.

The report, which specifically includes all tables and figures, is based on engineering analysis by SHA staff of data compiled during the course of the project. Except where specifically stated to the contrary, the information on which this study is based has been obtained from external sources. This external information has not been independently verified or otherwise examined by SHA to determine its accuracy and completeness. SHA has relied in good faith on this information and does not accept responsibility of any deficiency, misstatements or inaccuracies contained in the reports as a result of omissions, misinterpretation and/or fraudulent acts of the persons interviewed or contacted, or errors or omissions in the reviewed documentation.

The report is intended solely for the use of the Regional District of Okanagan-Similkameen. Any use which a third party makes of this report, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. SHA does not accept any responsibility for other uses of the material contained herein nor for damages, if any, suffered by any third party because of decisions made or actions based on this report. Copying of this intellectual property for other purposes is not permitted.

The findings and conclusions of this report are valid only as of the date of this report. The interpretations presented in this report and the conclusions and recommendations that are drawn are based on information that was made available to SHA during the course of this project. Should additional new data become available in the future, Sperling Hansen Associates should be requested to re-evaluate the findings of this report and modify the conclusions and recommendations drawn, as required.

Report prepared by:	**Report prepared by:**
Dr. Iqbal Bhuiyan, P.Eng **Senior Environmental Engineer**	**David Kvick , M.Sc.** **Environmental Scientist**

Report prepared by:

Scott Garthwaite
Office Manager & Civil Technologist

Report prepared by:

Megan Gardner, E.I.T
Environmental Engineer

Ali Abedini, PhD.
Senior Environmental Consultant

Report reviewed by:

Dr. Tony Sperling, P.Eng
President

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APPENDIX A
Operational Certificate

Appendix A

Operational Certificate 15274

January 8, 2015

Authorization Number: 15274
Tracking Number: 91

REGISTERED MAIL

Regional District Okanagan Similkameen
101 Martin Street
Penticton, BC V2A 5J9

Re: Operational Certificate 15274 – Campbell Mountain landfill

Enclosed is Operational Certificate 15274 issued under the provisions of the *Environmental Management Act*. This Operational Certificate supercedes Permit PR – 1597(03) which is cancelled in accordance with Section 24(10) of the *Environmental Management Act.* Your attention is respectfully directed to the terms and conditions outlined in the operational certificate. An annual fee will be determined according to the Permit Fees Regulation.

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

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

…/2

Ministry of Environment
Environmental Protection Division
102 Industrial Pl.
Penticton, BC V2A 7C8
Southern Interior Region - Okanagan
Telephone: (250) 490-8200
Facsimile: (250) 490-2231

Administration of this operational certificate will be carried out by staff from the Southern Interior Region - Okanagan. Plans, data and reports pertinent to the operational certificate are to be submitted to the Director, Environmental Protection, at Ministry of Environment, Regional Operations, Southern Interior Region - Okanagan, 102 Industrial Pl., Penticton, BC V2A 7C8.

Yours truly,

Carol Danyluk, P.Eng.
for Director, *Environmental Management Act*
Southern Interior Region - Okanagan

Enclosure

cc: Environment Canada

BRITISH COLUMBIA

MINISTRY OF ENVIRONMENT

OPERATIONAL CERTIFICATE

15274

Under the Provisions of the *Environmental Management Act*

REGIONAL DISTRICT OKANAGAN SIMILKAMEEN

101 MARTIN STREET
PENTICTON, BC V2A 5J9

is authorized to manage municipal solid waste and recyclable materials from the Regional District of Okanagan Similkameen (Regional District) at the Campbell Mountain landfill facility located approximately 5 km northeast of Penticton, British Columbia, subject to the conditions listed below. Contravention of any of these conditions is a violation of the *Environmental Management Act* and may result in prosecution.

"Director" means the Director or a person delegated to act on behalf of the Director, as defined in the *Environmental Management Act*.

1. AUTHORIZED DISCHARGES

1.1 This section applies to the discharge of refuse from municipal, commercial and light industrial sources to a sanitary landfill known as the Campbell Mountain Landfill. The site reference number for this discharge is E212375.

1.1.1 The maximum rate of discharge is 50,000 tonnes per year. The maximum quantity of waste discharged must not exceed the design capacity of the landfill as specified in an approved Design, Operations and Closure Plan. The final footprint and profile of the discharged waste must be within that specified in the Design, Operations and Closure Plan and approximately as shown on the attached locations map.

1.1.2 The characteristics of the waste discharged to the landfill are those of municipal solid waste as defined in the *Environmental Management Act* and other waste as may be authorized by the Director.

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for Director, *Environmental Management Act*
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1.1.3 The following types of wastes must not be discharged:

(1) Hazardous wastes, other than those specifically approved for disposal to authorized landfills, as defined in the Hazardous Waste Regulation under the *Environmental Management Act*.

(2) Anatomical, pathological, and untreated biomedical wastes as defined in the Guidelines for the Management of Biomedical Wastes in Canada (Canadian Council of Ministers of the Environment, February 1992).

(3) Bulk liquids and semi-solid wastes, which contain free liquids, as determined by US EPA Method 9095A Paint Filter Liquids Test, Test Methods for Evaluating Solid Wastes-Physical/Chemical Methods (EPA Publication No. Sw-846).

(4) Hog fuel, log yard debris and chipped wood waste. The reuse of these materials for temporary roads, dust control or a component of alternative daily cover is permitted.

(5) Recyclable materials, including automobiles, white goods, other large metallic objects and tires.

(6) Dead animals and slaughter house, fish hatchery and farming wastes or cannery wastes and by-products.

Burial of these wastes in dedicated locations (i.e. avoiding co-disposal) at a landfill site may be authorized by the Director only if there is no other viable alternative such as treatment/disposal, recycling, reprocessing or composting. The viability of alternatives is to be determined by the Director based on submission of pertinent information and cost data by the Regional District.

1.1.4 Notwithstanding the requirements of section 1.1.3(6), the burial of dead animals received from Conservation Officers, Road Maintenance Companies, SPCA (buried in the controlled waste cell) and the Veterinary Companies (buried in the controlled waste cell) is hereby authorized.

1.1.5 Notwithstanding the requirements of section 1.1.3(1), the disposal of waste asbestos in compliance with the requirements of Section 40 of the Hazardous Waste Regulation under the *Environmental Management Act* is hereby authorized.

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1.1.6 The deposit of hydrocarbon contaminated soils below the Hazardous Waste Regulation criteria is authorized at this landfill subject to the following conditions:

- Soil contaminated with hydrocarbons must be deposited in layers less than 0.3 meters; and
- Soil contaminated with hydrocarbons must be deposited a minimum of 1.2 meters above the seasonal high groundwater level and a minimum of 2.0 meters below the final grade of the landfill to prevent the impact on groundwater and any future vegetation on the site.

1.1.7 Composting of yard waste must be in accordance with the Organic Matter Recycling Regulation under the *Environmental Management Act*.

1.1.8 The location from which the discharge originates is generally Penticton and area, subject to the following:

Waste discharged to this landfill must not contravene the Regional Solid Waste Management Plan of the Regional District Okanagan Similkameen.

1.1.9 The location of the sanitary landfill facility for the management of municipal solid waste to which this Operational Certificate is applicable is described as: the approximate area of discharge is a portion of Lot 368, Similkameen Division of Yale District, as shown on the location map.

1.1.10 The works authorized are a sanitary landfill and related appurtenances as specified in the approved Design, Operations and Closure Plan. The landfill and any new works should be operated to meet or surpass the requirements for a sanitary landfill as described in the BC Landfill Criteria for Municipal Solid Waste unless otherwise approved by the Director.

1.1.11 Municipal solid waste that has value for the purposes of reuse or reprocessing may be considered recyclable material. Recyclable materials may be temporarily stored at the landfill facility prior to removal from the site. The nature of the recyclable material authorized for storage at the landfill facility must be to the satisfaction of the Director.

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for Director, *Environmental Management Act*
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2. OPERATING REQUIREMENTS

2.1 Design, Operation and Closure Plan

2.1.1 The Regional District must submit a Design, Operation and Closure Plan prepared by a suitably qualified professional for approval by the Director by June 30, 2016. The Design, Operation and Closure Plan must address, but not be limited to, each of the subsections in the Landfill Criteria for Municipal Solid Waste including performance, siting, design, operational, closure and post-closure criteria. The facilities must be developed, operated and closed in accordance with the Design, Operation and Closure Plan. Should there be any inconsistency between this Operational Certificate and the Design, Operation and Closure Plan, this Operational Certificate must take precedence.

Written authorization from the Director must be obtained prior to implementing any changes to the approved plans. Based on any information obtained in connection with this facility, the Director may require revision of, or addition to, the Design, Operating and Closure plans.

2.1.2 The Design, Operation and Closure Plan must meet or surpass the requirements of the BC Landfill Criteria for Municipal Solid Waste. As a minimum, the updated plan must address the following topics to the satisfaction of the Director:

(a) Anticipated total waste volumes and tonnage, and life of the landfill (ie: closure date);
(b) A topographic plan showing the final elevation contours of the landfill and surface water diversion and drainage controls;
(c) Design of the final cover including the thickness and permeability of barrier layers and drainage layers, and information on topsoil, vegetative cover and erosion prevention controls;
(d) Procedures for notifying the public about the closure and about alternative waste disposal facilities;
(e) Rodent and nuisance wildlife control procedures;
(f) Proposed end use of the property after closure;
(g) A plan and implementation schedule for monitoring groundwater, surface water and landfill gas, erosion and settlement for the contaminating lifespan of the landfill;
(h) A plan and accompanying design and implementation schedule for the collection, storage and treatment/use of landfill gas for the

contaminating lifespan of the landfill;

(i) A plan and implementation schedule for operation of any required pollution abatement engineering works such as leachate collection and treatment systems, for the contaminating lifespan of the landfill;
(j) A schedule of reserve funds or security to be collected each year until closure; to cover estimated costs of closure, post-closure and a contingency for remediation;
(k) A screening plan, ie: vegetative or berm;
(l) A perimeter fencing design;
(m) Litter and odour control measures;
(n) Contingency Plan & notification procedures in the event of an emergency;
(o) Training procedures for operators; and
(p) Any other site specific concerns as identified by the Director.

2.1.3 The Design, Operation and Closure Plan must be reviewed every 5 years throughout the operating life of the landfill and updated to encompass the next 10 years of landfill operation and/or post-closure activities. The updated landfill Design, Operation and Closure Plan must be prepared by a professional engineer or geoscientist licensed to practice in the province of British Columbia and knowledgeable in such matters. The updated plans must be submitted to the Director for approval and must include any information relevant to the design, operation, closure and post-closure care of the landfill

2.2 <u>Qualified Professionals</u>

All information, including plans, drawings, assessments, investigations, surveys, programs and reports, must be certified by a qualified professional. As-built plans and drawings of the facilities and works must be certified by a qualified professional

2.2.1 "qualified professional" means a person who:

(a) is registered in British Columbia with his or her appropriate professional association, acts under that professional association's code of ethics, and is subject to disciplinary action by that professional association; and
(b) through suitable education, experience, accreditation and knowledge may be reasonably relied on to provide advice within his or her area of expertise as it relates to this Operational Certificate

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2.2.2 Personnel must be trained to industry standards and at least one employee of the Regional District must be trained and certified as a Manager of Landfill Operations or a British Columbia Qualified Landfill Operator by the Solid Waste Association of North America or equivalent.

2.3 Maintenance of Works and Emergency Procedures

The authorized works must be inspected regularly and maintained in good working order. In the event of an emergency or condition beyond the control of the Regional District of Okanagan Similkameen including, but not limited to, unauthorized fires arising from spontaneous combustion or other causes, or detection of surfacing leachate on the property, the Regional District of Okanagan Similkameen must take appropriate remedial action and notify the Regional Ministry Office. The Director may reduce or suspend operations to protect the environment until the authorized works has been restored, and/or corrective steps taken to prevent unauthorized discharges.

2.4 Additional Information, Facilities or Works

The Director may, in writing, require investigations, surveys, the submission of additional information, and the construction of additional facilities or works. The Director may also, in writing, amend the information, including plans, drawings, assessments, investigations, surveys, programs and reports, required by this Operational Certificate. Any amendments to the information are without effect unless the Director has approved of such amendments in writing.

2.5 Ground and Surface Water Quality Impairment

2.5.1 The quality of ground and surface water at the property boundary must not exceed the appropriate (e.g. freshwater aquatic life, drinking water, etc.) water quality criteria in the British Columbia Approved Water Quality Guidelines and A Compendium of Working Water Quality Guidelines for British Columbia, as amended from time to time, or their replacements approved by the Director in writing. Where natural background water quality exceeds the appropriate water quality criteria, the quality of ground and surface water at the property boundary must not exceed natural background water quality. Water quality criteria from other jurisdictions may be approved for contaminants which have not been dealt with in the British Columbia Guidelines. After considering existing and potential future uses of ground and surface water, a qualified professional may recommend the appropriate water quality criteria. The appropriate water quality criteria are subject to the approval of the Director in writing.

2.5.2 If excursions result to the specified water quality criteria, the Director may require that leachate management control measures or works be undertaken. Terms of reference for any leachate management study and/or design work is subject to the authorization of the Director.

2.6 **Landfill Gas Management**

The Landfill must not cause combustible gas concentrations to exceed the lower explosive limit in soils at the property boundary or 25% of the lower explosive limit at or in on-site or off-site structures.

The Regional District of Okanagan Similkameen must ensure that the facility is in compliance with the requirements of the Landfill Gas Management Regulation (391/2008). The requirements of the regulation and its guideline documents must be incorporated by the Regional District into the Design and Operation Plan revisions as they come into effect and as applicable.

2.7 **Property Boundary**

The buffer zone between any municipal solid waste discharged and the property boundary is to be at least 50 metres of which the 15 metres closest to the property boundary must be reserved for natural or landscaped screening (berms or vegetative screens). Depending on adjacent land use and environmental factors, buffer zones of less than 50 metres but not less than 15 metres may be authorized by the Director.

2.8 **Setbacks**

The distance between the discharged municipal solid waste and the nearest residence, water supply intake, hotel, restaurant, food processing facility, school, church or public park is to be a minimum of 300 metres. The distance between the discharged municipal solid waste and the nearest surface water is to be a minimum of 100m. Greater or lesser separation distances may be authorized by the Director where justified.

2.9 **Natural Control Landfill**

2.9.1 The bottommost solid waste cell is to be at least 1.2 metres above the seasonal high water table. Greater or lesser separation depths may be authorized based on soil permeability and the leachate renovation capability of the soil.

2.9.2 There is to be at least a 2 metres thick layer of low permeability soil with a hydraulic conductivity of 1 x 10-6 cm/s or less (i.e. silt or clay), below each of the bottommost waste cells. Lesser thicknesses or no layer of low permeability soil may be authorized based on the potential for leachate generation and the unsaturated depth, permeability and leachate renovation capability of the existing soil.

2.10 **Water**

The disposal of municipal solid waste into water is unacceptable. Surface water diversion to restrict storm water runoff from contacting the wastes is required.

2.11 **Access Road**

An appropriately constructed and maintained access road to, and a road system within the landfill site capable of supporting all vehicles hauling waste, are required during the operating life of the landfill.

2.12 **Fencing and Access**

2.12.1 Fencing is required to be installed and maintained around the perimeter of the landfill. The type and extent of fencing will depend on the existing natural vegetation and topographic features and is to be authorized by the Director. All access points are to have locking gates.

2.12.2 Bears must be prevented from accessing all putrescible refuse from April to November inclusive, through the use of electric fencing or alternative means approved by the Director in writing.

2.13 **Designated Areas**

Maintain areas for the separation, handling and storage of recyclable or reusable materials where applicable.

When a separated recyclable material is a Hazardous Waste it is to be stored and managed in accordance with the Hazardous Waste Regulation.

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2.14 **Signs**

A sign is to be posted at each entrance of the landfill with the following current information:

- Site name
- Owner and operator
- Contact phone number and address for owner and operator
- Phone number in case of emergency (such as fire)
- Hours of operation (if applicable)
- Materials/wastes accepted for landfill and recycling
- Materials/wastes banned
- Tipping fees (if applicable)

Additional signs which clearly indicate the directions to the active tipping face, public disposal area, recycling and waste separation areas, etc. should also be displayed.

2.15 **Supervision**

A landfill operator that has received BC Qualified Landfill Operator training, is familiar with the requirements of the Operational Certificate and the specifications of the Design, Operations and Closure Plan, must be present at all times during operating hours. The gates are to be locked to prevent unauthorized access during non-operating hours. Properly designed and maintained public waste disposal and/or recyclable material bins situated outside the main gate may be provided for after hours use.

2.16 **Waste Reduction and Alternate Disposal**

The Provincial Government has developed policies to promote the reduction, reuse and recycling of wastes. The Regional District is encouraged to segregate for recycling and reuse, where possible, materials destined for disposal at this site.

Public scavenging must not be permitted at the landfill. The controlled salvaging of waste by the landfill operator or persons authorized by the Regional District is encouraged if areas or facilities for separation and storage of recyclable or reusable materials are provided.

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

2.17 Waste Compaction and Covering

2.17.1 Wastes are to be spread in thin layers (0.6 m or less) on the working face and compacted. The working face area should be minimized as much as possible. A compacted layer of cover material of at least 0.15 metre of soil or functionally equivalent depth of other cover material or use of an acceptable alternative daily cover, as authorized by the Director, is to be placed on all exposed solid waste at the end of each day of operation. If the landfill should operate continuously 24 hours per day, 0.15 m of cover material is to be applied at a frequency authorized by the Director. Under specific circumstances, such as during bear season, the Director may specify more stringent cover requirements. During periods of extreme weather conditions, such as those that cause the ground to freeze, an exemption to the normal cover requirements may be authorized at a frequency authorized by the Director.

2.17.2 An intermediate cover consisting of a compacted layer of at least 0.30 metre of soil or functionally equivalent depth of other cover material is to be placed where no additional solid waste has been deposited or will be deposited within a period of 30 days.

2.18 Public Health, Safety and Nuisance

The landfill must be operated in a manner such that it will not create a public nuisance or become a significant threat to public health or safety with respect to landfill gas, odours, unauthorized access, roads, traffic, airport activity, noise, dust, litter, vectors, or wildlife attraction.

2.19 Dust Control

Dust created within the landfill property is to be controlled, using methods and materials acceptable to the Director, such that it does not cause a public nuisance.

2.20 **Litter Control**

Litter is to be controlled by compacting the waste, minimizing the working face area, applying cover, providing litter control fences and instituting a regular litter pickup and general good housekeeping program or any other measures required by the Director.

2.21 **Vectors**

Vectors are to be controlled by the application of cover material at a specified frequency or by other control measures as required and authorized by the Director.

2.22 **Wildlife**

The landfill is to be operated so as to minimize the attraction of wildlife such as bears and birds by applying cover at required frequencies and instituting a good housekeeping program. Further control measures, such as bear control fences, and bird control devices, may be specified by the Director.

2.23 **Fire Protection**

Adequate fire-fighting equipment is to be available to extinguish surface or underground fires. Recyclables and reusable materials are to be stored in such a manner to not constitute a fire hazard.

3 MONITORING AND REPORTING REQUIREMENTS

3.1 **Municipal Solid Waste Measurement**

3.1.1 Provide and maintain a weigh scale and record the weight of refuse discharged to the landfill over a 24-hour period.

3.1.2 Record the weight of recyclable and reusable materials not being discharged and that are being separated, stored or processed at the landfill over a 24-hour period.

3.2 **Groundwater Monitoring Program**

The Regional District must implement and maintain a groundwater and surface water monitoring program, prepared by a qualified professional and approved by the Director. The monitoring program must identify potential environmental impacts of the authorized facility and must address but not be limited to the Landfill Criteria for Municipal Solid Waste and Guidelines for Environmental Monitoring. It must take into consideration results from previous monitoring programs and any other investigations conducted at the site to ensure that early detection of potential impacts is possible.

The monitoring program must be updated every five years and submitted to the satisfaction of the Director. The next monitoring plan update is required to be undertaken and completed in 2014. Monitoring must be conducted in accordance with the monitoring program.

The program must be designed to assess and identify:

- The design performance of the landfill as per the Design & Operations Plan including but not limited to compliance with water quality performance standards at the landfill boundary;
- Landfill leachate as a contaminant source;
- Residential well water quality; and
- Surface water quality.

Any changes to the above-noted ground and surface water monitoring program must be approved by the Director in writing.

3.3 **<u>Vegetation Monitoring</u>**

Inspect vegetation during the growing season in the vicinity of the landfill at least once per year to determine if any environmental impacts are occurring.

3.4 **<u>Sampling and Analyses</u>**

3.4.1 Sampling is to be carried out in accordance with the procedures described in the "British Columbia Field Sampling Manual for Continuous Monitoring and the Collection of Air, Air-Emission, Water, Wastewater, Soil, Sediment, and Biological Samples, 2003 Edition (Permittee)", or most recent edition, or by suitable alternative procedures as authorized by the Director.

A copy of the above manual is available on the Ministry web page at www.env.gov.bc.ca/epd/wamr/labsys/lab_meth_manual.html

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3.4.2 Analyses are to be carried out in accordance with procedures described in the "British Columbia Laboratory Manual (2009 Permittee Edition)", or the most recent edition, or by suitable alternative procedures as authorized by the Director.

A copy of the above manual is available on the Ministry web page at www.env.gov.bc.ca/epd/wamr/labsys/lab_meth_manual.html

3.5 **Quality Assurance**

The Permittee must obtain from the analytical laboratory(ies) their precision, accuracy and blank data for each sample set submitted as well as an evaluation of the data acceptability, based on the criteria set by the laboratory.
The analytical laboratory(ies) must be registered in accordance with CALA (Canadian Association for Laboratory Accreditation) unless otherwise instructed by the Director.

3.6 **Changes to Sampling and Monitoring Program**

On the basis of findings during routine inspections and any other information related to the effect of the discharge on the receiving environment, the Director may allow reductions or require additional sampling and monitoring of the discharge and receiving environment.

3.7 **Annual Report**

An annual operations and monitoring report is to be submitted to the Director by April 30th of each year. The report must contain at least the following information:

(a) an executive summary;

(b) the type and tonnage of waste received, recycled, stored on-site and discharged / landfilled for the year;

(c) Any proposed changes to the Design, Operations and Closure Plan and the environmental monitoring program (EMP), with rationale for the changes; a description of unanticipated occurrences and any changes to the closure or post-closure plans and funds;

(d) A review of the preceding year of operation or an operations update which summarizes landfill development work and airspace filled, work completed in the subject reporting year and work planned for the subsequent year. A summary of any new information or changes to the facilities and plans, assessments, surveys, programs and reports;

(e) Occurrences or observations of wildlife (medium and large carnivores) at the facility;

(f) A statement regarding the facility's progress in reducing the regional solid waste stream being landfilled and the objectives of the Regional Solid Waste Management Plan;

(g) An outline of the current Environmental Monitoring Program and a compendium of all environmental monitoring data in accordance with requirements specified in the most recent version of Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills and Landfill Criteria for Municipal Solid Waste. The annual report must document any effect of the discharge on the quality of the receiving environment using appropriate statistical and graphical analysis. Trend analyses, as well as an evaluation of the impacts of the discharges on the receiving environment must be included;

(h) A list of training programs completed for landfill operators during the previous year; and

(i) Any additional information requested by the Director.

All reports must be submitted, suitably formatted and tabulated in both print and electronic format (portable document format).

3.8 <u>Closure Plan and Post Closure</u>

The Regional District must perform closure and post-closure care in accordance with all applicable requirements of the BC Landfill Criteria for Municipal Solid Waste and the approved Design, Operations and Closure Plan.

A certification by a Qualified Professional attesting that all closure works have been completed in accordance with the Design, Operations and Closure Plan and Final Cover Design is to be submitted to the Director no later than 90 days after the implementation of the Final Cover Design.

The Regional District must submit a Post Closure or Aftercare Plan to the Ministry at least two years prior to the anticipated closure date of the landfill.

3.9 **Financial Security**

The Regional District must provide for the funding of progressive closure operations, final closure and operations beyond closure by maintaining a closure fund. The value of the closure fund must meet or exceed the estimated closure and post-closure costs as established in the approved Design, Operations and Closure Plan and updated in the annual report, plus a reasonable contingency for any remediation which may be required. Reported costs must be adjusted for inflation annually. Alternately, a closure and post-closure financial security acceptable to the Director may be built over time.

The Regional District must determine and ensure that the closure fund is adequate by preparing annually a financial statement of the fund which must be made available to the Director upon request. The financial statement must report the accrued capital, interest and additions to the fund for the previous year and review the sufficiency of the fund and the rate of accrual in consideration of the projected costs of closure and post-closure obligations.

3.10 **Buildings and Structures**

The construction of buildings and other structures on landfills containing putrescible wastes is not recommended for a minimum period of 25 years after closure due to concerns about combustible gas and excessive settlement. Such activity will only be considered and/or authorized after an investigation and report by qualified persons. The report is to be submitted for authorization to the Director prior to initiating construction activities.

3.11 **Operation of Gas Recovery and Management System**

Where landfill gas recovery and management is required, operation of the system should be considered an integral part of overall landfill management and arrangements made for its operation and maintenance for a minimum 25 year period after closure.

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for Director, *Environmental Management Act*
Southern Interior Region – Okanagan

3.12 **Operation of Other Control Systems**

Operation of other environmental control systems for leachate and run-off as well as monitoring of leachate, groundwater and surface water must be continued during the entire post closure period, for a minimum 25 year period after closure unless the early suspension of such operations or monitoring is authorized by the Director.

Date issued: January 8, 2015

Carol Danyluk, P.Eng.
for Director, *Environmental Management Act*
Southern Interior Region – Okanagan

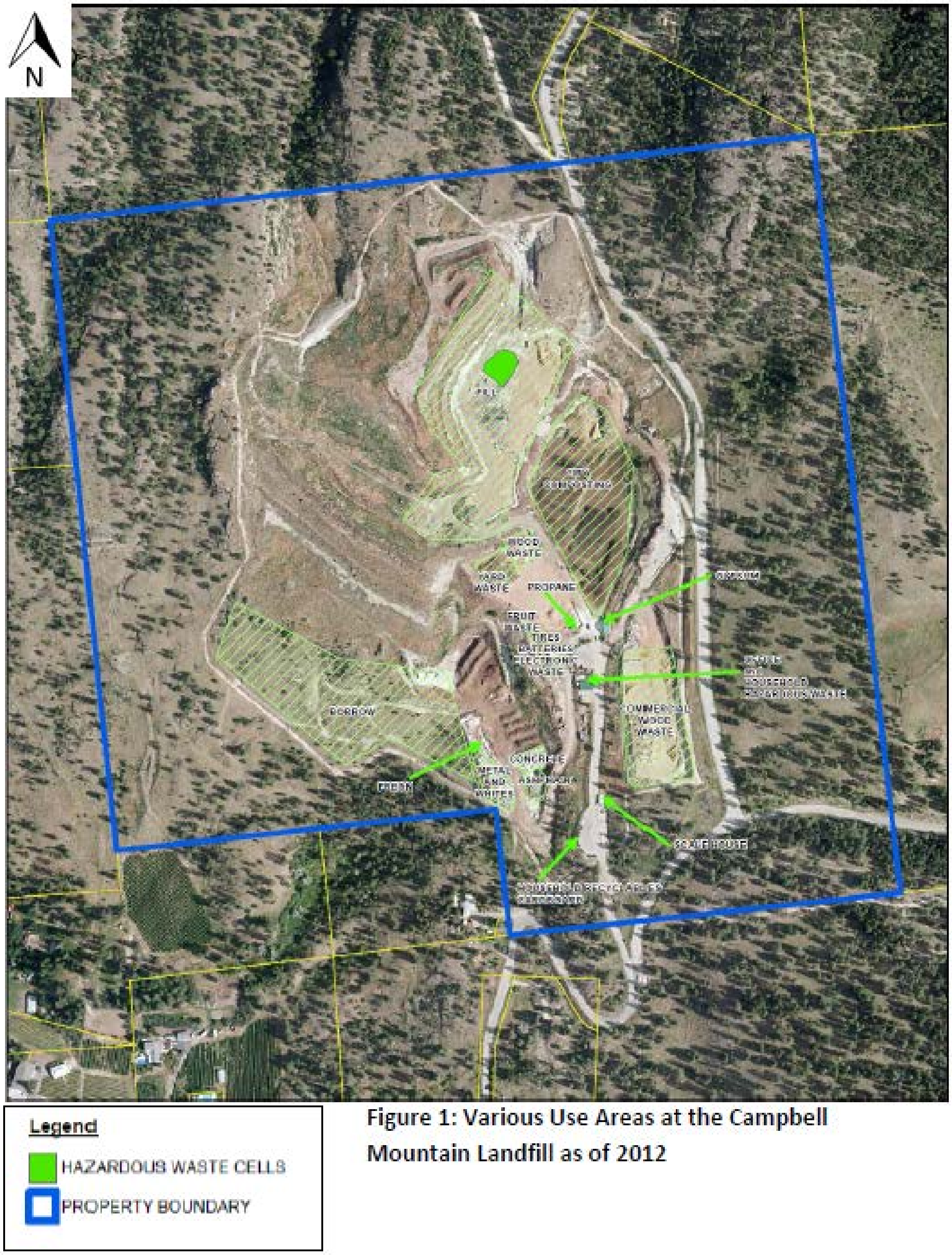


Figure 1: Various Use Areas at the Campbell Mountain Landfill as of 2012

Date issued: January 8, 2015

Carol Danyluk, P.Eng.
for Director, *Environmental Management Act*
Southern Interior Region – Okanagan

Site Plan of License Area for City of Penticton Composting Operation at Campbell Mountain Landfill

Date issued: January 8, 2015

Carol Danyluk, P.Eng.
for Director, *Environmental Management Act*
Southern Interior Region – Okanagan

APPENDIX B
Borehole Logs

Appendix B

Well Logs

PROJECT: Landfill

PROJECT LOCATION: Penticton

PROJECT NUMBER: 932-4175

Sampler Hammer: 63.5 kg., Drop 0.76m.

RECORD OF BOREHOLE - BH 101

BORING DATE: March 2,1994

BORING LOCATION: See Figure 1

SHEET: 1 OF 1

DATUM: Geodetic

BOREHOLE TYPE: 168mm Casing

DEPTH SCALE (m)	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV / DEPTH	SAMPLES: NUMBER	TYPE	BLOWS / 0.15m.	N	OTHER TESTS	PENETRATION RESISTANCE BLOWS/0.3m; WATER CONTENT, PERCENT Wp W Wl	PIEZOMETER OR STANDPIPE INSTALLATION
	Ground Surface		569.60							
0	Compact brown gravelly SAND with occasional cobbles. (FILL)		0.00 568.40	1	CS					
1	Compact brown cobbly sandy GRAVEL.		1.20 567.15	2	CS					Cuttings Bentonite Seal
2	Dense brown SAND and GRAVEL with a trace of silt and occasional cobbles.		2.45 566.40	3	CS					
3	Hard competent BEDROCK.		3.20 563.50	4	CS					Sand and Gravel 50mm PVC Slotted April 19/94
6	END OF BOREHOLE		6.10							

DRILL RIG: Cyclone TH-60

DRILLING CONTRACTOR: Cascade Drill.

DRILLER: Doug/ Rocky

Golder Associates

LOGGED: RT

CHECKED: RT

DATE: March 14/94

RECORD OF BOREHOLE - BH 102

PROJECT: Landfill
PROJECT LOCATION: Penticton
PROJECT NUMBER: 932-4175
Sampler Hammer: 63.5 kg., Drop 0.76m.
BORING DATE: March 2-3,9/94
BORING LOCATION: See Figure 1
DATUM: Geodetic
BOREHOLE TYPE: 168mm Casing

DEPTH (m)	DESCRIPTION	ELEV / DEPTH	NUMBER	TYPE	BLOWS / 0.15m.	N	OTHER TESTS (ppm)	PIEZOMETER OR STANDPIPE INSTALLATION
0	Ground Surface	565.67 / 0.00						
0–3.96	Landfill Refuse Wastes. (FILL)	561.71 / 3.96						Cuttings; Bentonite Seal
3.96–5.18	Compact dark grey cobbly SAND and GRAVEL.	560.49 / 5.18	1	CS			17.7	
5.18–6.40	Compact light grey SAND and GRAVEL with occasional cobbles grading to a gravelly SAND.	559.27 / 6.40	2	CS			11.2	
6.40–13.41	Compact light grey to brown medium to fine SAND with a trace of gravel grading to a light brown medium to fine SAND at depth.	552.26 / 13.41	3	CS			14.5	
			4	CS			4.8	50mm Solid PVC
			5	CS			4.8	
13.41–14.94	Compact light brown fine SAND with a trace of silt.	550.73 / 14.94	6	CS			4.8	
14.94–16.46	Compact light brown medium to fine SAND with a trace to some gravel.	549.21 / 16.46	7	CS			4.8	Cuttings
16.46–19.20	Dense brown to grey gravelly SAND with some silt and occasional cobbles.	546.47 / 19.20	8	CS			8.0	
19.20–			9	CS			4.8	

PENETRATION RESISTANCE BLOWS/0.3m — WATER CONTENT, PERCENT (Wp — W — Wl)

OTHER TESTS summarizes the Organic Vapor Concentrations detected using the OVM #580M monitor.

DRILL RIG: Cyclone TH-60
DRILLING CONTRACTOR: Cascade Drill.
DRILLER: Doug/ Rocky

Golder Associates

LOGGED: RT
CHECKED: RT
DATE: March 21/94

PROJECT: Landfill

PROJECT LOCATION: Penticton

PROJECT NUMBER: 932-4175

Sampler Hammer: 63.5 kg., Drop 0.76m.

RECORD OF BOREHOLE - BH 102

BORING DATE: March 2-3,9/94

BORING LOCATION: See Figure 1

SHEET: 2 OF 2

DATUM: Geodetic

BOREHOLE TYPE: 168mm Casing

DEPTH SCALE (m)	SOIL PROFILE: DESCRIPTION	ELEV / DEPTH	SAMPLES: NUMBER	TYPE	BLOWS / 0.15m.	N	OTHER TESTS	PENETRATION RESISTANCE BLOWS/0.3m; WATER CONTENT, PERCENT Wp —o W— Wl	PIEZOMETER OR STANDPIPE INSTALLATION
20–25.90	Dense grey gravelly fine SAND with a trace to some silt.	539.77 / 25.90	10	CS			1.6		Top of Casing
25.90–27.43	Dense COBBLES and BOULDERS.	538.24 / 27.43						Bottom of casing shoe set at a depth of 27.43m.	Bentonite Seal
27.43–30.18	Soft highly fractured and weathered BEDROCK.	535.49 / 30.18	11	CS			-		Apr. 29/94
			12	CS			-		#2/12 Frac Sand; Hole Cave
	END OF BOREHOLE								

Depth scale: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40

DRILL RIG: Cyclone TH-60

DRILLING CONTRACTOR: Cascade Drill.

DRILLER: Doug/ Rocky

Golder Associates

LOGGED: RT

CHECKED: RT

DATE: March 21/94

PROJECT: Landfill

PROJECT LOCATION: Penticton

PROJECT NUMBER: 932-4175

Sampler Hammer: 63.5 kg., Drop 0.76m.

RECORD OF BOREHOLE - BH 103

BORING DATE: March 8,1994

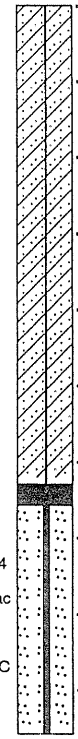
BORING LOCATION: See Figure 1

SHEET: 1 OF 1

DATUM: Geodetic

BOREHOLE TYPE: 168mm Casing

DEPTH SCALE (m)	SOIL PROFILE: DESCRIPTION	ELEV / DEPTH	SAMPLES: NUMBER	TYPE	BLOWS / 0.15m.	N	OTHER TESTS	PENETRATION RESISTANCE BLOWS/0.3m; WATER CONTENT, PERCENT Wp W Wl	PIEZOMETER OR STANDPIPE INSTALLATION
	Ground Surface	529.24							
0	Loose dark brown SAND and SILT with root fibres throughout. (TOPSOIL)	0.00 / 528.79 / 0.45	1	CS					
1–2	Compact brown SAND and GRAVEL with occasional cobbles grading to a sandy GRAVEL with some cobbles.	526.79 / 2.45	2	CS					
3–5	Compact to dense light brown to grey gravelly silty SAND with occasional cobbles.	524.04 / 5.20	3	CS					Cuttings
5	Loose brown SAND with a trace to some gravel.	523.44 / 5.80	4	CS					
6–7	Dense light brown to grey gravelly SAND with some silt and occasional thin sand layers throughout.	521.64 / 7.60	5	CS					Bentonite Seal; Apr. 29/94
8–9	Soft to hard BEDROCK.	519.64 / 9.60	6	CS					#2/12 Frac Sand; 50mm PVC Slotted
10	END OF BOREHOLE								



DRILL RIG: Cyclone TH-60

DRILLING CONTRACTOR: Cascade Drill.

DRILLER: Doug/ Rocky

Golder Associates

LOGGED: RT

CHECKED: RT

DATE: March 14/94

RECORD OF BOREHOLE - BH 104

PROJECT: Landfill
PROJECT LOCATION: Penticton
PROJECT NUMBER: 932-4175
Sampler Hammer: 63.5 kg., Drop 0.76m.

BORING DATE: March 9,1994
BORING LOCATION: See Figure 1

SHEET: 1 OF 1
DATUM: Geodetic
BOREHOLE TYPE: 168mm Casing

DEPTH SCALE (m)	SOIL PROFILE – DESCRIPTION	ELEV / DEPTH	SAMPLES – NUMBER	TYPE	BLOWS / 0.15m.	N	OTHER TESTS	PIEZOMETER OR STANDPIPE INSTALLATION
0	Ground Surface	587.03 / 0.00						
0–5.50	Compact light brown gravelly SAND with occasional cobbles grading to a SAND with a trace of gravel at depth. (Berm Construction FILL)	581.53 / 5.50	1	CS				Cuttings
5.50–5.80	Loose dark brown silty SAND, some gravel and root fibres. (Original Ground Surface)	5.80	2	CS				
5.80–6.40	Compact brown gravelly silty SAND with occasional root fibres.	580.63 / 6.40	3	CS				
6.40–8.50	Compact to dense light brown gravelly SAND with a trace of silt and occasional cobbles.	578.53 / 8.50	4	CS				
8.50–10.20	Dense brown cobbly SAND and GRAVEL with occasional boulders.	576.83 / 10.20	5	CS				Bentonite Seal
10.20–12.20	Soft fractured BEDROCK.	574.83 / 12.20	6	CS				Apr. 29/94 (water level); #2/12 Frac Sand
12.20–13.72	Hard BEDROCK.	573.31 / 13.72	7	CS				50mm PVC Slotted
13.72	END OF BOREHOLE							

PENETRATION RESISTANCE BLOWS/0.3m
WATER CONTENT, PERCENT Wp W Wl

DRILL RIG: Cyclone TH-60
DRILLING CONTRACTOR: Cascade Drill.
DRILLER: Doug/ Rocky

Golder Associates

LOGGED: RT
CHECKED: RT
DATE: March 14/94

RECORD OF BOREHOLE - BH 105

PROJECT: Landfill
PROJECT LOCATION: Penticton
PROJECT NUMBER: 932-4175
Sampler Hammer: 63.5 kg., Drop 0.76m.

BORING DATE: March 10,1994
BORING LOCATION: See Figure 1

SHEET: 1 OF 1
DATUM: Geodetic
BOREHOLE TYPE: 168mm Casing

DEPTH SCALE (m)	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV / DEPTH	SAMPLES: NUMBER	TYPE	BLOWS / 0.15m.	N	OTHER TESTS	PENETRATION RESISTANCE BLOWS/0.3m; WATER CONTENT, PERCENT Wp —O W— Wl	PIEZOMETER OR STANDPIPE INSTALLATION
0	Ground Surface		612.54 / 0.00							Bentonite Seal
1	Compact brown SAND and GRAVEL with some silt, occasional cobbles and boulders.		610.69 / 1.85	1	CS					Cuttings
2–3	Hard competent BEDROCK.		609.19 / 3.35	2	CS					Bentonite Seal
	Compact brown gravelly SAND with a trace of silt.		3.65	3	CS					Sand and Gravel
4–6	Soft weathered and fractured BEDROCK.		606.14 / 6.40	4	CS					#2/12 Frac Sand
7–8	Hard competent BEDROCK.		604.01 / 8.53	5	CS					Apr. 19/94 (water level); 50mm PVC Slotted
	END OF BOREHOLE									

DRILL RIG: Cyclone TH-60
DRILLING CONTRACTOR: Cascade Drill.
DRILLER: Doug/ Rocky

Golder Associates

LOGGED: RT
CHECKED: RT
DATE: March 21/94

PROJECT: RDSO Landfill

RECORD OF BOREHOLE - AH 1

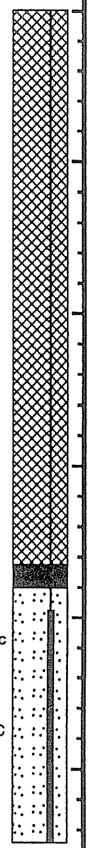
SHEET: 1 OF 1

PROJECT LOCATION: Penticton B.C. BORING DATE: Dec. 8/93 DATUM: Geodetic

PROJECT NUMBER: 932-4175 BORING LOCATION: Penticton B.C. BOREHOLE TYPE: Auger

Sampler Hammer: 63.5 kg., Drop 0.76m.

DEPTH SCALE (m)	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV / DEPTH	SAMPLES: NUMBER	TYPE	BLOWS / 0.15m.	N	OTHER TESTS	PENETRATION RESISTANCE BLOWS/0.3m; WATER CONTENT, PERCENT Wp W Wl	PIEZOMETER OR STANDPIPE INSTALLATION
0	GROUND SURFACE		592.82 / 0.00							
1	Loose brown sandy SILT with a 0.3m diameter boulder encountered at 0.6m. (FILL)									Cuttings Backfill
2	Loose dark brown SILT with some root matter. (FILL)		590.72 / 2.10						Gastech reading of 3% LEL inside augers.	
3	Compact brown SAND and GRAVEL with a trace, piece of glass, paper and wood. (FILL)		590.12 / 2.70	1	DO	16,12,5	17			
4	Loose brown SAND with a trace of gravel.		589.12 / 3.70							Bentonite Seal; #2/12 Frac Sand
	Compact to dense brown SAND and GRAVEL.		588.72 / 4.10							Slotted 50mm PVC
5	Weathered BEDROCK.		587.92 / 4.90							3/17/94
	AUGER REFUSAL WITHIN BEDROCK.		587.32 / 5.50							4/29/94
6										
7										
8										
9										
10										



DRILL RIG: CME 750

DRILLING CONTRACTOR: Thorman Drill.

DRILLER: C.MacKenzie

Golder Associates

LOGGED: RE

CHECKED: RE

DATE: Dec. 8/93

RECORD OF BOREHOLE - AH 2

PROJECT: RDSO Landfill
PROJECT LOCATION: Penticton B.C.
PROJECT NUMBER: 932-4175
Sampler Hammer: 63.5 kg., Drop 0.76m.

BORING DATE: Dec. 8/93
BORING LOCATION: Penticton B.C.

SHEET: 1 OF 1
DATUM: Geodetic
BOREHOLE TYPE: Auger

DEPTH SCALE (m)	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV / DEPTH	SAMPLES: NUMBER	TYPE	BLOWS / 0.15m.	N	OTHER TESTS	PENETRATION RESISTANCE BLOWS/0.3m; WATER CONTENT, PERCENT Wp —o W— Wl	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE		625.94							
0	Loose brown sandy SILT, some cobbles. (TOPSOIL)		0.00							
	Compact brown SAND and GRAVEL with a trace of silt and occasional cobbles.		625.64 / 0.30							
1	Dense silty gravelly SAND. (GLACIAL TILL)		625.04 / 0.90							
2	Refusal of carbide tipped auger. (Inferred Bedrock) (A second augerhole was drilled approximately 10m north of AH2 with refusal encountered at 2.4m)		623.54 / 2.40							
3										
4										
5										
6										
7										
8										
9										
10										

DRILL RIG: CME 750
DRILLING CONTRACTOR: Thorman Drill.
DRILLER: C. MacKenzie

Golder Associates

LOGGED: RE
CHECKED: RE
DATE: Dec. 8/93

RECORD OF BOREHOLE - AH 3

PROJECT: RDSO Landfill
PROJECT LOCATION: Penticton B.C.
PROJECT NUMBER: 932-4175
Sampler Hammer: 63.5 kg., Drop 0.76m.

BORING DATE: Dec. 8/93
BORING LOCATION: Penticton B.C.

SHEET: 1 OF 1
DATUM: Geodetic
BOREHOLE TYPE: Auger

DEPTH SCALE (m)	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV / DEPTH	SAMPLES: NUMBER	TYPE	BLOWS / 0.15m.	N	OTHER TESTS	PENETRATION RESISTANCE BLOWS/0.3m / WATER CONTENT, PERCENT Wp W Wl	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE		612.50							
0	Loose to compact brown SAND and GRAVEL with some silt and some cobbles.		0.00							
1			611.30							
	Refusal of carbide tipped auger. (Inferred Bedrock/Boulder)		1.20							
2										
3										
4										
5										
6										
7										
8										
9										
10										

DRILL RIG: CME 750
DRILLING CONTRACTOR: Thorman Drill.
DRILLER: C. MacKenzie

Golder Associates

LOGGED: RE
CHECKED: RE
DATE: Dec. 8/93

RECORD OF BOREHOLE - AH 4

PROJECT: RDSO Landfill
PROJECT LOCATION: Penticton B.C.
PROJECT NUMBER: 932-4175
Sampler Hammer: 63.5 kg., Drop 0.76m.

BORING DATE: Dec. 9/93
BORING LOCATION: Penticton B.C.

SHEET: 1 OF 1
DATUM: Geodetic
BOREHOLE TYPE: Auger

DEPTH SCALE (m)	SOIL PROFILE: DESCRIPTION	ELEV / DEPTH	SAMPLES: NUMBER	TYPE	BLOWS / 0.15m.	N	OTHER TESTS	PENETRATION RESISTANCE BLOWS/0.3m; WATER CONTENT, PERCENT Wp — W — Wl	PIEZOMETER OR STANDPIPE INSTALLATION
0	GROUND SURFACE	530.81							
	Loose dark brown sandy SILT, some cobbles. (TOPSOIL)	0.00							
	Loose brown gravelly sandy SILT with some cobbles and boulders.	530.51 / 0.30							
1 – 4	Compact brown gravelly SAND with some cobbles and boulders grading to a compact brown cobbly SAND and GRAVEL with a trace of silt and occasional boulders.	529.91 / 0.90	1	DO	20/0.15m			Bouncing on cobble/boulder	Cuttings Backfill; Bentonite Seal; #2/12 Frac Sand
5 – 6	Compact brown brown to grey gravelly SAND.	526.21 / 4.60	2	AS					Slotted 50mm PVC; Feb. 8/94; 4/29/94
	Refusal of carbide tipped auger. (Inferred Bedrock)	524.71 / 6.10							
7 – 10									

DRILL RIG: CME 750
DRILLING CONTRACTOR: Thorman Drill.
DRILLER: C. MacKenzie

Golder Associates

LOGGED: RE
CHECKED: RE
DATE: Dec. 9/93

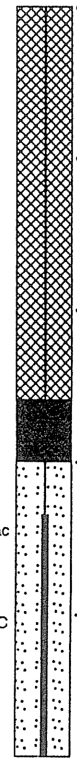
RECORD OF BOREHOLE - AH 5

PROJECT: RDSO Landfill
PROJECT LOCATION: Penticton B.C.
PROJECT NUMBER: 932-4175
Sampler Hammer: 63.5 kg., Drop 0.76m.

BORING DATE: Dec. 9/93
BORING LOCATION: Penticton B.C.

SHEET: 1 OF 1
DATUM: Geodetic
BOREHOLE TYPE: Auger

DEPTH SCALE (m)	SOIL PROFILE: DESCRIPTION	ELEV / DEPTH	SAMPLES: NUMBER	TYPE	BLOWS / 0.15m.	N	OTHER TESTS	PENETRATION RESISTANCE BLOWS/0.3m; WATER CONTENT, PERCENT Wp W Wl	PIEZOMETER OR STANDPIPE INSTALLATION
0	GROUND SURFACE	572.63							
0	Compact grey-brown fine SAND and SILT to a dense fine sandy SILT with a trace of gravel and occasional cobbles.	0.00							Cuttings Backfill
			1	DO	12,14,15	29			
									Bentonite Seal
									#2/12 Frac Sand
									Slotted 50mm PVC
	Dense to very dense brown SAND and GRAVEL with some silt. (GLACIAL TILL)	568.33 / 4.30							
			2	DO	43,50/0.08m				
5	Refusal of carbide tipped auger. (Inferred bedrock)	567.73 / 4.90							Dry Hole



Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

DRILL RIG: CME 750
DRILLING CONTRACTOR: Thorman Drill.
DRILLER: C. MacKenzie

Golder Associates

LOGGED: RE
CHECKED: RE
DATE: Dec. 9/93

RECORD OF BOREHOLE - AH 6

PROJECT: RDSO Landfill
PROJECT LOCATION: Penticton B.C.
PROJECT NUMBER: 932-4175
Sampler Hammer: 63.5 kg., Drop 0.76m.

BORING DATE: Dec. 10/93
BORING LOCATION: Penticton B.C.

SHEET: 1 OF 1
DATUM: Geodetic
BOREHOLE TYPE: Auger

DEPTH SCALE (m)	DESCRIPTION	ELEV / DEPTH	SAMPLE NUMBER	TYPE	BLOWS / 0.15m.	N	OTHER TESTS	PENETRATION RESISTANCE BLOWS/0.3m / WATER CONTENT, PERCENT Wp W Wl	PIEZOMETER OR STANDPIPE INSTALLATION
0	GROUND SURFACE	562.87 / 0.00							
0–1.50	Compact brown cobbly sandy SILT with occasional cobbles.	561.37 / 1.50							
1.50–1.80	Compact brown SAND and GRAVEL with occasional cobbles and boulders.	1.80							
1.80–3.40	Compact brown SAND with a trace to some gravel and occasional cobbles.	559.47 / 3.40	1	DO	6,10,11	21			
3.40–9.30	Compact brown gravelly SAND grading to a SAND and GRAVEL with occasional cobbles.	553.57 / 9.30	2	DO	5,11,17	28			
9.30–11.00	Compact brown medium to fine SAND.	551.87 / 11.00							
11.00–18.70	Dense brown to grey SAND and GRAVEL with a trace of silt.		3	DO	13,20,20	40		Gastech reading of 3% LEL detected on outside of augers. Reading of 1% LEL detected within sample no. 3.	
		544.47							
18.70	Very dense grey fine gravelly SAND with some silt.	544.17 / 18.70	4	DO	26,40,68	108			
	END OF BOREHOLE.								

DRILL RIG: CME 750
DRILLING CONTRACTOR: Thorman Drill.
DRILLER: C. MacKenzie

Golder Associates

LOGGED: RE
CHECKED: RE
DATE: Dec. 10/93

RECORD OF BOREHOLE - AH 7

PROJECT: RDSO Landfill
PROJECT LOCATION: Penticton B.C.
PROJECT NUMBER: 932-4175
Sampler Hammer: 63.5 kg., Drop 0.76m.

BORING DATE: Dec. 10/93
BORING LOCATION: Penticton B.C.

SHEET: 1 OF 1
DATUM: Geodetic
BOREHOLE TYPE: Auger

DEPTH SCALE (m)	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV / DEPTH	SAMPLES: NUMBER	TYPE	BLOWS / 0.15m.	N	OTHER TESTS	PENETRATION RESISTANCE BLOWS/0.3m; WATER CONTENT, PERCENT Wp —W— Wl	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE		569.30							
0	Loose dark brown cobbly SILT.		0.00 / 569.00							
	Compact brown SAND with a trace of silt and occasional cobbles.		0.30 / 568.70							
1–2	Loose brown COBBLES and BOULDERS with occasional sand layers throughout.		0.60 / 567.00							
	Refusal of carbide tipped auger. (Inferred bedrock)		2.30							

DRILL RIG: CME 750
DRILLING CONTRACTOR: Thorman Drill.
DRILLER: C. MacKenzie

Golder Associates

LOGGED: RE
CHECKED: RE
DATE: Dec. 10/93

BOREHOLE LOG

SPERLING HANSEN ASSOCIATES

Borehole:	BH2000-1
Client:	Regional District of Okanagan-Similkameen
Project:	Liquid Waste Facility Assessment
Site:	Campbell Mountain Landfill
Project Num:	PRJ00005
Date:	May 7,2000
Logged By:	Cliff Syroid

Graphic Log

Depth	From (m)	To (m)	Description
	0.0	11.7	Silty SAND few pebbles
5 m			
10 m			
	11.74	13.26	Bedrock
15 m			

Completion Details

From (m)	To (m)	Material
0.0	0.5	Concrete
0.5	1.5	Bentonite Seal
1.5	7.6	Backfill with Native Material
7.6	8.1	Bentonite Seal
8.1	11.8	Sand Pack

From (m)	To (m)	
		Blanks
		Screen 3.05m length

END OF BOREHOLE @ 13.26 m

Borehole Location: Access by gate on switchback before landfill scale, down steep access road beside bear fence.

Notes:
All depth are from ground surface.
Stickup of 51mm PVC = 0.88 m.

BOREHOLE LOG

SPERLING HANSEN ASSOCIATES

Borehole:	**BH2000-2**
Client:	Regional District of Okanagan-Similkameen
Project:	Liquid Waste Facility Assessment
Site:	Campbell Mountain Landfill
Project Num:	PRJ00005
Date:	08-May-00
Logged By:	Cliff Syroid

Graphic Log

From (m)	To (m)	Description
0.0	7.9	Silty SAND few pebbles
7.93	10.26	Bedrock

Completion Details

From (m)	To (m)	Material
0.0	0.5	Concrete
0.5	1.5	Bentonite Seal
1.5	5.8	Backfill with Native Material
5.8	6.4	Bentonite Seal
6.40	10.26	Sand Pack

From (m)	To (m)
	Blanks
	Screen 3.05m length

Depth: 5 m, 10 m

END OF BOREHOLE @ 10.26 m

Borehole Location: Access by gate on switchback before landfill scale, down steep access road beside bear fence. Lower bench area on west side of property.

Notes: All depth are from ground surface. Stickup of 51mm PVC = 0.78 m.

BOREHOLE LOG

SPERLING HANSEN ASSOCIATES

Borehole:	**BH2000-3**	Project Num:	PRJ00005
Client:	Regional District of Okanagan-Similkameen	Date:	April 9, 200
Project:	Liquid Waste Facility Assessment	Logged By:	Cliff Syroid
Site:	Campbell Mountain Landfill		

Depth	From (m)	To (m)	Description (Graphic Log)	Completion From (m)	Completion To (m)	Completion Details	From (m)	To (m)
	0.0	2.4	Silty SAND few pebbles	0.0	1.0	Concrete		
				1.0	1.8	Bentonite Seal		
				1.0	12.3	Backfill with Native Material		
5 m								Blanks
10 m								
	13.0	17.2	Bedrock	12.3	12.8	Bentonite Seal		
				12.80	17.20	Sand Pack		
15 m								Screen

END OF BOREHOLE @ 17.16 m

Borehole Location: East side of access road, inside the fence around the existing septage pit area.

Notes: All depth are from ground surface.
Stickup of 51mm PVC = 0.81 m.

BOREHOLE LOG

SPERLING HANSEN ASSOCIATES

Borehole:	BH2000-4	Project Num:	PRJ00005
Client:	Regional District of Okanagan-Similkameen	Date:	09-May-00
Project:	Liquid Waste Facility Assessment	Logged By:	Cliff Syroid
Site:	Campbell Mountain Landfill		

Graphic Log

From (m)	To (m)	Description
0.0	2.4	Fill and WASTE (no cuttings returned to surface as the end of the drill stem was plugged)
2.4	18.0	Silty SAND few pebbles
18.0	20.3	Bedrock

Completion Details

From (m)	To (m)	Material
0.0	1.0	Concrete
1.0	1.8	Bentonite Seal
1.0	14.1	Backfill with Native Material
14.1	17.2	Bentonite Seal
17.1	20.3	Sand Pack

From (m)	To (m)	
		Blanks
17.2	20.3	Screen

Depth: 5 m, 10 m, 15 m, 20 m

END OF BOREHOLE @ 20.27 m

Borehole Location: West side of main access road, near wood waste area.

Notes: All depth are from ground surface.
Stickup of 51mm PVC = 0.84 m.

PROJECT No.: 04-1480-056

LOCATION: Campbell Mountain Landfill

RECORD OF BOREHOLE: BH04-1

BORING DATE: 30/9/2004

SHEET 1 OF 1

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp —○W— Wl (10 20 30 40)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION BH04-1
0		GROUND SURFACE		545.71							
	CASCADE AIR ROTARY TH-60	Compact brown SAND and GRAVEL with cobbles and boulders, with occasional layers of fine sand with a trace to some silt.		0.00	1	GRAB					Bentonite Seal
					2	GRAB					12mm PVC
					3	GRAB					
5		Compact brown to grey SAND and GRAVEL with some silt and cobbles and boulders.		540.68 / 5.03	4	GRAB					25/11/2004 ▽
					5	GRAB					
6		BEDROCK		539.61 / 6.10	6	GRAB					
					7	GRAB					Slotted PVC
					8	GRAB					Cuttings
10		End of BOREHOLE.		535.35 / 10.36							

DEPTH SCALE 1 : 75

Golder Associates

LOGGED: AR

CHECKED: RT

BOREHOLE 2004_BOREHOLES.GPJ GLDR_CAN.GDT 20/1/05

PROJECT No.: 04-1480-056

RECORD OF BOREHOLE: BH04-2

SHEET 1 OF 1

LOCATION: Campbell Mountain Landfill

BORING DATE: 27/9/2004

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES – NUMBER	TYPE	PIEZOMETER OR STANDPIPE INSTALLATION BH04-2
0		GROUND SURFACE	570.92 / 0.00			Bentonite Seal
0–3.35	CASCADE, AIR ROTARY TH-60	Compact light brown to grey fine SAND and SILT with a trace of gravel.	567.57 / 3.35	1	GRAB	Cuttings
				2	GRAB	25/11/2004 ▽
3.35–4.42		Compact to dense grey SAND and GRAVEL with a trace to some silt and cobbles.	566.50 / 4.42	3	GRAB	
4.42–8.08		BEDROCK	562.84 / 8.08	4	GRAB	2/12 FRAC Sand 50mm PVC
				5	GRAB	
8.08		End of BOREHOLE.				

Other column headings (no data recorded): STRATA PLOT; BLOWS/0.3m; DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●, rem V. ⊕ U - ○; 20 40 60 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT (Wp ⊢—○W—⊣ Wl; 10 20 30 40); ADDITIONAL LAB. TESTING

DEPTH SCALE 1 : 75

Golder Associates

LOGGED: AR

CHECKED: RT

RECORD OF BOREHOLE: BH04-3

PROJECT No.: 04-1480-056

LOCATION: Campbell Mountain Landfill

BORING DATE: 6/10/2004

DATUM: Geodetic

BORING METHOD: CASCADE AIR ROTARY TH-60

DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	PIEZOMETER OR STANDPIPE INSTALLATION BH04-3
GROUND SURFACE	555.87			
Compact brown cobbly SAND and GRAVEL with boulders between 2.1 and 2.4m.	0.00	1	GRAB	Bentonite Seal
		2	GRAB	
Compact brown-grey interlayered fine SAND and SILT with gravelly SAND.	552.21 / 3.66	3	GRAB	
		4	GRAB	
Dense brown cobbly SAND and GRAVEL, trace of silt, occasional layers of sand and silty sand.	550.69 / 5.18	5	GRAB	12mm PVC
		6	GRAB	
Compact to dense light brown gravelly SAND, some silt.	547.95 / 7.92	7	GRAB	
Compact light grey fine SAND and SILT, some gravel.	547.34 / 8.53	8	GRAB	25/11/2004 ∇
BEDROCK	544.90 / 10.97	9	GRAB	Sand Pack Slotted PVC
End of BOREHOLE.	541.32 / 14.55			

Column headings: DEPTH SCALE METRES; BORING METHOD; SOIL PROFILE (DESCRIPTION, STRATA PLOT, ELEV. DEPTH (m)); SAMPLES (NUMBER, TYPE, BLOWS/0.3m); DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa nat V. + Q- ● rem V. ⊕ U- ○ (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (10, 20, 30, 40); ADDITIONAL LAB. TESTING; PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: RT

CHECKED: RT

PROJECT No.: 04-1480-056

RECORD OF BOREHOLE: BH04-4

LOCATION: Campbell Mountain Landfill

BORING DATE: 1/10/2004

DATUM: Geodetic

BORING METHOD: CASCADE AIR ROTARY TH-60

Depth (m)	Description	Elev. / Depth (m)	Sample Number	Type	Piezometer or Standpipe Installation BH04-4
0	GROUND SURFACE	555.62 / 0.00			Bentonite Seal
0.00–3.66	Compact brown sandy gravelly COBBLES and BOULDERS grading to a cobbly SAND and GRAVEL with boulders.	551.96 / 3.66	1, 2	GRAB	
3.66–5.18	Compact light grey gravelly SAND with some silt and cobbles and boulders.	550.44 / 5.18	3	GRAB	Cuttings
5.18–10.06	Compact light brown fine SAND with some silt and a trace of gravel.	545.56 / 10.06	4, 5, 6	GRAB	50mm PVC; Casing length between 6.1 and 13.7m; Bentonite Seal
10.06–11.28	Compact brown gravelly fine SAND.	544.34 / 11.28	7	GRAB	
11.28–12.50	Compact brown SAND and GRAVEL, trace of silt, with cobbles and boulders.	543.12 / 12.50	8	GRAB	
12.50–15	Dense brown silty SAND and GRAVEL with cobbles and boulders.		9	GRAB	

Column headings: DEPTH SCALE METRES; BORING METHOD; SOIL PROFILE (DESCRIPTION, STRATA PLOT, ELEV. DEPTH (m)); SAMPLES (NUMBER, TYPE, BLOWS/0.3m); DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (10 20 30 40); ADDITIONAL LAB. TESTING; PIEZOMETER OR STANDPIPE INSTALLATION

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DEPTH SCALE
1 : 75

Golder Associates

LOGGED: AR/RT
CHECKED: RT

RECORD OF BOREHOLE: BH04-4

PROJECT No.: 04-1480-056

LOCATION: Campbell Mountain Landfill

BORING DATE: 1/10/2004

SHEET 2 OF 2

DATUM: Geodetic

BORING METHOD: CASCADE AIR ROTARY TH-60

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	PIEZOMETER OR STANDPIPE INSTALLATION BH04-4
15	Dense brown silty SAND and GRAVEL with cobbles and boulders *(continued)*	539.77 / 15.85	10	GRAB	
16	Dense brown to grey silty SAND and GRAVEL with cobbles and boulders.	538.25 / 17.37	11	GRAB	
17–20	Dense grey silty gravelly SAND with cobbles.	535.50 / 20.12	12	GRAB	25/11/2004 ∇
			13	GRAB	15/10/2004 ∇
20	Dense brown to grey SAND and GRAVEL with a trace of silt and cobbles.	534.28 / 21.34	14	GRAB	Slough
21–24	Dense grey gravelly silty SAND grading to a gravelly SAND and SILT with cobbles.	530.93 / 24.69	15	GRAB	Bentonite Seal
			16	GRAB	Casing and Shoe between 23.8 and 24.7m; Slough
25	BEDROCK	529.41 / 26.21	17	GRAB	
26	End of BOREHOLE.				

Column headings: SOIL PROFILE (DESCRIPTION, STRATA PLOT, ELEV. DEPTH (m)); SAMPLES (NUMBER, TYPE, BLOWS/0.3m); DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp —○W— Wl (10, 20, 30, 40); ADDITIONAL LAB. TESTING.

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: AR/RT

CHECKED: RT

PROJECT No.: 04-1480-056

RECORD OF BOREHOLE: BH04-5

LOCATION: Campbell Mountain Landfill

BORING DATE: 28/9/2004

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q- ● rem V. ⊕ U- ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp —○W— Wl (10 20 30 40)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION BH04-5
0		GROUND SURFACE		579.06							
0	CASCADE AIR ROTARY TH-60	LANFILL REFUSE		0.00							Bentonite Seal; Cuttings
6.71		Compact grey SAND and GRAVEL with a trace to some silt.		572.35 / 6.71	1	GRAB					Bentonite Seal
7.62		Compact to loose grey to brown sandy GRAVEL with a trace of silt with cobbles and boulders.		571.44 / 7.62	2	GRAB					Cuttings
					3	GRAB					
10.97		Dense grey SAND and GRAVEL with cobbles and boulders, trace to some silt.		568.09 / 10.97	4	GRAB					
11.89		Compact brown fine SAND with a trace of gravel.		567.17 / 11.89	5	GRAB					
13.11		Dense grey gravelly SAND with a trace of silt.		565.95 / 13.11	6	GRAB					Bentonite Seal; Slotted 50mm PVC
15				564.12							

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DEPTH SCALE
1 : 75

Golder Associates

LOGGED: AR
CHECKED: RT

PROJECT No.: 04-1480-056

RECORD OF BOREHOLE: BH04-5

LOCATION: Campbell Mountain Landfill

BORING DATE: 28/9/2004

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢ ⊖W ⊣ Wl (10 20 30 40)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION BH04-5
15	CASCADE AIR ROTARY TH-60	BEDROCK *(continued)*		14.94	7	GRAB					Slotted 50mm PVC
16					8	GRAB					
17					9	GRAB					Bentonite Seal
18		End of BOREHOLE.		561.08 17.98							Dry (Nov. 25/04)
19											
20											
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											

DEPTH SCALE

1 : 75

Golder Associates

LOGGED: AR

CHECKED: RT

RECORD OF BOREHOLE: BH04-6

PROJECT No.: 04-1480-056
LOCATION: Campbell Mountain Landfill
BORING DATE: 6/10/2004

DATUM: Geodetic

BORING METHOD: CASCADE AIR ROTARY TH-60

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	PIEZOMETER OR STANDPIPE INSTALLATION BH04-6
0	GROUND SURFACE	573.18			
	SAND and GRAVEL Drilling PAD (FILL)	0.00			Bentonite Seal
1	LANDFILL REFUSE	572.57 0.61			Cuttings
7					Slough
8	Compact light brown gravelly SAND.	564.95 8.23	1	GRAB	
9	Compact light brown SAND and GRAVEL grading to a sandy GRAVEL with cobbles, occasional sand layers and boulders.	564.04 9.14	2	GRAB	
11			3	GRAB	Casing and Shoe Cutoff (12.6 and 13.1m
12					Bentonite Seal
13	BEDROCK	560.07 13.11	4	GRAB	2/12 Frac Sand
15					

Column headings (no data recorded): DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa, nat V. + Q - ● rem V. ⊕ U - ○ (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp —○W— Wl (10, 20, 30, 40); BLOWS/0.3m; ADDITIONAL LAB. TESTING.

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 75

Golder Associates

LOGGED: RT
CHECKED: RT

PROJECT No.: 04-1480-056

RECORD OF BOREHOLE: BH04-6

LOCATION: Campbell Mountain Landfill

BORING DATE: 6/10/2004

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (10 20 30 40)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION BH04-6
15–19.20	CASCADE / AIR ROTARY TH-60	BEDROCK *(continued)*			4	GRAB					2/12 Frac Sand
					5	GRAB					50mm Slotted PVC
				553.98 / 19.20							
		End of BOREHOLE.									Dry (Nov. 25/04)

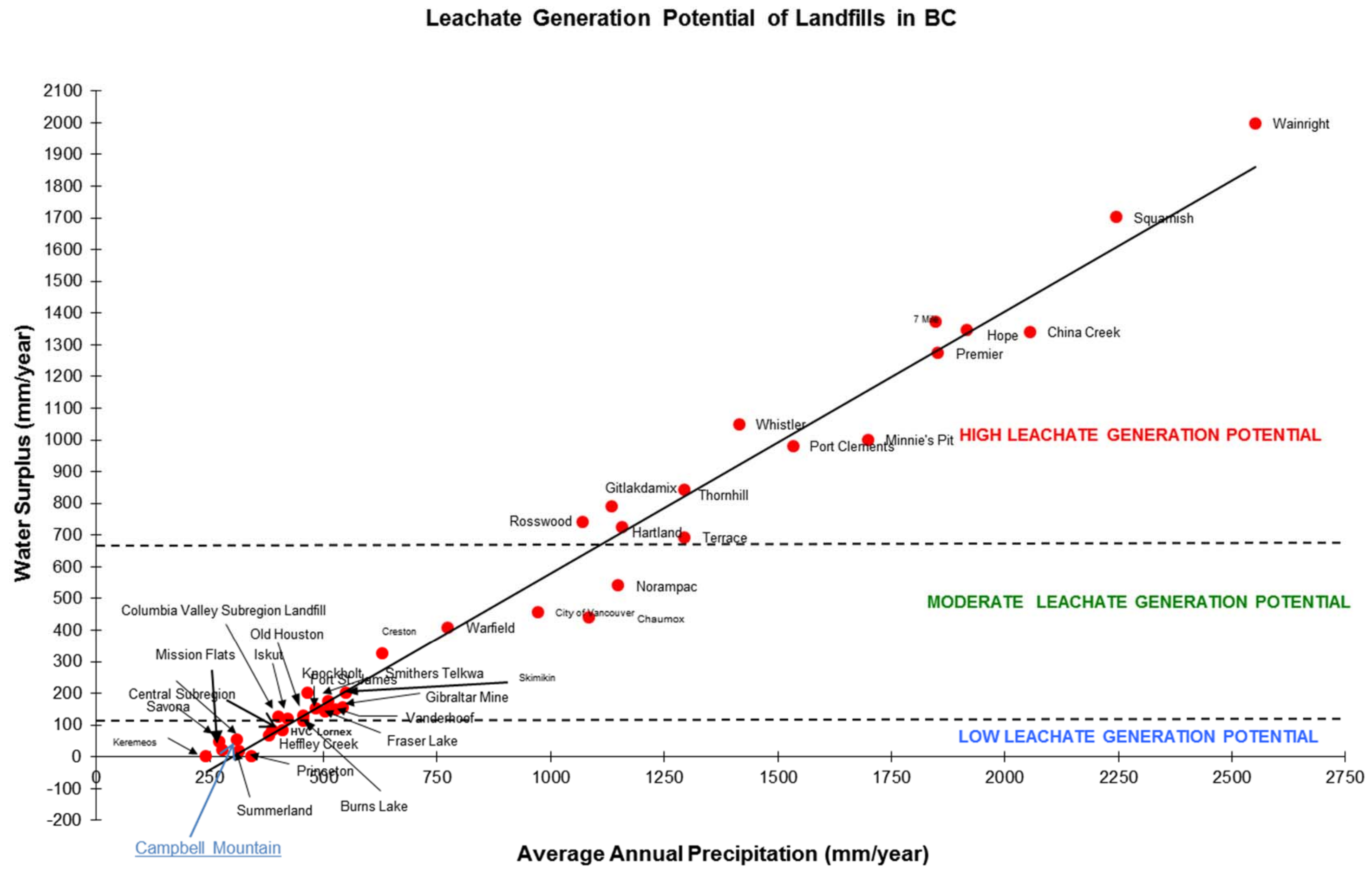
DEPTH SCALE 1 : 75

Golder Associates

LOGGED: RT

CHECKED: RT

APPENDIX C
Leachate Generation Potential



SPERLING HANSEN ASSOCIATES	Regional District of Okanagan-Similkameen	PROJECT: Campbell Mountain Landfill Design, Operations and Closure Plan	TITLE: **Leachate Generation Potential Of CMLF**	SCALE: N/A; DATE: 2016/05/22 (yyyy/mm/dd); PROJECT NO: 15061; DESIGNED: IB; DRAWN: IB; CHECKED: TS; DRAWING NO: **FIGURE C-1**

APPENDIX C-1

POTENTIAL LEACHATE GENERATION POTENTIAL CALCULATION

Campbell Mountain Landfill

$$MC_{dw} = \frac{M_w}{M_{rdw}}$$

$$= \frac{M_w}{M_{rww} - M_w}$$

$$M_w = M_{rww}\left(\frac{MC}{MC + 1}\right)$$

Where:

MC_{dw} = Moisture content on a dry weight basis

M_w = Mass of water

M_{rdw} = Mass of refuse on a dry weight basis

M_{rww} = Mass of refuse on a wet weight basis

Example: Water Required to Reach Field Capacity

Incoming Waste (M_{rww}) =	30,000	tonnes/year wet weight
Incoming Moisture Content (MC_{dw}) =	30%	dry weight basis
Field Capacity Moisture Content (MC_{dw}) =	70%	dry weight basis
Incoming Mass of Water (M_w) =	6,923	tonnes/year
Mass of Water at Field Capacity (M_w) =	12,353	tonnes/year
Water Adsorbed =	5,430	tonnes/year
=	5,430	m^3/year

Scenario	Incoming Waste	Incoming Water	Field Capacity	Water Adsorbed	Precipitation			Potential Leachate Generation		
					Footprint	Surplus	Volume			
	(tonnes/year	(m^3/year)	(m^3/year)	(m^3/year)	(ha)	(mm)	(m^3/year)	(m^3/year)	(L/S)	(m^3/m^2/year)
Current Conditions	30,000	6,923	12,353	5,430	22	149	32,739	27,310	0.87	0.12

Note: Precipitation Surplus includes Run-off

APPENDIX B-2

POTENTIAL LEACHATE GENERATION POTENTIAL CALCULATION

Whitecourt Landfill

$$MC_{dw} = \frac{M_w}{M_{rdw}}$$

$$= \frac{M_w}{M_{rww} - M_w}$$

$$M_w = M_{rww}\left(\frac{MC}{MC + 1}\right)$$

Example: Water Required to Reach Field Capacity

Incoming Waste (M_{rww}) =	30,000	tonnes/year wet weight
Incoming Moisture Content (MC_{dw}) =	30%	dry weight basis
Field Capacity Moisture Content (MC_{dw}) =	70%	dry weight basis
Incoming Mass of Water (M_w) =	6,923	tonnes/year
Mass of Water at Field Capacity (M_w) =	12,353	tonnes/year
Water Adsorbed =	5,430	tonnes/year
=	5,430	m^3/year

Where:

MC_{dw} = Moisture content on a dry weight basis

M_w = Mass of water

M_{rdw} = Mass of refuse on a dry weight basis

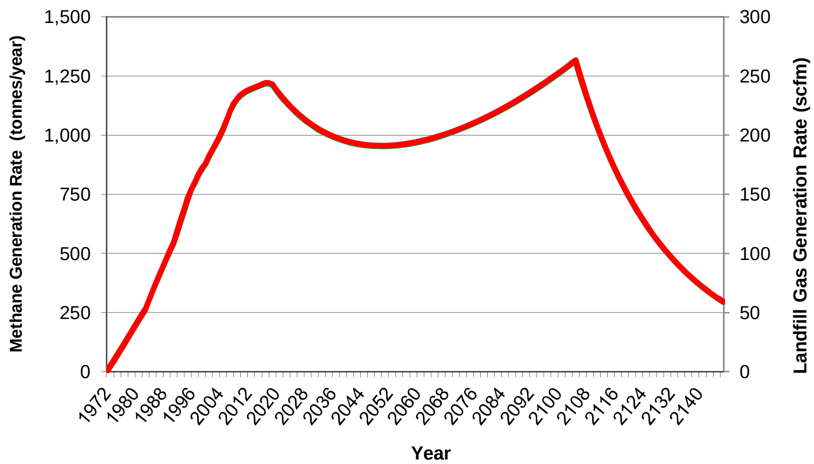
M_{rww} = Mass of refuse on a wet weight basis

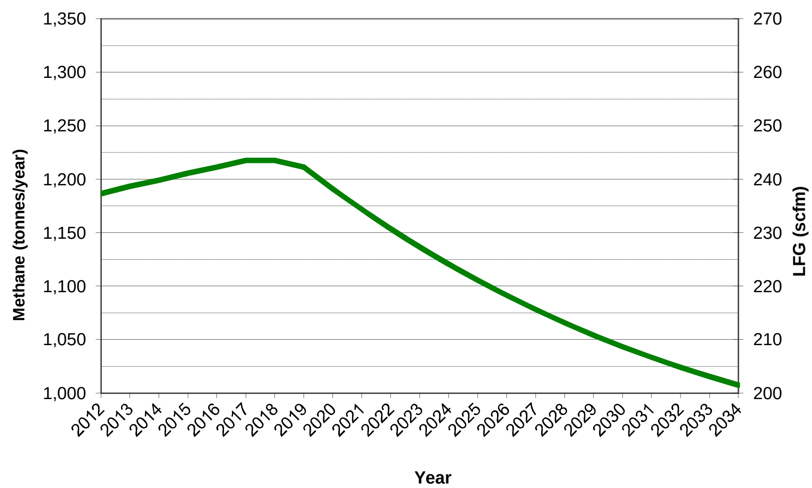
Scenario	Incoming Waste	Incoming Water	Field Capacity	Water Adsorbed	Precipitation			Potential Leachate Generation		
					Footprint	Surplus	Volume			
	(tonnes/year	(m^3/year)	(m^3/year)	(m^3/year)	(ha)	(mm)	(m^3/year)	(m^3/year)	L/S	(m^3/m^2/year)
Current Conditions	30,000	6,923	12,353	5,430	22	28	6,082	652	0.02	0.00

APPENDIX D
LFG Calculations

Table D.1- Updated LFG Generation Modeling Results (Organic Diversion Increased to 73% by 2019)

Year	CH4	CH4	CH4	CO2-e	LFG
	Mg (tonne)	m3	scfm	Mg (tone)	scfm
1972	0	0	0	0	0
1973	24	35167	2	495	5
1974	47	70225	5	988	9
1975	71	105233	7	1481	14
1976	94	140251	9	1973	19
1977	118	175399	12	2468	24
1978	142	211473	14	2975	28
1979	167	248808	17	3501	33
1980	192	286011	19	4024	38
1981	216	323092	22	4546	43
1982	240	358713	24	5047	48
1983	263	392938	26	5529	53
1984	302	450084	30	6333	60
1985	338	504970	34	7105	68
1986	374	557695	37	7847	75
1987	409	610375	41	8588	82
1988	443	660997	44	9300	89
1989	477	711672	48	10013	96
1990	512	763725	51	10746	103
1991	543	810126	54	11398	109
1992	589	879737	59	12378	118
1993	637	950693	64	13376	128
1994	685	1021707	69	14375	137
1995	734	1094787	74	15404	147
1996	771	1150512	77	16188	155
1997	799	1193054	80	16786	160
1998	832	1242176	83	17477	167
1999	857	1279095	86	17997	172
2000	878	1310399	88	18437	176
2001	910	1358349	91	19112	183
2002	937	1397821	94	19667	188
2003	964	1439205	97	20250	193
2004	990	1478320	99	20800	199
2005	1024	1528057	103	21500	205
2006	1063	1586204	107	22318	213
2007	1100	1642084	110	23104	221
2008	1131	1687372	113	23741	227
2009	1152	1719308	116	24191	231
2010	1167	1741743	117	24506	234
2011	1178	1758139	118	24737	236
2012	1187	1771027	119	24918	238
2013	1193	1781186	120	25061	239
2014	1199	1789615	120	25180	**240**
2015	1206	1799380	121	25317	242
2016	1211	1808102	121	25440	243
2017	1218	1817304	122	25569	244
2018	1217	1817105	122	25567	244
2019	1211	1808097	121	25440	243
2020	1191	1777649	119	25012	239
2021	1172	1748939	118	24608	235
2022	1154	1721889	116	24227	231
2023	1137	1696427	114	23869	228
2024	1121	1672483	112	23532	225
2025	1105	1649993	111	23215	222
2026	1091	1628894	109	22919	219
2027	1078	1609127	108	22640	216
2028	1066	1590636	107	22380	214
2029	1054	1573366	106	22137	211
2030	1043	1557269	105	21911	209
2031	1033	1542294	104	21700	207
2032	1024	1528397	103	21505	205
2033	1015	1515533	102	21324	**204**
2034	1007	1503661	101	21157	202
2035	1000	1492742	100	21003	201
2036	993	1482739	100	20862	199
2037	987	1473614	99	20734	198
2038	982	1465336	98	20617	197
2039	977	1457870	98	20512	196





Year	CH4	CH4	CH4	CO2-e	LFG
	Mg (tonne)	m3	scfm	Mg (tone)	scfm
2040	972	1451188	98	20418	195
2041	968	1445259	97	20335	194
2042	965	1440055	97	20262	194
2043	962	1435552	96	20198	193
2044	959	1431722	96	20144	192
2045	957	1428543	96	20100	192
2046	955	1425992	96	20064	192
2047	954	1424047	96	20036	191
2048	953	1422688	96	20017	191
2049	953	1421895	96	20006	191
2050	953	1421650	96	20003	191
2051	953	1421935	96	20007	191
2052	953	1422734	96	20018	191
2053	954	1424030	96	20036	191
2054	955	1425808	96	20061	192
2055	957	1428054	96	20093	192
2056	959	1430754	96	20131	192
2057	961	1433895	96	20175	193
2058	963	1437466	97	20225	193
2059	966	1441453	97	20281	194
2060	969	1445847	97	20343	**194**
2061	972	1450636	97	20410	195
2062	975	1455810	98	20483	196
2063	979	1461360	98	20561	196
2064	983	1467277	99	20645	197
2065	987	1473552	99	20733	198
2066	992	1480178	99	20826	199
2067	996	1487145	100	20924	200
2068	1001	1494448	100	21027	201
2069	1006	1502079	101	21134	202
2070	1012	1510032	101	21246	203
2071	1017	1518300	102	21362	204
2072	1023	1526878	103	21483	205
2073	1029	1535760	103	21608	206
2074	1035	1544941	104	21737	208
2075	1041	1554416	104	21871	209
2076	1048	1564180	105	22008	210
2077	1055	1574229	106	22149	212
2078	1062	1584558	106	22295	213
2079	1069	1595165	107	22444	214
2080	1076	1606045	108	22597	216
2081	1084	1617195	109	22754	217
2082	1091	1628611	109	22915	219
2083	1099	1640292	110	23079	220
2084	1107	1652233	111	23247	222
2085	1115	1664433	112	23419	224
2086	1124	1676888	113	23594	225
2087	1132	1689597	114	23773	227
2088	1141	1702558	114	23955	229
2089	1150	1715769	115	24141	231
2090	1159	1729228	116	24330	232
2091	1168	1742933	117	24523	234
2092	1177	1756883	118	24719	236
2093	1187	1771077	119	24919	238
2094	1196	1785514	120	25122	240
2095	1206	1800192	121	25329	242
2096	1216	1815110	122	25539	244
2097	1226	1830269	123	25752	246
2098	1237	1845666	124	25969	248
2099	1247	1861302	125	26189	250
2100	1258	1877176	126	26412	252

APPENDIX E
Stormwater Retention Pond and Ditches

Campbell Mountain Landfill
Rational Method

n Flows - Rational Method (BC Agricultural Drainage Manual - 1

$Q = 0.0028 C i A$
Q = peak runoff rate (m^3/s)
i = rainfall intensity (mm/hr) for design period and for time of concent
A = watershed area (m^2)

$T_c = 0.0195 L^{0.77} S^{-0.385}$
T_c = time of concentration (min)
L = maximum length of flow (m)
S = drainage area grade (m/m)

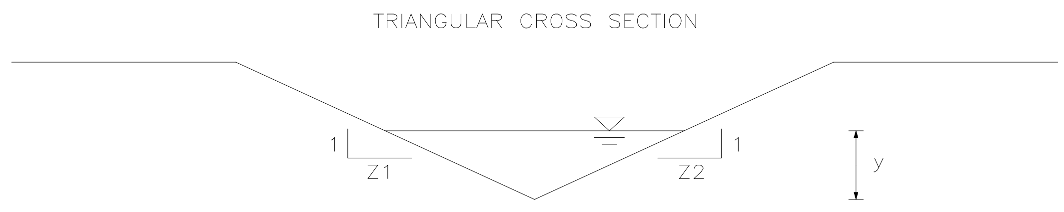
$$C = \frac{Sum(C_1A_1 + C_2A_2 \ldots)}{Sum(A_1 + A_2 \ldots)}$$

Typical Catchment Area

	Typical Area
Material	Top Soil
Vegetation	Pasture
Topography	Rolling

	South Toe Ditch	
Catchment Area (A, m^2) =	263,000	
Catchment Area (A, ha) =	26.30	
Runoff Coefficient - C =	0.7	
Time of concentration - T_c		
Typical slope (S, m/m) =	0.330	
Length of flow (L, m) =	1000	
T_c (min) =	6.101	
T_c (hrs) =	**0.102**	
If T_c <5mins, use	**5mins**	
Peak Storm Intensity for in 100 Yr Rainfall (i, mm/hr) =	**160**	
Peak Flow (Q, m^3/s) =	**8.25**	
Peak Flow (Q, L/s) =	**8248**	
Volume for 5 minute Flow (Q, L/s) =	**2474**	
'eak Storm Intensity for 1 in 100 Yr Rainfall (i, mm/hr) =	**2**	(for 24h hour event)
Peak Flow (Q, m^3/s) =	**0.10**	
Peak Flow (Q, L/s) =	**103**	
For 24 hr Volume (m3)=	**8907**	
Peak Storm Intensity for 1 in 50 Yr Rainfall (i, mm/hr) =	**1.8**	(for 24h hour event)
Peak Flow (Q, m^3/s) =	**0.09**	
Peak Flow (Q, L/s) =	**93**	
For 24 hr Volume (m3)=	**8017**	
Peak Storm Intensity for 1 in 25 Yr Rainfall (i, mm/hr) =	**1.6**	(for 24h hour event)
Peak Flow (Q, m^3/s) =	**0.08**	
Peak Flow (Q, L/s) =	**82**	
For 24 hr Volume (m3)=	**7126**	

Campbell Mountain Landfill
Toe Ditch
Rational Method



Z_1 = 2.5
Z_2 = 2.5

Flow Depth (y) = 0.75 m
Bottom Width (b) = 0 m (Trapezoid Sections Only)

Area (A) = 1.4063 m^2
Wetted Perimeter (P) = 4.0389 m
Hydraulic Radius (R) = 0.3482 m
Longitudinal Ditch Slope (S) = 0.250 m/m

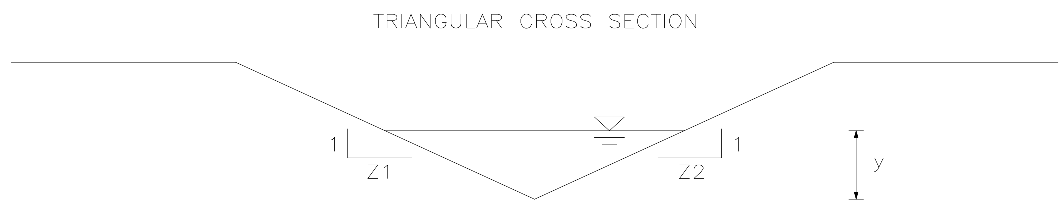
Manning's n = 0.02 Rip rap Lined

$$Q = \frac{AR^{2/3}S^{1/2}}{n}$$

$Q_{required}$ = 8.25 m^3/s
$Q_{available}$ = **17.40** m^3/s
17400 L/s

Velocity = **23.688** m/s 77.72 ft/s

Campbell Mountain Landfill
Toe Ditch
Rational Method



Z_1 =	2.5		
Z_2 =	2.5		
Flow Depth (y) =	0.75	m	
Bottom Width (b) =	0	m	(Trapezoid Sections Only)
Area (A) =	1.4063	m^2	
Wetted Perimeter (P) =	4.0389	m	
Hydraulic Radius (R) =	0.3482	m	
Longitudinal Ditch Slope (S) =	0.250	m/m	
Manning's n =	0.02	Rip rap Lined	

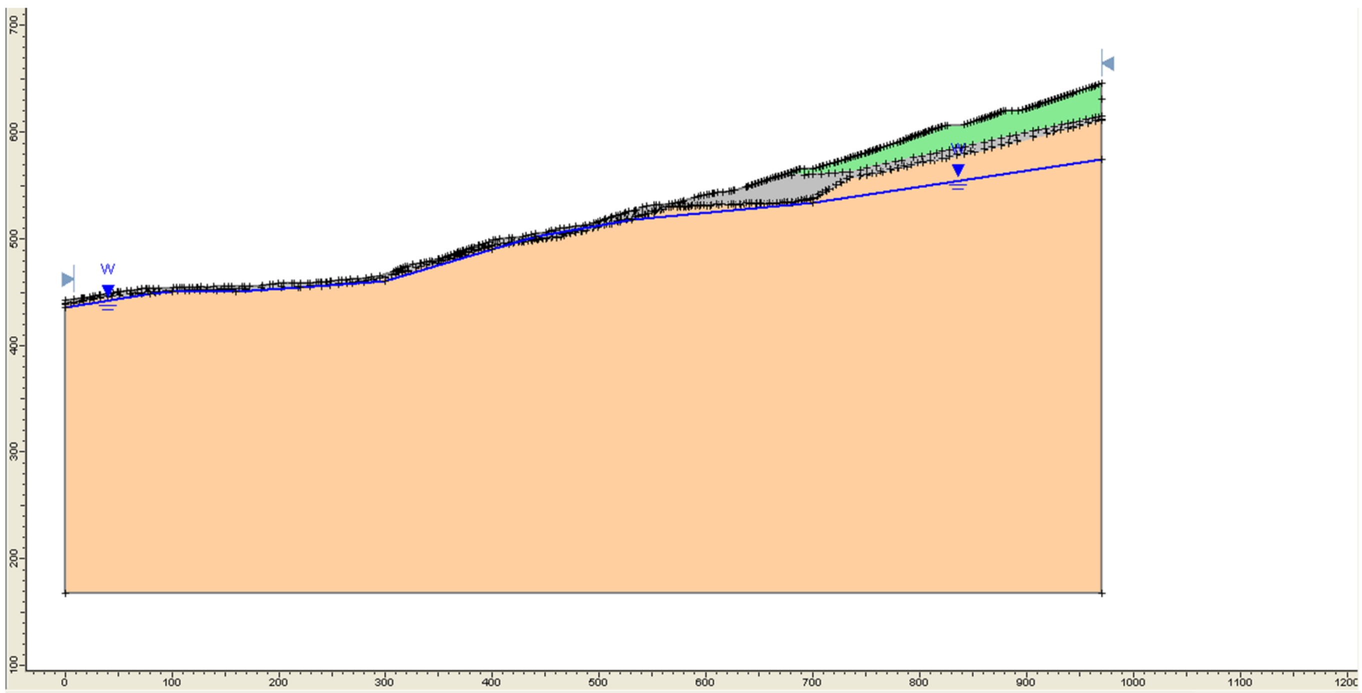
$$Q = \frac{AR^{2/3}S^{1/2}}{n}$$

$Q_{required}$ =	8.25	m^3/s	
$Q_{available}$ =	**17.40**	m^3/s	
	17400	L/s	
Velocity =	**23.688**	m/s	77.72 ft/s

APPENDIX F
Slope Stability Sections

Layers	Unit Weight Saturated (KN/m³)	Unit Weight Unsaturated (KN/m³)	Cohession (KN/m²)	Friction angle (degree)
Fractured Bed Rock	20	20	0	45
Sand	16	18	0	32
Waste	10	12	10	25

Waste
Sand
Fractured Bed Rock



Sperling Hansen Associates

Regional District of Okanagan-Similkameen

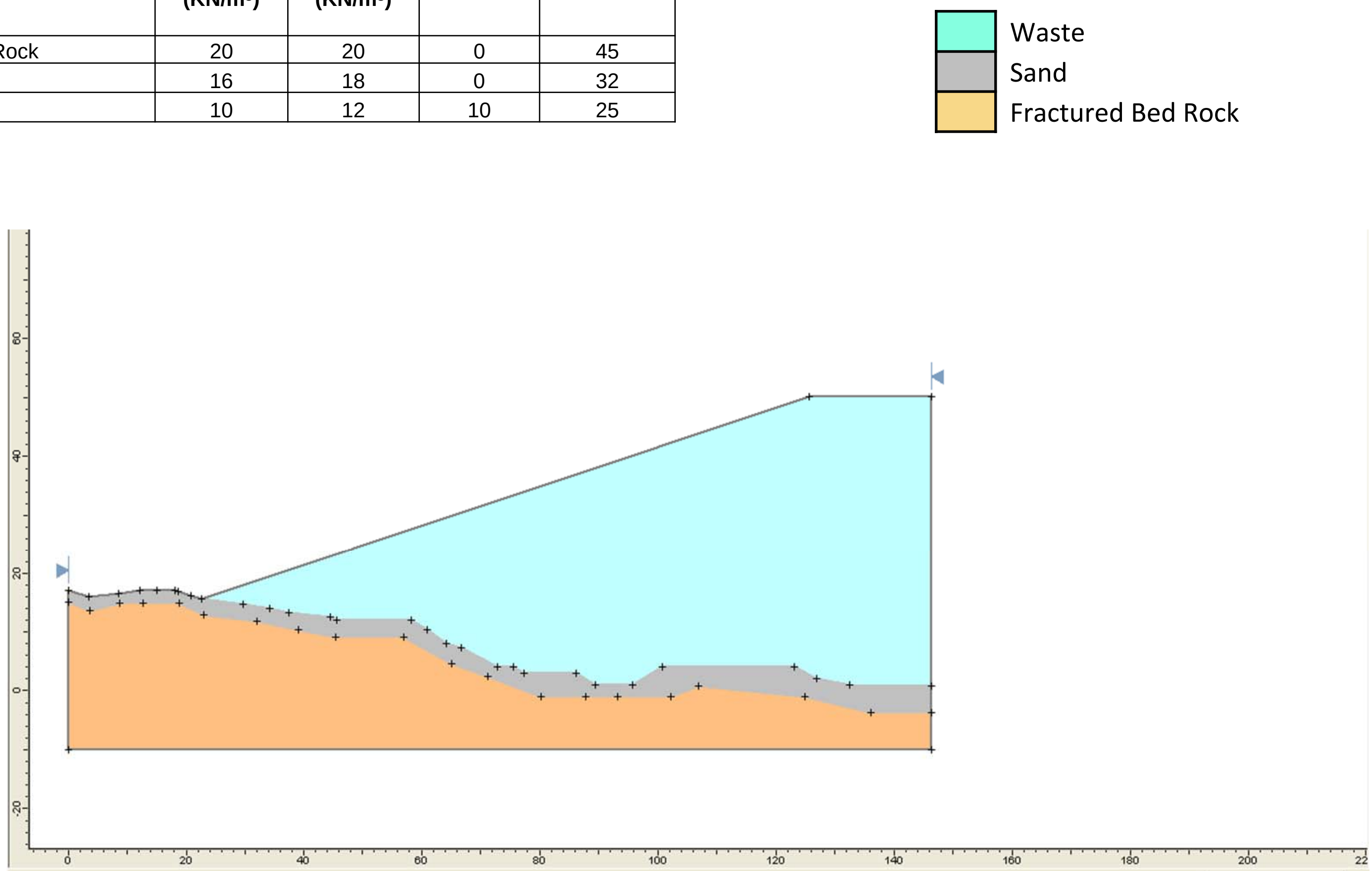
PROJECT:
Campbell Mountain Landfill Design, Operations and Closure Plan

TITLE:
SECTION 1-1' PROPOSED

SCALE:	DATE:	PROJECT NO:
N/A	2016/05/22 yyyy/mm/dd	**15061**

DESIGNED	IB	DRAWING NO:
DRAWN	IB	**FIGURE F-1**
CHECKED	TS	

Layers	Unit Weight		Cohession	Friction angle
	Saturated (KN/m³)	Unsaturated (KN/m³)	(KN/m²)	(degree)
Fractured Bed Rock	20	20	0	45
Sand	16	18	0	32
Waste	10	12	10	25



Sperling Hansen Associates

Regional District of Okanagan-Similkameen

PROJECT: Campbell Mountain Landfill Design, Operations and Closure Plan

TITLE: **SECTION 2-2' PROPOSED**

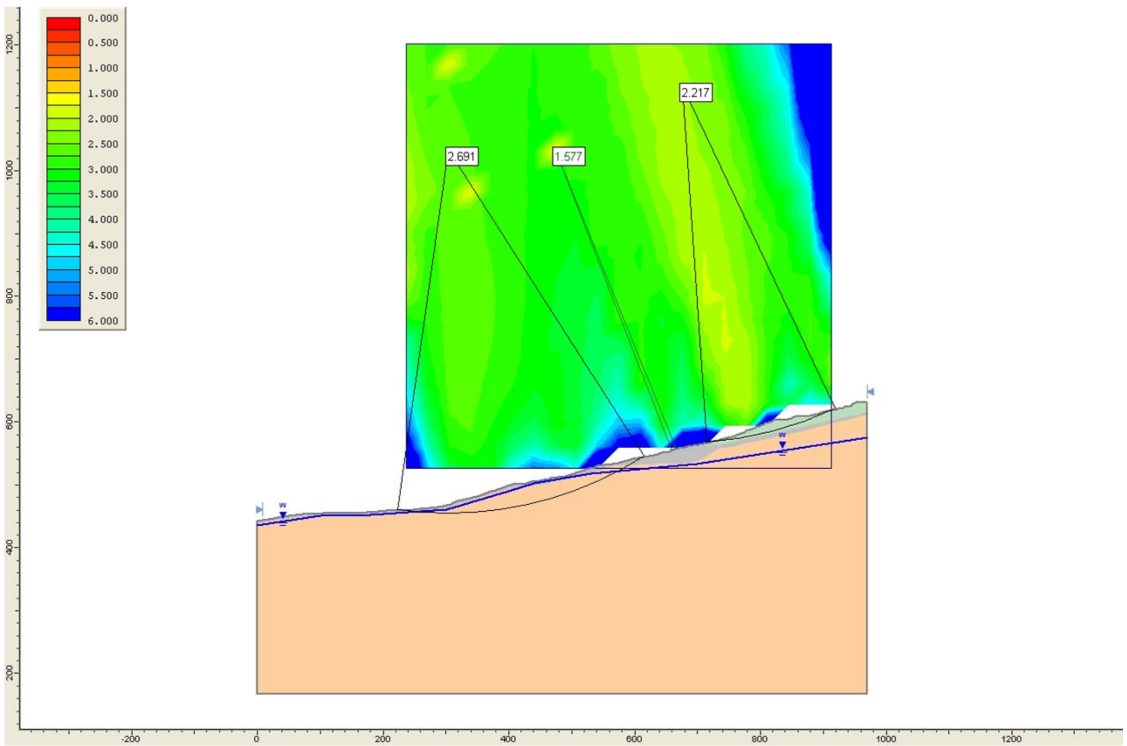
SCALE:	DATE:	PROJECT NO:
N/A	2016/05/22 (yyyy/mm/dd)	**15061**

DESIGNED	IB	DRAWING NO:
DRAWN	IB	**FIGURE F-2**
CHECKED	TS	

APPENDIX G
Slope Stability Results

Layers	Unit Weight Saturated (KN/m³)	Unit Weight Unsaturated (KN/m³)	Cohession (KN/m²)	Friction angle (degree)
Fractured Bed Rock	20	20	0	45
Sand	16	18	0	32
Waste	10	12	10	25

Waste
Sand
Fractured Bed Rock



Sperling Hansen Associates

Regional District of Okanagan-Similkameen

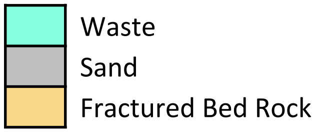
PROJECT:
Campbell Mountain Landfill Design, Operations and Closure Plan

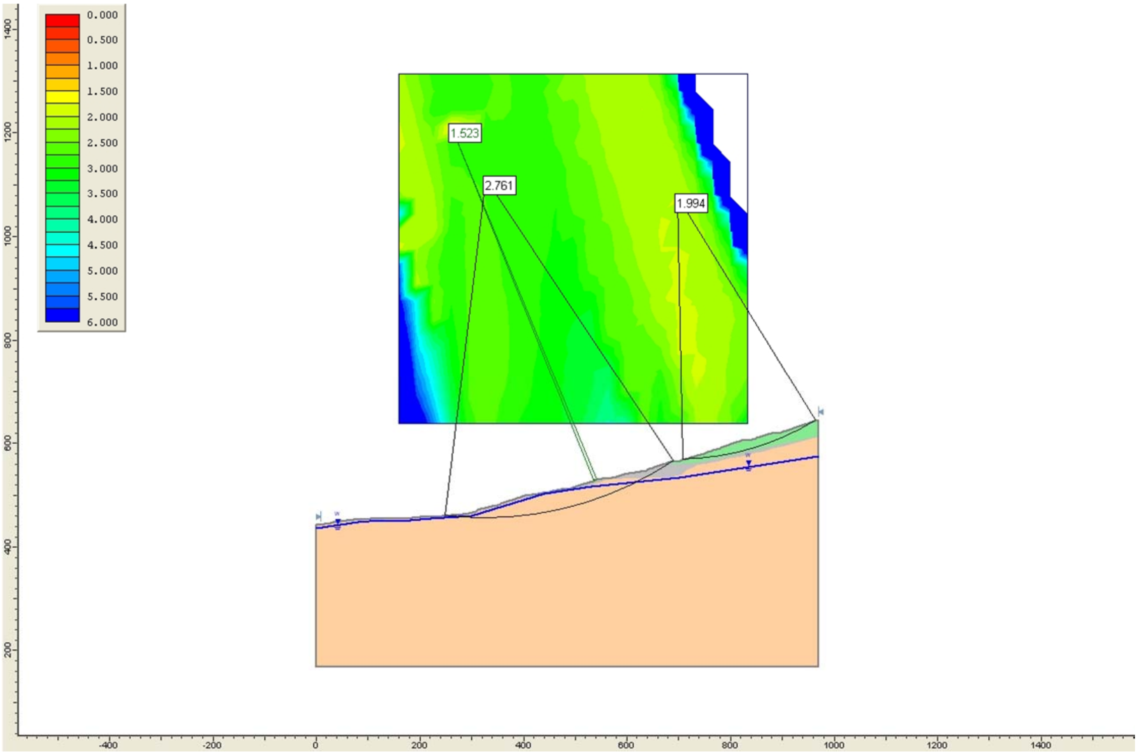
TITLE:
SECTION 1-1' EXISTING STATIC

SCALE:	DATE:	PROJECT NO:
N/A	2016/05/22 (yyyy/mm/dd)	15061

DESIGNED	IB	DRAWING NO:
DRAWN	IB	**FIGURE G-1**
CHECKED	TS	

Layers	Unit Weight Saturated (KN/m³)	Unit Weight Unsaturated (KN/m³)	Cohession (KN/m²)	Friction angle (degree)
Fractured Bed Rock	20	20	0	45
Sand	16	18	0	32
Waste	10	12	10	25
Clay	15	16	10	20
Topsoil/Biocover	14	15	2	30
Glass	18	18	0	35





Sperling Hansen Associates

Regional District of Okanagan-Similkameen

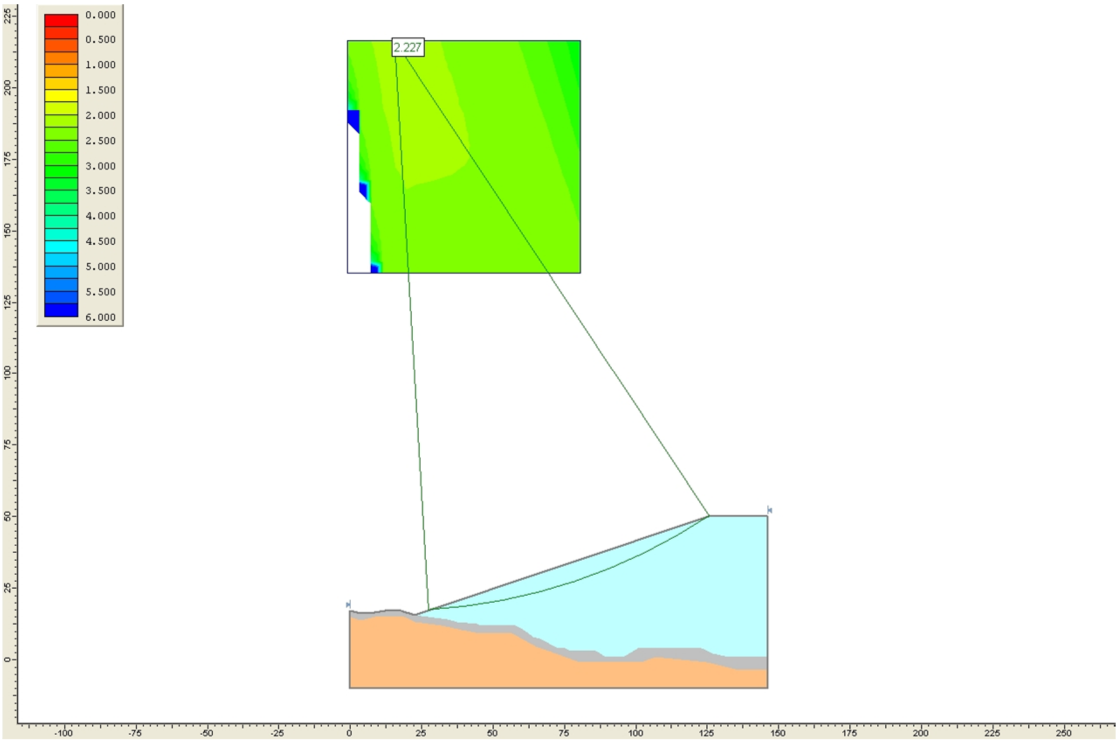
PROJECT:
Campbell Mountain Landfill Design, Operations and Closure Plan

TITLE:
SECTION 1-1' PROPSED STATIC

SCALE:	DATE:	PROJECT NO:
N/A	2016/05/22 (yyyy/mm/dd)	**15061**
DESIGNED: IB	DRAWING NO:	
DRAWN: IB	**FIGURE G-2**	
CHECKED: TS		

Layers	Unit Weight Saturated (KN/m³)	Unit Weight Unsaturated (KN/m³)	Cohession (KN/m²)	Friction angle (degree)
Fractured Bed Rock	20	20	0	45
Sand	16	18	0	32
Waste	10	12	10	25
Clay	15	16	10	20
Topsoil/Biocover	14	15	2	30
Glass	18	18	0	35

Waste
Sand
Fractured Bed Rock



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Regional District of Okanagan-Similkameen

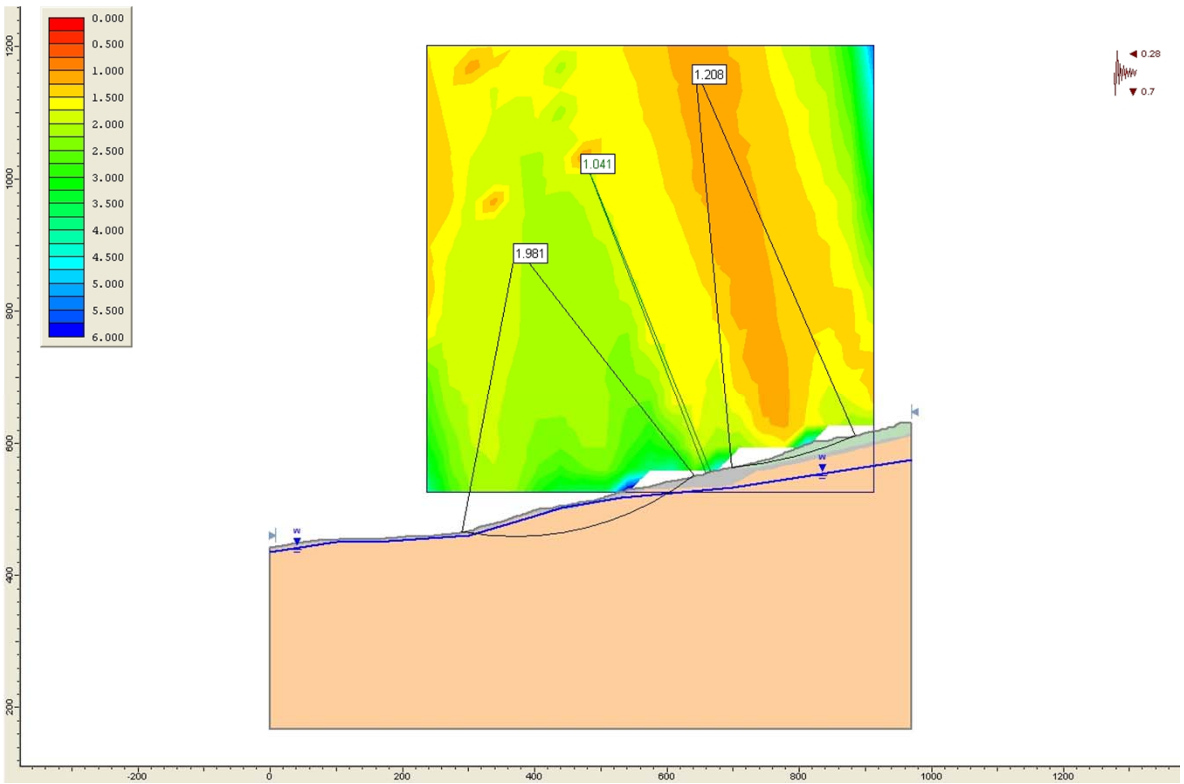
PROJECT:
Campbell Mountain Landfill Design, Operations and Closure Plan

TITLE:
SECTION 2-2' PROPOSED STATIC

SCALE:	DATE:	PROJECT NO:
N/A	2016/05/22 yyyy/mm/dd	**15061**
DESIGNED IB		DRAWING NO:
DRAWN IB		**FIGURE G-3**
CHECKED TS		

Layers	Unit Weight Saturated (KN/m³)	Unit Weight Unsaturated (KN/m³)	Cohession (KN/m²)	Friction angle (degree)
Fractured Bed Rock	20	20	0	45
Sand	16	18	0	32
Waste	10	12	10	25

Waste
Sand
Fractured Bed Rock



Sperling Hansen Associates

Regional District of Okanagan-Similkameen

PROJECT:
Campbell Mountain Landfill Design, Operations and Closure Plan

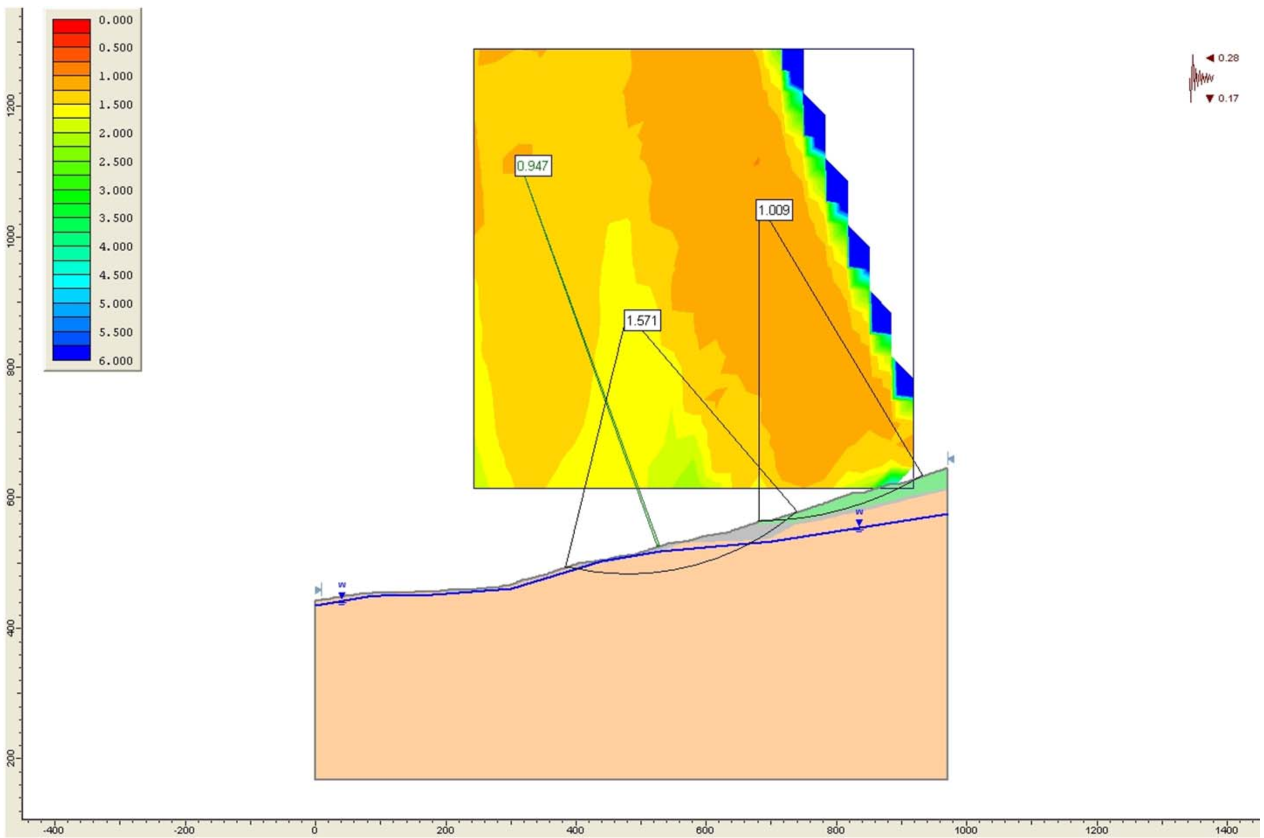
TITLE:
SECTION 1-1' EXISTING SEISMIC

SCALE:	DATE:	PROJECT NO:
N/A	2016/05/22 yyyy/mm/dd	**15061**

DESIGNED	IB	DRAWING NO:
DRAWN	IB	**FIGURE G-4**
CHECKED	TS	

Layers	Unit Weight		Cohession	Friction angle
	Saturated (KN/m³)	Unsaturated (KN/m³)	(KN/m²)	(degree)
Fractured Bed Rock	20	20	0	45
Sand	16	18	0	32
Waste	10	12	10	25

Waste
Sand
Fractured Bed Rock



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Regional District of Okanagan-Similkameen

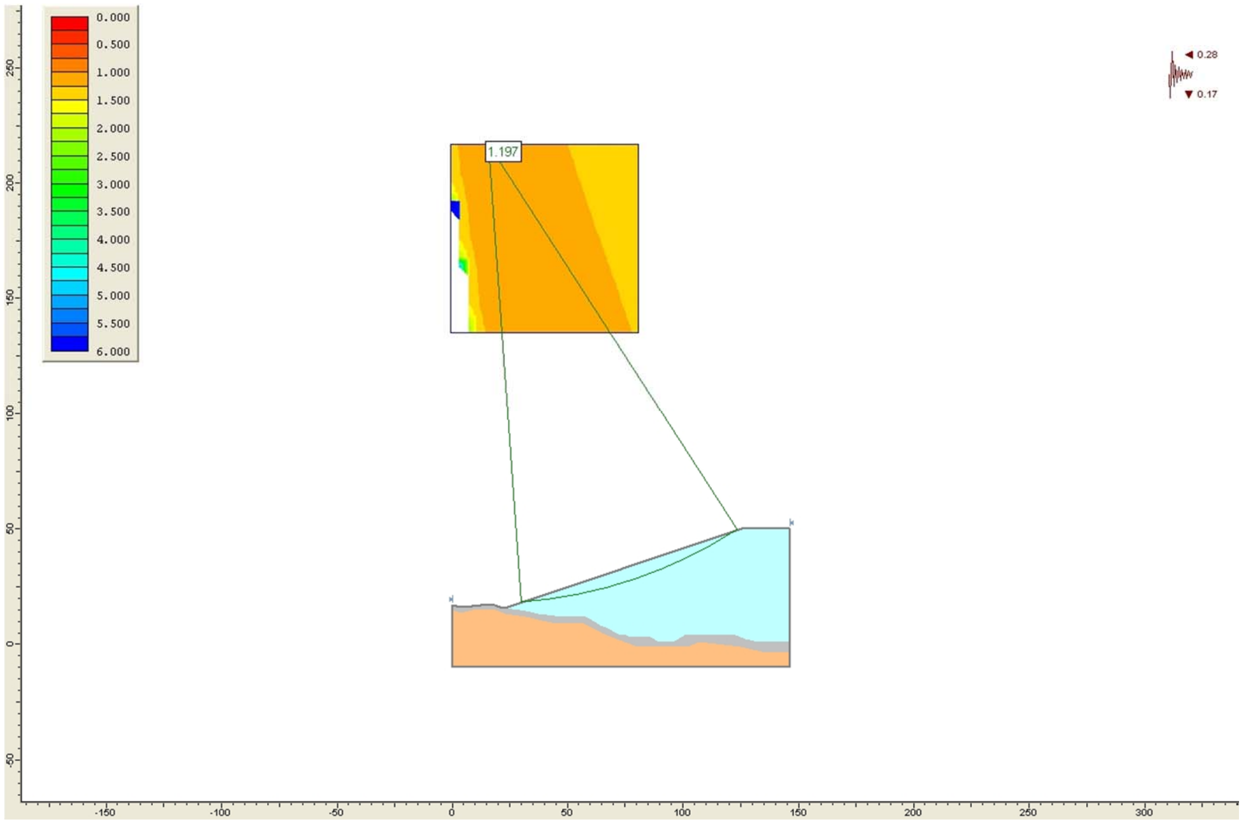
PROJECT:
Campbell Mountain Landfill Design, Operations and Closure Plan

TITLE:
SECTION 1-1' PROPSED SEISMIC

SCALE:	DATE:	PROJECT NO:
N/A	2016/05/22 (yyyy/mm/dd)	**15061**
DESIGNED	IB	DRAWING NO:
DRAWN	IB	**FIGURE G-5**
CHECKED	TS	

Layers	Unit Weight Saturated (KN/m³)	Unit Weight Unsaturated (KN/m³)	Cohession (KN/m²)	Friction angle (degree)
Fractured Bed Rock	20	20	0	45
Sand	16	18	0	32
Waste	10	12	10	25

Waste
Sand
Fractured Bed Rock



Sperling Hansen Associates

Regional District of Okanagan-Similkameen

PROJECT:
Campbell Mountain Landfill Design, Operations and Closure Plan

TITLE:
SECTION 2-2' PROPOSED SEISMIC

SCALE:	DATE:	PROJECT NO:
N/A	2016/05/22 yyyy/mm/dd	15061
DESIGNED IB	DRAWING NO:	
DRAWN IB	FIGURE G-6	
CHECKED TS		

APPENDIX H
Proposed Newmark

SPERLING HANSEN ASSOCIATES

NEWMARK SEISMIC DEFORMATION ANALYSIS

PROJECT: Campbell Mountain Landfill Design, Operations and Closure Plan

PROJECT NUMBER: PRJ15061

LOCATION: Penticton, BC

UTM COORDINATES:	Northing	Easting	Elevation (m)
	$49^0 31'25''$	$119^0 32'51''$	620

DESIGN SCENARIO: Proposed Section S1-1

SEISMIC PARAMETERS

Return Period	40% Chance of Exceedance in 50 yrs (1:100 yr event)	22% Chance of Exceedance in 50 yrs (1:200 yr event)	10% Chance of Exceedance in 50 yrs (1:475 yr event)
Peak Horizontal Ground Acceleration (g)	0.089	0.13	0.23
Peak Horizontal Ground Velocity (m/s)	0.077	0.12	0.21

SLOPE PARAMETERS

Maximum Height	85	(m)
Slope Angle	3H:1V	H:V
Refuse Friction Angle	25	(degrees)
Refuse Cohesion	10	(kPa)
Slip Surface Interface	Peat, Silt, Waste	
Slip Surface Friction Angle	N/A	(degrees)
Slip Surface Cohesion	N/A	(kPa)
Yield Acceleration	0.24	(g)

N/A RATIO

2.696629213	1.846153846	1.043478261

CALCULATED NEWMARK DEFORMATION

Return Period	40% Chance of Exceedance in 50 yrs (1:100 yr event)	22% Chance of Exceedance in 50 yrs (1:200 yr event)	10% Chance of Exceedance in 50 yrs (1:475 yr event)
Horizontal Displacement (m) Upper Limit	0.000466928	0.001656473	0.008975217
Horizontal Displacement (m) Medium Range	-0.000792204	-0.001401631	-0.000390227
Horizontal Displacement (m) Lower Limit	0.007554791	0.018348624	0.056192661

Notes:
Upper limit calculated by equation: $V^2/(2gN)*(A/N)$
Medium range calculated by equation: $V^2/(2gN)*(1-N/A)*(A/N)$
Lower limit calculated by equation: $6*V^2/(2gN)$
Lower limit applicable for N/A ratios < 0.167 (1/6)

ANALYSIS BY: Iqbal Bhuiyan
DATE May 25th, 2016

SPERLING HANSEN ASSOCIATES

NEWMARK SEISMIC DEFORMATION ANALYSIS

PROJECT: Campbell Mountain Landfill Design, Operations and Closure Plan

PROJECT NUMBER: PRJ15061

LOCATION: Penticton, BC

UTM COORDINATES:	Northing	Easting	Elevation (m)
	$49^0$31'25"	$119^0$32'51"	620

DESIGN SCENARIO: Proposed Section S2-2

SEISMIC PARAMETERS

Return Period	40% Chance of Exceedance in 50 yrs (1:100 yr event)	22% Chance of Exceedance in 50 yrs (1:200 yr event)	10% Chance of Exceedance in 50 yrs (1:475 yr event)
Peak Horizontal Ground Acceleration (g)	0.089	0.13	0.23
Peak Horizontal Ground Velocity (m/s)	0.077	0.12	0.21

SLOPE PARAMETERS

Maximum Height	35	(m)
Slope Angle	3H:1V	H:V
Refuse Friction Angle	25	(degrees)
Refuse Cohesion	10	(kPa)
Slip Surface Interface	Peat, Silt, Waste	
Slip Surface Friction Angle	N/A	(degrees)
Slip Surface Cohesion	N/A	(kPa)
Yield Acceleration	0.42	(g)

N/A RATIO

	4.719101124	3.230769231	1.826086957

CALCULATED NEWMARK DEFORMATION

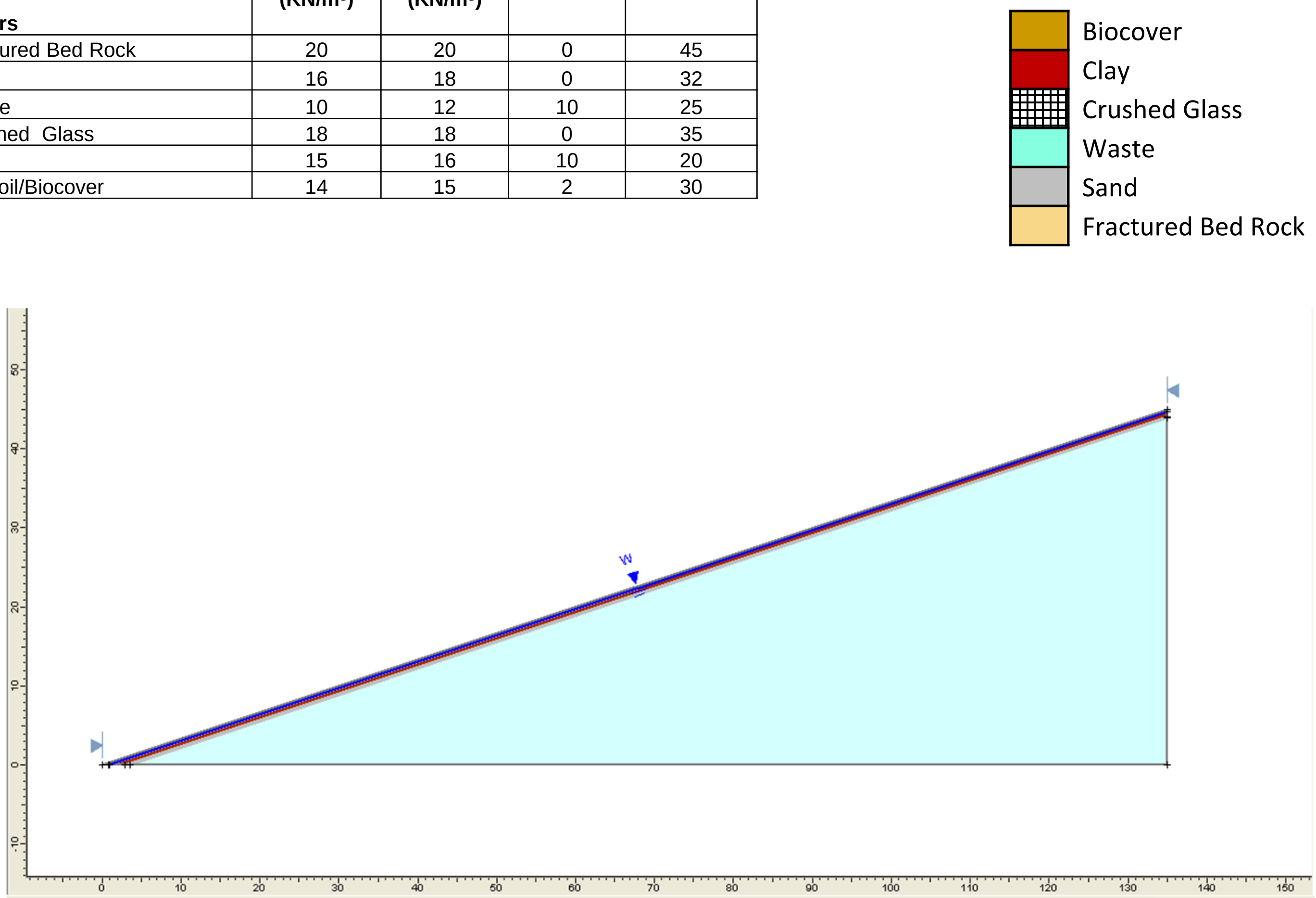
Return Period	40% Chance of Exceedance in 50 yrs (1:100 yr event)	22% Chance of Exceedance in 50 yrs (1:200 yr event)	10% Chance of Exceedance in 50 yrs (1:475 yr event)
Horizontal Displacement (m) Upper Limit	0.000152466	0.000540889	0.002930683
Horizontal Displacement (m) Medium Range	-0.000567038	-0.001206599	-0.002420999
Horizontal Displacement (m) Lower Limit	0.004317023	0.010484928	0.032110092

Notes:
Upper limit calculated by equation: $V^2/(2gN)*(A/N)$
Medium range calculated by equation: $V^2/(2gN)*(1-N/A)*(A/N)$
Lower limit calculated by equation: $6*V^2/(2gN)$
Lower limit applicable for N/A ratios < 0.167 (1/6)

ANALYSIS BY: Iqbal Bhuiyan
DATE May 25th, 2016

APPENDIX I
Cover Section

Layers	Unit Weight Saturated (KN/m³)	Unit Weight Unsaturated (KN/m³)	Cohession (KN/m²)	Friction angle (degree)
Fractured Bed Rock	20	20	0	45
Sand	16	18	0	32
Waste	10	12	10	25
Crushed Glass	18	18	0	35
Clay	15	16	10	20
Topsoil/Biocover	14	15	2	30



SPERLING HANSEN ASSOCIATES

Regional District of Okanagan-Similkameen

PROJECT: Campbell Mountain Landfill Design, Operations and Closure Plan

TITLE: **Cover Section**

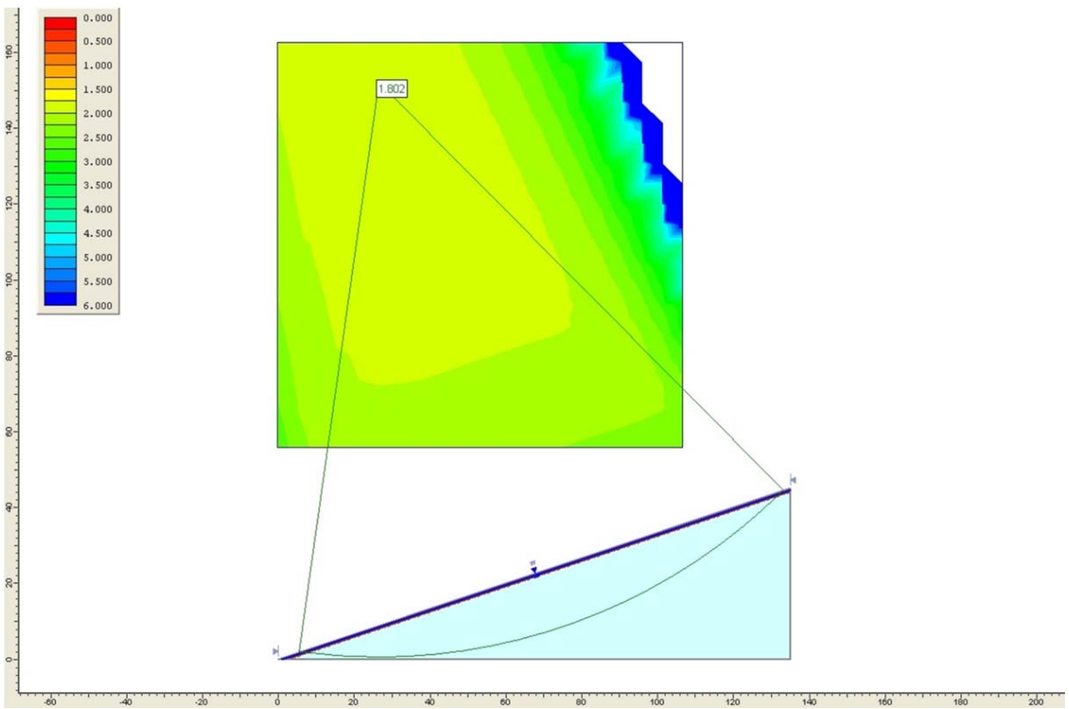
SCALE:	DATE:	PROJECT NO:
N/A	2016/05/22 (yyyy/mm/dd)	15061

DESIGNED	IB	DRAWING NO:
DRAWN	IB	**FIGURE I-1**
CHECKED	TS	

APPENDIX J
Veneer Stability Results

Layers	Unit Weight		Cohession	Friction angle
	Saturated (KN/m³)	Unsaturated (KN/m³)	(KN/m²)	(degree)
Fractured Bed Rock	20	20	0	45
Sand	16	18	0	32
Waste	10	12	10	25
Crushed Glass	18	18	0	35
Clay	15	16	10	20
Topsoil/Biocover	14	15	2	30

- Biocover
- Clay
- Crushed Glass
- Waste
- Sand
- Fractured Bed Rock



Sperling Hansen Associates

Regional District of Okanagan-Similkameen

PROJECT:
Campbell Mountain Landfill Design, Operations and Closure Plan

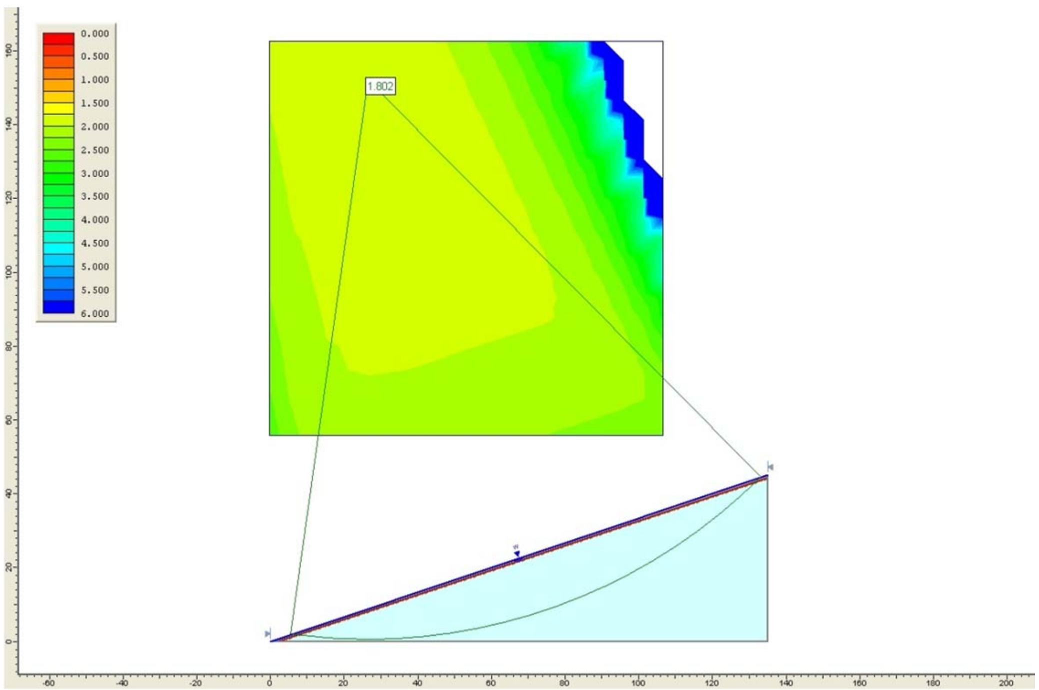
TITLE:
30 mm MOUNDING STATIC

SCALE:	DATE:	PROJECT NO:
N/A	2016/05/22 (yyyy/mm/dd)	15061

DESIGNED	IB	DRAWING NO:
DRAWN	IB	**FIGURE J-1**
CHECKED	TS	

Layers	Unit Weight Saturated (KN/m³)	Unit Weight Unsaturated (KN/m³)	Cohession (KN/m²)	Friction angle (degree)
Fractured Bed Rock	20	20	0	45
Sand	16	18	0	32
Waste	10	12	10	25
Crushed Glass	18	18	0	35
Clay	15	16	10	20
Topsoil/Biocover	14	15	2	30

- Biocover
- Clay
- Crushed Glass
- Waste
- Sand
- Fractured Bed Rock



Sperling Hansen Associates

Regional District of Okanagan-Similkameen

PROJECT:
Campbell Mountain Landfill
Design, Operations and Closure Plan

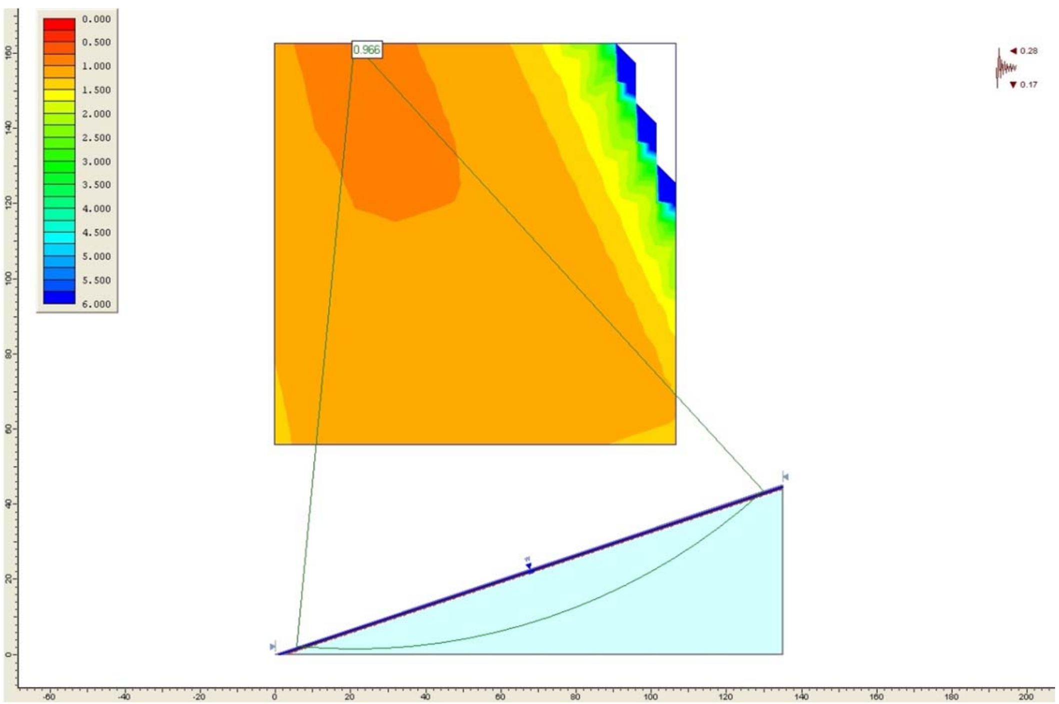
TITLE:
300 mm MOUNDING STATIC

SCALE:	DATE:	PROJECT NO:
N/A	2016/05/22 (yyyy/mm/dd)	**15061**

DESIGNED	IB	DRAWING NO:
DRAWN	IB	**FIGURE J-2**
CHECKED	TS	

Layers	Unit Weight		Cohession	Friction angle
	Saturated (KN/m³)	Unsaturated (KN/m³)	(KN/m²)	(degree)
Fractured Bed Rock	20	20	0	45
Sand	16	18	0	32
Waste	10	12	10	25
Crushed Glass	18	18	0	35
Clay	15	16	10	20
Topsoil/Biocover	14	15	2	30

- Biocover
- Clay
- Crushed Glass
- Waste
- Sand
- Fractured Bed Rock



Sperling Hansen Associates

Regional District of Okanagan-Similkameen

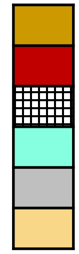
PROJECT:
Campbell Mountain Landfill
Design, Operations and Closure Plan

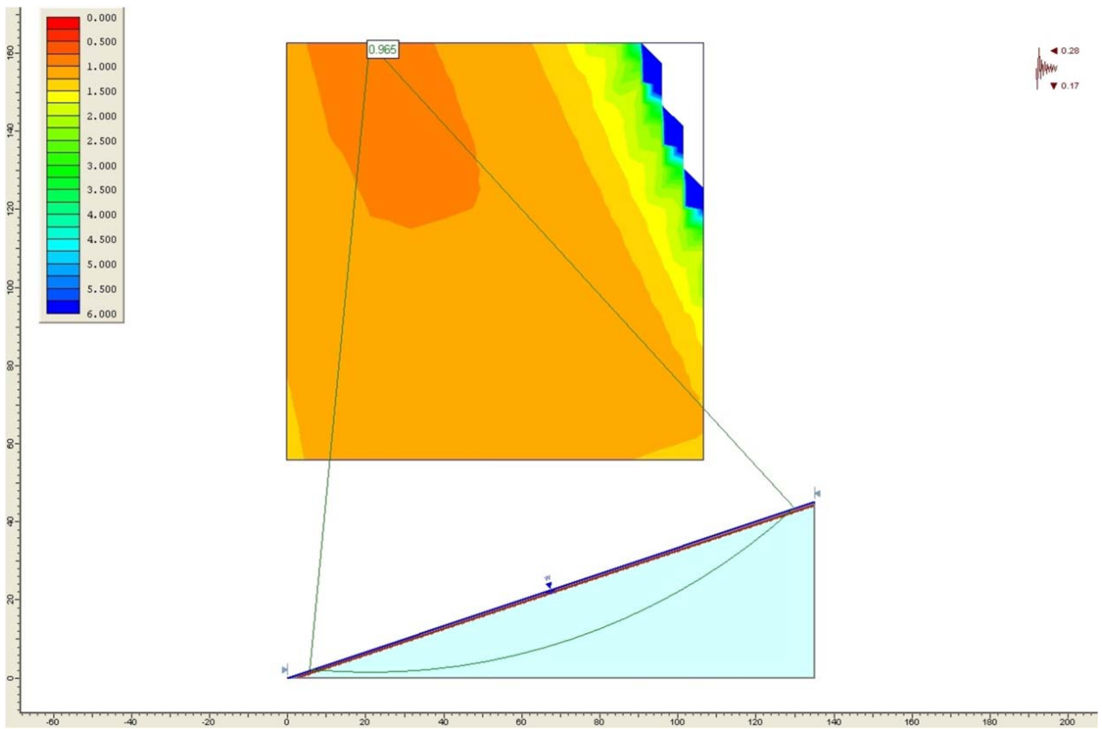
TITLE:
30 mm MOUNDING SEISMIC

SCALE:	DATE:	PROJECT NO:
N/A	2016/05/22 (yyyy/mm/dd)	**15061**

		DRAWING NO:
DESIGNED	IB	
DRAWN	IB	**FIGURE J-3**
CHECKED	TS	

Layers	Unit Weight Saturated (KN/m³)	Unit Weight Unsaturated (KN/m³)	Cohession (KN/m²)	Friction angle (degree)
Fractured Bed Rock	20	20	0	45
Sand	16	18	0	32
Waste	10	12	10	25
Crushed Glass	18	18	0	35
Clay	15	16	10	20
Topsoil/Biocover	14	15	2	30





Sperling Hansen Associates	Regional District of Okanagan-Similkameen	PROJECT: Campbell Mountain Landfill Design, Operations and Closure Plan	TITLE: **300 mm MOUNDING SEISMIC**	SCALE: N/A; DATE: 2016/05/22 (yyyy/mm/dd); PROJECT NO: **15061**

DESIGNED	IB	DRAWING NO:
DRAWN	IB	**FIGURE J-4**
CHECKED	TS	