May 12th, 2017 PRJ17037

Thompson Nicola Regional District
300-465 Victoria St.
Kamloops, B.C. V2C 2A9

Attention: **Kory Ryde**
EHS Technologist

Dear Mr. Ryde,

Re: Lower Nicola Landfill 2015 Greenhouse Gas (GHG) Emissions Reduction Quantification

Sperling Hansen Associates (SHA) are pleased to submit this letter report on *2016 greenhouse gas (GHG) emissions reduction for the Lower Nicola Landfill.*

Landfill Information

The Lower Nicola Landfill is located 2 km west of Lower Nicola on Highway #8 in British Columbia (BC). The site serves approximately 12,293 people from the City of Merritt and surrounding rural areas and also accepts refuse from the Thompson Nicola Regional District (TNRD) transfer stations in Aspen Grove, Mamit Lake, Spences Bridge and surrounding First Nation communities. The landfill footprint, Lot B which encompasses approximately 16 Ha, is surrounded by the TNRD land titled District Lot 4553 of approximately 25 Ha.

The Lower Nicola Landfill was originally permitted as a waste management site in September, 1976 for the disposal of municipal refuse from Merritt, Lower Nicola and surrounding rural areas. Historically, waste filling activities at the Lower Nicola Landfill have been in the central and southern portions of the site and have been completed using a combination of the trench and ramp methods.

Landfill Gas (LFG) Generation Assessment

In 2014, SHA completed a LFG generation assessment for the Lower Nicola Landfill. The LFG generation estimates showed that the annual methane generation at this site was about 271 tonnes/year. Figure 1 shows the methane generation estimate at the Lower Nicola Landfill from 1984 to 2018.

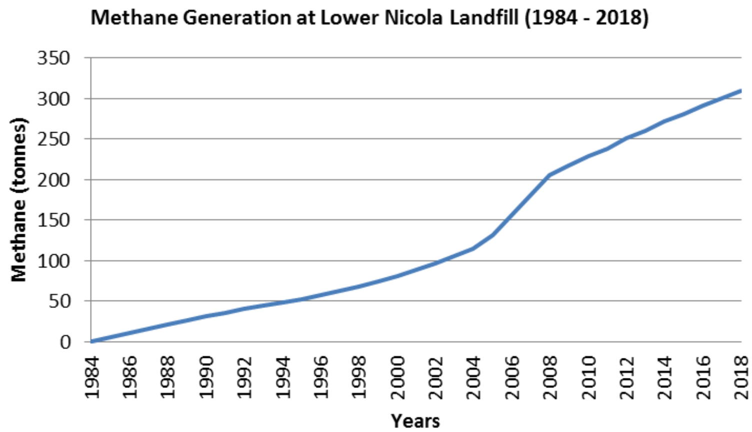

Figure 1 Methane Generation Estimate at Lower Nicola Landfill

Because the methane generation at the Lower Nicola Landfill is estimated to be far below the 1,000 tonnes per year threshold set by the BC Ministry of Environment (MOE) as per LFG Management Regulation (2008), this site is not required to install an active LFG management system. Therefore, the relatively small amount of the generated methane can be released to the atmosphere without any active LFG management. Nevertheless, SHA suggested that the TNRD reduce the GHG emissions from this site and take advantage of the carbon credits. We suggested that one of the most feasible options of generating carbon credits for small sites, such as Lower Nicola Landfill, is biological oxidization of the methane using a biocover system.

The TNRD adopted this approach and implemented biocover system over top of the closed areas of the Lower Nicola Landfill in the central and southern portions of the site early 2015. The implementation of the biocover system at the Lower Nicola Landfill started after a baseline GHG emission measurement was completed at this site by SHA in October 2014. Subsequently, SHA completed a round two of GHG emission measurement in 2016 and concluded that a biocover system with an efficiency of 21% was installed at this site with total GHG emissions reduction of 369.5 tonnes CO_2-e achieved in 2015.

The TNRD retained SHA to conduct 3rd round of measurements at the Lower Nicola Landfill, to evaluate effectiveness of the biocover system and to quantify the 2016 GHG emission reduction achieved at this site throughout 2016.

Literature Review on Biological Oxidation of Methane

Methane oxidation in landfill cover soil reduces GHG emissions from landfills. There are a number of published and peer reviewed scientific research papers that have reported methane (CH_4) oxidation fractions through operational soil cover at 22-55% (Whalen et al., 1990; Chanton et al., 2009; Chanton et al., 2011). The U.S. Environmental Protection Agency (USEPA, 2004) also reported an average methane oxidation rate of 10-25% with lower rates for clay cover soil and higher rates for topsoil.

However, due to the challenges of accurately measuring CH_4 oxidation and lack of standard quantifying methods, the U.S. EPA recommends a default average value of 10% methane oxidation for cover soil (USEPA, 2004). This minimum baseline methane oxidation rate for landfill cover soil is also adopted by Climate Action Reserve (CAR) protocol, Pacific Carbon Trust (PCT) LFG management protocol, as well as the Intergovernmental Panel on Climate Change (IPCC) guidelines and protocols for national GHG inventories. In the following analysis, the 10% baseline methane oxidation rate is ignored as it is already taken into account when the baseline methane emission measurement is completed.

For engineered fabricated biocovers, the methane oxidation rate is reported to be between 50-100%, depending on the methane loading rate on the biocover (Barlaz et al., 2004; Stern et al., 2007; Abichou et al., 2009). Proper installation and maintenance of the biocover system is required to ensure effectiveness of the system and to avoid methane displacement and creation of emission hot spots.

<u>Biocover Application and Monitoring</u>

The fabricated biocover was placed by the TNRD on the crest areas (Crest 1 and Crest 2 in Figure 2) as well as the side slope areas (Slopes 1 through 4 in Figure 2) of the central and southern parts of the Lower Nicola landfill. This was done in early 2015, followed by additional biocover that was placed on the areas that SHA identified as “Hot Spots” in its 2015 GHG emission quantification report for this site.

The following photos show the Slope 3 area before biocover application (2014), after the first round of biocover application (2016) and recently, with additional biocover (2017).

Photo 1 – Slope 3 (S3) Area before application of biocover (2014)

Photo 2 – Slope 3 (S3) Area after round 1 biocover application (2016)

Photo 3 – Slope 3 (S3) Area after round 2 biocover application (2017)

As part of the landfill operation and waste disposal activities in 2016, a small portion of the biocover in Slope 3 area was buried under next lifts of MSW. This area, which is shown in enclosed Figure 2, was removed from 2016 GHG emission reduction calculations.

The third round of field work was completed in May 8th 2017, similar to previous years, using an advanced technique to measure the fugitive methane emissions and to quantify the GHG emission reductions achieved by application of biocover. The methodology and the results of these site investigations are fully explained in the next section.

LFG Emission Measurement Methodology

The fugitive methane emission measurements were conducted through an approach developed by Abedini and Atwater (2014). This methodology involves measurement of surface methane concentrations from the area of interest, as well as conducting flux chamber measurements in representative portions of the landfill.

The surface methane concentration (SMC) scan using a flame ionization detector (FID) is an approved methodology used across the US, when is required by the U.S. Environmental Protection Agency's (EPA) New Source Performance Standard (NSPS) Regulation. Because quantification of methane emissions is not economically feasible for all landfills, the NSPS Regulation requires that the average methane concentrations at the surface of the regulated landfills to be kept below certain levels. If the FID field measurements register values above the threshold then the owner would have to implement control measures within a given period of time.

The flux chamber technique is also an approved methodology by the US EPA and is used when technique of methane emissions is required. However, because it is a very time consuming methodology, it's been rarely implemented in full scale at MSW landfills. On the other hand, due to the relatively high detection limit of the technique, it would be difficult to achieve reliable data from flux chamber measurements on top of the biocover areas where methane is almost fully oxidized. However, the FID instruments can detect methane concentrations down to 0.1 ppm levels (i.e. 1 x 10^{-5} percent).

Photo 4 – SMC Scan Using a Portable FID Instrument

The methodology adopted to evaluate the Lower Nicola Landfill biocover performance is a combination of the two aforementioned techniques. This methodology was developed through the Ph.D. research of Dr. Ali Abedini, SHA's LFG specialist. Abedini's methodology was developed based on comprehensive field investigations including an FID surface scan of about 18 Ha and approximately 190 flux chamber measurements conducted at the Vancouver Landfill. In order to apply the same technique to evaluate the effectiveness of the biocover placed at the Lower Nicola Landfill, measurements had to be completed in two rounds. SHA used the emission measurement results that were acquired before implementation of the biocover system as the baseline data (round 1). The second round of field measurement, for the purpose of this report, was completed in May 8th, 2017. The results of the field measurements are discussed in the following sections.

<u>Surface Methane Concentration Scan</u>

A surface methane concentration (SMC) scan was conducted over approximately 3.2 Ha area at the Lower Nicola Landfill. In 2016, this total biocover area was reduced to 3.1 Ha. In May 2017, new round of surface scan was conducted over the central and southern areas of landfill that were accessible. A *Thermo Scientific TVA 2020* FID instrument was used to measure and log methane concentrations at the landfill's surface. The scanned area was walked on approximately 10 m spaced pathways while logging methane concentration every 3 seconds. The FID instrument was calibrated using calibration gas from a tank before and after conducting each set of measurements. Accordingly, the recorded methane concentrations were adjusted when a drift in the calibration gas reading was observed. Photo 4 shows SHA's staff Dr. Abedini conducting FID measurement on a similar project. From previous experiences at this site, we knew that due to low levels of methane emissions, application of flux chamber would not generate reliable data. Therefore, we used the index factor that was previously developed by Abedini, (2014) to translate the FID scan results to methane emission rates at the Lower Nicola Landfill.

Climate Effect

A very important aspect of measurement of fugitive methane emissions from landfills is the effect of barometric pressure (BP) on the gas flux intensity. The BP variations were monitored during the field work and the emissions measurement results were adjusted for the rate of change in BP values. The climate data, presented in Figures, were acquired from the Kamloops Airport Weather Station during the days of field investigation in 2017.

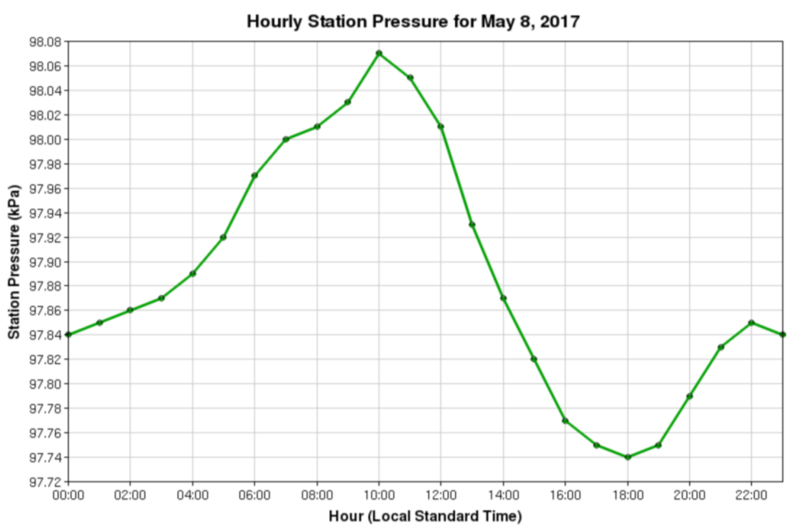

Figure 3 - Climate Data for May 8th, 2017 (Source: Kamloops Airport Weather Station)

Results

The total GHG emissions reduction achieved through biological oxidation of methane in biocover at the Lower Nicola Landfill includes "baseline" reductions and "additional" reductions. The average baseline reduction is normally the 10% methane oxidation that naturally occurs when methane travels through the cover soil placed at the top of the completed phases. By quantifying the emission rates in two rounds, before and after placement of the biocover, the "additional" oxidation resulted from the application of biocover was estimated at the Lower Nicola Landfill.

Due to the low baseline methane emission rates at this site (less than 3 $g/m^2/day$) flux chamber measurements did not produce meaningful results. Therefore, the surface methane concentrations were translated into the methane emission rates based on Abedini's methodology. As reported in our previous report, (*Lower Nicola Landfill 2015 Greenhouse Gas (GHG) Emissions Reduction*

Quantification), the FID surface methane concentrations (SMC) scan showed an average methane concentration of 0.5 to 7 ppm in different areas before the placement of biocover. In 2015, after 1st round of biocover application, these values were reduced to values ranging from 0.2 to 2.4 ppm. The range that we measured during the recent field work was 0.07 to 2 ppm.

The overall methane emission reduction that was resulted for 2015 was approximately 21%. This value for 2016 was increased to 30%. Effectiveness of the biocover system in different areas is different and ranges between 8% and 55%. Notably, the biocover system in side slope areas that have a shallower slope (i.e. Slope 3 with ~ 3H:1V slope) shows much better performance in comparison with the biocover system placed on steep slopes (e.g. Slope 2). Steep side slopes results in instability of the biocover system, high erosion and washout of the biocover, and formation of cracks and fissures in the biocover from which methane escape was observed. Photo 5 below shows a major emission hot spot identified during the recent FID scan in May 2017. The biocover that was initially placed in this area was washed out during 2016 heavy storm. Photo 6 shows slope of this area at 27° (i.e. ~ 2H:1V)

Photo 5 – High methane emission zones in Area S2 with biocover installed (Hot Spots)

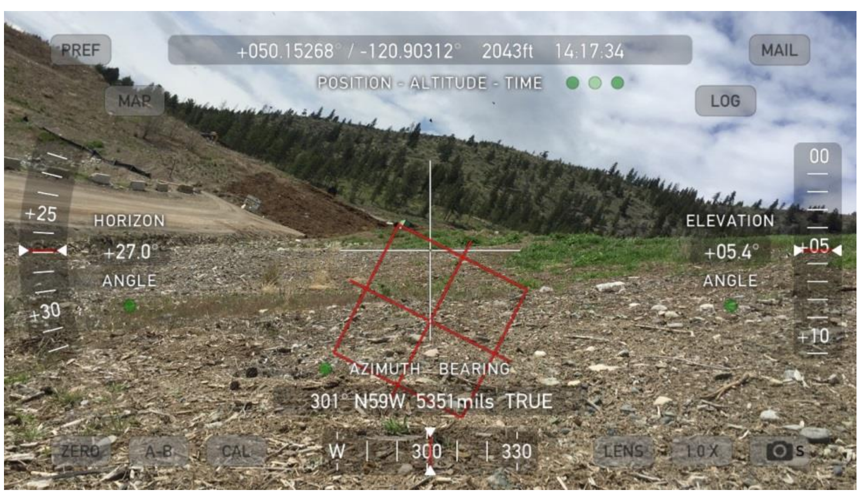

Photo 6 – Steep slope in Area S2 (2H:1V)

Except for steep slope areas where material was relocated and/or washed out, the biocover system at the Lower Nicola Landfill performed satisfactory and most of the emission hot spots that were located during the previous FID scan were fully covered. The hot spots that were identified during this round of the FID scan are shown in Figure 2 included at the end of this report.

Table 1 below summarizes the finding and the results of the first and second round of the filed investigations at the Lower Nicola Landfill.

Table 1. Summary of Methane Emission Measurement Results at the Lower Nicola Landfill

	Grid Number	Footprint Area	Surface Methane Concentration			CH_4 Emission Rate ($g/m^2/d$)		Average CH_4 Emission Rate	% Reduction from Baseline	GHG Emission
			MIN	MAX	AVG.	(Abedini, 2014)				
		m^2	ppm	ppm	ppm	MER	±ΔMER	kg/y	%	tonnes CO_2-e
Round 1 (Baseline)	S1	2,810	1.61	62.74	2.85	2.30	0.85	3,576	-	89.4
	S2	1,890	1.04	10.40	2.65	2.24	0.85	2,339	-	58.5
	S3	5,550	1.91	58.45	6.93	3.61	0.99	11,074	-	276.9
	S4	11,550	1.69	5.04	2.05	2.05	0.82	13,066	-	326.7
	C1	10,000	1.99	2.55	2.22	2.10	0.83	11,615	-	290.4
	C2	11,780	-	7.80	0.54	1.56	0.77	10,189	-	254.7
	TOTAL	**43,580**			**2.87**			**51,860**		**1296**
Round 3 (2017)	S1	2,810	-	19.60	0.59	1.58	0.77	2,452	31%	61.3
	S2	1,890	-	261.30	2.11	2.07	0.83	2,160	8%	54.0
	S3	4780*	-	80.70	1.60	1.90	0.81	5,032	55%	125.8
	S4	11,550	-	265.70	0.63	1.59	0.78	10,157	22%	253.9
	C1	10,000	-	2.20	0.07	1.41	0.76	7,814	33%	195.3
	C2	11,780	-	40.60	0.55	1.57	0.77	10,211		255.3
	TOTAL	**38,030**	**-**	**111.68**	**0.93**			**37,825**	**30%**	**946**

* Reduced area due to waste diposal in active face

Annual Reduction (tonnes CO_2-e): 350.9

Taking into account the total footprint of the scanned area at the Lower Nicola Landfill, SHA estimated that a total of 14 tonnes of methane, equivalent to 351 tonnes of CO_2-e, was reduced through oxidization in the biocover system at this site in 2016.

Conclusion

The current analyses showed that the implementation of biocover system at the Lower Nicola Landfill has resulted in GHG emissions reduction equivalent to 351 tonnes CO_2-e in 2016. The overall effectiveness of the biocover system at the Lower Nicola Landfill was increased from 21% to 30% between 2015 and 2016, respectively. We recommend that the TNRD continues to expand the biocover system, specially, in the areas sown as emission hot spots in the attached Figure 2.

Quantification of the methane emission rates at the Lower Nicola Landfill was conducted through utilization of an advanced technique. These results show an average of 30% reduction in emission rates between the two measurements. The total methane emissions reduction from the Lower Nicola Landfill was approximately 14 tonnes of methane in 2016. This amount, based on the methane global warming potential of 25, is equivalent to 351 tonnes of CO2-e GHG emission reduction achieved in 2016.

LIMITATIONS

This report has been prepared by Sperling Hansen Associates (SHA) for the Thompson Nicola Regional District (TNRD) in accordance with generally accepted engineering practices to a level of care and skill normally exercised by other members of the engineering and gas 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 on 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 for 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 TNRD. 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, SHA should be requested to re-evaluate the findings of this report and modify the conclusions and recommendations drawn, as required.

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May 12th, 2017

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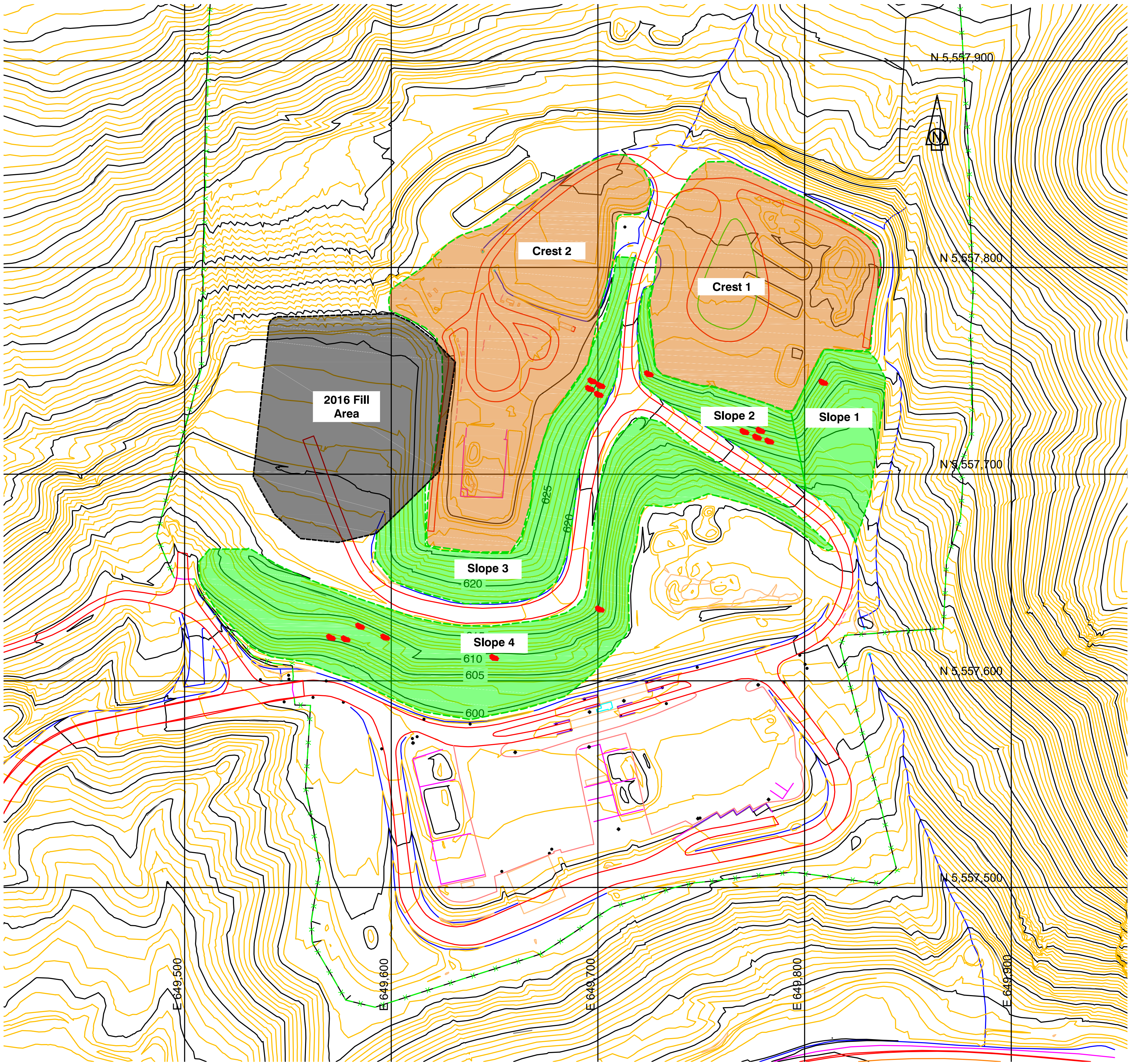

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LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- FENCE
- DITCH LINE
- ROAD
- CH4 EMISSION HOT SPOT
- SIDE SLOPE AREA
- CREST AREA
- 2016/2017 WASTE DISPOSAL

CLIENT: THOMPSON-NICOLA REGIONAL DISTRICT (TNRD)

PROJECT:

LOWER NICOLA LANDFILL BIOCOVER 016 GHG CREDIT QUANTIFICATION

TITLE:

FIID SURFACE SCAN AREAS

SCALE:	DATE:	PROJECT NO:
1:2,000	2017/05/01 (yyyy/mm/dd)	PRJ 17037

DESIGNED	AA	DRAWING NO:
DRAWN	AA	FIGURE 2
CHECKED	IB	