23 October 2013

REPORT ON

Concept Design Report for Pasminco Cockle Creek Smelter Containment Cell Expansion

Submitted to:
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REPORT

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1.0 INTRODUCTION

1.1 Terms of Reference

This report outlines our design considerations for the expansion of the Pasminco Cockle Creek Smelter (PCCS) containment cell. As instructed by Ferrier Hodgson (email dated 18 September 2013), Golder has prepared a concept level expanded containment cell landform. The concept expansion design comprises a revised containment cell landform that provides an increased airspace of approximately 250,000 cubic meter (cu.m.) through raising the top of the cell to up to RL 42.15 mAHD.

The intention of this letter is to describe the design considerations for the containment cell expansion for consideration by the mine subsidence board (MSB) and relevant approval agencies.

1.2 Background

The PCCS site is a former lead and zinc smelter located approximately 13 km south west of Newcastle and just above the northernmost point of Lake Macquarie at Boolaroo. Smelting operations have caused contamination of the site with heavy metals, chiefly lead, zinc and cadmium. PCCS Services (PCCSS) is currently remediating the PCCS lands associated with the former on-site lead and zinc smelting operations as well as the adjacent Incitec Fertiliser Limited (IFL) lands. Remediation comprises excavation of contaminated soil and placement of the soil in a containment cell within the PCCS site.

The original PCCS containment cell design, the '2008 Approved Cell Design', was prepared by Golder Associates (Golder 2007) and subsequently approved by the NSW EPA.

In 2010, the footprint of the cell was extended to accommodate a larger than expected amount of contaminated soil. Design drawings and calculations (Golder 2010c) were provided to EPA.

In 2011, at the request of Ferrier Hodgson on behalf of PCCS, Golder prepared a submission proposing changes to the containment cell capping system design and the surface slopes (Golder 2011) on the top of the landform. The top of the cell landform is referred to as the cell 'platform'. The proposed changes have been approved by the DoPI, subject to the conditions outlined in the August 2012 s75W Modification issued on 10 August 2012.

In 2012, at the request of Ferrier Hodgson on behalf of PCCS, Golder prepared a design providing an expanded landform to contain contaminated material from the adjacent IFL site and to expand the total containment cell capacity to 1.65 million cu.m (Golder 2012) with a maximum approved height of RL38m. The expansion design was approved by the DoPI in the December 2012 s75W Modification MOD 4 issued on 17 December 2012.

The currently approved project comprises the 2008 Approved Cell Design, the 2010 Approved Cell Design, the August 2012 s75W Modification and the December 2012 s75W Modification and is referred to herein as the 'Consolidated PCCS Part 3A Approval Design'.

2.0 PROPOSED LANDFORM

2.1 Cell Volume Increase

The design for expansion of the PCCS containment cell provides increased cell storage volume[1], also referred to as 'airspace.' The increased airspace is achieved primarily through modifications to the cell landform in the Consolidated PCCS Part 3A Approval Design, namely by increasing the height of the cell. Importantly, these modifications are achieved without changing the cell footprint or the slope angle of the cell batters (i.e., side slopes).

[1] The containment cell airspace is measured as the volume between the leachate floor (the bottom of the leachate collection layer) and the bottom of the capping system.

The maximum increase in airspace proposed is approximately 250 000 cubic metre (cu.m.), which includes a contingency of 110 000 cu.m. (as informed by PCCS). The following table compares the airspace of the 2010 Approved Cell Design with the proposed design.

Table 1: Cell Airspace

	Consolidated PCCS Part 3A Approval Design Airspace (cu.m.)	Proposed Design Airspace – rounded (cu.m.)	Approximate Airspace Gained (cu.m.)
Cell	1 593 100	1 843 100	250 000
Cell 2	26 300	26 300	0
Total	***1 619 400 (rounded to 1,650,000)***	***1 869 400 (rounded to 1,890,000)***	***250 000***

The containment cell footprint remains unchanged at approximately 19.4 ha.

2.2 Landform Features

A plan view of the proposed landform is shown in Figure 1 and cross-sections of the proposed landform are shown in Figure 2.

As shown in the figures, the proposed landform comprises cell batters with a slope of 5(H):1(V) and a cell platform with a surface slope of 2% (2 m fall over 100 m). The cell height increase has been achieved by a height increase of 2.5 m at a batter slope of 5(H):1(V) with a setback of 25 m from the western batter and a height increase by an additional 2.5 m at a batter slope of 5(H):1(V) with a setback of 50 m from the top of the first 2.5 m raise.

The cell platform has an area of 6.5 ha, including the small set back batters. The peak of the landform is located in the eastern part of the cell platform. The cell batters occupy approximately 12.9 ha.

Table 2 below provides a comparison of the landform features of the Consolidated PCCS Part 3A Approval Design and the proposed design. It can be seen from the table that the proposed design has a platform area that is approximately 1.9 ha smaller than the platform area of the Consolidated PCCS Part 3A Approval Design.

Table 2: Cell Areas and Slopes

	Consolidated PCCS Part 3A Approval Design	Proposed Cell Expansion Design
Platform slope	2%	2%
Batter slope	5(H):1(V)	5(H):1(V)
Batter area (Ha)	11.0	12.9
Platform area (Ha)	8.4	6.5
Total area (Ha)	19.4	19.4

The batters are highest on the western side of the cell, with heights varying from 17 m to 24 m above proposed surrounding ground levels. The height of the western batter has not been modified by this expansion. The eastern batter is generally smaller than the western batter, with the batter height ranging from 15 m to 18 m above proposed surrounding ground levels.

One additional bench has been designed for part of the eastern batter. We intend to further assess the need for a bench on the remaining portion of the eastern batter during detailed design. The primary purpose of the benches is to provide additional slope stability for the high western batter and to interrupt the flow of surface water down the batter slope, thus reducing flow velocity and erosion potential.

Surface water management on the cell platform is achieved by collection and diversion of water flowing from the landform peak towards surface water 'drop structures'. The detailed layout of the surface water diversion structures on the platform and the drop structures will be developed during the detailed design stage, but is likely to comprise berms as has been the case in the detailed Consolidated PCCS Part 3A Approval Design.

Water management on the cell batters is generally as follows:

- stormwater on the eastern batter located above the bench will be partially collected in the bench and diverted towards either the drop structure on the western batter or the perimeter drains;
- stormwater on the majority of the eastern batter located below the bench will flow towards the surface water perimeter drains surrounding the cell;
- stormwater on the western batter will be partially collected in the benches and diverted towards either the drop structure on the western batter or the perimeter drains; and
- stormwater falling on the western batter below the lowest bench will flow directly into the perimeter drains.

A provision for vehicular access to the cell platform has been provided along the eastern batter of the cell. This has been achieved by flattening the cell batter along a 16 m wide corridor at a gradient of 16%, which should provide an acceptable grade and width for road access.

2.3 Cell Filling Sequence

The filling sequence outlined in the Consolidated PCCS Part 3A Approval Design has been followed to date. Filling of the cell is ongoing, with levels in some parts of the cell approaching the Consolidated PCCS Part 3A Approval Design levels.

It should be noted that the cell filling sequence will be flexible to allow for changes in the volume of contaminated material received from across the site. Any changes to the proposed final landform resulting from less than 250 000 cu.m. of contaminated materials requiring placement in the cell would be consistent with the design parameters and slope angles outlined in this report.

2.4 Land Use

The proposed land use for the containment cell remains the same as for the Consolidated PCCS Part 3A Approval Design, being passive recreation/open space use.

The concept design of the containment cell landform has been developed, however, such that additional land uses are feasible from an engineering standpoint. Specifically, the landform is considered suitable for development of playing fields and associated amenities, with the platform area reduced when compared to the Consolidated PCCS Part 3A Approval Design. The potential for a playing field land use was recognised in the Aug 2012 and the Dec 2012 s75W Modifications, but any actual land use will need to be the subject of any further planning applications as required by applicable planning controls at the relevant time.

3.0 ENGINEERING CONSIDERATIONS FOR PROPOSED LANDFORM

3.1 Cell Platform Settlement

Construction of the cell to the proposed increased cell height for the concept design will result in increased vertical stresses within cell materials and underlying soil. The effect of these increased stresses has been considered with respect to cell platform settlement, as discussed in this Section, and also with respect to landform slope stability (refer Section 3.2) and leachate collection system pipe stability (refer Section 4.3).

The increased stresses will affect differential settlement of the cell platform surface and the potential for poor surface drainage or local surface grade reversal (i.e., ponding). Therefore, the concept design included a settlement assessment based on the platform design slope of 2%. The assessment (Appendix A) concludes that the anticipated performance is acceptable. Specifically, the assessment concludes that the calculated maximum long-term surface settlement is less than 600 mm and that the calculated surface slope remains greater than 0.5% in all areas, indicating low risk of unacceptable drainage performance or ponding. This issue will also be managed through an inspection, monitoring and maintenance program after construction (refer Section 3.5).

3.2 Slope Stability

Slope stability of the containment cell is governed primarily by the cell landform geometry, seismic loading parameters, and site geotechnical conditions. The concept design for the cell expansion is based on the same seismic loading parameters used in the Consolidated PCCS Part 3A Approval Design, but includes changes to the cell landform geometry, as described below. Therefore, a slope stability assessment has been conducted for the proposed cell expansion design.

The assessment considered both static and seismic loading conditions using the same analysis methodology as for the 2008, 2010 and the Consolidated PCCS Part 3A Approval Design and focussing on the stability of the highest cell batter, i.e., along the western edge of the cell. Compared to the Consolidated PCCS Part 3A Approval Design, the maximum cell batter height remains the same (24 m). However, the cell height has been increased by 2.5 m with a setback of 25 m from the western batter and by an additional 2.5 m with a setback of 50 m from the top of the first 2.5 m raise. Due to the setbacks of the raises, the slope instability factors of safety will essentially remain the same. The analyses used the shear strength of emplaced cell materials based on the results of the ongoing compaction density testing during cell filling, which indicate that an average density of 103% of standard maximum dry density has been achieved (Golder 2011), and on results of recent in situ testing.

The slope stability assessment (Appendix B) concludes that acceptable levels of overall slope stability are achieved for the proposed cell expansion design.

3.3 Surface Water Management on Cell

The surface water management approach and design features for the proposed cell expansion are substantially the same as those in the Consolidated PCCS Part 3A Approval Design. Required changes are summarised in the points below.

- Some features, such as the drop structures that convey water down the cell batter, will require realignment and lengthening during detailed design to suit the new landform.
- Features to assist in directing water on the cell platform surface toward the drop structures will require modification to suit the revised cell platform shape and the small batters located on the cell platform. The design of these features will be developed during detailed design and may comprise small surface berms as for detailed design prepared for the Consolidated PCCS Part 3A Approval Design.
- An additional bench has been designed on part of the eastern cell batter to manage surface water flow given the increased batter height.

These changes are considered feasible, and relatively minor, and will be further developed during detailed design.

3.4 Mine Subsidence

The concept design for the cell expansion does not affect the ability of the cell to tolerate deformations from mine subsidence. This is discussed below for the key components at the cell base and cap.

- The severity of deformation that could occur due to potential mine subsidence beneath the cell is related primarily to the dimension and location of the mining voids that could potentially collapse, and not to the overall ground stress conditions. Therefore, stress changes related to the cell height increase are not anticipated have a significant effect on the risk of deformation from mine subsidence.
- The cell expansion design does not alter the design or specification of the soil materials and pipes in the cell base and leachate collection system from that in the Consolidated PCCS Part 3A Approval

Design. Therefore, the ability of these materials to tolerate deformations from mining subsidence is unchanged and remains acceptable.

- The cell expansion design does not change the design or specification of the capping system materials from that in the Consolidated PCCS Part 3A Approval Design. Therefore, the ability of these materials to tolerate deformations from mining subsidence is unchanged and remains acceptable.

In summary, cell performance with respect to potential mine subsidence will not be significantly affected by the cell expansion design because there are no significant changes likely to occur in the magnitude of mine subsidence-induced deformations and the deformation resistance of the key cell components.

3.5 Post-Construction Operation and Maintenance

After the construction of the containment cell is complete, a program of inspection, monitoring and maintenance will be conducted. This program will provide additional management of design issues associated with the cell landform such as settlement, slope stability, surface water drainage, and capping system stability, as discussed in the preceding sections.

The existing Cell Operation and Maintenance Plan (COMP) (Golder, 2008) will be updated at an appropriate time prior to cell expansion construction in order to suit the features of the cell expansion design. This update should also include certain features of the capping system as identified in the August and December 2012 s75W Modifications and in any modification granted for the proposed expansion in this report.

4.0 EFFECT ON EXISTING CELL INFRASTRUCTURE

4.1 Surface Water Management

Management of surface water around the containment cell perimeter will not be affected significantly by the proposed cell expansion. Specifically, no significant changes to the alignment and flow capacity of perimeter drains will be required because the containment cell footprint remains the same. Overall runoff volumes internal and external to the cell footprint will remain the same.

The philosophy of cell surface water management as outlined in Section 2.2 is not altered by the cell expansion. Surface water management features on the cell will require relatively minor changes as indicated in Section 3.3.

4.2 Groundwater Management (Cutoff Drains)

The design of the upgradient and downgradient groundwater cutoff drains remains the same as in the Consolidated PCCS Part 3A Approval Design. The drains comprise 600 mm wide gravel-filled trenches with 160 mm HDPE collection pipes at the trench base. Groundwater is collected in five sumps (sumps A through to E) from where the water is pumped to a treatment system. The alignment of the drains is along the edge of the cell footprint. Construction of the upgradient drain and the downgradient drain is already complete.

The downgradient cutoff drain is designed to capture potentially impacted groundwater from below the cell within the shallow aquifer. The cutoff drain includes a filter geotextile on both sides of the aggregate drainage layer, as seepage into the trench may occur from both sides. The upgradient cutoff drain is intended to lower groundwater levels underneath the containment cell footprint.

The alignment, depth and design details of the cutoff drains are not affected by the proposed cell expansion design. This is because the cell footprint remains the same and therefore stresses and strains imposed on the drains are unchanged. In addition, no changes are required to drain inspection and monitoring points.

The overall amount of groundwater expected to be collected in the cutoff drains is not significantly affected by the proposed cell expansion design. This is because the drain alignment and depth remains the same and because the proposed design does not include any features expected to change overall groundwater levels.

4.3 Leachate Collection System

The design of the leachate collection system remains the same as in the Consolidated PCCS Part 3A Approval Design. The leachate collection system consists of a continuous 150 mm thick layer of drainage material, incorporating a network of high density polyethylene (HDPE) leachate drainage pipes with drainage aggregate surrounds. Construction of the leachate collection system is already complete for the majority of the cell.

The cell expansion design results in increased stresses acting on some leachate collection pipes due to the increased cell height. Compared to the Consolidated PCCS Part 3A Approval Design, the maximum height of cell material overlying the pipes is increased from 20.7 m to 24.5 m. Therefore, the concept design includes pipe stress analysis to assess the effect of the increased loading. The analysis indicates that the leachate collection pipes remain suitable to withstand the loadings imposed by the proposed cell expansion (Appendix C), with a minor exceedance of one of the previously adopted criteria.

The leachate collection system includes pipe inspection and clean out points. No changes are required in these points as a result of the cell expansion design, with the exception of one clean out point located on the cell platform. This is due to the fact that they are located along the edge of the cell footprint and will remain accessible because the cell footprint remains the same.

The maximum flow rate expected for leachate collected in the leachate collection system is not significantly affected by the proposed cell expansion design. This is because leachate is generated principally from rainwater infiltrating through the containment cell cap and the area of the cap remains the same.

4.4 Groundwater and Leachate Treatment

The design and management approach for collected groundwater and leachate remains the same as in the Consolidated PCCS Part 3A Approval Design. Groundwater extracted from the cutoff drains as well as leachate collected from the leachate collection is delivered to an Effluent Treatment Plant (ETP).

The ability of the ETP to treat contaminated leachate and groundwater from the cell may be affected generally by two factors: (a) an increase in average or peak flow rate of water requiring treatment, if above the plant capacity; or (b) a change in inflow water quality, if outside the specified treatment range. With respect to the first factor, required treatment flow rates are not expected to be significantly affected by the cell expansion design as discussed in Sections 4.2 and 4.3. With respect to the second factor, there is no reason to believe that additional materials to be placed in the cell would be of different composition to materials already placed in the cell and therefore the composition of water to be treated in the ETP is not expected to be affected significantly by the proposed cell expansion.

In summary, no changes are required to the water treatment approach and ETP design as a result of the cell expansion.

4.5 Landfill Gas Collection System

The landfill gas collection approach and design features for the proposed cell expansion are substantially the same as those in the Consolidated PCCS Part 3A Approval Design. The system comprises a number of gravel- filled trenches and gravel blanket collection areas, incorporating gas collection pipes, beneath the capping system in the cell platform area. A riser pipe in each gravel blanket area vents any captured gas.

Required changes for the cell expansion design are summarised in the points below.

- Some blanket collection areas and riser pipes will require relocation to suit the cell platform area of the proposed landform.
- Some collection trenches will require realignment to suit the cell platform area of the proposed landform.

These changes are considered feasible, and relatively minor, and will be further developed during detailed design.

5.0 LIMITATIONS

Please refer to Appendix D for limitations relating to this report.

Report Signature Page

GOLDER ASSOCIATES PTY LTD

Daniel Dohle	Gary Schmertmann
Senior Waste Management Engineer	Principal Geotechnical Engineer

DD/GRS/df

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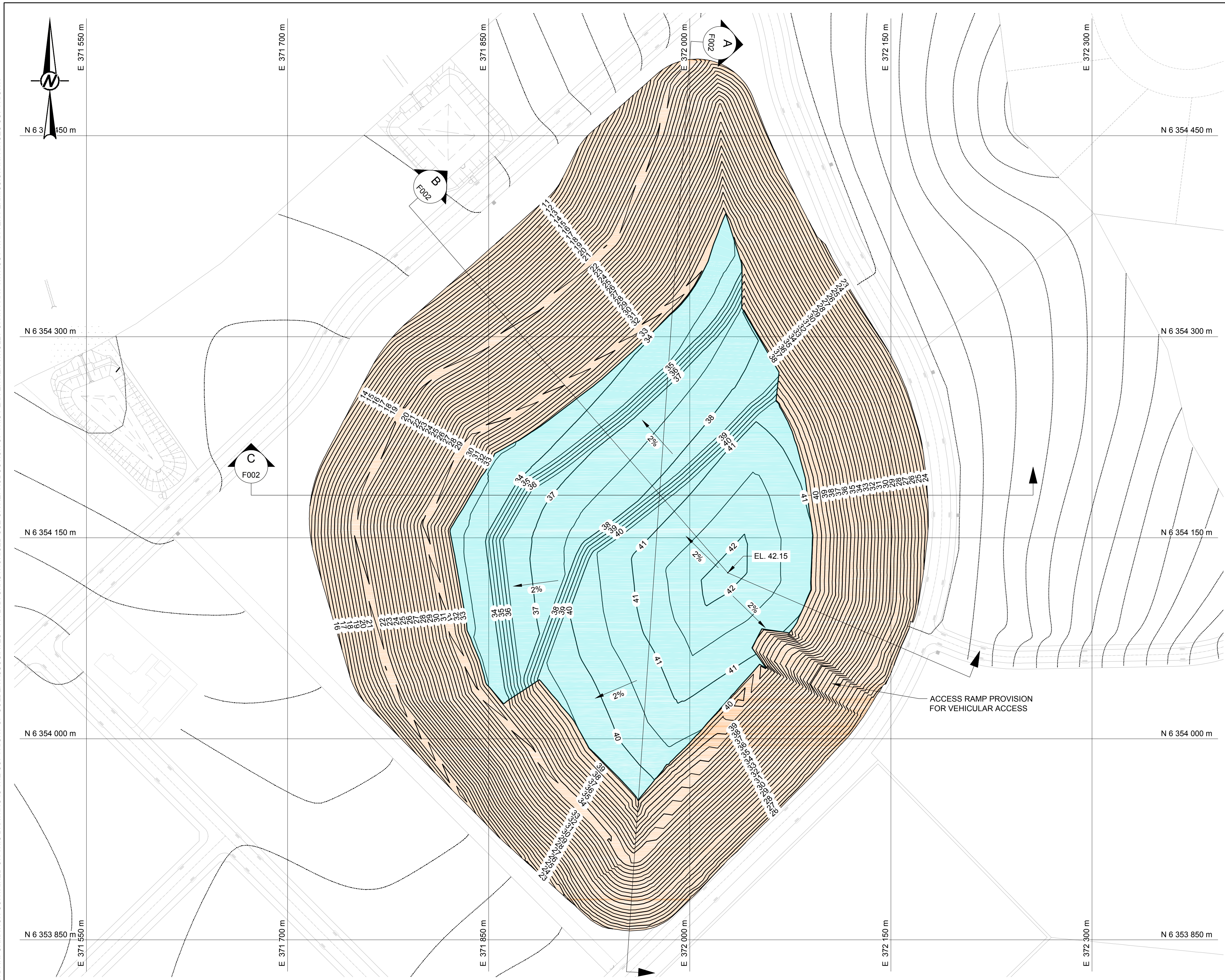

LEGEND

- AREA OF PLATFORM CAPPING SYSTEM (GEOMEMBRANE) (REFER DETAIL ON F002)
- AREA OF BATTER CAPPING SYSTEM (COMPACTED CLAY) (REFER DETAIL ON F002)

NOTE: DRAFT, SUBJECT TO ONGOING ENGINEERING CALCULATIONS.

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DRAFT

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DRAWING REFERENCES:

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	CHECKED BY: DD	DATE: 15.10.2013		
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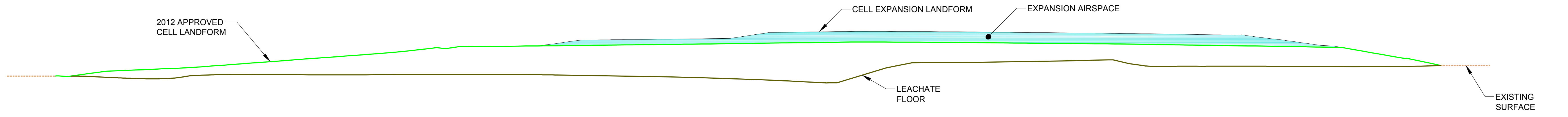

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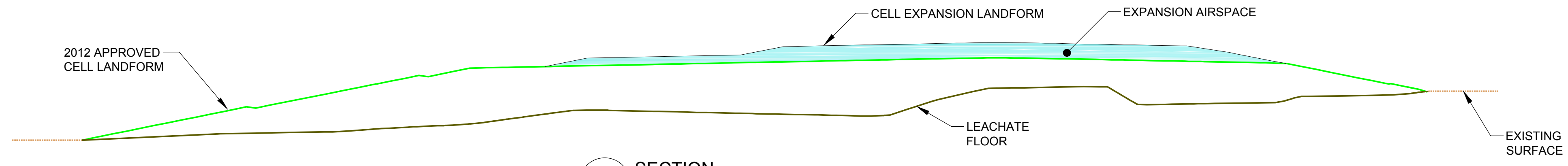

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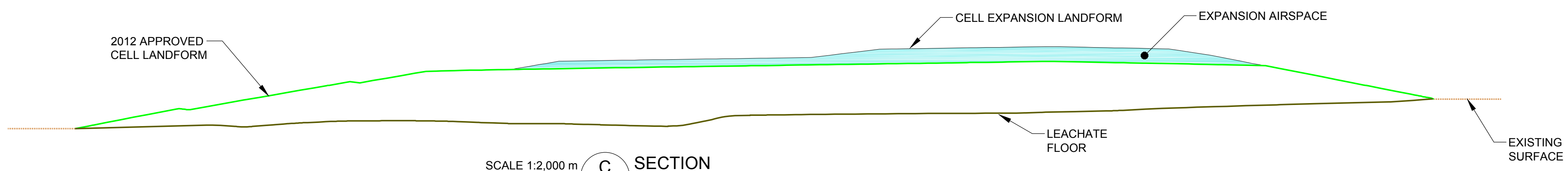

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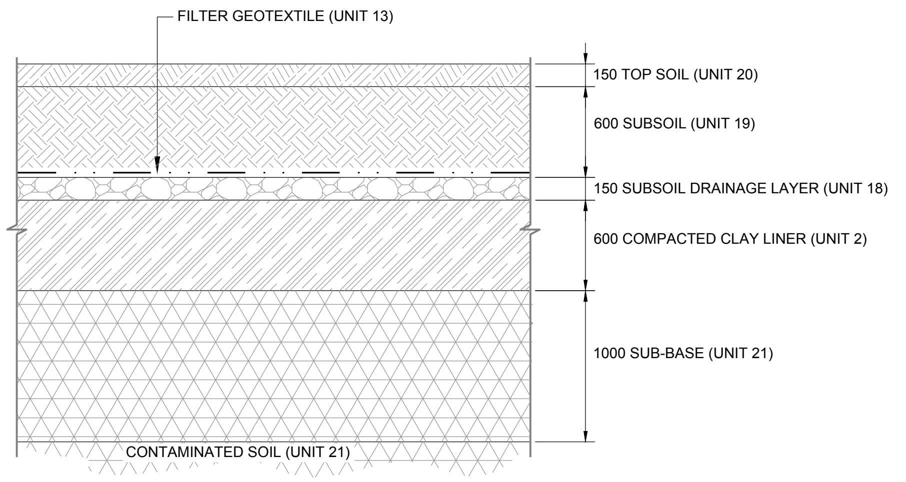

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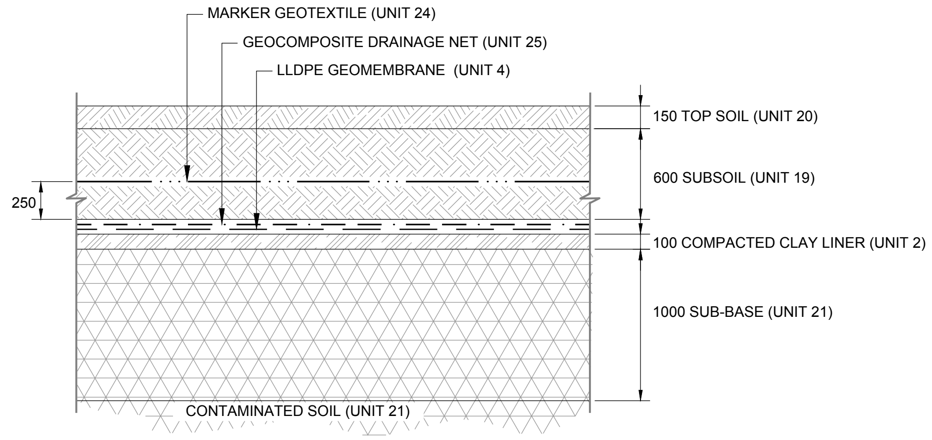

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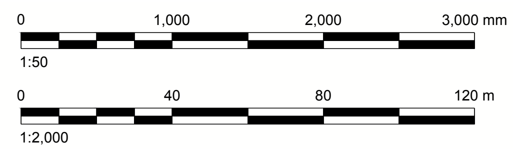

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www.golder.com GOLDER ASSOCIATES PTY. LTD.	SCALE: AS SHOWN		SHEET SIZE: A3	PROJECT No: 137625003	DOC No: 036	DOC TYPE: L	FIGURE No: F002	REVISION: 0	FIGURE 2

APPENDIX A

Cell Settlement Calculations

October 2013 Project No. 137625003-042-L-Rev0

Mr Wayne Woodward
Ferrier Hodgson
PO Box 42
Boolaroo NSW 2284

PROPOSED EXPANSION OF PASMINCO CONTAINMENT CELL – ASSESSMENT OF CELL PLATFORM SETTLEMENT

Dear Wayne

This letter concerns the proposed expansion of the Pasminco Cockle Creek Smelter (PCCS) containment cell to accommodate approximately 250 000 cubic meter (cu.m.) of additional contaminated material. This letter presents an assessment of potential settlements on the cell platform of the proposed expanded cell.

1.0 BACKGROUND AND PURPOSE

The relatively flat portion of the top of the PCCS cell landform is referred to as the 'cell platform'. The currently approved slope of the cell platform is 2% as per the August 2012 s75W Modification. Golder previously performed two assessments and concluded that there was low risk of surface ponding due to settlement of the cell platform if sloped at 2%:

- Golder letter 06623099-674-L-Rev0, dated 5 Sept 2011,submitted as supporting information for the August 2012 s75W Modification (Golder 2011)
- Golder letter 06623099-801-L-Rev0, dated 28 September 2012, submitted as supporting information for the December 2012 s75W Modification (Golder 2012).

The currently proposed expansion of the PCCS cell comprises changing the cell landform by raising the cell height and maintaining the 2% slope of the cell platform. The increased cell height will result in increased compression of cell materials and underlying foundation soils and increased settlement potential for the cell platform surface.

The purpose of this letter is to present the results of an updated settlement assessment that reflects the proposed cell expansion landform.

As with the previous assessment, the updated assessment has been undertaken to assess likely settlements and risk implications for the cell platform surface. The main performance issue associated with the cell platform slope is the potential for localised grade reversal and associated ponding on the cell surface. Very small gradients and/or ponding on the cell platform could increase maintenance costs and/or affect the future potential use of the cell. Sustained ponding could also result in increased water infiltration into the containment cell and increased leachate generation.

2.0 ASSESSMENT METHODOLOGY

The updated assessment has been performed using the same methodology as in the previous assessments (Golder 2011, 2012). The methodology is described below in text sourced from the previous assessments with relevant revisions.

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Settlement predictions for the PCCS containment cell have been assessed using simplified methods based on estimated material compressibility input parameters. The reliability of these input parameters is relatively low given there is limited investigation and testing data which can be used to correlate against material compressibility. Also, the spatial distribution of boreholes is limited, the intrinsic variability of site materials, including fill materials, is relatively high and localised soft materials could exist along narrow relic drainage channels that may be potentially present within foundation soils.

The uncertainties in material compressibility are partly mitigated because we understand that the site preparation process undertaken by PCCS involves treating known unsuitable cell foundation areas. This involves removing areas of known near-surface soft soil and sludge materials within the cell footprint and replacing these with controlled fill, including crushed concrete. Other areas of existing fill underlying the proposed waste cell materials have been improved using High Energy Impact Compaction (HEIC). These preparation processes have been documented in milestone submissions by PCCS and other project stakeholders.

Considering the input uncertainties, the reliability of the settlement calculations should be regarded as approximate and some contingency for settlement-related maintenance should be allowed for when making planning decisions about the future site use.

The following tasks have been undertaken to provide estimates of future cell surface settlements:

- Review existing data to understand the type and distribution of materials and potential for buried compressible channel features, and to select cross sections for analysis;
- Estimate engineering properties of site materials based on available geotechnical and construction quality control data (laboratory compaction and grading tests, geotechnical investigation data);
- Base Case: Calculate one-dimensional cell surface settlements using proprietary spreadsheet software 'PCON' at representative locations, due to cell fill self-weight and compression of underlying materials; and
- Sensitivity Case: Estimate the local surface settlement profile that could potentially develop above a compressible foundation zone, e.g. softened natural materials representative of a soft clay channel underlying the cell fill. Superimpose the local settlement profile on the one-dimensional settlement results from the Base Case. We note that the risk of unsuitable compressible material occurring within the future cell fill is low due to the specification and testing regime applied to the cell material during placement.

We consider this simplified approach is appropriate for this assessment, taking into consideration the input uncertainty.

3.0 INPUTS AND ASSUMPTIONS

The updated assessment has been performed using the same inputs and assumptions as in the previous assessments (Golder 2011, 2002), with updated cell landform geometry for the proposed cell expansion. The inputs and assumptions are described below.

Based on our review of site investigation data and published correlations and technical papers, a geotechnical model has been developed, incorporating material compressibility values as shown in Table 1 below.

Table 1: Geotechnical Model and Input Parameters

Unit No.	Description	Stiffness E' (MPa)	Coeff. of Compressibility, Mv (m^2/MN)	Coeff. of Consolidation Cv (m^2/Yr)	Compression Index, Cc/(1+e0)	Creep Index, C∝ (%)	Unit Weight (Saturated), kN/m^3
1	New Cell Fill (Silty Clay)	20	0.037	-	-	0.3	17
2	In-Situ Fill (Mainly granular)	30	0.025	-	-	0.2	19
3	Existing Landfill (former plant refuse)	-	-	2	0.058	1.0	11
4	Residual Soil	30	0.025	-	-	0.15	18
5	Bedrock	Assumed incompressible					

Note: Some materials such as those previously referred to as ISF and LBF stockpiles and sludge have been omitted due to them either having been removed as part of the cell filling process, or not inferred to occur at analysed locations.

Key analysis assumptions are as follows:

- Waste cell fill is placed rapidly, and is homogeneous;
- In previously filled areas of in-situ fill and existing landfill, the effects of historic preloading are conservatively ignored;
- No live load is applied to the new cell fill surface; and
- Groundwater level is assumed constant at RL-15m AHD.

Two cross sections (A and B) were selected for settlement analysis, as shown on Figures 1 and 2. Please note that the cell landform geometry shown in Figures 1 and 2 is the 2011 cell geometry and has been updated for this assessment to reflect the proposed cell expansion landform shown in Figure 3, including the 2% cell platform slopes. Along both of these sections, points at borehole locations were selected for one-dimensional settlement analysis, with results projected onto the nearest relevant cross section. The analysis locations have been selected to target relatively ‘hard’ and ‘soft’ profiles to enable assessment of locations having the greatest potential for differential settlement. Each location analysed along the respective cross sections is shown highlighted in yellow on Figure 2, attached.

A graphical representation of the subsurface profile at each analysed location along the sections is provided in Figure 4.

Settlement at the cell landform peak, which lies between borehole locations A10 and A11 on cross section B (Figure 2), has been interpolated between the calculated settlements at locations A10 and A11. This assumption is conservative in that the peak of the proposed expanded landform is positioned near the crest of the batter of the underlying lead blast furnace slag (LBF) monolith, a stockpile of solidified slag, (refer Figure 2) and is therefore expected to undergo relatively small settlement. It is generally conservative to overestimate settlement at the landform peak when considering the risk of ponding on the cell platform.

Settlement at borehole location A10 on cross section B (Figure 2) has been assumed to be zero. This assumption is conservative because the actual settlement of the fill at this location will be greater that zero. It is generally conservative to underestimate settlement to the east of the landform peak when considering the risk of ponding due to poor eastward drainage on the cell platform.

4.0 RESULTS AND DISCUSSION

Analyses were undertaken to quantify settlements along sections A and B at future time intervals after full-height cell filling for the Base Case and the Sensitivity (soft spot) Case. To capture settlement at future time intervals due to on-going creep and consolidation, settlements have been calculated at nominal time intervals of 1, 10, 20 and 50 years. Overall settlement-induced changes in slope of the cell platform are calculated by comparing the difference in settlement between adjacent locations to the horizontal distance between the locations.

Base Case

Calculated long-term one-dimensional settlements at various locations are in the general range of 200 mm to 600 mm. Calculated long-term overall slope changes on the cell platform range from 0.2% steeper to 0.5% flatter, which can be compared to the design grades of 2%.

Sensitivity Case

We note that the calculations done to explore how local surface settlement profiles are influenced by ground movements at depth involved adapting empirical methods which predict settlement troughs above tunnels of various sizes, as described by CIRIA Report No. 30[1].

To estimate the influence of various sizes of possible buried soft spots on surface settlements, the CIRIA method was then used to reproduce the predicted soft layer settlements to estimate the resulting surface settlement depression. Soft zones of varying width were then assessed to explore the sensitivity of surface settlements to soft zone size (Refer Figure A, below).

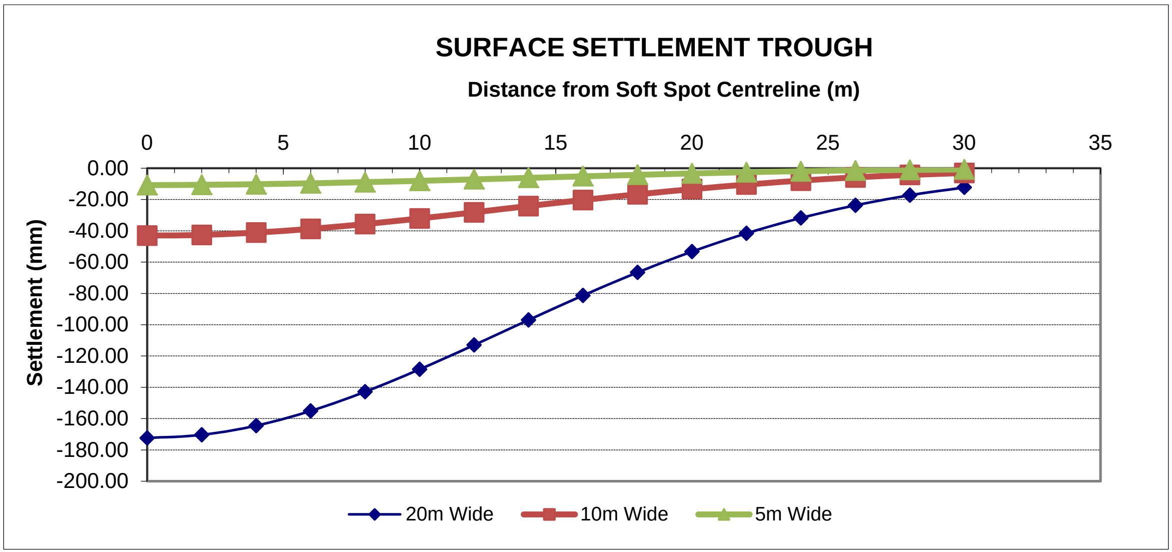


Figure A: Estimates Surface Settlements for Soft Zones of Varying Width.

On the assumption that it is reasonable to allow for a 2m thick softened zone in natural materials underlying the cell with a thickness of 2m and a maximum width of 10 m, the shape of the resulting settlement trough at the surface is shown in the central line in Figure A, above. The maximum slope of this trough profile is approximately 0.6%.

Superimposing the calculated maximum overall slope change from the Base Case, 0.5%, on the calculated maximum local slope from soft spot settlement, 0.6%, results in a maximum slope change of 1.1%. Applying this slope change to a 2% design slope of the cell platform indicates that the residual gradient would remain satisfactory at approximately 1%.

[1] CIRIA Report 30 (1996) Prediction and effects of ground movements caused by tunnelling in soft ground beneath urban areas

Consideration of Ponding Risk

Although these calculations provide a basis for estimating the magnitude and extent of settlements, to make rational management decisions it is necessary to consider the impact of settlement in terms of a risk management framework. Given the uncertainty of input variables and simplified nature of this study, it is appropriate to consider risk in terms of qualitative rather than quantitative terms.

Qualitative risk can be expressed using the widely accepted approach and terminology presented in the AGS landslide risk management framework[2]. Table 2, below provides a guide to the risk of ponding on the cell platform considering the estimated likelihood of the calculated settlements occurring, and the potential consequences of these settlements in the event that they occur.

Table 2: Risk Summary

Initial Slope of Cell Platform	Likelihood of ponding[1]	Consequence[2]	Risk (=Consequence x Likelihood)
2%	Unlikely	Minor	**Low** – Usually acceptable, ongoing maintenance may be required.

Notes: 1. Likelihood: Rare: The event is conceivable but only under exceptional circumstances over the design life
Unlikely: The event might occur under very adverse circumstances over the design life
Possible: The event could occur under adverse circumstances over the design life

2. Consequence is assumed to be 'minor' (i.e. limited damage to part of the site requiring some reinstatement works). Note: If loss of potential suture land use amenity is considered then these risk levels may increase.

This qualitative risk assessment indicates that use of a slope of 2% for the cell platform is a reasonable design approach, associated with a low risk of ponding. This approach implicitly accepts the potential need for cell inspection and maintenance to address ponding risk.

5.0 CONCLUSIONS AND RECOMMENDATIONS

This report contains a basic quantitative assessment of predicted surface settlements for the platform of the proposed PCCS cell expansion, including sensitivity to localised soft zones in underlying materials. To assist decision making, we have also provided qualitative risk assessment that considers the likelihood and consequence of predicted settlements.

Key outcomes are as follows:

- Calculations using the assumed input parameters indicate that long-term surface settlements on the cell platform after completion of filling to the proposed cell expansion landform are likely to be typically in the range of 200 mm to 600 mm. Settlements could potentially increase by approximately 100 mm if the cell is underlain by a hypothetical 10m wide, 2m thick soft clay zone.

- In terms of qualitative risk, the simplistic calculations indicate that there is a low risk of grade reversal causing widespread ponding following cell completion for the cell platform slope constructed with an initial 2% surface slope.

- To help manage this risk, we recommend maintaining current quality control requirements during construction to remove unsuitable natural materials at the cell foundation level and to provide high levels of compaction for the cell filling material. We also recommend monitoring of surface settlements by surface survey as per the Cell Operations and Maintenance Plan (COMP, Golder 2008), for a period of at least 5 years immediately following cell completion, or until it can be demonstrated that on-going settlements are within acceptable limits. The (COMP) should be updated appropriately to reflect the cell expansion landform geometry.

- In the event that structures, road/footpath infrastructure or utilities are constructed on the containment cell, we would recommend additional settlement studies are undertaken to assess potential settlement effects.

[2] Practice Note Guidelines for landslide risk Management 2007, Australian Geomechanics Society Landslide Taskforce, Landslide Practice Note Working Group, Australian Geomechanics Vol 42 No 1 March 2007

6.0 REFERENCES

Golder 2008 Golder Associates, *Cell Operation and Maintenance Plan, Containment Cell Construction, Former Pasminco Cockle Creek Smelter, Consultants Ref.: 06623099_081_RI4*, December 2008

Please contact the undersigned if you have any questions regarding this document.

GOLDER ASSOCIATES PTY LTD

Daniel Dohle
Senior Engineer

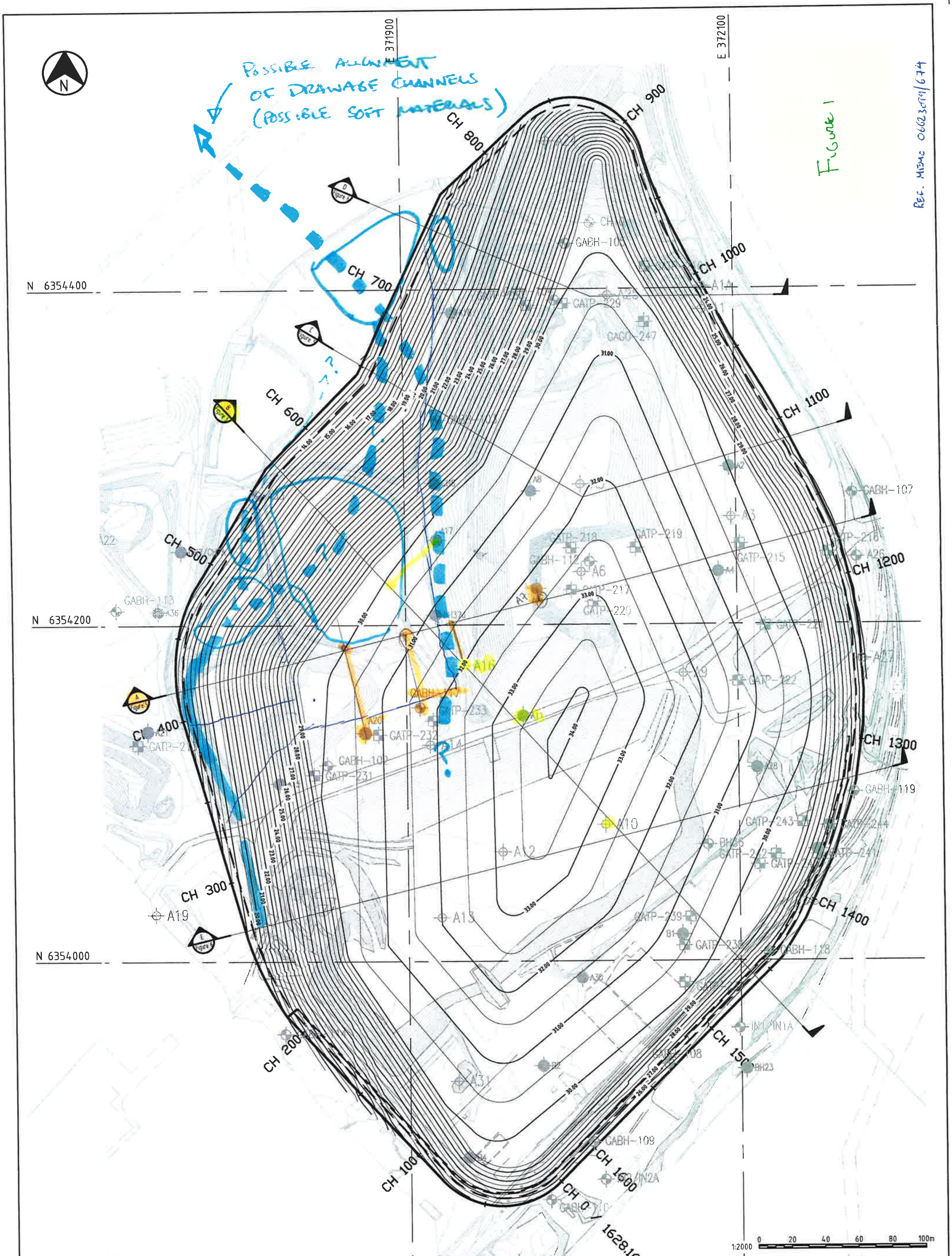
Gary Schmertmann
Associate

PD,DD/GRS/df

CC:

Attachments: Figure 1 – Site Plan and Location of Analysis Cross Sections
Figure 2 – Cross Sections
Figure 3 – Proposed Containment Cell Landform
Figure 4 – Subsurface Design Profiles
Limitations

j:\civ\2013\137625003_ferrier hodgson_rehabilitation_boolaroo\correspondence out\137625003_042_l_rev0 cell platform settlement for cell expansion.docx



DRAWING TAKEN FROM MONTEATH & POWYS
DRG. No. 04026AS.dwg DATED 03/11/06

Golder Associates
88 CHANDOS STREET ST. LEONARDS, N.S.W. 2065
Telephone (02) 9478 3900 Facsimile (02) 9478 3901

CLIENT	FERRIER HODGSON	PROJECT	PCC-CELL DESIGN
DRAWN	DAT 18.01.07	TITLE	GEOTECHICAL CROSS-SECTION PLAN
CHECKED			
SCALE	1:2000 A3	PROJECT No 06623099	FIGURE No FIGURE 7

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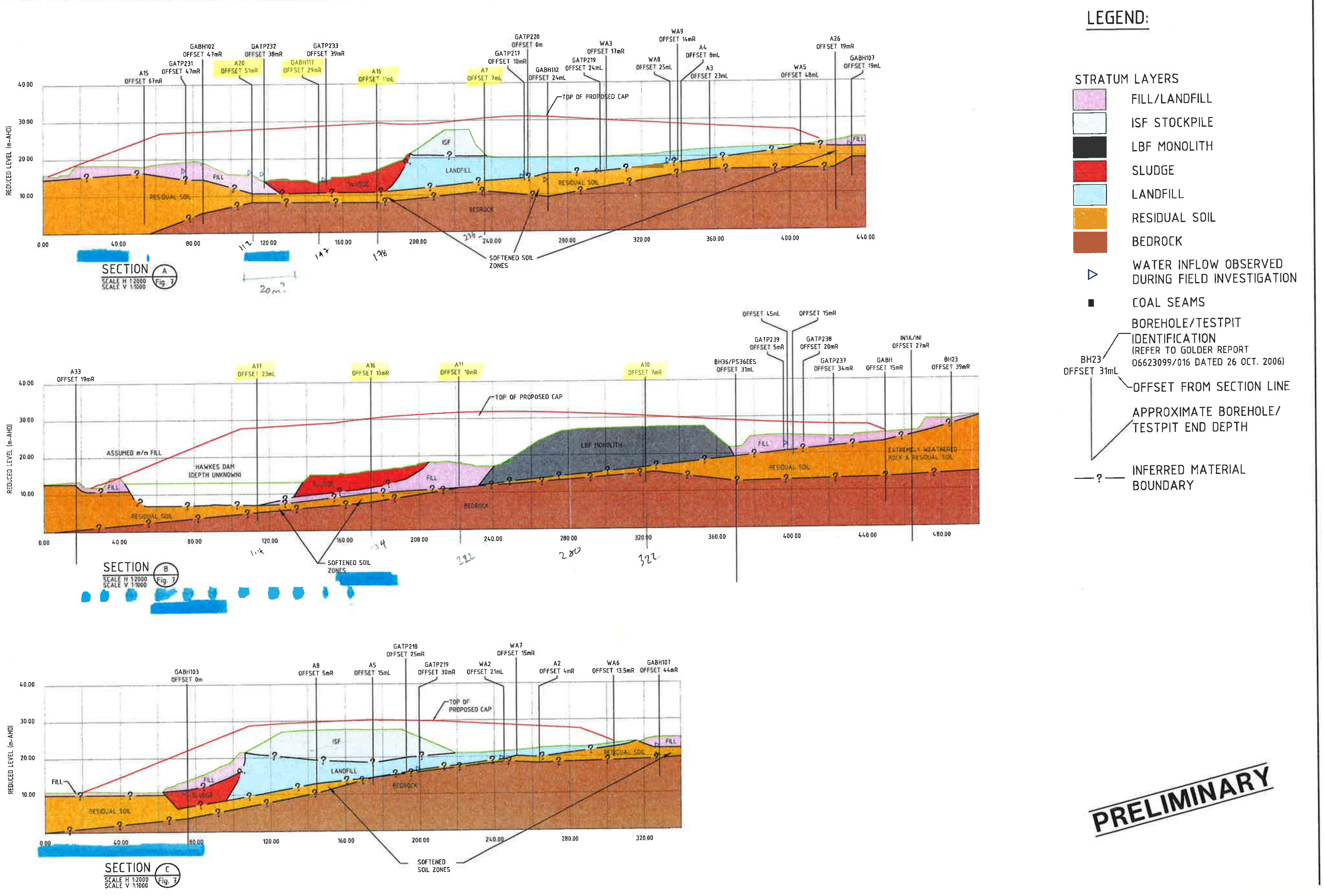

Golder Associates	CLIENT: FERRIER HODGSON	PROJECT: PCC-CELL DESI	
88 CHANDOS STREET ST. LEONARDS, N.S.W 2065	DRAWN: MJM 29.01.07	TITLE: INFERRED SUBSU CROSS- SECTIONS	
Telephone (02) 9478 3900 Facsimile (02) 9478 3901	CHECKED:		
	SCALE: AS SHOWN A3	PROJECT No: 06623099/F05	FIGURE No:

Figure 2

REF. MEMO 06623099/674

xref:- cadfile:- J:\\Sys1-s-file01\Jobs\06Pro\051-100\06623099 - Pasminco\DRAWINGS\Figures 027099F05.dwg

Borehole Profile / Cross Section Location

Depth below Finished Surface Level (m): 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27

Section A			Section A+B	Section B		
A7	A20	GABH117	A16[1]	A10[2]	A11	A17
Unit 1 New Fill (12m)	Unit 1 New Fill (13m)	Unit 1 New Fill (16m)	Unit 1 New Fill (14m)	Unit 1 New Fill (8m)	Unit 1 New Fill (18m)	Unit 1 New Fill (20m)
Unit 3 Existing Landfill (6m)	Unit 2 In-Situ Fill (4m)	Unit 1 New Fill (3m) – Replacing sludge	Unit 1 New Fill (4m) – Replacing sludge	LBF Monolith (11 m)	Unit 2 In-Situ Fill (5m)	Unit 4 Residual (2m)
Unit 4 Residual (2m)	Unit 4 Residual (2m)	Unit 4 Residual (2m)	Unit 2 In-Situ Fill (1m)	Unit 4 Residual (1m)	Unit 5 Bedrock	Unit 5 Bedrock
Unit 5 Bedrock	Unit 5 Bedrock	Unit 5 Bedrock	Unit 4 Residual (2m)	Unit 5 Bedrock		
			Unit 5 Bedrock			

Note:

1. Analyses have been undertaken for a) Base Case (as shown) and b) Sensitivity Cases, whereby Unit 4 (Residual Soil) was replaced with Unit 6 (Soft Clay) and modified for soft zone size.
2. All materials at A10 are considered as incompressible, which results in a conservative differential settlement outcome relative to this hard spot. Predicted settlements at the waste cell crest between A10 and A11 are interpolated between these locations.

Golder Associates

CLIENT Ferrier Hodgson		PROJECT Pasminco Cockle Creek Smelter Waste Cell	
DRAWN DD	DATE 23/10/2013	TITLE Feasibility Assessment for Platform Grades Design Profiles for One Dimensional Settlement Assessment	
CHECKED	DATE 23/10/2013		
SCALE NTS	A4	PROJECT No 137625003-042-L	FIGURE No 3

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APPENDIX B

Slope Stability Calculations

23 October 2013 Reference No. 137625003-046-L-Rev0

Mr Richard Bastow
Ferrier Hodgson
Level 29
600 Bourke Street
Melbourne VIC 3000

PROPOSED PASMINCO CONTAINMENT CELL EXPANSION DESIGN – SLOPE STABILITY MODELLING

Dear Richard

1.0 INTRODUCTION

This letter provides the results of additional slope stability analyses carried out for the proposed expansion design of the containment cell at the former Pasminco site.

This letter was prepared in accordance with your instruction for a cell expansion design, dated 18 September 2013.

2.0 BACKGROUND

Golder developed a geotechnical model for the containment cell as part of the 2008 Approved Design (Golder 2007). We carried out slope stability modelling on selected cross sections of the geotechnical model using the SLOPE/W software package, and reported outcomes in our letter report dated 08 March 2007 (Golder 2007).

Additional site knowledge was gained through geotechnical site investigations of areas for the potential occurrence of soft soils and through the remediation works carried out, which led to Golder refining the model in 2010 (Golder 2010).

In 2012, at the request of Ferrier Hodgson on behalf of Pasminco Cockle Creek Smelter Pty Ltd (PCCS) (Subject to Deed of Company Arrangement), Golder prepared a submission proposing an expanded landform to contain contaminated material from the adjacent IFL site to expand the total containment cell capacity to1.65 million cubic metres (cu.m.) (Golder 2012). The expansion design included slope stability modelling.

This letter should be read in conjunction with the above documents.

We understand that PCCS wishes to place up to an additional 250 000 cu.m of material in the PCCS cell, bringing the total containment cell volume to approximately 1 900 000 cu.m.

The expansion design (Golder 2013) provides a cell with a maximum final elevation of approximately RL 42.15 m AHD (reduced level in Australian Height Datum) compared to a maximum final elevation of RL 37.15 m AHD in the 2012 Design. Slope stability assessment is required to demonstrate that adequate design performance is achievable for the cell expansion design.

3.0 SCOPE OF SERVICES

We carried out the following tasks for this assessment:

- Slope stability analyses using the proposed design reduced levels (RLs) as per Figure 4 'Proposed Containment Cell Landform' as presented in Golder (2012a). Note: Figure 4 is provided as Attachment 1 to this letter.
- Sensitivity analyses for variation in undrained shear strength of subgrade materials such as sludge; and
- Interpretation and discussion of the slope stability results.

4.0 PREVIOUS SLOPE STABILITY ASSESSMENT

Previous stability assessments were carried out in January 2007 for five geotechnical cross sections along the cell, Sections A to E (refer Attachment 2 for location of sections which have been sketched on to the Robert Carr and Associates (RCA) site investigation plan). The assessment assumed a compaction of material placed in the cell achieved 90% of the Standard Maximum Dry Density Ratio (SMDD). The results of these previous stability assessments were presented in Golder (2007).

Additional stability analyses were carried out in March 2010 which took account of the site investigation information obtained by RCA regarding the extent of sludge material in the cell subgrade. The analyses were carried out for two critical sections, Section A and Section C, where the greatest sludge extents were inferred based on the RCA site investigation. The results of the assessments were presented in Golder memorandum 476 Rev0 (Golder 2010).

The results of the March 2010 stability analyses indicated that an acceptable factor of safety for slope instability during a seismic event could be achieved within three years following construction of the cell. This assessment estimated that there is an improvement of sludge shear strength over a 3 year period to an undrained shear strength of at least 40 kPa due to cell fill loading. However, if a seismic event occurs within three years of cell construction, there would be an increased risk of slope instability on the basis that the shear strength of the sludge material may be lower than the estimated shear strength of 40 kPa.

Based on our site supervision and information provided by you, we understand that the sludge material has been excavated by PCCS Services, the cell construction contractor, from the majority of the cell footprint and replaced with crushed concrete as part of the cell subgrade preparation works. No survey information verifying this is available apart from completion reports for high energy impact compaction.

5.0 REVISED SLOPE STABILITY ASSESSMENT

5.1 Landform

The slope stability analyses presented in this letter have been carried out for the critical sections (Section A and Section C) as shown in Attachments 3 and 4 to this report. The cell surface is modelled as per the design surface levels presented in Figure 1 in attachment 1, which is sourced from Golder (2013).

5.2 Parameters

Parameters and general assumptions for the assessment (soil parameters and seismic acceleration) are generally as discussed in Golder document 055 Rev0, Golder memo 476 Rev0 (Golder 2010) and letter 756_Rev0 (Golder 2012).As part of the 2012 letter, the inferred shear strength of the material placed in the containment cell was increased from 50 kPa to 75 kPa as a result of additional site knowledge and testing data.

Due to uncertainty as to the extent over which the sludge has been removed and replaced with crushed concrete, we have assumed the extent of the sludge material below the cell is as described in our memorandum 476 Rev0 (Golder 2010).

Drained shear strength parameters were used to assess the long term stability of the proposed containment cell batter slope. Undrained shear strength parameters were used to assess the short-term stability of the containment cell batter slope during a seismic event, under 50% of an unfactored peak site ground acceleration of 0.375g. Where existing landfill material and fill material above sludge is predominantly granular (gravel and sand), drained shear strength values were used in the seismic analyses.

6.0 RESULTS OF STABILITY ASSESSMENT

A summary of the results of the updated stability analyses is presented in Table 1, below. Figures are provided in Attachments 3 and 4.

Table 1: Summary of Results of Stability Analyses

Section ID	Conditions of Analysis		Seismic Ground Acceleration	Undrained Cohesion of Sludge	Calculated FOS value	Target FOS value**	Figure No.*
Section A	Long Term	Drained***	Nil	N/A	2.0	1.5	-
	Short Term	Undrained	Nil	15 kPa	2.5	1.3	1
	Short Term	Undrained	0.1875g	15 kPa	1.0	1.0	2
	Short Term	Undrained	0.1875g	40 kPa	1.0	1.0	3
Section C	Long Term	Drained***	Nil	N/A	1.8	1.5	-
	Short Term	Undrained	Nil	15 kPa	1.8	1.3	7
	Short Term	Undrained	0.1875g	15 kPa	***0.9***	1.0	8
	Short Term	Undrained	0.1875g	40 kPa	1.0	1.0	9

Note: FOS = factor of safety
Numbers in bold italics have lower FOS than target FOS
*Figures are attached to this letter
**FOS has been calculated using optimised slip surfaces
***Drained sludge parameters are based on an effective friction angle of 15 degrees

Based on this stability assessment, the stability of the cell batters is expected to be lowest during an earthquake event. The calculated FOS values for long term and short term stability (without earthquake loads) were greater than commonly accepted target factor of safety values.

For short-term earthquake stability case of Section C, the factor of safety is less than the target factor of safety of 1.0 when the unimproved strength of the sludge is modelled as 15 kPa. When the sludge has undrained shear strength of 40 kPa, the calculated factor of safety increases and the target factor of safety of 1 is achieved.

7.0 DISCUSSION OF STABILITY ASSESSMENT RESULTS

7.1 Section A

We consider that an acceptable factor of safety for slope instability under static (i.e. non-earthquake) conditions can be achieved. We consider that an acceptable factor of safety for slope instability during a seismic event can be achieved. For the seismic case this relies on improvement of sludge shear strength to an undrained shear strength of at least 15 kPa due to cell fill loading (as assumed in our initial assessment (Golder 2010)) or due to excavation and replacement of sludge.

7.2 Section C

We consider that an acceptable factor of safety for slope instability under static (i.e. non-earthquake) conditions can be achieved. We consider that an acceptable factor of safety for slope instability during a seismic event should be achieved within three years following construction of the cell. For the seismic case, this relies on improvement of sludge shear strength to an undrained shear strength of at least 40 kPa due to cell fill loading (as estimated in our previous assessment (Golder 2010)) or due to excavation and replacement of sludge. This is considered to be an acceptable situation given that in the three years prior to the sludge achieving the assumed undrained shear strength of 40 kPa, there is a 1 in 167 chance (0.6% of the design earthquake occurring. The design earthquake has an intensity of ground shaking that has a 10% chance of being exceeded within 50 years, which generally corresponds to an earthquake with a 500-year return period.

8.0 SUMMARY

The results of this slope stability assessment indicate that the proposed cell expansion design achieves acceptable levels of slope stability.

9.0 REFERENCES

Golder 2012a, *Concept Design Report, Expansion of Pasminco Cockle Creek Smelter Containment Cell,* Consultant's Reference 06623099-780-R-Rev0, September 2012

Golder 2010, *Slope Stability and Settlement Assessment*, Consultant's Reference: 06623099-476-M-Rev0, March 2010.

Golder 2007, *Containment Cell Detailed Design and Management Plan, Pasminco Cockle Creek Smelter, Boolaroo, NSW, Appendix D Rationale for Seismicity study and stability assessment*, Consultant's Reference 06623099-055, dated, March 2007.

Please contact us should you have any questions about this letter.

GOLDER ASSOCIATES PTY LTD

Daniel Dohle
Senior Waste Management Engineer

MK,DD/GRS/df

Attachments:

Attachment 1 – Proposed Containment Cell Land Form, Figure 4

Attachment 2 – Marked up RCA Figure – Plan showing location of geotechnical cross-sections

Attachment 3 – Results of Stability Analyses for Section A

Attachment 4 – Results of Stability Analyses for Section C

Attachment 5 – Limitations

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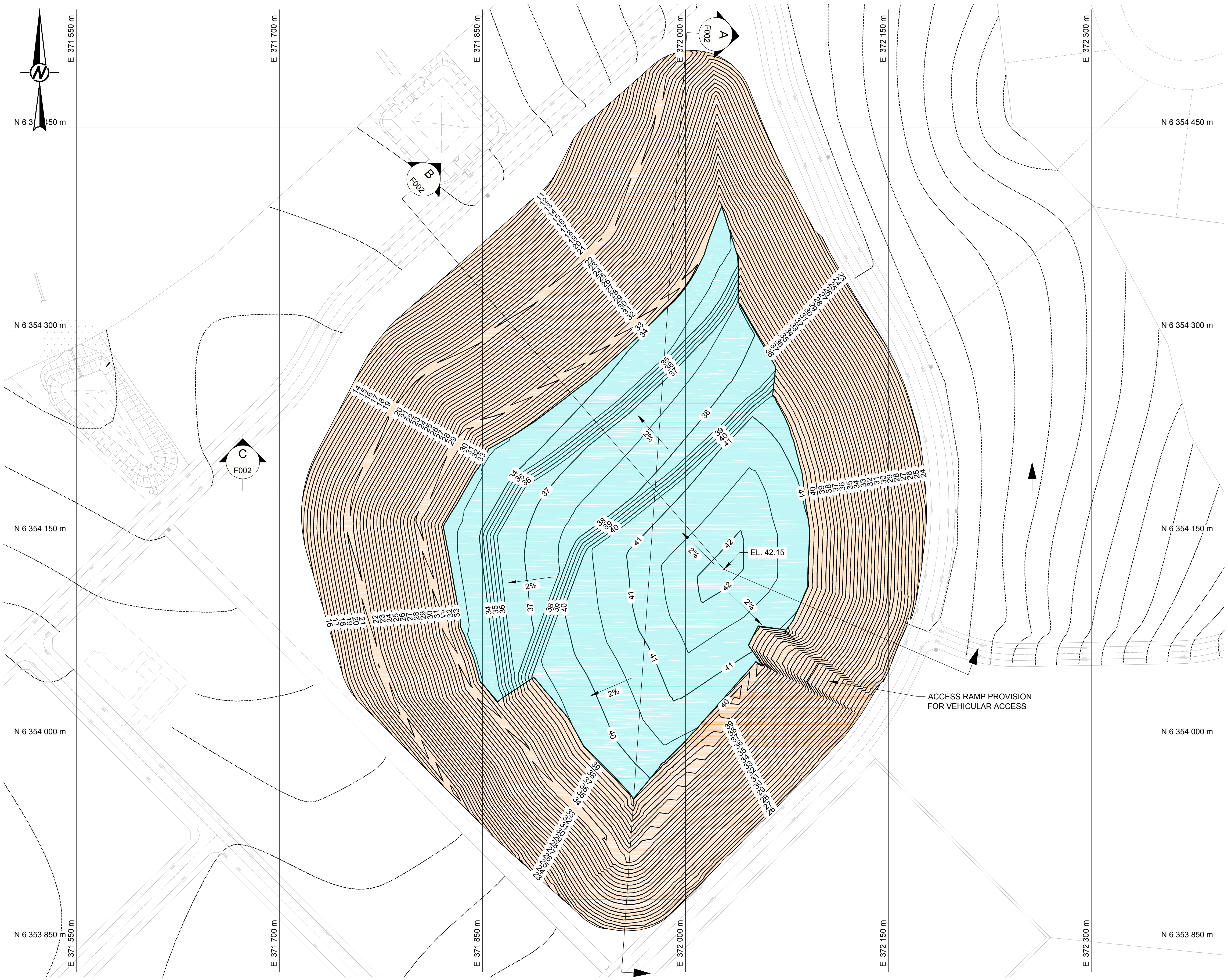
ATTACHMENT 1

Proposed Containment Cell Land Form



LEGEND

AREA OF PLATFORM CAPPING SYSTEM (GEOMEMBRANE)
(REFER DETAIL ON F002)

AREA OF BATTER CAPPING SYSTEM (COMPACTED CLAY)
(REFER DETAIL ON F002)

NOTE: DRAFT, SUBJECT TO ONGOING ENGINEERING CALCULATIONS.

NOT FOR CONSTRUCTION - ISSUED FOR

DRAFT

0 60 120 180 m
1:3,000

DRAWING REFERENCES:

ACOR DRAWING NO. X_080685_DA_MOD_BOUND280110.dwg, DATED 29TH JANUARY 2010 WITH
WARD CIVIL DRAWING 543TOTALCLAYBASE.B.dwg, DATED 19 FEBRUARY 2010 AND
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WARD CIVIL DRAWING 543FINALASBUILT.A.dwg< DATED 18 JANUARY 2010
PSSC EXCEL FILE DATA B2-4_SURVEYED 31 MAY 2012

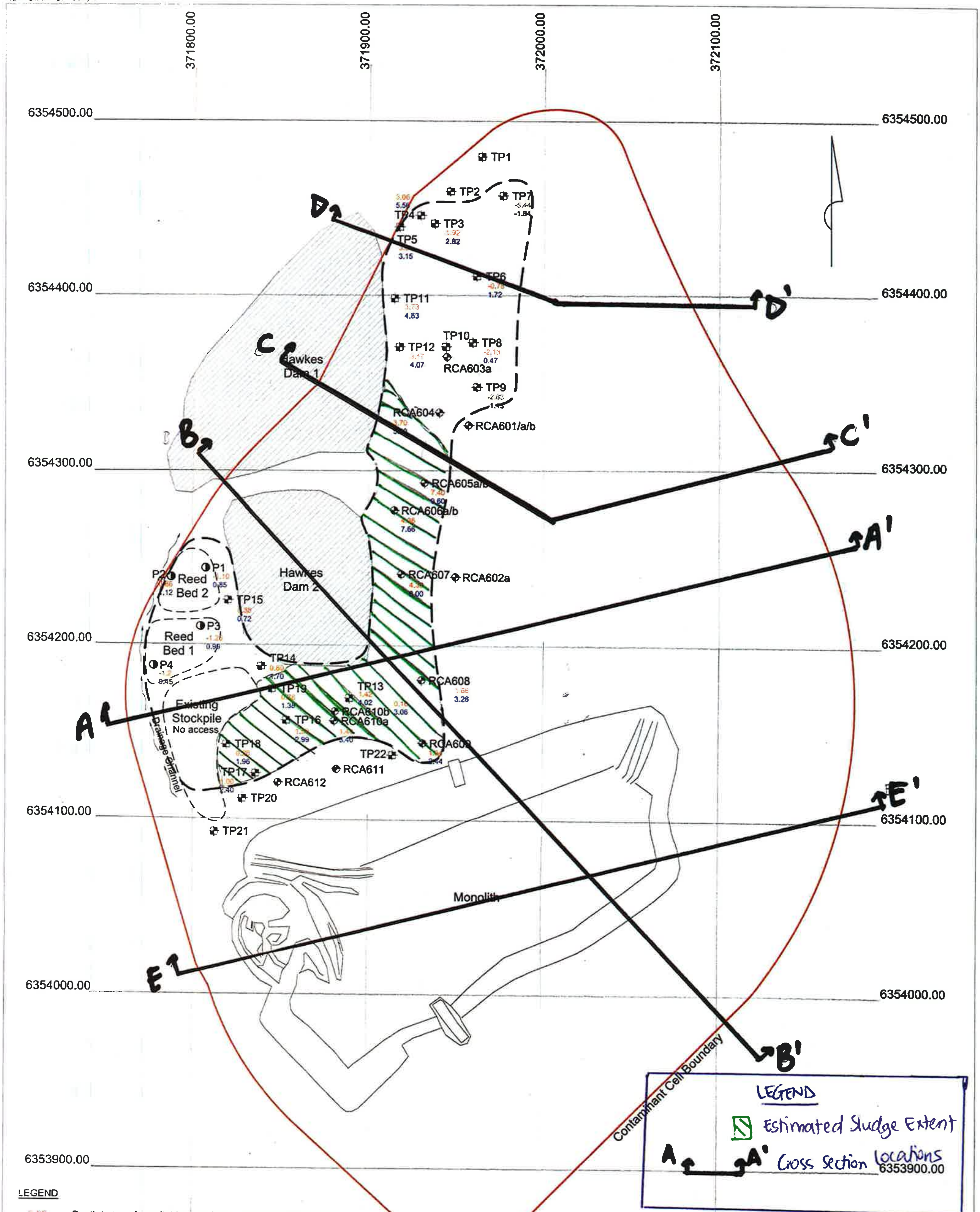
www.golder.com GOLDER ASSOCIATES PTY. LTD.	CLIENT: FERRIER HODGSON		PROJECT: PCCS - CELL EXPANSION	
	DRAWN BY: EJJ	DATE: 15.10.2013	DRAWING TITLE: PROPOSED CONTAINMENT CELL LANDFORM	
	CHECKED BY: DD	DATE: 15.10.2013		
	SCALE: 1:3000	SHEET SIZE: A3	PROJECT No: 137625003; DOC No: 036; DOC TYPE: L; FIGURE No: F001; REVISION: 0	FIGURE 1

Plot Date: 15 October 2013 Time:12:57:31 PM By: Jeet, Elvin Path: J:\civ\2013\137625003_Ferrier Hodgson_Rehabilitation_Boolaroo\Technical Docs\CADD\FIGURES - File Name:137625003-036-L-F001_REV_.dwg
Xref: GAP_LOGO-A3.dwg; 137625003-XREF-X_080685_DA_MOD_bound280110.dwg;

ATTACHMENT 2

Marked up RCA Figure – Plan showing location of geotechnical cross-sections

ATTACHMENT 2



LEGEND

- 3.06 Depth to top of unsuitable material layer below Ward Civil SGL
  Note: Re number indicate height above Ward Civil SCL
- 3.06 Depth to base of unsuitable material layer below Ward Civil SGL
  Note: Re number indicate height above Ward Civil SCL
- Inferred extent of unsuitable material layer
- DCP test in reed bed
- RCA test pit location, July 2009
- RCA borehole location, August 2009

NOTE: Drawing adapted from plan supplied by Ward Civil Engineering Ref No 543123a, Dated 7/8/2009

0 20 40 60 80 100
metres

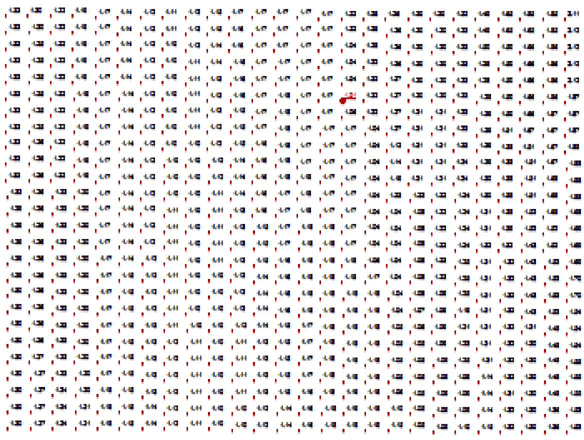
RCA AUSTRALIA
GEOTECHNICAL • ENVIRONMENTAL

INFERRED EXTENT OF UNSUITABLE MATERIALS BASED ON RCA INVESTIGATION
AUGUST 2009
BUNDERRA REDEVELOPMENT
PSSC, COCKLE CREEK

CLIENT	Ward Civil Engineering			PROJECT No	7014-600
DRAWN BY	JE	SCALE	1 : 2000 (A3)	DRAWING No	3	REV 0
APPROVED BY	RJC	DATE	1/9/2009	OFFICE	NEWCASTLE

ATTACHMENT 3

Results of Stability Analyses for Section A



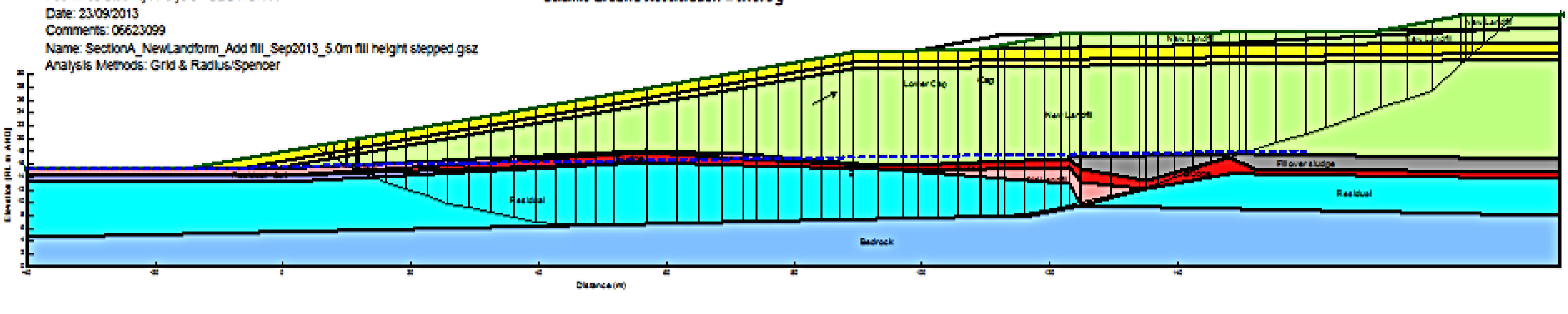
Cap	Undrained (Phi=0)	18 kN/m³	100 kPa	
New Landfill	Undrained (Phi=0)	18 kN/m³	75 kPa	
Old Landfill	Undrained (Phi=0)	17 kN/m³	30 kPa	
Residual	Undrained (Phi=0)	18 kN/m³	100 kPa	
Residual - Soft	Undrained (Phi=0)	18 kN/m³	30 kPa	
Bedrock	Bedrock (Impenetrable)			
Sludge	Undrained (Phi=0)	15 kN/m³	40 kPa	
Lower Cap	Undrained (Phi=0)	18 kN/m³	75 kPa	
Fill over sludge	Mohr-Coulomb	18 kN/m³	0 kPa	32 °

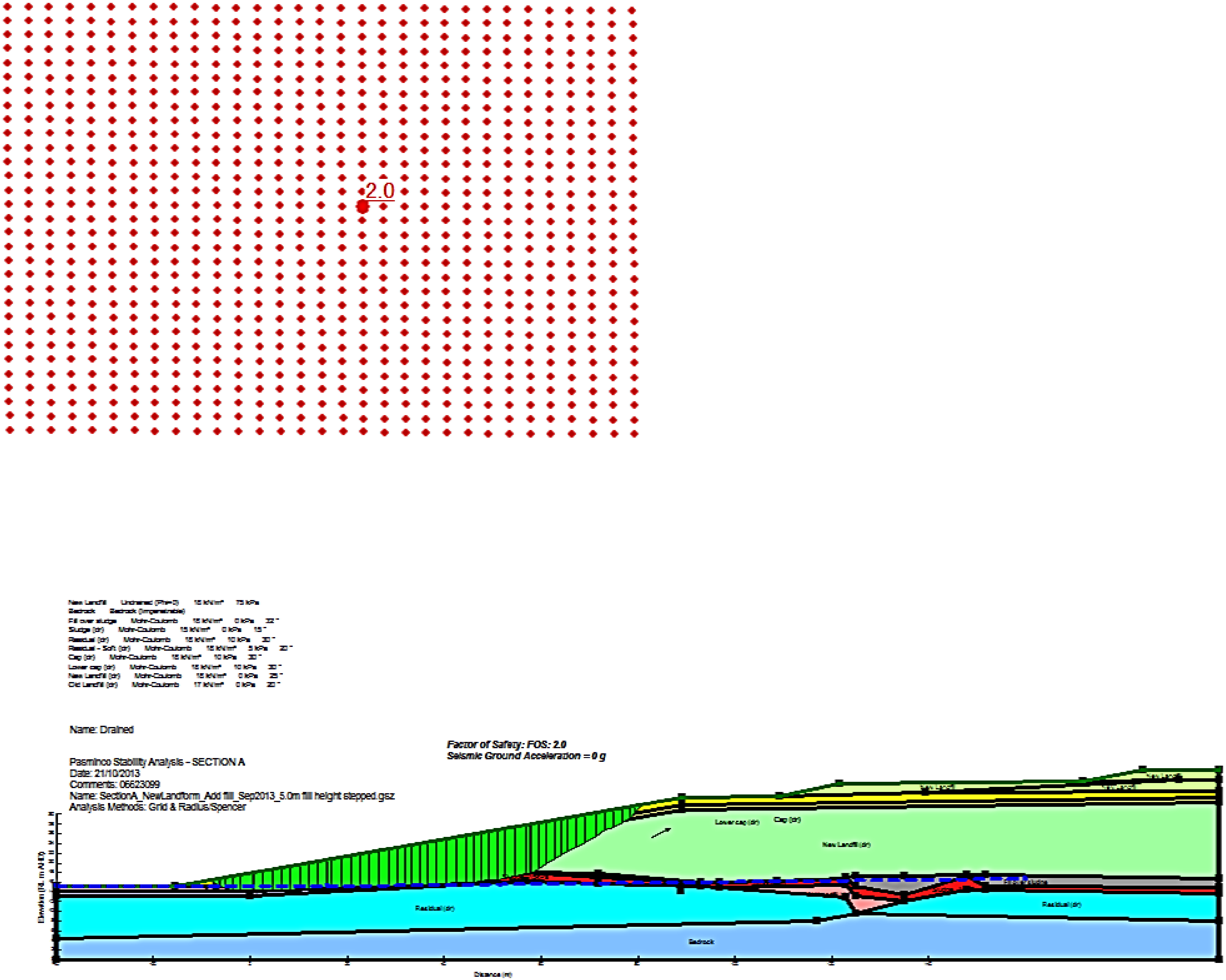
5.0 m new fill - 20m offset and 50 m offset

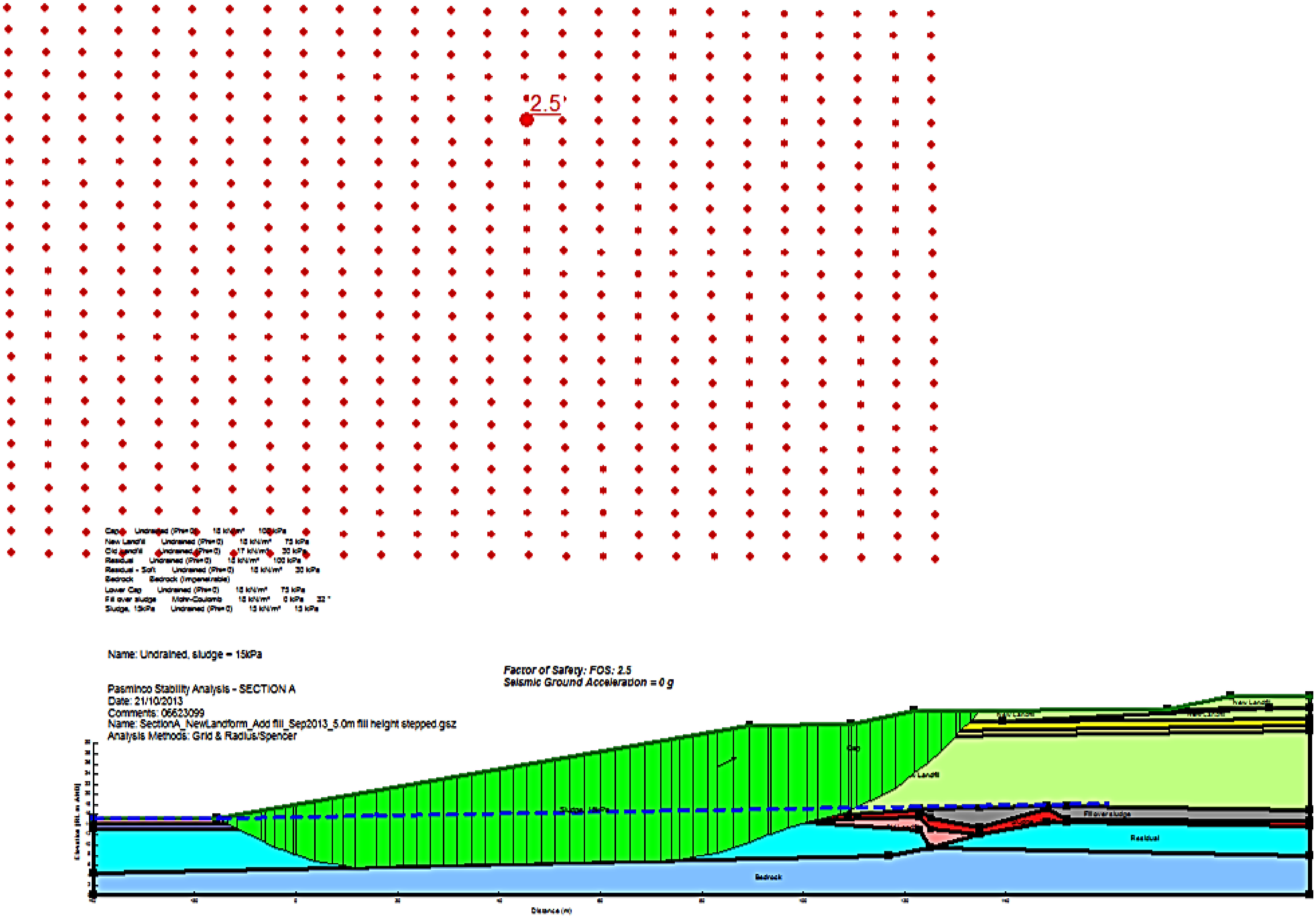
Name: Undrained, with earthquake, sludge = 40kPa

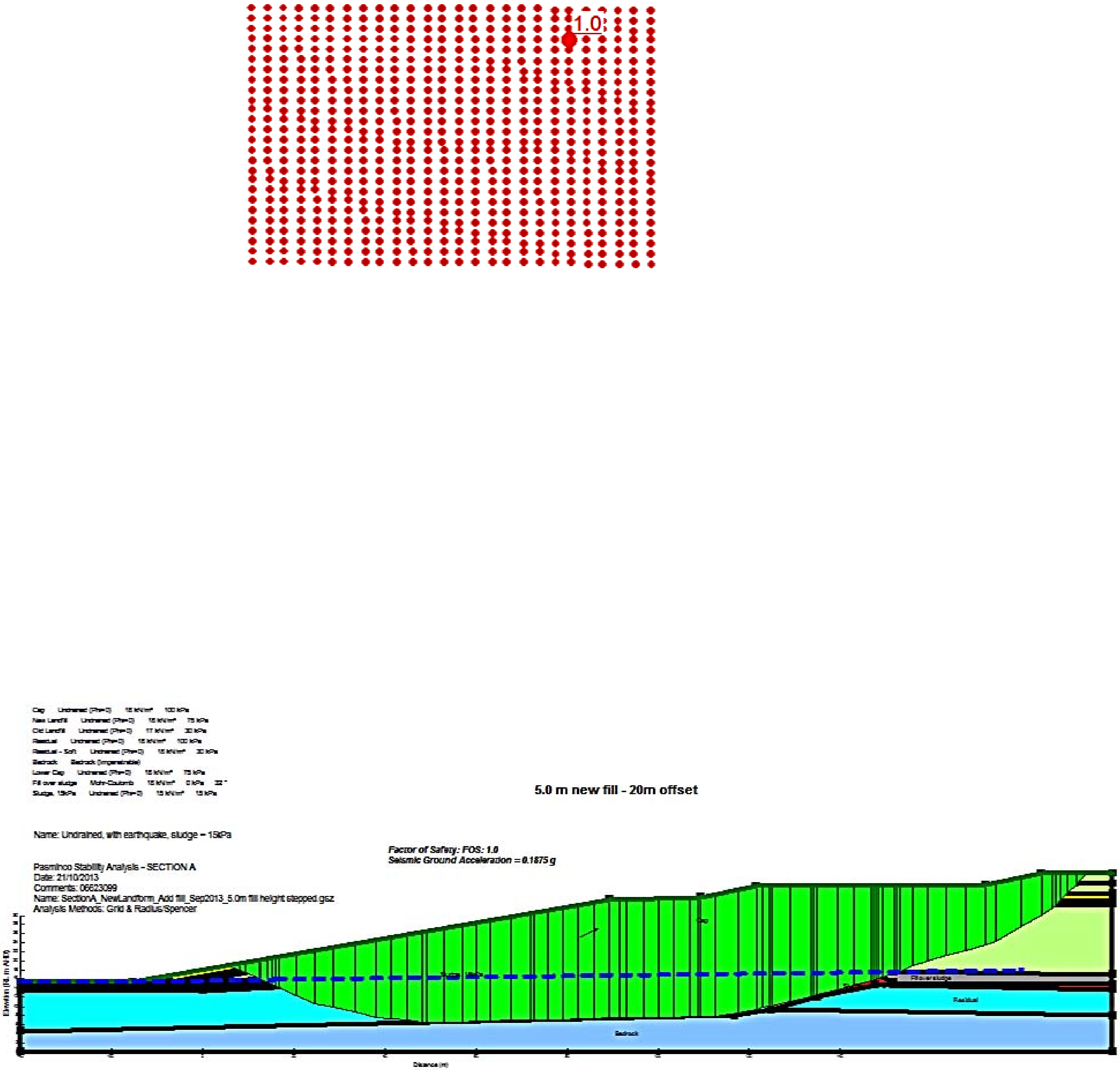
Pasminco Stability Analysis - SECTION A
Date: 23/09/2013
Comments: 06623099
Name: SectionA_NewLandform_Add fill_Sep2013_5.0m fill height stepped.gsz
Analysis Methods: Grid & Radius/Spencer

Factor of Safety: FOS: 1.01
Seismic Ground Acceleration = 0.1875 g



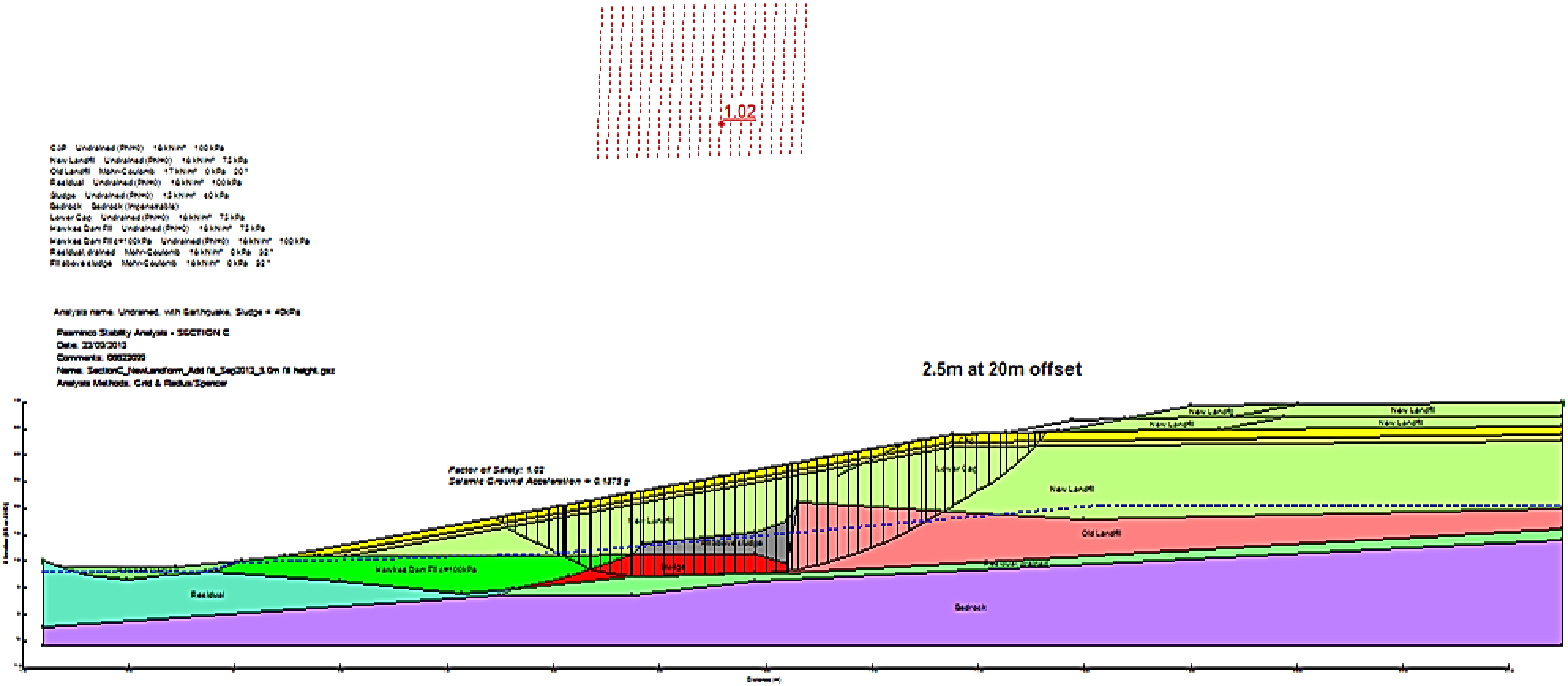

2.0
New Landfill Undrained (Phi=0)
Bedrock Bedrock (Impenetrable)
Fill over sludge Mohr-Coulomb
Sludge (dr) Mohr-Coulomb
Residual (dr) Mohr-Coulomb
Residual - Soft (dr) Mohr-Coulomb
Cap (dr) Mohr-Coulomb
Lower cap (dr) Mohr-Coulomb
New Landfill (dr) Mohr-Coulomb
Old Landfill (dr) Mohr-Coulomb
Name: Drained
Factor of Safety: FOS: 2.0
Seismic Ground Acceleration = 0 g
Pasminco Stability Analysis - SECTION A
Date: 21/10/2013
Comments: 06623099
Name: SectionA_NewLandform_Add fill_Sep2013_5.0m fill height stepped.gsz
Analysis Methods: Grid & Radius/Spencer
Lower cap (dr)
Cap (dr)
New Landfill (dr)
Residual (dr)
Bedrock

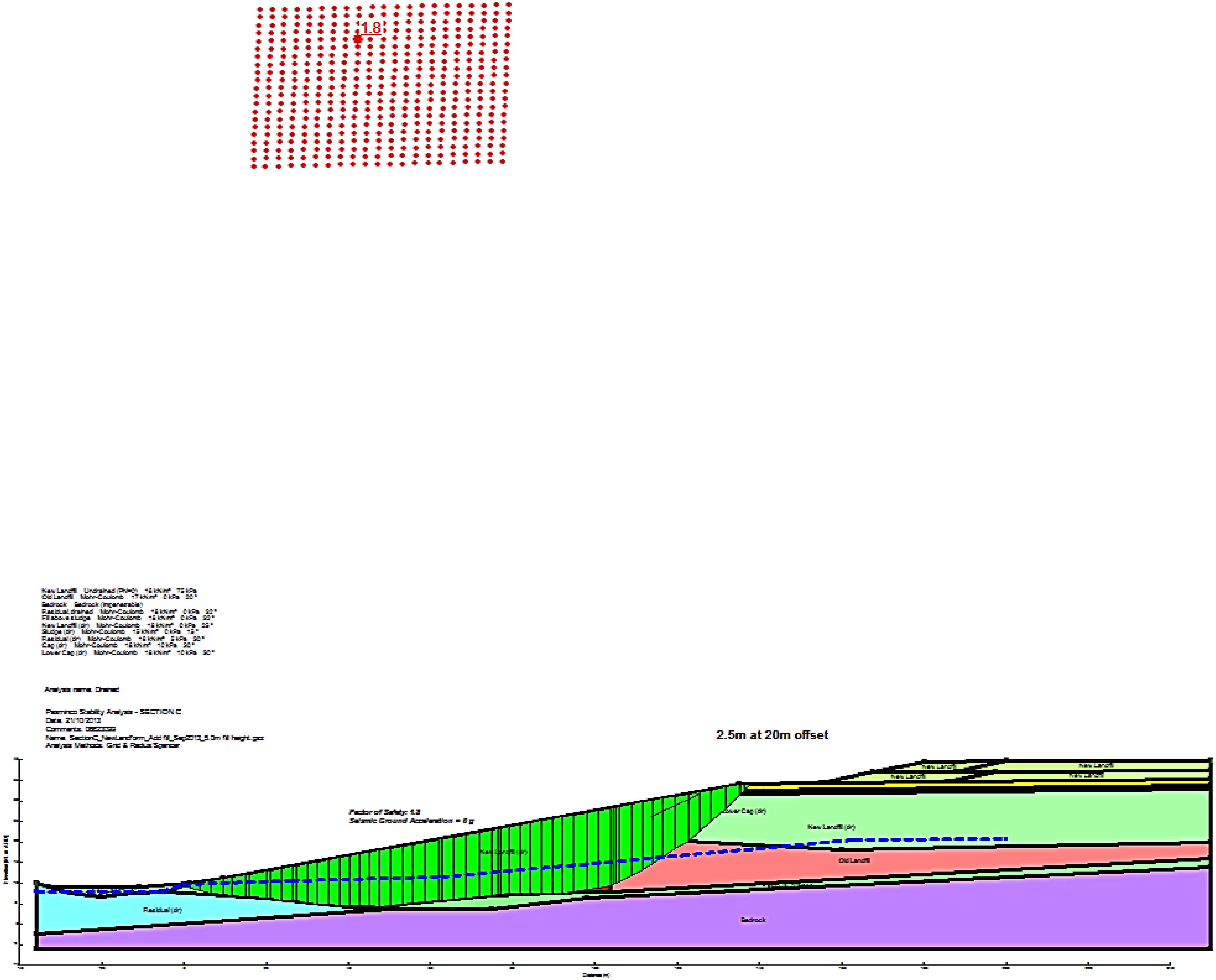

2.5
Cap Undrained (Phi=0) 18 kN/m³ 100 kPa
New Landfill Undrained (Phi=0) 18 kN/m³ 75 kPa
Old Landfill Undrained (Phi=0) 17 kN/m³ 30 kPa
Residual Undrained (Phi=0) 18 kN/m³ 100 kPa
Residual - Soft Undrained (Phi=0) 18 kN/m³ 30 kPa
Bedrock Bedrock (Impenetrable)
Lower Cap Undrained (Phi=0) 18 kN/m³ 75 kPa
Fill over sludge Mohr-Coulomb 18 kN/m³ 0 kPa 32 °
Sludge, 15kPa Undrained (Phi=0) 15 kN/m³ 15 kPa
Name: Undrained, sludge = 15kPa
Factor of Safety: FOS: 2.5
Seismic Ground Acceleration = 0 g
Pasminco Stability Analysis - SECTION A
Date: 21/10/2013
Comments: 06623099
Name: SectionA_NewLandform_Add fill_Sep2013_5.0m fill height stepped.gsz
Analysis Methods: Grid & Radius/Spencer
Cap
Fill over sludge
Residual
Bedrock
Distance (m)


1.0
5.0 m new fill - 20m offset
Name: Undrained, with earthquake, sludge = 15kPa
Factor of Safety: FOS: 1.0
Seismic Ground Acceleration = 0.1875 g
Pasminco Stability Analysis - SECTION A
Date: 21/10/2013
Comments: 06623099
Name: SectionA_NewLandform_Add fill_Sep2013_5.0m fill height stepped.gsz
Analysis Methods: Grid & Radius/Spencer
Fill over sludge
Residual
Bedrock

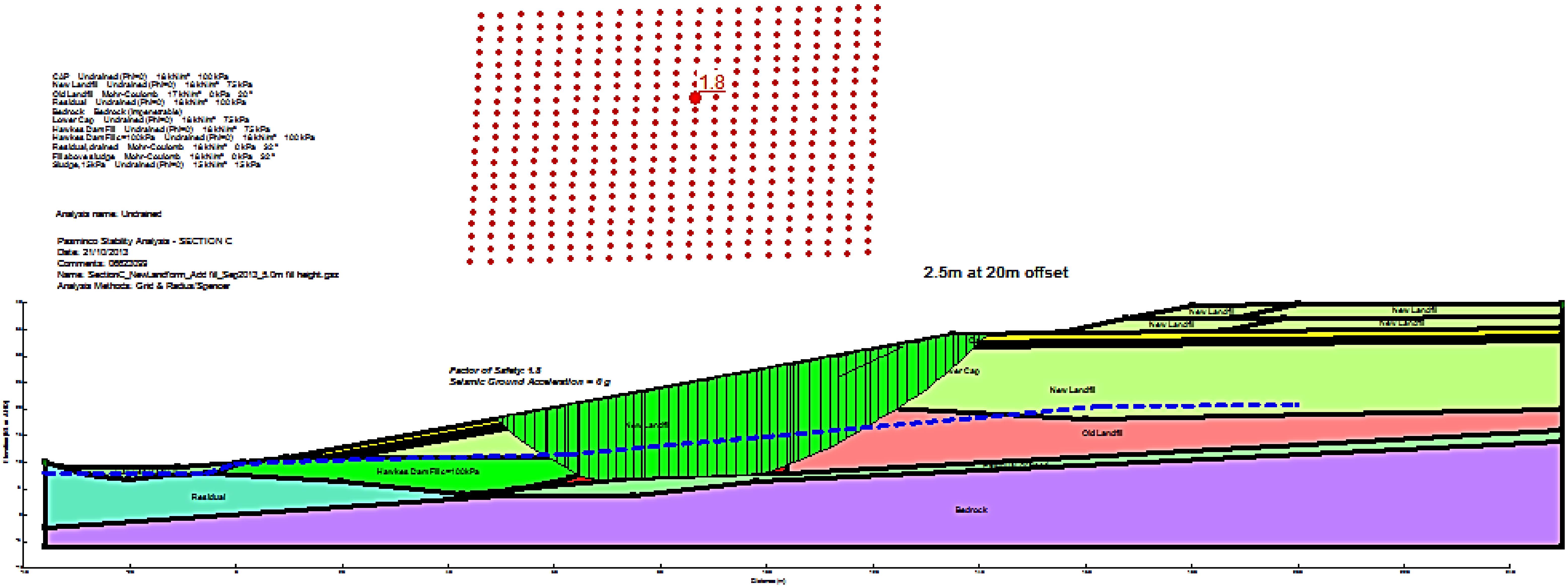
ATTACHMENT 4

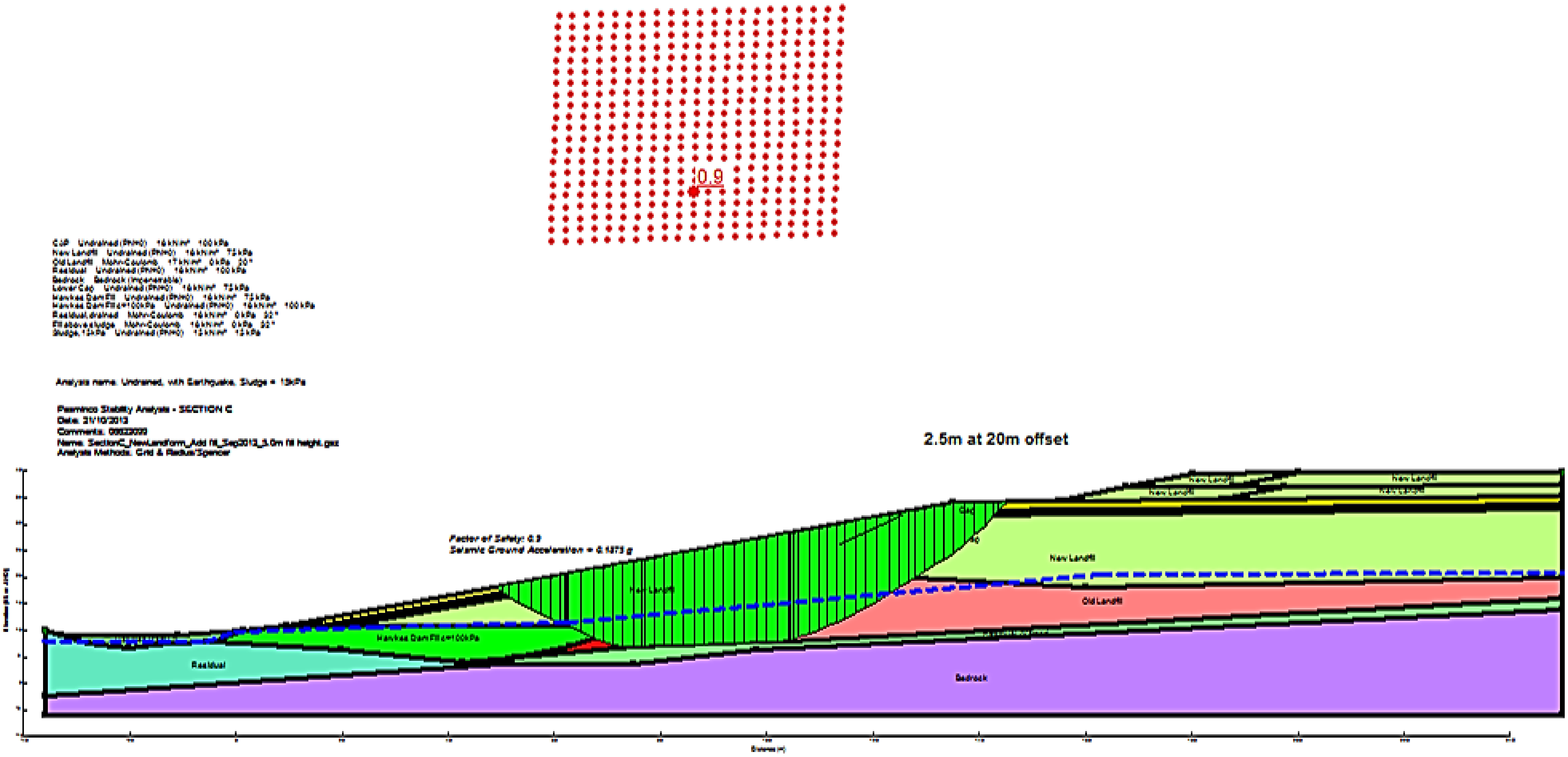
Results of Stability Analyses for Section C


1.02
CAP Undrained (Phi=0) 16 kN/m³ 100 kPa
New Landfill Undrained (Phi=0) 16 kN/m³ 72 kPa
Old Landfill Mohr-Coulomb 17 kN/m³ 0 kPa 30 °
Residual Undrained (Phi=0) 16 kN/m³ 100 kPa
Sludge Undrained (Phi=0) 13 kN/m³ 40 kPa
Bedrock Bedrock (Impenetrable)
Lower Cap Undrained (Phi=0) 16 kN/m³ 72 kPa
Hawkes Dam Fill Undrained (Phi=0) 16 kN/m³ 72 kPa
Hawkes Dam Fill c=100kPa Undrained (Phi=0) 16 kN/m³ 100 kPa
Residual,drained Mohr-Coulomb 16 kN/m³ 0 kPa 32 °
Fill above sludge Mohr-Coulomb 16 kN/m³ 0 kPa 32 °
Analysis name: Undrained, with Earthquake, Sludge = 40kPa
Stability Analysis - SECTION C
Analysis Methods: Grid & Radius/Spencer
2.5m at 20m offset
Factor of Safety: 1.02
New Landfill
Lower Cap
Old Landfill
Hawkes Dam Fill c=100kPa
Sludge
Residual
Bedrock



1.8
Analysis name: Drained
SECTION C
Date: 21/10/2013
Analysis Methods: Grid & Radius Spencer
2.5m at 20m offset
Factor of Safety: 1.8
Seismic Ground Acceleration = 0 g
New Landfill
New Landfill (dr)
Lower Cap (dr)
Old Landfill
Residual (dr)
Bedrock


CAP Undrained (Phi=0) 18 kN/m³ 100 kPa
New Landfill Undrained (Phi=0) 18 kN/m³ 75 kPa
Old Landfill Mohr-Coulomb 17 kN/m³ 0 kPa 30 °
Residual Undrained (Phi=0) 18 kN/m³ 100 kPa
Bedrock Bedrock (Impenetrable)
Lower Cap Undrained (Phi=0) 18 kN/m³ 75 kPa
Hawkes Dam Fill Undrained (Phi=0) 18 kN/m³ 75 kPa
Hawkes Dam Fill c=100kPa Undrained (Phi=0) 18 kN/m³ 100 kPa
Residual, drained Mohr-Coulomb 18 kN/m³ 0 kPa 32 °
Fill above sludge Mohr-Coulomb 18 kN/m³ 0 kPa 32 °
Sludge, 15kPa Undrained (Phi=0) 15 kN/m³ 15 kPa
Analysis name: Undrained
Paminco Stability Analysis - SECTION C
Date: 21/10/2013
Name: SectionC_NewLandform_Add fill_Sep2013_5.0m fill height.gsz
Analysis Methods: Grid & Radius/Spencer
1.8
2.5m at 20m offset
Factor of Safety: 1.8
Seismic Ground Acceleration = 0 g
New Landfill
Old Landfill
Hawkes Dam Fill c=100kPa
Residual
Bedrock



0.9
Analysis name: Undrained, with Earthquake, Sludge = 12kPa
Pasminco Stability Analysis - SECTION C
Analysis Methods: Grid & Radius/Spencer
2.5m at 20m offset
Factor of Safety: 0.9
New Landfill
Hawkes Dam Fill<=100kPa
Residual
Old Landfill
Bedrock

ATTACHMENT 5

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APPENDIX C

Pipe Stability Calculations

LEACHATE COLLECTION SYSTEM – PIPE STRESS ANALYSIS FOR PROPOSED LANDFILL EXPANSION DESIGN

The attached spreadsheet provides a calculation for stresses and deflections for the most highly loaded leachate pipe segment within the proposed landfill expansion. The pipe segment of interest is located near the crest of the western cell batter where the thickness of overlying cell materials is at a maximum for the proposed landfill expansion, i.e. 24.5 m. The calculation considers pipe loading, pipe bedding material type, pipe material and dimensions, and the effect of the holes drilled in the pipe to allow leachate collection. Key calculation results are as follows:

- the factor of safety against pipe buckling is calculated to be 10.63 and significantly exceeds the recommended minimum acceptable value of 2; and
- the pipe deflection ratio, which indicates pipe 'out-of-roundness', is calculated to be 3.59% and is slightly higher than the recommended maximum acceptable value of 3.4% as per Qian et al. (2002), which is the adopted value for this design.

The risk of pipe collapse associated with this exceedance of the adopted criteria for pipe deflection rate is uncertain.

While the pipe deflection ratio exceeds the specified limit, we consider the design acceptable for the following reasons:

- The specified limit is exceeded by a small margin, less than 10%, and the area where the allowable loads are exceeded is limited
- The location of the excessive pipe deflection occurs at a relatively upstream location within the leachate collection system
- There are a number of redundancies in the design of the leachate collection system. In the case of localised pipe collapse:
  - A collapse pipe would remain capable of conveying some degree of leachate flow
  - The leachate pipes have been constructed with a gravel surround to provide pipe support and an additional leachate flow path. In the case of local pipe collapse, leachate could flow through the gravel and into the intact pipe downstream
  - Leachate is ultimately captured in the downgradient cutoff drain, even if no leachate collection system were present.

Attachments: Spreadsheet 'Pipe Stress Analysis for Proposed Landfill Expansion Design'

j:\civ\2013\137625003_ferrier hodgson_rehabilitation_boolaroo\correspondence out\137625003_036_r_reva appendices\c pipes\137625003_036_r_reva appendix c.docx

as per Qian, Koerner, Gray, *Geotechnical Aspects of Landfill Design and Construction* , 2002, Section 9.4

$$\Delta X = \frac{D_L \cdot K \cdot W_C \cdot r^3}{E \cdot I + 0.061 \cdot E' \cdot r^3}$$

$$W_C = \frac{(\sum \gamma_i \cdot H_i) \cdot D_O}{(1 - n \cdot d / 12)}$$

$$P_{cr} = 2 \cdot \{[E'/(1-\mu^2)] \cdot (E \cdot I / r^3)\}^{1/2}$$

Pipe Specification:
SDR 13.6, PN12.5, PE 100 HDPE, 160 mm

	Description	Unit		Value	Source*	Rationale
ΔX	horizontal deflection	m		**0.0055**	**F9.16**	
K	Bedding constant	-		**0.11**	**T9.1**	
D_L	Deflection lag factor	-		**1**	**T9.2**	
W_C	vertical load per unit length	kN/m	kg/s^2	**78.56**	**F9.18**	
r	mean pipe radius	m		**0.07705**	**F9.20**	1/2 D
D	mean diameter pipe	m		**0.1541**	**F9.20**	(Do-Di)/2
E	elastic modulus pipe material	kN/m^2	kg/s^{2}m	**1000000**	**E9.2**	**For fresh pipe material based on various manufacturer's spec sheets**
I	moment of inertia pipe	m^4/m	m^3	**1.4E-07**	**P305**	I=t^3/12
t	pipe wall thickness	m		**0.0118**		**From Iplex pipelines specification**
E'	soil reaction modulus	kN/m^2	kg/s^{2}m	**20700**	**T9.3**	Crushed rock, moderate compaction (Unit 8 - Drainage Aggregate)
γ_i	unit weight of material on pipe	kN/m^3	kg/s^{2}m^2	**20**		Assumed density of compacted clay rich soils
H_i	thickness of material on pipe	m		**24.5**		Approximate maximum from leachate pipe invert to top of cell
D_O	outside diameter of pipe	m		**0.16**	**Spec**	
d	diameter perforated hole/slot on pipe	m		**0.006**	**P300**	
n	number of holes/slots per row per foot	-		**4**		**Very low leachate flow, so not many holes needed**
P_{cr}	critical pipe buckling pressure	kN/m^2	kg/s^{2}m	**5218.77**	**F9.30**	
μ	Poisson's ratio pipe material	-		**0.3**	**E9.2**	
P_{tp}	vertical pressure on pipe	kN/m^2	kg/s^{2}m	**490.98**	**F9.23**	
FS	Factor of Safety pipe buckling	-		**10.63**	**F9.33**	Pcr/Ptp (recommended to be larger than 2)
D_R	Deflection Ratio	%		**3.59%**	**T9.4**	To be <3.4 % for pipes with SDR=13.5 as per Table 9.4

Input Values
Calculated Values
Output

Prepared by: DD, 10 September 2012
Checked By: GRS, KD, 11 September 2012

as per Qian, Koerner, Gray, *Geotechnical Aspects of Landfill Design and Construction* , 2001, Section 9.4

$$\Delta X = \frac{D_L \cdot K \cdot W_C \cdot r^3}{E \cdot I + 0.061 \cdot E' \cdot r^3}$$

$$W_C = \frac{(\sum \gamma_i \cdot H_i) \cdot D_O}{(1 - n \cdot d / 12)}$$

$$P_{cr} = 2 \cdot \{[E'/(1-\mu^2)] \cdot (E \cdot I / r^3)\}^{1/2}$$

	Description	Unit		Value	Source	Rationale
ΔX	horizontal deflection	m		**0.0380**	**F9.16**	
K	Bedding constant	-		**0.1**	**T9.1**	
D_L	Deflection lag factor	-		**1**	**?**	**Guess taken from book**
W_C	vertical load per unit length	kN/m	kg/s^2	**181.82**	**F9.18**	
r	mean pipe radius	m		**0.21673**	**F9.20**	1/2 D
D	mean diameter pipe	m		**0.43345**	**F9.20**	(Do-Di)/2
E	elastic modulus pipe material	kN/m^2	kg/s^2m	**194000**	**?**	**Guess taken from book**
I	moment of inertia pipe	m^4/m	m^3	**3.0E-06**	**P305**	$I=t^3/12$
t	pipe wall thickness	m		**0.0331**	**?**	**Guess taken from Iplex pipelines**
E'	soil reaction modulus	kN/m^2	kg/s^2m	**6900**	**T9.3**	Coarse grained soil with little or no fines, slight compaction
γ_i	unit weight of material on pipe	kN/m^3	kg/s^2m^2	**20**		
H_i	thickness of material on pipe	m		**20**		
D_O	outside diameter of pipe	m		**0.45**	**Spec**	
d	diameter perforated hole/slot on pipe	m		**0.012**	**P300**	
n	number of holes/slots per row per foot	-		**10**	**?**	**Guess - very low leachate flow, so not many holes needed**
P_{cr}	critical pipe buckling pressure	kN/m^2	kg/s^2m	**1321.67**	**F9.30**	
μ	Poisson's ratio pipe material	-		**0.3**	**?**	**Guess taken from book**
P_{tp}	vertical pressure on pipe	kN/m^2	kg/s^2m	**404.04**	**F9.23**	
FS	Factor of Safety pipe buckling	-		**3.27**	**F9.33**	Pcr/Ptp (recommended to be larger than 2)

as per Qian, Koerner, Gray, *Geotechnical Aspects of Landfill Design and Construction* , 2001, Section 9.4

$$\Delta X = \frac{D_L \cdot K \cdot W_C \cdot r^3}{E \cdot I + 0.061 \cdot E' \cdot r^3}$$

$$W_C = \frac{(\sum \gamma_i \cdot H_i) \cdot D_O}{(1 - n \cdot d / 12)}$$

$$P_{cr} = 2 \cdot \{[E' / (1 - \mu^2)] \cdot (E \cdot I / r^3)\}^{1/2}$$

	Description	Unit		Value	Source	Rationale
ΔX	horizontal deflection	m		**0.0056**	**F9.16**	
K	Bedding constant	-		**0.1**	**T9.1**	
D_L	Deflection lag factor	-		**1**	**?**	**Guess taken from book**
W_C	vertical load per unit length	kN/m	kg/s^2	**24.07**	**F9.18**	
r	mean pipe radius	m		**0.09808**	**F9.20**	1/2 D
D	mean diameter pipe	m		**0.19615**	**F9.20**	(Do-Di)/2
E	elastic modulus pipe material	kN/m^2	kg/s^2m	**194000**	**?**	**Guess taken from book**
I	moment of inertia pipe	m^4/m	m^3	**3.8E-08**	**P305**	$I=t^3/12$
t	pipe wall thickness	m		**0.0077**	**?**	**Guess taken from Iplex pipelines**
E'	soil reaction modulus	kN/m^2	kg/s^2m	**6900**	**T9.3**	Coarse grained soil with little or no fines, slight compaction
γ_i	unit weight of material on pipe	kN/m^3	kg/s^2m^2	**20**		
H_i	thickness of material on pipe	m		**6**		
D_O	outside diameter of pipe	m		**0.2**	**Spec**	
d	diameter perforated hole/slot on pipe	m		**0.006**	**P300**	
n	number of holes/slots per row per foot	-		**6**	**?**	**Guess - very low leachate flow, so not many holes needed**
P_{cr}	critical pipe buckling pressure	kN/m^2	kg/s^2m	**487.13**	**F9.30**	
μ	Poisson's ratio pipe material	-		**0.3**	**?**	**Guess taken from book**
P_{tp}	vertical pressure on pipe	kN/m^2	kg/s^2m	**120.36**	**F9.23**	
FS	Factor of Safety pipe buckling	-		**4.05**	**F9.33**	Pcr/Ptp (recommended to be larger than 2)

APPENDIX D

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