Valley Planning Pty Ltd

Geotechnical Slope Risk Assessment

Proposed Subdivision

18 Winterlake Road, Warners Bay

Report No. RGS02268.1-ABrev1

5 February 2020

REGIONAL GEOTECHNICAL SOLUTIONS

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Manning-Great Lakes
Port Macquarie
Coffs Harbour

RGS02268.1-ABrev1

5 February 2020

Valley Planning Pty Ltd
PO Box 3064
THORNTON NSW 2322

Attention: Mr Chris Speek

Dear Chris

RE: Proposed Subdivision – 18 Winterlake Road, Warners Bay

Geotechnical Slope Risk Assessment

Regional Geotechnical Solutions Pty Ltd (RGS) has undertaken a geotechnical assessment for the proposed rezoning for residential subdivision of a parcel of land located at 18 Winterlake Road, Warners Bay. The site is situated in an area with a history of slope instability. This report presents the findings of the assessment, delineates the geotechnical terrain of the area, identifies potential landslide hazards, and provides general recommendations regarding the geotechnical constraints and measures that would be required to allow limited residential development of the site.

The assessment was undertaken in accordance with the Australian Geomechanics Society 2007 *Practice Note Guidelines for Landslide Risk Management*. The assessment indicates the risk of slope instability to be High in areas identified as potentially affected by rotational or translational sliding of the existing soil and weathered rock profile.

The report provides recommendations for remedial works which would reduce both the likelihood of failure and the potential downslope movement of debris to the extent that, post remediation, the risk to developments within the proposed development areas outlined herein could be reduced to Low.

Based on the findings of the assessment therefore, it has been concluded that residential development on the slopes on the southern side of the site is feasible from a geotechnical perspective, pending appropriate construction and adherence to geotechnical constraints.

An area of recently active landslide was identified near the southern site boundary, and to the west (upslope) of the proposed development area, encroaching from similar activity on the slope on the neighbouring property to the south. Development cannot be undertaken in that area due to an upper limit of RL54m on development, however, remedial works for the proposed development area should extend into this upslope zone.

If you have any questions regarding this project, please contact the undersigned.

For and on behalf of

Regional Geotechnical Solutions Pty Ltd

Steve Morton

Principal Geotechnical Engineer

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1 INTRODUCTION

At the request of Mr Chris Speek, of Valley Planning Pty Ltd, Regional Geotechnical Solutions Pty Ltd (RGS) has undertaken a geotechnical slope stability assessment on the property located at No. 18 Winterlake Road, Warners Bay.

The site is bounded to the east by residential subdivision development, however, it falls within the East Munibung Hill Area Plan delineated under Section 4.20 of the Lake Macquarie City Council Development Control Plan 1 (DCP1). The plan designates the foothills of Munibung Hill as an area that will remain largely undeveloped with no further subdivision due to geotechnical and other constraints.

The geotechnical constraints pertain to the site being located in a region of known previous landslide activity. There is also a planning restriction that applies to the site which precludes construction at an elevation above RL54mAHD. Zoning maps within the DCP indicate portion of the site below RL54mAHD to be within an area designated "Further development may be possible" pending appropriate investigations including geotechnical.

The site is situated on the southeast facing slopes of Munibung Hill and is irregular in shape. Surface elevations over the existing property range from approximately RL34m AHD at the eastern boundary, to approximately 90m AHD at the western boundary. Residential development, however, is limited to below RL54m due to the Lake Macquarie City Council planning constraint.

There is currently a proposal to establish residential development on three lots to be subdivided from within an area that occupies a small proportion of the current property. The western (upslope) limits of the property are defined by the RL54 limitation. The site setting for No.18, and the proposed development area within the property, are shown in Plate 1 below. The proposed subdivision configuration is shown on Figure 1.

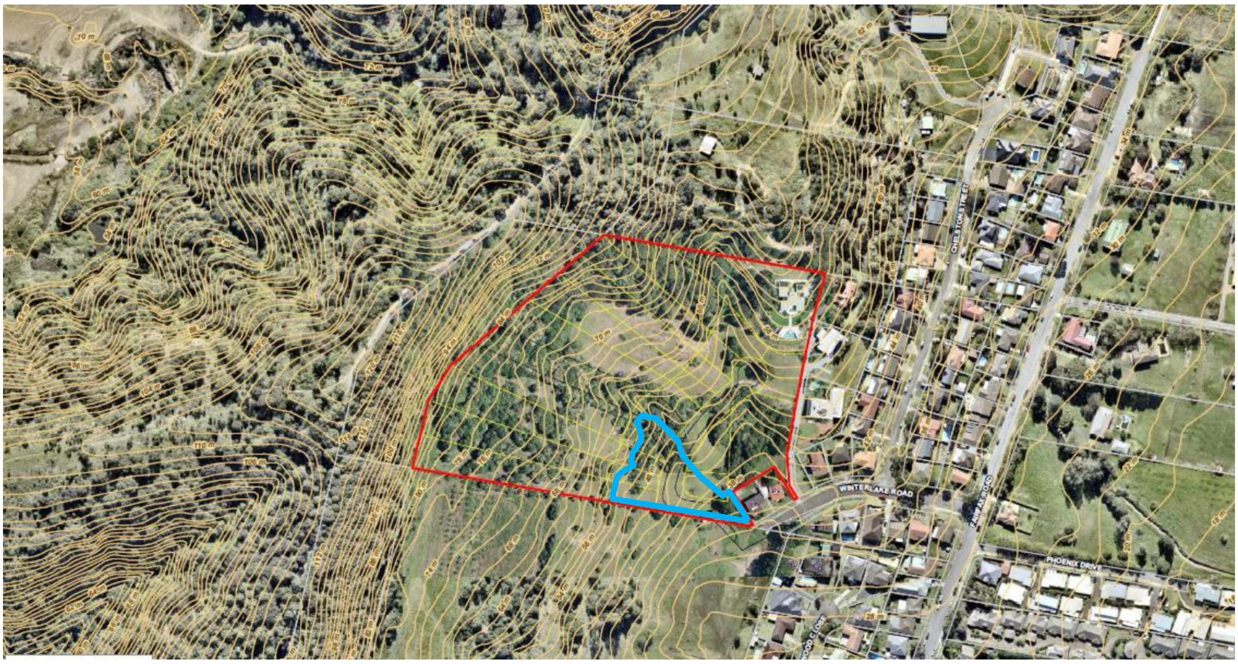


Plate 1. *Total property area of No. 18 Winterlake Road shown in red outline. Proposed residential development area shown in blue.*

Taking into account the planning constraints and slope stability concerns, the purpose of the work presented herein was to assess the site with regard to the geotechnical feasibility of developing the proposed development area for the purposes of a residential subdivision. The assessment has been undertaken in accordance with the AGS 2007 *Practice Note Guidelines for Landslide Risk Management* (Ref.1).

2 SITE INVESTIGATIONS

The assessment of the site involved the following:

- Review of a previous Slope Risk Assessment report undertaken by Cardno Geotech Solutions in July 2015 (Ref. CGS2708);
- Review of other available reports and published information regarding slope stability and landslide issues in the area;
- Walkover site assessment to observe surface conditions that may be relevant to slope stability – evidence of past landslides, unusual ground formations, drainage conditions, the presence of disturbed or hummocky ground etc;
- Excavation, logging, and sampling of test pits within proposed development area. The logging involved assessment of profile conditions, evidence of disturbed ground, water inflows, presence of potential shear planes on which failure could occur;
- Identification, on the basis of the above information, of areas having the potential for residential development.

The test pit locations are shown on Figure 2. Test pit logs are included as Appendix A.

3 BACKGROUND AND GEOTECHNICAL SETTING

3.1 Regional Geology

The site is situated within an area underlain by the Moon Island Beach sub-group of the Newcastle Coal Measures. The elevated ridges and steep slopes nearing the crest of Munibung Hill to the west of the site are formed by the weathering resistant thick conglomerate and sandstone beds of the Teralba Conglomerate member. This is directly underlain by the Booragul Tuff and the Great Northern seam that sub-crop on the mid-slopes, directly below the steeply sloping scarps that delineate the edge of the Teralba Conglomerate sub-crop. These units generally comprise tuffaceous claystones of low shear strength. Water which infiltrates through widely spaced joints in the overlying conglomerate concentrates at the interface of the conglomerate and these underlying claystone units. The water tends to flow laterally through these layers and daylights as seepage on the slopes below.

The lower slopes are typically underlain by the fine grained tuffaceous sandstones, siltstones and claystones of the Awaba Tuff. This directly overlies the Fassifern coal seam, which sub-crops slightly above the level of the rear of the existing properties fronting Winterlake Road, as shown in Figure 3.

The approximate sub-crops of the Great Northern Seams and an un-named coal plie, as mapped by Shirley Partners in 1987 (Ref 2) are also marked on Figure 3.

A previous study by RGS at the northern end of Fairfax Road, approximately 450m northeast of the subject site, encountered Teralba Conglomerate overlying the Great Northern Seam, with the seam encountered at approximately RL55m AHD.

3.2 History of Slope Instability in the Area

The site is situated in an area where large scale landslides are known to have occurred periodically through the 1920's, 1950's and into the 1970's. In the 1950's a large scale landslide above Chelston Street, to the west of Fairfax Road and north of the current site, resulted in a debris flow extending some 250m, with the debris crossing Fairfax Road and extending to the east.

Numerous studies and reports have been prepared in relation to the landslides in the area. These previous works have indicated that the landslides typically occur due to the following slope evolution processes:

- Valley formation within the uplifted and eroding coal measures sequence causes a stress release in the formation that results in lateral spreading and movement of large, joint-bound conglomerate and sandstone blocks over underlying, near horizontal tuffaceous claystone beds. This is exacerbated by a combination of concentrated water flows and low shear strengths on the weathered claystone horizons;

- Initial, typically large scale and deep seated landslides occur as a result of this ongoing valley formation and lateral spreading. The large slides form debris flows and deposit large volumes of debris as colluvial soil deposits on the mid to lower slopes, resulting in hillside profiles of deep colluvial soils comprising gravelly clay soils with large boulders and zones of disturbed coal and claystone, overlying interbedded sandstone, conglomerate, coal and claystone;

- The jointed conglomerate of the upper slopes allows inflow of water to the profile, which then flows laterally within the sequence through zones of preferred flow above aquitards such as the low permeability claystone horizons, or through the highly fractured coal seams. Low permeability colluvial clay deposits inhibit egress of water from the profile and the resultant build-up of water pressures activates localised rotational and translational sliding of colluvial deposits over the steep underlying weathered rock surface.

Groundwater levels in the area have been shown to be a major contributor to triggering of the landslides with a study by Fell et al (Ref.3) indicating that landslides occurred on these slopes when groundwater levels rose to, or near to, the ground surface and that, based on available records at the time, this was likely to occur on an average return interval of approximately 25 to 30 years. The Fell paper included broad scale mapping of landslide-related zones within the study area. This mapping is overlain on the current subject site in Figure 4.

In 1988 Lake Macquarie City Council undertook major works to install deep (up to 10m) subsoil drains within the landslide area to the west of Chelston Street, which is located to the north of the current site, but at a similar position within the slope profile and geological profile. The drains extended down to zones of water flow at the top of the claystone beds above the Great Northern Seam. The purpose of these deep drains was to discharge water from the potential slide planes and prevent the buildup of groundwater levels and piezometric pressures in response to rainfall. It is understood there have been no significant landslides in the Chelston Street area since the installation of the drains.

4 SITE CONDITIONS

4.1 Surface Conditions

The site is situated on the southeast slopes of Munibung Hill, and is located to the northwest of the termination of the existing Winterlake Road. It is accessed by a narrow accessway off Winterlake Road, at the southeastern corner of the site. The proposed development area is unoccupied but is bordered by residential development to the east.

Topographically, the site is situated on the mid to lower slopes of the prominent Munibung Hill, and is dominated by a deep, generally southeasterly trending drainage gully, likely to have been formed from the weathering and erosion of a geological fault based on orientation and the presence of similarly aligned and configured drainage gullies to the north and south along the flanks of the hill.

To the north of the drainage gully, beyond the proposed development area, is a rounded ridge spur that appears disturbed by previous earthworks and possibly by some ancient landslide activity. The lobe of the possible former landslide activity extends in a southeasterly direction, forming a broad spur that follows the eastern edge of the proposed development area, before crossing the southeastern third of the area, as shown by zone A2 on Figure 4.

To the south of the deep drainage gully, the majority of the proposed development area is occupied by an irregular slope underlain by deep colluvial soil deposits.

Much of the land was previously cleared for orcharding and grazing of livestock and the majority is cleared, with the exception of thick vegetation in the deep gully and scattered stands of trees across the site.

The proposed development area is situated entirely below, and bounded on the upslope western side by, the RL54m contour. Above this level the site is occupied by the toe of a steep escarpment that slopes from RL 90m AHD, to about 80m. Below this, the slope grades onto a gentle to moderate, convex upper slope that has an overall slope to the southeast, and ranges in elevation from RL 80m down to RL 70m. This area is vegetated by generally low bushland that appears to be regeneration of formerly cleared land.

Below RL70 the ground steepens onto a steeper mid-slope zone that occupies the western two thirds of the proposed development area below RL 54m. This zone slopes steeply to the east and southeast at angles of between 20 and 30 degree and has some irregular slope features including localised breaks of slope. This zone is vegetated by a combination of cleared grass land and regrowth vegetation following past clearing for agricultural uses.

	
Surface condition at southeastern corner of site where ground conditions appear to indicate lobe of former landslide, noted as A2 on Figure 4.	*Irregular ground on colluvial slopes through most of the proposed development area.*

Below approximately RL40mAHD the lower, footslopes grade gently towards the east and southeast. There are some areas of irregular ground that may be due to the deposition of landslide debris in the past from a former landslide encroaching onto the area from the northwest, as shown as Zone A2 on Figure 4. The lower slopes grade onto a gentle footslope area that encountered minor seepage or water inflow into the test pits during the fieldwork, which was undertaken during a period of prolonged dry weather in late 2019.

The ground surface was trafficable at the time of the fieldwork.

The southeastern site boundary borders onto a neighbouring residential property to the east, which contains a two storey brick residence and a brick outbuilding at the rear or western end of the property. The outbuilding appears to be at least partly constructed on a pad of fill. The building contains a large crack and visible displacement of the brick work. It is not clear from observation, whether the cracking is due to settlement of the fill, shrink-swell related movements in the foundation, or lateral movement associated with landslide activity. The side walls of the outbuilding, and the brick walls of the residence did not show visible cracking, and therefore lateral foundation movement due to landslide is considered unlikely to be the cause of the damage to the outbuilding.

Beyond the southern site boundary, on the neighbouring property to the south, there is evidence of possible recent re-activation of a former slide in the colluvial soil profile (See Zone A1 in Figure 4). Such evidence includes irregular, hummocky ground, visible lobes of debris, scarps at the rear of the slide area, and erosion of soils disturbed and re-deposited by former landslides.

	
Cracking in outbuilding on neighbouring property to east. Cracking appears top-down. No other displacement or cracking is visible within the structure or adjacent structures.	*Neighbouring property to the south, where toe of re-activated landslide can be seen on lower slope, right of image*

4.2 Subsurface Conditions

The subsurface materials encountered in the test pits varied across the site, however, the findings correlate well with the known regional geology. Based on the profiles encountered in the test pits and the regional geological setting discussed in Section 3.1 above, a geotechnical model for the site is presented in Figure 5.

The following points are noted from Figure 5 and the subsurface conditions encountered by this and previous investigations:

- In most locations, the ground surface was underlain by a soil profile comprising colluvial clay soils. These varied in depth from 2.4 to >3m, where they were underlain by residual clay soils and extremely weathered to highly weathered rock.

- TP4 at the upslope edge of the development area encountered the un-named coal plie identified by the Shirley Partners in 1987.

- The rock profile was weathered and rock types comprised conglomerate and sandstone on the upper slopes, and interbedded extremely to highly weathered tuffaceous claystone, siltstone, and fine grained sandstone on the lower slopes.

- Minor water inflows were encountered at 4m depth in test pit TP2 on the footslope of the development area.

5 SLOPE STABILITY ASSESSMENT

5.1 Risk Assessment

The risk of slope instability at the subject site has been assessed using the principles and protocols of the Australian Geomechanics Society publication *Practice Note Guidelines for Landslide Risk Management*, 2007 (Ref.1). This methodology represents the currently accepted state of practice for landslide risk assessment in Australia.

The slope risk assessment process involves identification of a potential slope failure event, or hazard, followed by an estimation of the likelihood of the event occurring, and the potential consequences should the event occur.

The terms used in the risk assessment process are defined below:

Hazard: A condition with the potential for causing an undesirable consequence.

Likelihood: The estimated probability that the hazardous event will occur.

Consequence: Loss or damage resulting from a hazard event.

Risk: A term combining the likelihood and consequence of an event in terms of adverse effects to property or the environment.

5.2 Hazard Identification

The following potential slope stability hazards were assessed in relation to the site and the proposed development:

Hazard 1: Large scale translational slide of conglomerate blocks over saturated tuffaceous claystone layers large movements and possible debris flow and involving more than >100m^3 of material. Such a failure could cause complete destruction or large scale damage of several structures within a typical residential subdivision;

Hazard 2: Translational or rotational slide through the colluvial and residual soil profile. Should such a failure occur it could potentially cause extensive structural damage and require large scale, costly repairs, and possibly temporary evacuation of a typical residential building until repairs are complete. Maintaining good slope drainage to prevent buildup of water pressures within the profile is recommended;

Hazard 3: Soil creep. Creep is an imperceptibly slow movement that takes place on sloping soil sites. It is an ongoing, natural slope process involving the progressive downslope movement of soils over the underlying rock profile. Creep will occur within the soil profile overlying weathered rock at this site, and will require management by undertaking good hillside construction practice as recommended in this report;

Hazard 4: Translational or rotational slide of soil and weathered rock profile resulting from ongoing stress relief due to erosion and valley formation processes on the outer slope. Should such a failure occur it could potentially cause extensive structural damage and require large scale, costly repairs, and possibly temporary evacuation of buildings until repairs are complete.

Hazard 5: Small scale slide (<100m^3) due to failure of unsupported cuts and fills or poorly designed, constructed, or otherwise inadequate retaining walls. Such a failure could cause localised damage requiring moderate repairs to part of the structure.

Each of the identified hazards is illustrated on Figure 6.

5.3 Risk Evaluation for Existing Site Conditions

Table 1 summarises the factors affecting slope stability in relation to each of the hazards identified and assesses the risk of slope instability for each using the risk assessment matrix provided in Appendix C of the Australian Geomechanics Society (AGS) publication Practice Note Guidelines for Landslide Risk Management, 2007. A copy of the AGS risk matrix is presented as Appendix B.

Table 1: Slope Risk Assessment Based on AGS2007 method

Hazard	H1 – Large scale translational landslide and debris flow	H2 – Translational failure of colluvial soils over weathered rock profile	H3 - Soil Creep	H4 - Translational failure through weathered rock profile	H5 - Localised failure of poorly retained cuts
Slope height	50m	10 - 20m	50m	20 – 30m	Up to 3m
Cause or trigger	Slope deterioration and weathering, exceptionally prolonged and intense rainfall	Slope deterioration (10 - 100yr) followed by extreme weather (1in 1,000yr event)	Ongoing process of imperceptibly slow soil movement	Ongoing erosion, stress release, adverse wet weather event (1 in 20 - 30 yr event)	Cut steeper than angle of repose, unsupported,1 in 10yr rain event
Estimated probability	10^{-6} yr (inconceivable except under extreme exceptional circumstances)	10^{-5} yr	10^{-1} yr	10^{-3} yr	10^{-3} yr
Assessed Risk Without Mitigation					
Likelihood	Rare	Unlikely	Almost Certain	Possible	Possible
Consequence	Extensive damage to numerous structures within downslope area	Damage to one or possibly more structures requiring extensive repair	Ongoing, slow movement of foundation, displacement of services, possible minor distortion of pathways etc. Generally manageable within life of structure	Extensive damage to structure if within active zone (upper slope). Moderate to minor damage to structure(s) if within debris zone on footslope	Localised minor damage to some of structure requiring minor repairs
	Catastrophic	Major	Insignificant	Major (Upper) Medium (Lower)	Minor
Risk	Moderate	Moderate	Low	High (Upper) Moderate (Lower)	Moderate

Hazard	H1 – Large scale translational landslide and debris flow	H2 – Translational failure of colluvial soils over weathered rock profile	H3 - Soil Creep	H4 - Translational failure through weathered rock profile	H5 - Localised failure of poorly retained cuts
Proposed Mitigation, Management, Development Restrictions	Undertake deep drainage measures and some regrade/ reconstruction of upper slope. Undertake subdivision works in accordance with good hillside practice.	Install deep subsoil drains. Found all structures in weathered rock. Excavate and reconstruct lower slope A2 zone with deep rock blanket and controlled fill.	Found all structures in weathered rock. Use good hillside construction/ drainage measures.	Install drainage/ remedial measures on upper slope and reconstruct lower slope as controlled fill with deep drainage measures.	Avoid or retain cuts >1m on sloping areas of the site
Assessed Risk with Mitigation, Management, Development Restrictions					
Likelihood	Barely Credible	Rare	Almost Certain	Unlikely	Rare
Consequence	Catastrophic	Major	Insignificant	Medium	Minor
Risk	Low	Low	Low	Low	Very Low

5.4 Evaluation of Risk Level

The assessment indicates the risk of slope instability to be High in the areas potentially affected by rotational or translational sliding of the colluvial soil and weathered rock profile. It is recommended that prior to development in this area, remedial measures be undertaken to reduce the likelihood of further activation of this type of landslide.

The proposed remedial works will, however, reduce both the likelihood of failure and the potential downslope movement of debris to the extent that, post remediation, the risk of developments within the proposed development area delineated on Figure 1 could be reduced to Low.

As shown in Table 1, by adopting the recommendations of this report, the risks of landslide activity affecting the proposed development area of the site can be reduced to Low. Development should not be undertaken within areas outside the proposed development area shown on Figure 1.

6 GEOTECHNICAL CONSIDERATIONS FOR DESIGN AND CONSTRUCTION

6.1 Potential Development Area

The site contains features indicative of past landslide activity from above the site having previously impacted parts of the site and contains areas of deep colluvial soils. There are also some steep-sided gully areas where residential development should not occur.

On consideration of the site conditions and site constraints, it is considered that residential development on part of each of the three lots could meet the requirements of a Low risk rating in accordance with AGS2007 pending strict adherence to good hillside construction practice and some specific site remediation and management practices as outlined in subsequent sections of this report. Preventative or remedial measures will include implementation of deep subsoil drains and, in some areas of the site, excavation of former landslide debris followed by placement of rock drainage blankets and reconstruction of the slope as controlled fill prior to construction.

The areas of each lot where residential development would be feasible are shown on Figure 7.

General recommendations to assist in the design and construction of a residential subdivision development on the site are provided in the following sections of this report. Design of remedial measures and drainage works will require additional investigations to obtain the specific information required for design.

6.2 Type of structure

There are no specific constraints regarding the type of structure considered suitable for the slope, provided design and construction is undertaken in accordance with the recommendations of this report. Development should, though, be designed to accommodate the slope profile and to minimise cut and fill.

6.3 Foundations

As a general guide, for development on the sloping areas of Lot 1 and Lot 2, it is recommended that all structures be supported by footings that extend through the colluvial and residual soil profile to found in the underlying weathered rock. This may require the use of bored piles or similar to extend through into the weathered rock profile.

For the footslope areas of Lot 2, and for Lot 3, residential construction would require complete excavation of the former landslide debris and disturbed or affected soils, followed by reconstruction of a Controlled Fill profile over a durable rock underdrainage blanket.

Following reconstruction of the slope in this manner, structures may be placed on the Controlled Fill provided they are designed and constructed in accordance with the guidance provided in AS2870-2011 Residential Slabs and Footings.

Further investigations will be required to facilitate design of remedial measures, and to provide site classifications on completion of site earthworks.

6.4 Support of Excavations and Filling

Cuts or fills exceeding 1m in height should be avoided where practicable. Cuts and fills of up to 1m can be battered at 1V:2H or flatter. Deeper cuts and fills should be supported by engineer designed and properly constructed retaining walls.

All retaining walls should be provided with complete drainage at the back of the wall that drains to an ag drain, weep-hole or similar that allows free discharge of water from behind the wall.

Retaining walls must be designed to accommodate surcharge loading from all slopes, structures, or foreseeable traffic above the wall.

Further recommendations and design advice for retaining walls can be provided once the layout and configuration of the proposed development are known.

6.5 Access and driveway

The construction of driveways and site access must comply with the recommendations provided herein regarding limitations to, and support of, cuts and fills. Where cuts of more than 1m are required for access construction, they must be supported by engineer-designed retaining walls. Driveways must be designed and configured so as to not impede the drainage of the slope.

6.6 Control of Stormwater

All stormwater should be collected from surface and roof runoff and should be discharged well beyond the building area into the street stormwater drainage system or a reticulated stormwater drainage system that discharges stormwater off site.

On site stormwater detention is feasible, provided detention occurs in impermeable holding tanks or ponds. No collected stormwater should be allowed to infiltrate the site.

6.7 Subsoil Drains

For development on the mid to upper slope areas of Lot 1 and Lot 2 (delineated in yellow on Figure 7), it is important that measures be taken to prevent water travelling through the soil and weathered rock profile from becoming trapped beneath the low permeability colluvial clay soils that cover the slope. To assist in preventing buildup of water pressures beneath the slope profile, it is recommended that a series of subsoil drains be installed within the proposed building area.

Prior to undertaking these works, additional geotechnical investigations should be undertaken to further define the slope conditions and allow the layout and configuration of the drains to be designed appropriately.

7 REMEDIAL MEASURES

7.1 Mid to upper slopes of Lot 1 and 2

These are the areas delineated in yellow on Figure 7. Prior to development of these slopes, the area will require remediation to reduce the risk of slope instability to a level that would achieve a Low Risk classification in accordance with AGS2007.

Remedial measures are likely to involve:

- Installation of drainage measures such as subsoil drains and/or horizontal drains to promote drainage of the slope and prevent buildup of pore water pressures within the slope;
- Regrading of the failed area to reduce locally steep slope angles and lope changes, and to promote run-off and slope drainage.

Concept sketches showing the works required are shown in Figure 8.

7.2 Area to west (upslope) of development area

Prior to development of the slopes below RL54m, remedial works will be required as outlined in Section 7.1, it is recommended that, in some locations, the remedial measures extend upslope of RL54m to be implemented on the steeply sloping area above. Such measures are likely to involve:

- Installation of drainage measures such as subsoil drains or horizontal drains to promote drainage of the slope and prevent buildup of pore water pressures within the slope;
- Regrading of the outer slope to allow control of erosion and remove soils that appear prone to short term onset of instability.

Concept sketches showing the works required are shown in Figure 8.

7.3 Footslope areas of Lot 2 and 3

These are the areas delineated in green on Figure 7. The findings of the investigation indicated a deep, disturbed profile and some subsurface water within the area defined as former landslide debris (A2) in Figure 4.

Where the proposed development area extends onto and across this area, development will require works to remediate the landslide and improve subsurface drainage.

The use of subsoil drains would improve drainage and assist in alleviating pore water pressures within the landslide area, however, the highly disturbed ground would remain within the proposed building areas of the lots and this is not recommended.

It is therefore proposed to remediate this area by completely excavating the former landslide debris and associated disturbed soils, and reconstructing the slope incorporating a rockfill drainage blanket, overlain by controlled fill that would be placed and compacted in a manner suitable for the support of high-level residential footings. This methodology not only removes the landslide, but improves site drainage, rehabilitates the landslide area, and allows reconstruction of the slope to a surface form that is more conducive to residential development than the current morphology.

The remediation will involve:

- Undertake additional geotechnical investigation involving drilling to identify the depth of the landslide and landslide debris. This will allow quantification of earthworks volumes and design of the remedial works;
- Excavate the disturbed area down to the base of the former landslide, and stockpile the materials for subsequent re-use. Materials are expected to be predominantly suitable for reuse as engineered fill, pending some drying back to a suitable moisture content;
- Install a geofabric-wrapped drainage blanket of hard, durable rock across the full floor of the excavation. This drainage blanket would be designed to intercept all subsurface flows beneath the area and discharge them to the street stormwater drainage via an appropriately designed system of drainage easements and subsoil drains;
- Following moisture conditioning of the excavated material, place it back into the excavated area as Controlled Fill (AS2870-2011) under Level 1 supervision (AS3798-2007) to the design finished subdivision landform.

Placement of a drainage blanket and controlled backfilling of the excavation in this manner has the following advantages:

- Reduced delays in terms of investigation, monitoring, design, and post-drain installation monitoring prior to construction;
- Removes, reconstructs, and rehabilitates the disturbed ground and provides complete under-drainage as well as a rockfill berm to provide gravitational retention of the reconstructed soil mass upslope;
- Reduced risk associated with long term performance of residential structures on the re-engineered controlled fill – ie. removes the risk of differential settlement between pile-

supported structure and surrounding services, accessways, and utilities on the surrounding disturbed material;

- Reconstructs the site to a landform that suits residential development.

A concept sketch that shows the general remediation method proposed is shown in Figure 9.

7.4 Investigation and design of remedial measures

Further investigation and monitoring will be required in order to obtain the information for the design of the appropriate remedial measures. This will include drilling of boreholes to allow refinement of the slope model and obtain samples for laboratory testing so that appropriate design parameters can be adopted, and test pitting to further define the depth and distribution of colluvial soils, presence of coal seams, and identification of zones of water inflow within the profile.

Subsequent monitoring of inclinometers and piezometers would then be undertaken to identify water levels and possible movement horizons within the slope that would allow compilation of a more accurate subsurface model upon which to base the design of the remedial works.

8 LIMITATIONS

The findings presented in the report and used as the basis for recommendations presented herein were obtained using normal, industry accepted geotechnical design practises and standards. To our knowledge, they represent a reasonable interpretation of the general condition of the site. Under no circumstances, however, can it be considered that these findings represent the actual state of the site at all points. If site conditions encountered during construction vary significantly from those discussed in this report, Regional Geotechnical Solutions Pty Ltd should be contacted for further advice.

This report alone should not be used by contractors as the basis for preparation of tender documents or project estimates. Contractors using this report as a basis for preparation of tender documents should avail themselves of all relevant background information regarding the site before deciding on selection of construction materials and equipment.

If you have any questions regarding this project, or require any additional consultations, please contact the undersigned.

For and on behalf of

Regional Geotechnical Solutions Pty Ltd

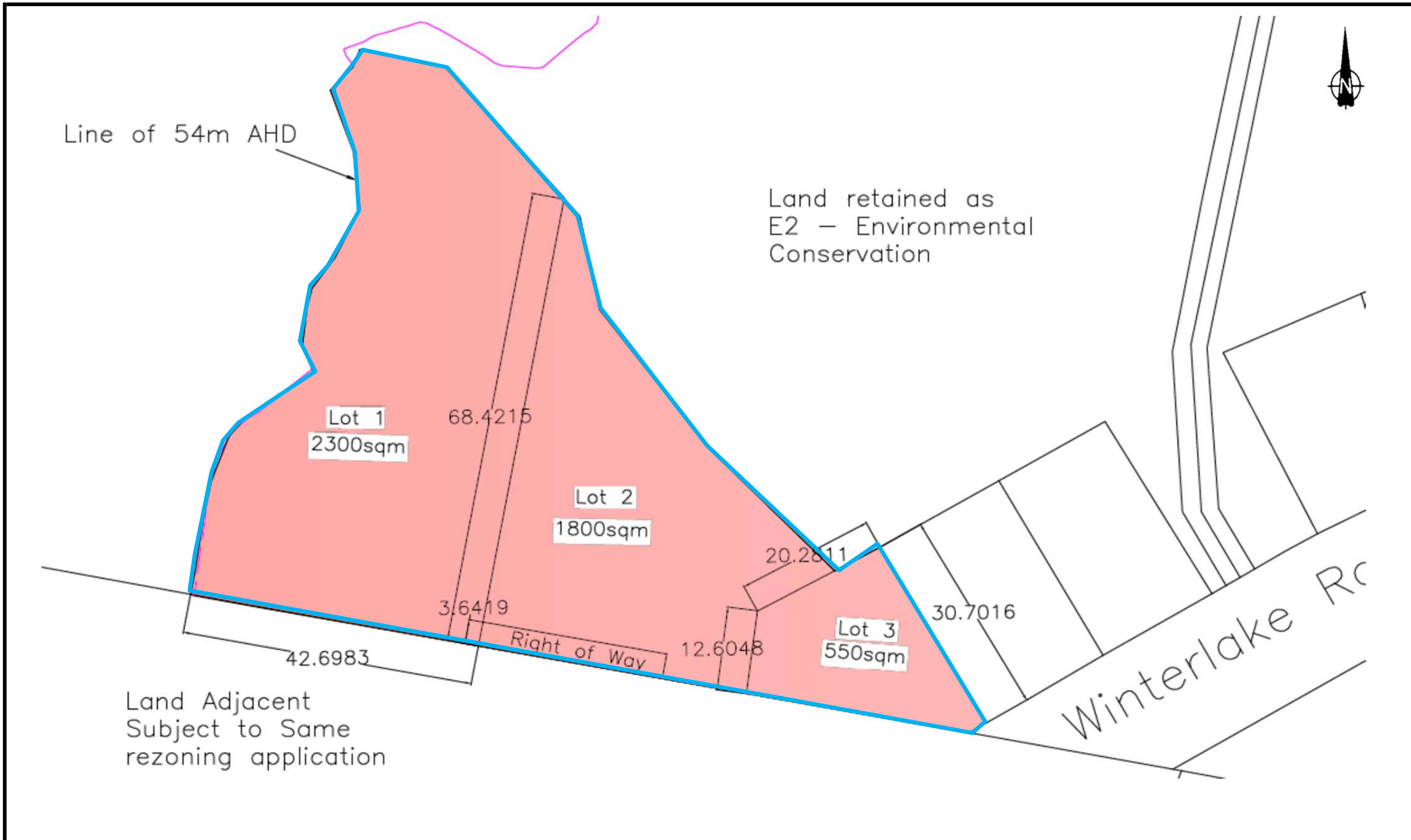
Steve Morton

Principal Geotechnical Engineer

References:

1. Australian Geomechanics Society, *Practice Note Guidelines for Landslide Risk Management*, Journal and News of the Australian Geomechanics Society, Vol 42, No 1, March 2007.
2. Shirley Partners Pty Ltd, Report RN84051/1/K051, *Geotechnical Report on Proposed Townhouse Development at Winterlake Street, Speers Point*, June 1987.
3. Fell, R, Sullivan, TD, and Parker, C. *The Speers Point Landslides* in Soil Slope Instability and Stabilisation, Walker & Fell eds, 1987

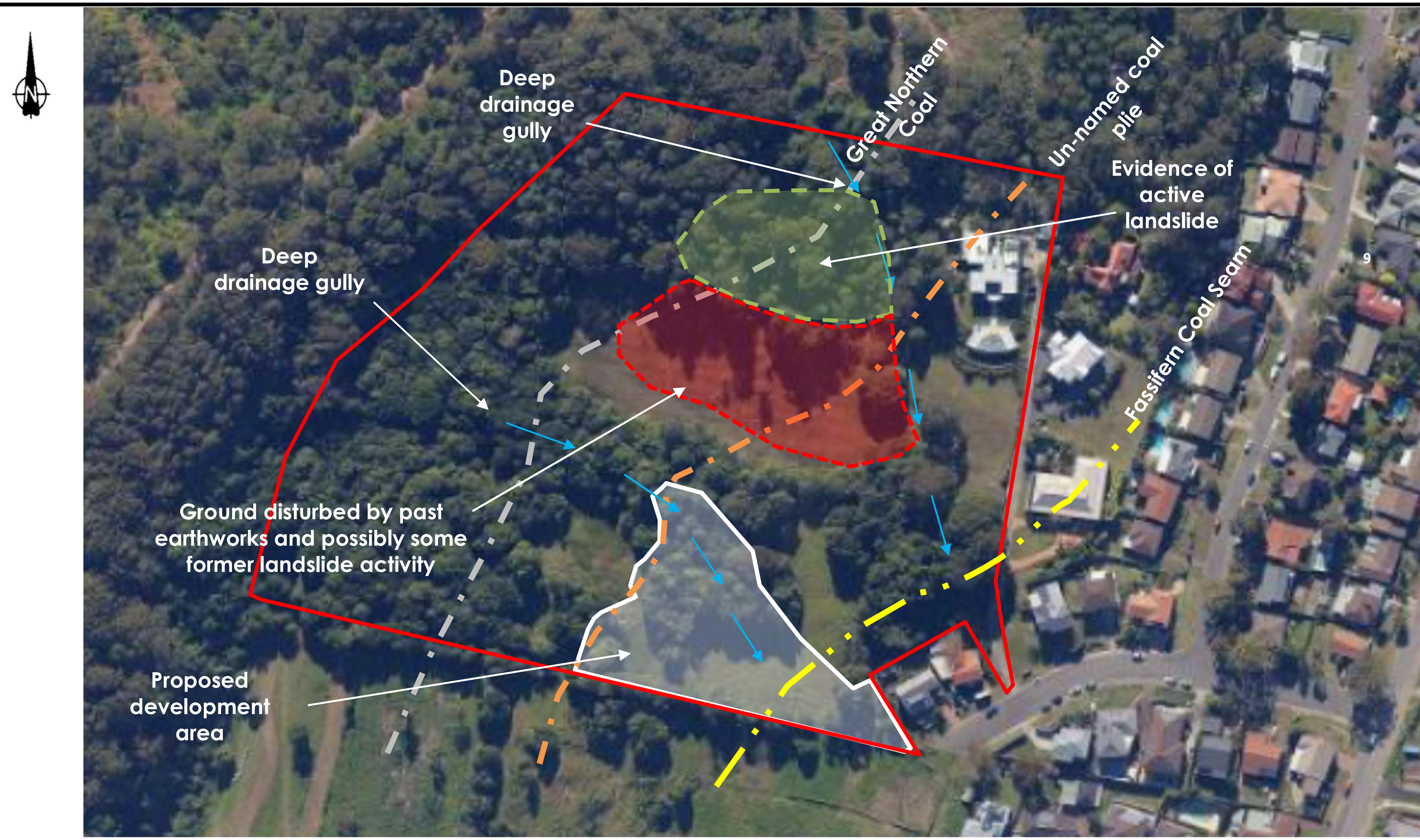
Figures



REGIONAL GEOTECHNICAL SOLUTIONS

Client:	Valley Planning Pty Ltd	Job No.	RGS02268.1
Project:	Proposed residential subdivision 18 Winterlake Road, Warners Bay	Drawn By:	SRM
		Scale:	shown
		Date:	30-Jan-20
Title:	Proposed Subdivision Configuration	Drawing No.	**Figure 1**

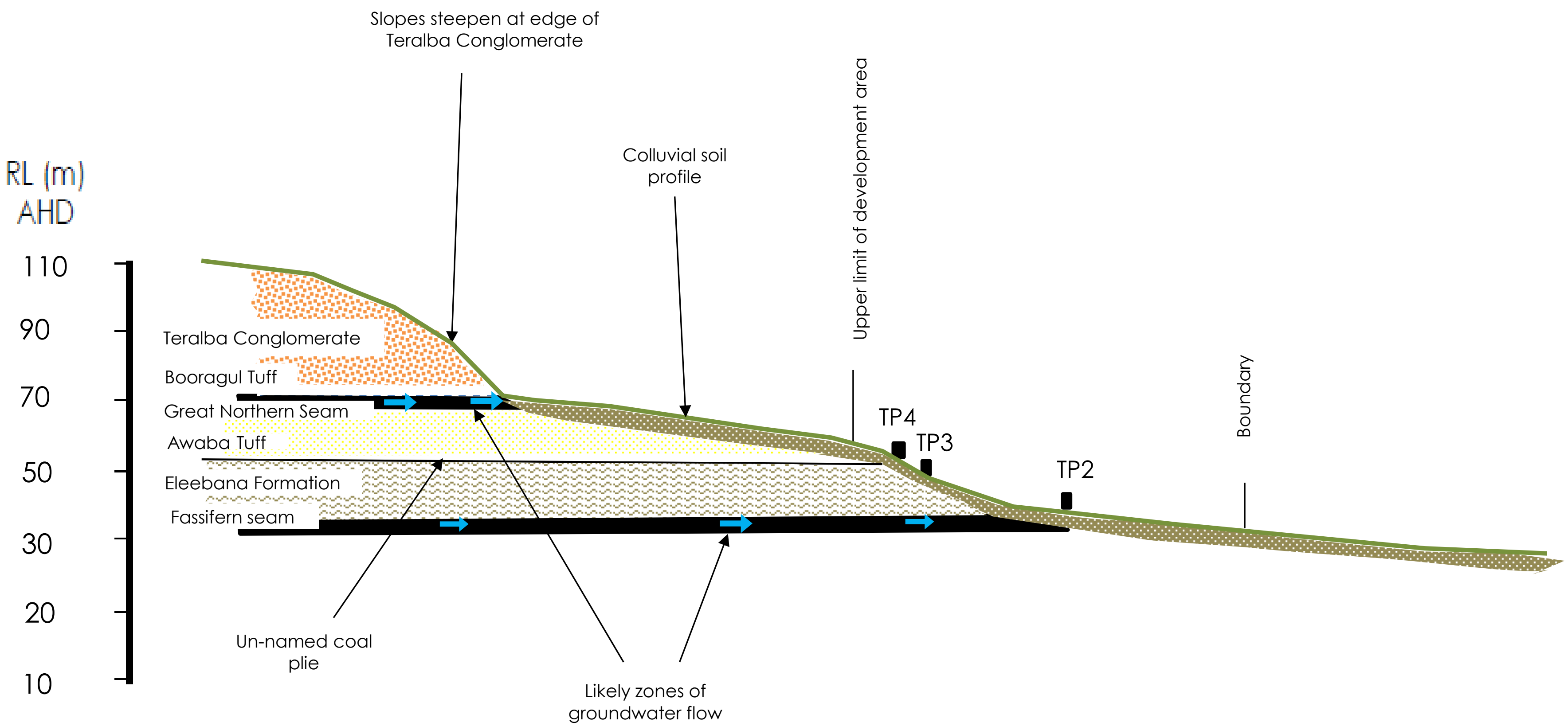
REGIONAL GEOTECHNICAL SOLUTIONS	**Client:**	Valley Planning Pty Ltd	Job No.	RGS02268.1
	Project:	Proposed residential subdivision 18 Winterlake Road, Warners Bay	Drawn By:	SRM
			Scale:	NTS
			Date:	30-Jan-20
	Title:	Test Pit Location Plan	Drawing No.	**Figure 2**



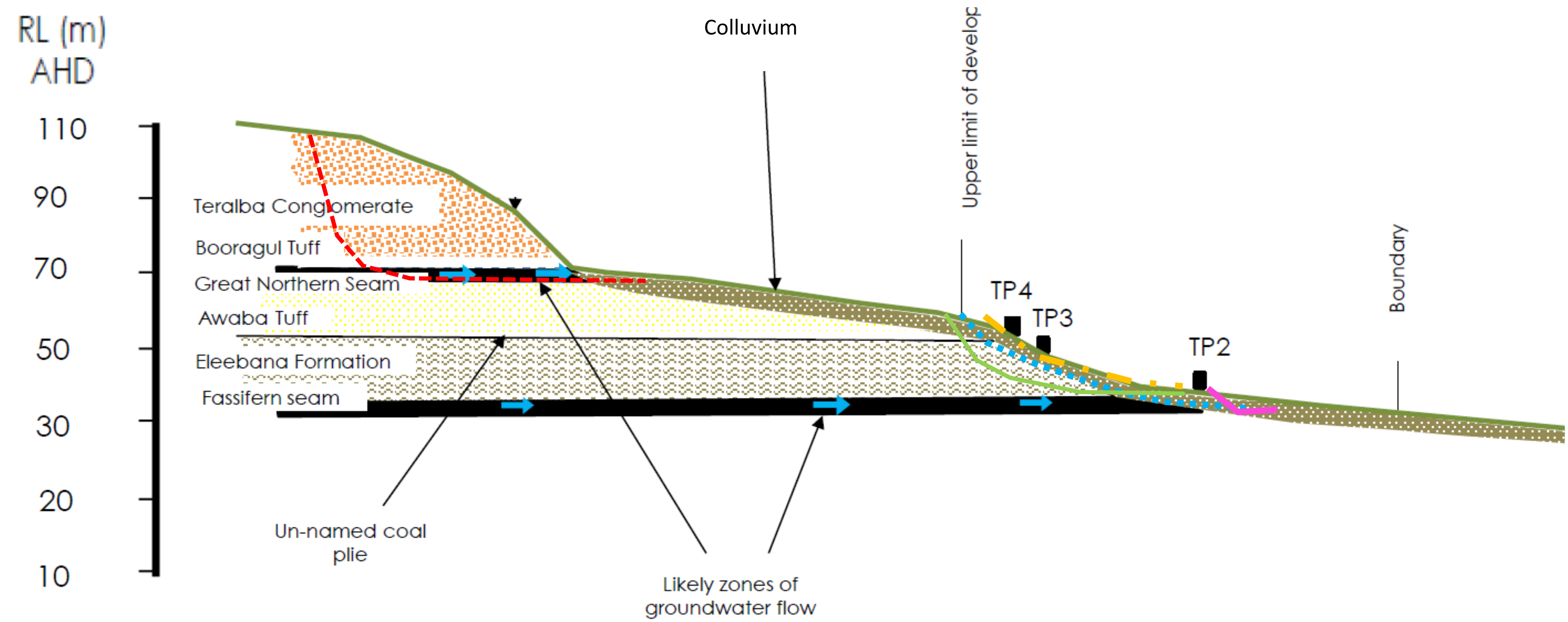
REGIONAL GEOTECHNICAL SOLUTIONS

Client:	Valley Planning Pty Ltd	Job No.	RGS02268.1
Project:	Proposed residential subdivision 18 Winterlake Road, Warners Bay	Drawn By:	SRM
		Scale:	NTS
		Date:	30-Jan-20
Title:	Site features and geology	Drawing No.	**Figure 3**

REGIONAL GEOTECHNICAL SOLUTIONS	**Client:**	Valley Planning Pty Ltd	Job No.	RGS02268.1
	Project:	Proposed residential subdivision 18 Winterlake Road, Warners Bay	Drawn By:	SRM
			Scale:	NTS
			Date:	30-Jan-20
	Title:	Landslide Zones (Fell) Relative to Subject Site	Drawing No.	**Figure 4**



REGIONAL GEOTECHNICAL SOLUTIONS	**Client**	Valley Planning Pty Ltd	Job No.	RGS02268.1
	Project:	Proposed residential subdivision	Drawn By:	SRM
		18 Winterlake Road, Warners Bay	Date:	31-Jan-20
	Title:	Interpreted Geological Cross Section	Drawing No	**Figure 5**



HAZARD H1 - Large scale translational slide of conglomerate blocks over saturated claystone causing debris flow

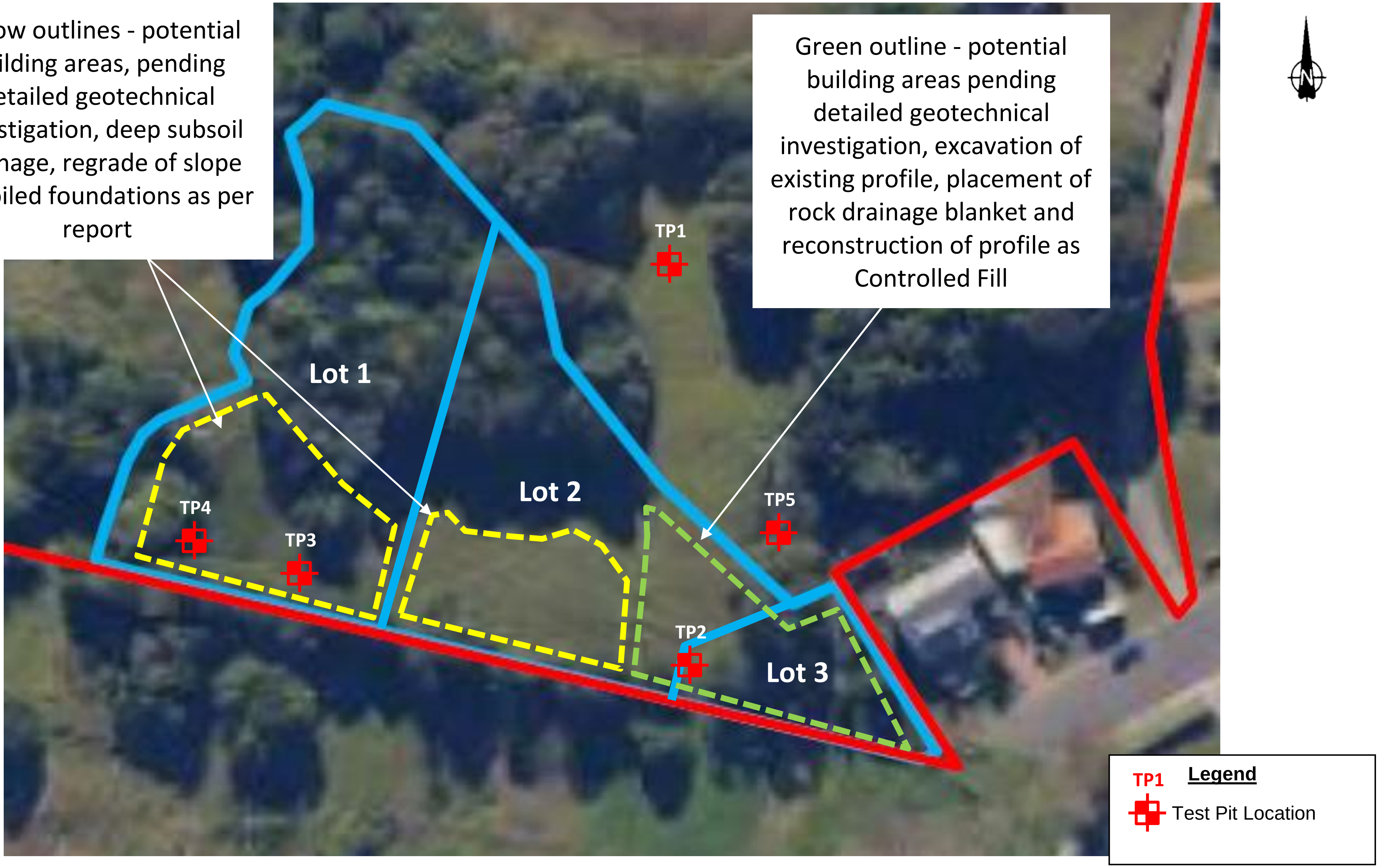
HAZARD H2 - Translational or rotational slide through colluvial and residual soil profile

HAZARD H3 - Ongoing soil creep in colluvial soil profile

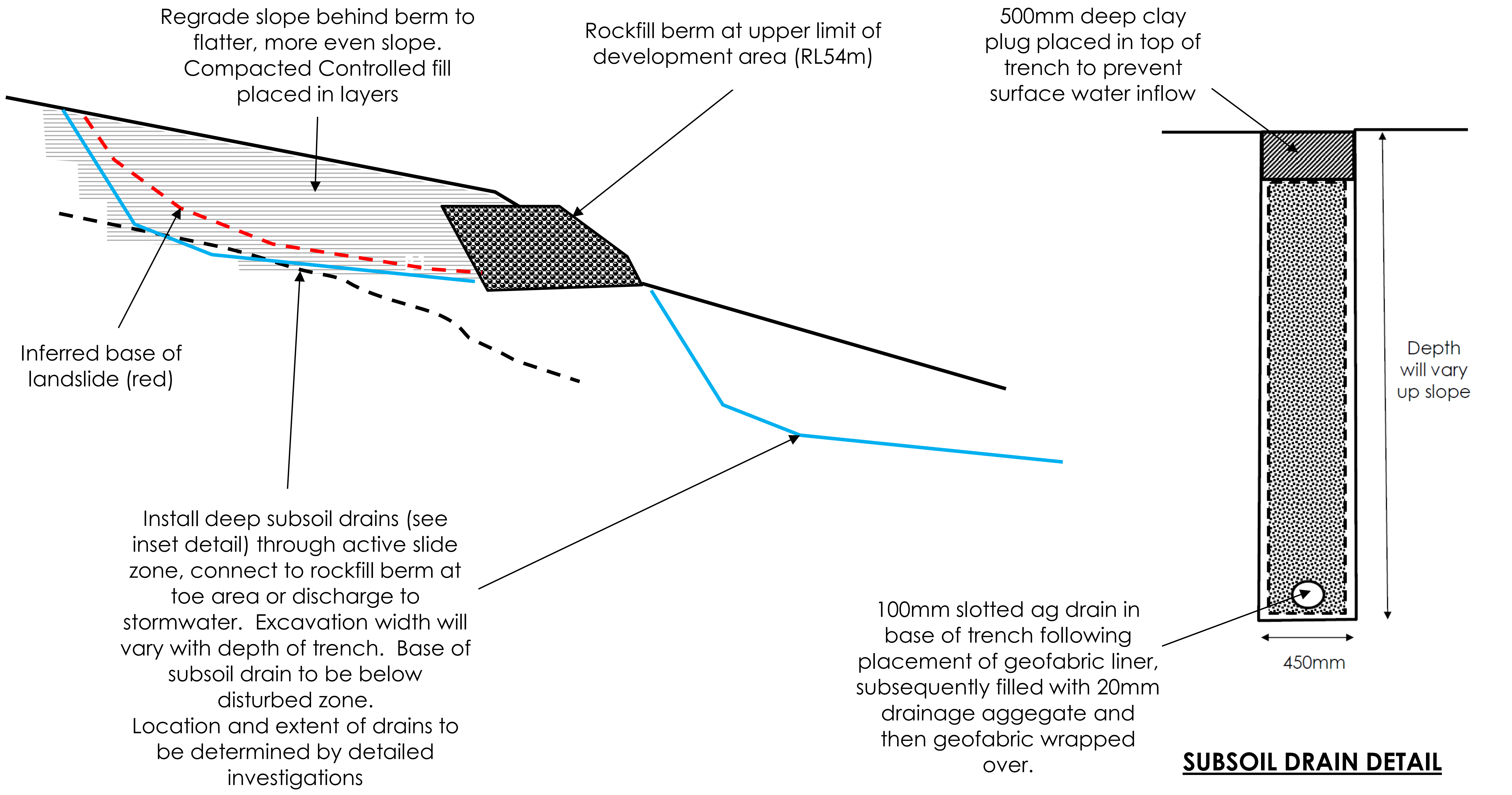
HAZARD H4 - Translational slide in weathered rock and soil profile - existing slide to south of site

HAZARD H5 - Rotational Failure in unsupported or inadequately retained cuts or fills

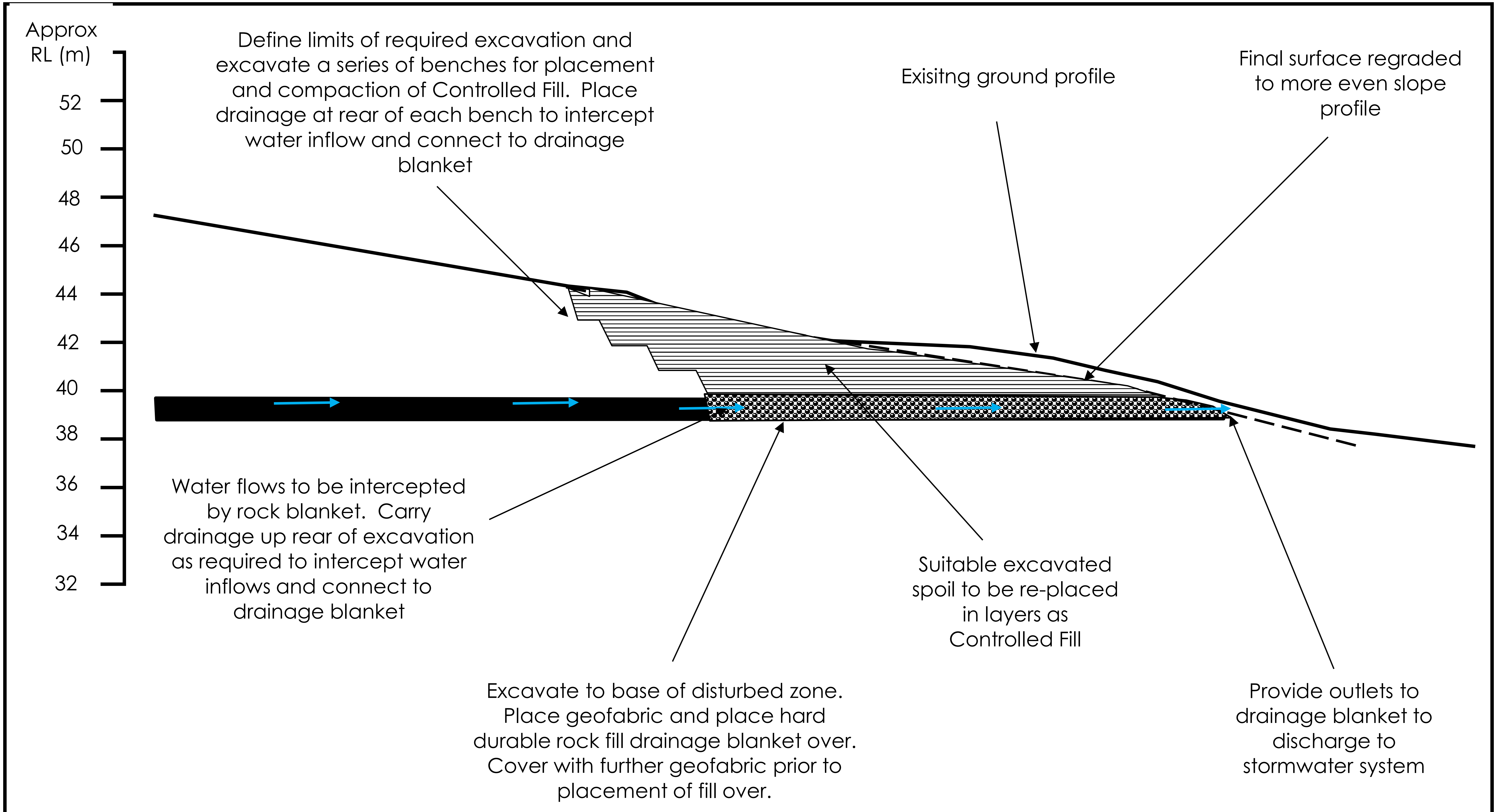
REGIONAL GEOTECHNICAL SOLUTIONS	**Client:**	Valley Planning Pty Ltd	Job No.	RGS02268.1
	Project:	Proposed residential subdivision 18 Winterlake Road, Warners Bay	Drawn By:	SRM
			Scale:	NTS
			Date:	30-Jan-20
	Title:	Identified Landslide Hazards	Drawing No.	**Figure 6**



REGIONAL GEOTECHNICAL SOLUTIONS	**Client:**	Valley Planning Pty Ltd	Job No.	RGS02268.1
	Project:	Proposed residential subdivision 18 Winterlake Road, Warners Bay	Drawn By:	SRM
			Scale:	NTS
			Date:	30-Jan-20
	Title:	Potential Building Areas and Geotechnical Requirements	Drawing No.	**Figure 7**



REGIONAL GEOTECHNICAL SOLUTIONS	**Client**	Valley Planning Pty Ltd	Job No.	RGS02268.1-AB
	Project:	Proposed Residential Subdivision 18 Winterlake Road, Warners Bay	Drawn By:	SRM
			Date:	30-Jan-20
	Title:	Proposed Landslide Remediation Works - Mid to Upper Slope	Drawing No.	**Figure 8**



REGIONAL GEOTECHNICAL SOLUTIONS

Client	Valley Planning Pty Ltd	Job No.	RGS02268.1-AB
Project:	Proposed Residential Subdivision	Drawn By:	SRM
	18 Winterlake Road, Warners Bay	Date:	30-Jan-20
Title:	Proposed Remediation Works - Lower Slope	Drawing No.	**Figure 9**

Appendix A

Results of Field Investigations

ENGINEERING LOG - TEST PIT

REGIONAL GEOTECHNICAL SOLUTIONS

CLIENT:	Valley Planning	TEST PIT NO:	TP1
PROJECT NAME:		PAGE:	1 of 1
SITE LOCATION:	18 Winterlake Road, Warners Bay	JOB NO:	RGS02268.1
TEST LOCATION:	Refer to Figure 1	LOGGED BY:	SRM
		DATE:	2/12/19

EQUIPMENT TYPE:	8.5T Excavtor	EASTING:		SURFACE RL:	
TEST PIT LENGTH:	3.2 m WIDTH: 0.6 m	NORTHING:		DATUM:	AHD

METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
Excavator	Not Encountered			0.00–0.40m	SM	**TOPSOIL:** Clayey Silty SAND, fine to medium grained, grey, low plasticity, some gravel and roots	D	D			TOPSOIL
				0.40–0.90m	CL	**Gravelly Sandy CLAY:** Low plasticity, pale grey, gravel and sand fine to coarse grained		H / Fb			COLLUVIUM
				0.90–2.40m	CL	**Gravelly Sandy CLAY:** Low to medium plasticity, pale grey and orange-brown, sand and gravel fine to coarse grained	M < W_P	VSt - H	HP HP HP	450 320 280	COLLUVIUM
				2.40–3.60m	CH	**Sandy CLAY:** High plasticity, grey, sand fine to medium grained, some roots	M > W_P	St - VSt	HP HP	200 180	RESIDUAL Some fissuring
				3.60m		Hole Terminated at 3.60 m					

LEGEND:

Water
- Water Level (Date and time shown)
- Water Inflow
- Water Outflow

Strata Changes
- Gradational or transitional strata
- Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample
ASS	Acid Sulfate Soil Sample
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		UCS (kPa)
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - TEST PIT

REGIONAL GEOTECHNICAL SOLUTIONS

CLIENT: Valley Planning
PROJECT NAME:
SITE LOCATION: 18 Winterlake Road, Warners Bay
TEST LOCATION: Refer to Figure 1

TEST PIT NO: TP2
PAGE: 1 of 1
JOB NO: RGS02268.1
LOGGED BY: SRM
DATE: 2/12/19

EQUIPMENT TYPE: 8.5T Excavtor
TEST PIT LENGTH: 4.2 m **WIDTH:** 0.6 m
EASTING:
NORTHING:
SURFACE RL:
DATUM: AHD

METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics, colour, minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
Excavator				0.00–0.30m	SM	**TOPSOIL:** Gravelly Silty SAND, fine to medium grained, grey, some clay	D				TOPSOIL
				0.30–0.90m	GC	**Clayey Sandy GRAVEL:** Fine to coarse grained, pale grey, sand fine to coarse grained, clay low plasticity					COLLUVIUM
				0.90–2.40m	CL	**Sandy Gravelly CLAY/Clayey Sandy GRAVEL:** Fine to coarse grained, orange-brown and grey, sand fine to coarse grained, clay low to medium plasticity	M < Wp	VSt - H			COLLUVIUM
				2.40–3.40m	CL	**Sandy Gravelly CLAY:** Medium plasticity, yellow-brown, grey, orange-brown, sand and gravel fine to coarse grained	M > Wp	VSt - Fb	HP HP	240 260	RESIDUAL Disturbed Conglomerate derived residual
	Water Inflow (approx. 4.05m)			3.40–4.40m	CH	**Sandy CLAY:** Medium to high plasticity, grey, some dark grey, some white sand fine to medium grained, bands of cherty gravel	M > Wp				RESIDUAL CLAYSTONE Disturbed coal pile and disturbed chert bed Minor seepage
				4.40m		Hole Terminated at 4.40 m					

LEGEND:

Water
- Water Level (Date and time shown)
- Water Inflow
- Water Outflow

Strata Changes
- Gradational or transitional strata
- Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample
ASS	Acid Sulfate Soil Sample
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		UCS (kPa)
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

RG LIB 1.04.4.GLB Log RG NON-CORED BOREHOLE - TEST PIT RGS02268.1 LOGS.GPJ <<DrawingFile>> 10/12/2019 10:50 8.30.004 Datgel Lab and In Situ Tool

ENGINEERING LOG - TEST PIT

REGIONAL GEOTECHNICAL SOLUTIONS

CLIENT:	Valley Planning	**TEST PIT NO:**	**TP3**
PROJECT NAME:		**PAGE:**	1 of 1
SITE LOCATION:	18 Winterlake Road, Warners Bay	**JOB NO:**	RGS02268.1
TEST LOCATION:	Refer to Figure 1	**LOGGED BY:**	SRM
		DATE:	2/12/19

EQUIPMENT TYPE: 8.5T Excavtor		**EASTING:**	**SURFACE RL:**
TEST PIT LENGTH: 3.6 m	**WIDTH:** 0.6 m	**NORTHING:**	**DATUM:** AHD

METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
Excavator	Not Encountered			0.00–0.20m	SM	**TOPSOIL:** Silty SAND, pale grey	D				TOPSOIL
				0.20–0.80m	CL	**Sandy Gravelly CLAY:** medium plasticity, pale yellow, orange-grey, sand and gravel fine to medium grained	D	VSt - H			COLLUVIUM
				0.80–3.10m	CH	**Sandy Gravelly CLAY:** Medium to high plasticity, pale orange-grey and brown, band of angular cobble sized tuffaceous	M < W_P (to ~2.1m); M > W_P	VSt - Fb	HP (~1.5m); HP (~2.4m); HP (~2.5m)	300; 280; 260	COLLUVIUM
				3.10m		Hole Terminated at 3.10 m					

LEGEND:

Water
- Water Level (Date and time shown)
- Water Inflow
- Water Outflow

Strata Changes
- Gradational or transitional strata
- Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample
ASS	Acid Sulfate Soil Sample
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		UCS (kPa)
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - TEST PIT

REGIONAL GEOTECHNICAL SOLUTIONS

CLIENT:	Valley Planning	TEST PIT NO:	TP4
PROJECT NAME:		PAGE:	1 of 1
SITE LOCATION:	18 Winterlake Road, Warners Bay	JOB NO:	RGS02268.1
TEST LOCATION:	Refer to Figure 1	LOGGED BY:	SRM
		DATE:	2/12/19

EQUIPMENT TYPE:	8.5T Excavtor		EASTING:	SURFACE RL:	
TEST PIT LENGTH:	3.1 m	WIDTH: 0.6 m	NORTHING:	DATUM:	AHD

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
Excavator	Not Encountered			0.10m		SM	**TOPSOIL:** Gravelly Silty SAND	D	H / Fb			TOPSOIL
				0.5, 1.0, 1.5, 2.0		CL	**Sandy Gravelly CLAY:** Low to medium plasticity, pale orange-brown, grey, sand and gravel fine to coarse grained Disturbed 150mm thick coal pile in upslope corner of pit	M < W_P M > W_P				COLLUVIUM
				2.40m		CH	**Sandy CLAY:** Medium to high plasticity, grey-pale grey, some dark grey-black, sand fine to medium grained		VSt			RESIDUAL With carbonaceous shale bands. Fossilifeous
				3.20m			**CLAYSTONE:** Pale grey, yellow, white bands of tuffaceous siltstone		Fb			EXTREMELY WEATHERED TUFF Fractured, water on fracture surfaces
				3.90m			Hole Terminated at 3.90 m					

LEGEND:

Water

- Water Level (Date and time shown)
- Water Inflow
- Water Outflow

Strata Changes

- Gradational or transitional strata
- Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample
ASS	Acid Sulfate Soil Sample
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		UCS (kPa)
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - TEST PIT

REGIONAL GEOTECHNICAL SOLUTIONS

CLIENT:	Valley Planning	TEST PIT NO:	TP5
PROJECT NAME:		PAGE:	1 of 1
SITE LOCATION:	18 Winterlake Road, Warners Bay	JOB NO:	RGS02268.1
TEST LOCATION:	Refer to Figure 1	LOGGED BY:	SRM
		DATE:	2/12/19

EQUIPMENT TYPE:	8.5T Excavtor		EASTING:		SURFACE RL:
TEST PIT LENGTH:	3.5 m	WIDTH: 0.6 m	NORTHING:		DATUM: AHD

METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
Excavator	Not Encountered			0.00–0.30m	SM	**TOPSOIL:** Gravelly Silty SAND, grey	D	H			TOPSOIL
				0.30–1.90m	CL	**Sandy Gravelly CLAY:** Low to medium plasticity, grey, sand and gravel fine to medium grained Becoming pale yellow-orange-brown	M < Wp	VSt - H			COLLUVIUM
				1.90–2.90m	CH	**Sandy Gravelly CLAY:** Medium to high plasticity, orange-brown and yellow, some pale grey, sand and gravel fine to coarse grained	M < Wp	St - VSt			COLLUVIUM
				2.90m		Boulder in west slope cover of pit					
				2.90–3.40m		**SANDSTONE:** Sandstone boulders in matrix of wet clay					
				3.40m		Hole Terminated at 3.40 m					

LEGEND:

Water
- Water Level (Date and time shown)
- Water Inflow
- Water Outflow

Strata Changes
- Gradational or transitional strata
- Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample
ASS	Acid Sulfate Soil Sample
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		UCS (kPa)
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

RG LIB 1.04.4.GLB Log RG NON-CORED BOREHOLE - TEST PIT RGS02268.1 LOGS.GPJ <<DrawingFile>> 10/12/2019 10:50 8.30.004 Datgel Lab and In Situ Tool

Appendix B

AGS2007 Risk matrix

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	**Notional Boundary**					
10^{-1}	$5x10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5x10^{-3}$	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-4}$	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-5}$	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-6}$	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		Description	Descriptor	Level
Indicative Value	**Notional Boundary**			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	1: CATASTROPHIC 200%	2: MAJOR 60%	3: MEDIUM 20%	4: MINOR 5%	5: INSIGNIFICANT 0.5%
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (5)
B - LIKELY	10^{-2}	VH	VH	H	M	**L**
C - POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D - UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E - RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F - BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

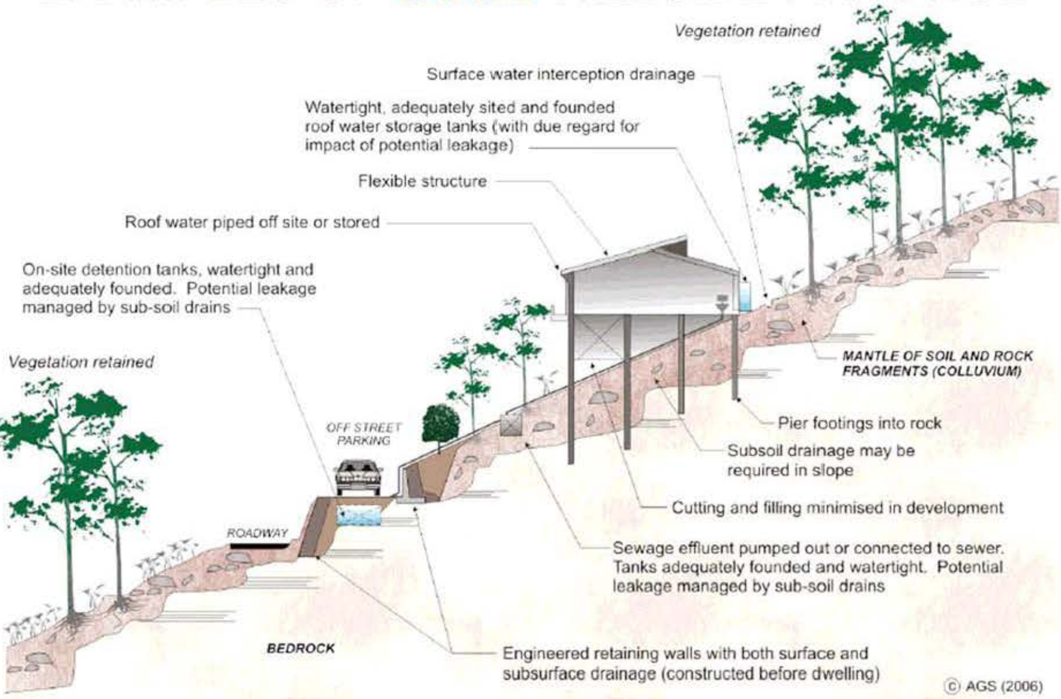
Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.
(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

EXAMPLES OF **GOOD** HILLSIDE PRACTICE



EXAMPLES OF **POOR** HILLSIDE PRACTICE