To:	As required		
Phone:			
Email:			
Subject:	Alexandria landfill slope failure		
Media Officer:	Alisha Allen	**Date:**	21/05/15
Prepared by:	Jack Mc Govern		

HOLDING LINES

BACKGROUND

The Alexandria landfill site was previously used as a quarry for brick making material and is characterised by extensive pits. The quarry has subsequently been filled with various landfill materials. The slope failure occurred within an area of the site where historically, there have been instances of landslip.

Based on the available information some mechanisms that may have contributed to the slope failure include the following:

- The heavy rainfall in April will likely have saturated the slope, resulting in a reduction in strength of the supporting materials. The total rainfall at Observatory Hill was 366.8mm in April, nearly 3 times the recorded average of 128.6mm (Bureau of Meteorology).
- The existing slope of the embankment comprises uncontrolled fill material. The batter angle is considered steep for this material.
- Drains along the access road at the top of the slope are blocked causing potential runoff down the slope causing erosion and saturation of the embankment

WDA has spoken with the owner of 310 Princes Highway and the pop-up shop (238 Princes Highway).

MEDIA RESPONSE

The slip is in a part of the site which has previously been prone to landslip. It occurred after an extended period of heavy rain in Sydney. WestConnex Delivery Authority (WDA) has not done any work around the slip site.

WestConnex Delivery Authority (WDA) has engaged a team of specialists to investigate the causes of the landslip and develop ways to rectify it.

WDA is working with stakeholders including business tenants closest to the slip area.

APPROVED BY

- Ken Reynolds
- Ken Reid
- Dimitry Belov.

Briefing for Chief Operating Officer

Transport
WestConnex
Delivery Authority

To: Robert Rust – Chief Operating Officer, WestConnex Delivery Authority

From: Ken Reynolds– Project Delivery Director New M5, WestConnex Delivery Authority

Title: Approval of the Reimbursable Work Notice (RWN001). Emergency slope stabilisation variation.

Objective Ref:

Purpose:

To approve the RWN to allow Wards, under the management contractor contract to begin works on the emergency slope stabilisation and ALF;

Key Issues for Consideration / Risk Factors:

WDA assumed ownership of the main Alexandria Landfill on Friday 19th December 201. The landfill has experienced a couple of minor slope stability issues after major rain events that has resulted in the high wall in the southern corner to fret away and slip, the slip is very close to the site boundary and existing buildings on Princes Highway.
Aecom conducted a survey and study, developed a design for the buttressing and support of that face in order to make it safe and ensure ongoing stability of the high wall.

Proposed Solution / Options for Resolution:

Ward CEE, acting as managing contractor in ALF, was instructed to price, programme and workshop the delivery of the Aecom design, with a view to starting ASAP. (see attached proposal.)

Costs Overview;

The costs associated with the works are estimated in Wards proposal attached, will be managed and reconciled by our Project manager, reporting to Ken Reid and claimed under the management contractor contract.

Stakeholder Consultation and Communication:

N/A

Accountability and Timeframe:

Ken Reynolds will be responsible for managing delivery contracts relating to WestConnex M5.

Recommendation:

It is recommended that approval be given to: instruct Wards to deliver the works in reimbursable Work Notice 001.

Proposed by:	**Endorsed by:**
Ken Reid	**Ken Reynolds**
Position	Position
WestConnex Delivery Authority	WestConnex Delivery Authority
date 8/7/15	date

Project Director's comments:

Approved / Not Approved / Noted

Chief Operating Officer's comments:

Approved / Not Approved / Noted

Transport
WestConnex
Delivery Authority

Mr Tom Wright , Project Manager
Ward Civil and Environmental Engineering Pty Ltd
Suite 2, level 4, 65 Epping Road
North Ryde
NSW 2113

Westconnex Delivery Authority

Date: 7th July 2015

Notice:- Reimbursable Work (RWN 001)-Slope Stabilisation Works
Managing Contractor Contract :St Peters Interchange

Dear Tom Wright
WDA hereby gives you notice under clause 24A1 that it requires you to carry out the following item *Reimbursable Work*.

Emergency slope stabilisation works adjacent to Stockpile 21b- in accordance with Aecom detail design dated 18th June 2015.

This *Reimbursable Work* is to be priced on a [choose one]:

(A) direct cost basis;

This Reimbursable Work is to be completed no later than 16th October 2015 (inline with WCEE attached programme)

WDA requires the following in relation to this Reimbursable work

(i) a detailed scope of the proposed work to be undertaken as part of the *Reimbursable Work*;

(ii) a detailed methodology addressing the following:

(A) a description of the resource methodology that will be used to undertake the proposed works;

(B) details of how the *Managing Contractor* will ensure that the quality of the proposed works complies with the *Contract*;

(C) a statement as to how the *Managing Contractor* will ensure the proposed works are carried out in an efficient manner; and

(D) a description of the information and particulars the *Managing Contractor* will provide to the *Principal's* representative supporting any progress claim made by the *Managing Contractor* for carrying out the proposed works (if applicable);

(iii) the target budget (including contingency) for the proposed works broken down into sufficient detail;

(iv) the time for commencement and completion of the proposed works;

(v) the number of resources (man power) and the anticipated total hours to carry out the proposed works onsite and offsite;

(vi) the cost of any materials and equipment the *Managing Contractor* intends to purchase as part of the *Reimbursable Work* for use in the proposed works; and

the type and number of *construction plant* and the anticipated total hours/days the construction plant will be used to carry out the proposed works.

Signed

Ken Reynolds
Project Director Stage 2 -Delivery(WDA)

WARD CIVIL ENGINEERING
WARD CIVIL AND ENVIRONMENTAL ENGINEERING PTY LTD
ABN 65 098 942 459

6th July 2015
Ref: 655.V01.02
Westconnex Delivery Authority
Level 9
101 Miller St,
North Sydney NSW 2060

Attention: Dimitry Belov

RE: Westconnex, St Peters interchange - Slope Stabilisation Works Budget

Ward Civil and Environmental Engineering Pty Ltd (Ward) is pleased to submit a budget estimate, attached to this letter, for St Peters Interchange, slope stabilisation works.

As per the AECOM design detail version dated 18 June 2015 we have provided a budget price and program for the earthworks component based on the volume of 31,000 m3.

Our budget price for the **Earthworks component** Redacted
Redacted

Our attached program outlines the sequence of works. The program has been based on the below assumptions / allowances. The following list is to assist in determining factors and to flag any items which may have an impact on the budget and construction periods.

1. We have assumed that certain activities can continue through wet weather, however the timeframes provided do not allow for the downtime during significant wet weather events. The program has allowed 4 days of wet weather per month.
2. We have allowed for an additional supervisor and engineer for the duration of the works.
3. The works have been allowed to be performed as 'emergency works" under the contract
4. No allowance for asbestos works in the budget prices or rates provided. We have however provided rates in previous submissions for these works which would apply.
5. No allowance in budget price for spoil or green waste to be removed offsite eg. The shrubs/ overgrowth on the batters.
6. Assumed earthworks compaction in 300mm layers. Compaction requirements nominated by Aecom may influence time period/ budget for compaction. We have allowed approx. 4 passes of a roller for each layer.
7. We have assumed the existing site material on which the platform is to be constructed is suitable for constructing an earthworks buttress / platform above. i.e. no allowance to replace or remove unsuitable ground or key in material.
8. Two water carts have been allowed for the duration of the works.
9. Two rollers have been allowed the duration of the earth fill works. Rollers have been allowed with 40% utilisation during this period.

Head Office
Suite 2, Level 4, 65 Epping Road
North Ryde NSW 2113

PO Box 1067
North Ryde BC NSW 1670

T 02 9438 3666
F 02 9439 7187

www.wardgroup.com.au

WARD CIVIL ENGINEERING

10. Approximately 7000m^3 will be required for access ramps and hard stand areas. No time or money has been allowed to remove this material following the works.
11. No allowance for dewatering / pumping etc.
12. Imported material not subject to landfill levies, royalties or fees.
13. Assumed stabilisation works during period Wards onsite for main site preparation works.

Please give me a call if you would like to discuss further.

Yours faithfully
Ward Civil and Environmental Engineering Pty Ltd

Tom Wright

Tom Wright
Project Manager
0409 321 609

Variation Budget Calculation

Ward Civil & Environmental Engineering ABN 065 098 942 459

Client: WDA

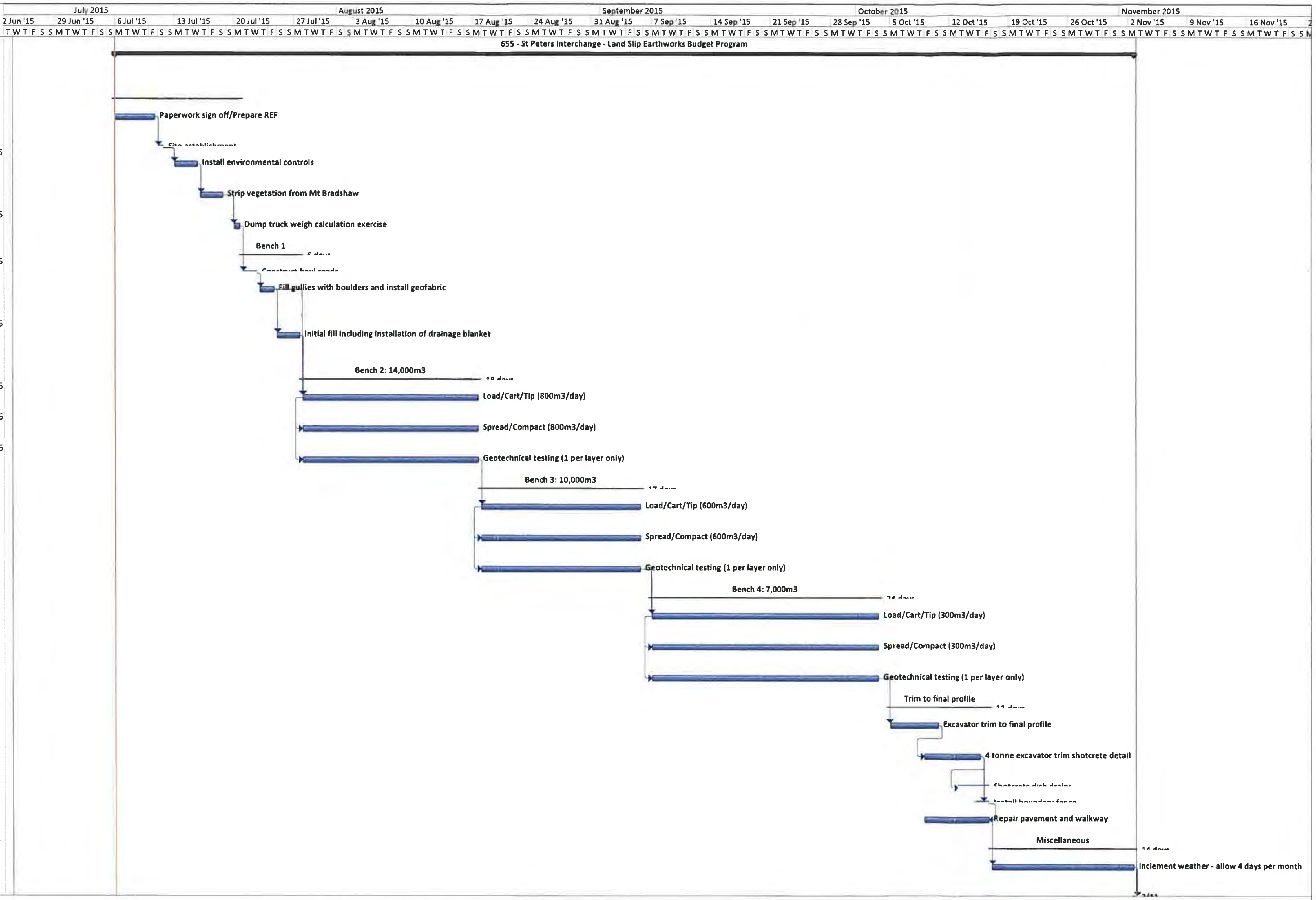
Client Contact Name: Dimitry Belov — **Client Ref:**

Project: St Peters Interchange — **Date:** 6/07/2015

Description: Land Slip Emergency Works — **WCEE Code:** 655.V01.TW

Item	Description	Unit	Quantity	Redacted
1	**Land Slip Emergency Works - Variation Budget Price Breakdown**			
1.1	**Supervision**			
1.1.1	Site Supervisor (for duration)	hr	931.00	
1.1.2	Project Engineer (for duration)	hr	931.00	
1.1.3	Site Ute (for duration)	hr	931.00	
1.2	**Labour**			
1.2.1	Labour (Normal Time)	hr	2,680.00	
1.2.2	Labour (Time and half)	hr	630.50	
1.2.3	Labour (Double time)	hr	335.00	
1.2.4	Traffic Controller (Normal Time) (x1)	hr	640.00	
1.2.5	Traffic Controller (Time and half) (x1)	hr	120.00	
1.2.6	Traffic Controller (Double time) (x1)	hr	80.00	
1.3	**Plant**			
1.3.1	36 tonne excavator	hr	731.50	
1.3.2	36 tonne excavator float	item	1.00	
1.3.3	D6 dozer	hr	674.50	
1.3.4	D6 dozer float	item	1.00	
1.3.5	25 tonne dump truck (x3)	hr	2,023.50	
1.3.6	25 tonne dump truck float (x3)	item	3.00	
1.3.7	20 tonne excavator (GPS)	hr	266.00	
1.3.8	20 tonne excavator float	item	1.00	
1.3.9	5 tonne excavator	hr	114.00	
1.3.10	5 tonne excavator float	item	1.00	
1.3.11	Roller x 2 (Pad foot/Smooth drum)	hr	539.60	
1.3.12	Roller Float	item	2.00	
1.3.13	Watercart x 2	hr	1,862.00	
1.3.14	Shotcrete Pump	hr	48.00	
1.3.15	Bogie tipper	hr	20.00	
1.4	**Subcontractors**			
1.4.1	Surveyor	hr	200.00	
1.4.2	GPS Base Station & Rover	Month	4.40	
1.4.3	Geotechnical testing (1 per layer only)	test	100.00	
1.4.4	Level 1 Geotechnical Supervision (for duration of fill activities only)	day	65.00	
1.4.5	Dilapidation Survey	item	1.00	
1.5	**Materials**			
1.5.1	Geofabric	m2	5,000.00	
1.5.2	Strip Drains	roll	30.00	
1.5.3	Shotcrete (32MPa)	m3	165.00	
1.5.4	Fencing	item	1.00	
1.5.5	Stormwater Piping (down batter chute)	item	1.00	
1.6	**Safety & Environmental**			
1.6.1	Safety materials (signage, flagging, bollards, PPE, road plates)	item	1.00	
1.6.2	Prepare REF	item	1.00	
1.7	**Contingency**			
1.7.1	10% Contingency - Compaction trials/poor material/unforseen	item	1.00	
		Subtotal of Vari		
		G.S.T		
		Total		

ID	Task Name	Duration	Start	Finish
1	**655 - St Peters Interchange - Land Slip Earthworks Budget Program**	**103 days**	**Mon 6/07/15**	**Mon 2/11/15**
2	**Site Preparation Works**	**13 days**	**Mon 6/07/15**	**Mon**
3	Paperwork sign off/Prepare REF	5 days	Mon 6/07/15	Fri 10/07/15
4	Site establishment	1 day	Sat 11/07/15	Sat 11/07/15
5	Install environmental controls	3 days	Mon 13/07/15	Wed 15/07/15
6	Strip vegetation from Mt Bradshaw	3 days	Thu 16/07/15	Sat 18/07/15
7	Dump truck weigh calculation exercise	1 day	Mon 20/07/15	Mon 20/07/15
8	**Bench 1**	**6 days**	**Tue 21/07/15**	**Mon**
9	Construct haul roads	2 days	Tue 21/07/15	Wed 22/07/15
10	Fill gullies with boulders and install geofabric	2 days	Thu 23/07/15	Fri 24/07/15
11	Initial fill including installation of drainage blanket	2 days	Sat 25/07/15	Mon 27/07/15
12	**Bench 2: 14,000m3**	**18 days**	**Tue 28/07/15**	**Mon**
13	Load/Cart/Tip (800m3/day)	18 days	Tue 28/07/15	Mon 17/08/15
14	Spread/Compact (800m3/day)	18 days	Tue 28/07/15	Mon 17/08/15
15	Geotechnical testing (1 per layer only)	18 days	Tue 28/07/15	Mon 17/08/15
16	**Bench 3: 10,000m3**	**17 days**	**Tue 18/08/15**	**Sat 5/09/15**
17	Load/Cart/Tip (600m3/day)	17 days	Tue 18/08/15	Sat 5/09/15
18	Spread/Compact (600m3/day)	17 days	Tue 18/08/15	Sat 5/09/15
19	Geotechnical testing (1 per layer only)	17 days	Tue 18/08/15	Sat 5/09/15
20	**Bench 4: 7,000m3**	**24 days**	**Mon 7/09/15**	**Sat 3/10/15**
21	Load/Cart/Tip (300m3/day)	24 days	Mon 7/09/15	Sat 3/10/15
22	Spread/Compact (300m3/day)	24 days	Mon 7/09/15	Sat 3/10/15
23	Geotechnical testing (1 per layer only)	24 days	Mon 7/09/15	Sat 3/10/15
24	**Trim to final profile**	**11 days**	**Mon 5/10/15**	**Fri 16/10/15**
25	Excavator trim to final profile	6 days	Mon 5/10/15	Sat 10/10/15
26	4 tonne excavator trim shotcrete detail	6 days	Fri 9/10/15	Thu 15/10/15
27	Shotcrete dish drains	4 days	Tue 13/10/15	Fri 16/10/15
28	Install boundary fence	2 days	Thu 15/10/15	Fri 16/10/15
29	Repair pavement and walkway	7 days	Fri 9/10/15	Fri 16/10/15
30	**Miscellaneous**	**14 days**	**Sat 17/10/15**	**Mon 2/11/15**
31	Inclement weather - allow 4 days per month	14 days	Sat 17/10/15	Mon 2/11/15
32	Completion	0 days	Mon 2/11/15	Mon 2/11/15



Project: 655 St Peters Interchange Land Slip Budget Program
Date: 6/7/15

Task | Milestone | Project Summary | External Milestone | Inactive Milestone | Manual Task | Manual Summary Rollup | Start-only | Deadline
Split | Summary | External Tasks | Inactive Task | Inactive Summary | Duration-only | Manual Summary | Finish-only | Progress

AECOM Australia Pty Ltd
Level 21, 420 George Street
Sydney NSW 2000
PO Box Q410
QVB Post Office NSW 1230
Australia
www.aecom.com

+61 2 8934 0000 tel
+61 2 8934 0001 fax
ABN 20 093 846 925

27 May 2015

Westconnex Delivery Authority
Locked Bay 928
North Sydney
NSW 2059

Dear Dimitry Belov

Site Inspection Report - St Peters Interchange Slope Failure (Previously Dial a Dump Industries)

1.0 Introduction

Following WestConnex Delivery Authority (WDA) email request on the 5th of May 2015, AECOM carried out a site inspection of a slope failure that occurred at the proposed WestConnex St Peters Interchange (SPI) site, previously owned by Dial a Dump Industries (DADI).

A site inspection of the slope failure was carried out on the 6th of May 2015 within the SPI siteand from public spaces surrounding the site. However the crest of the slope is located in private property and was subsequently visited on the 20th of May 2015, once permission was received from the property owner.

The purpose of the site visit was to inspect the area of the slope failure and to report on observations made of the failure area and advise WDA of potential risks associated with the landslide. Additionally AECOM has also prepared some preliminary recommendations associated with the recent slope failure.

2.0 Site description

The DADI site is an irregular shaped site at St Peters/Alexandria approximately 6 km from the Sydney CBD. The site was previously used as a quarry for brick making material and is characterised by extensive pits. Based on current survey information from the Westconnex GIS portal, surface levels range from 21m AHD to -11m AHD. Based on historical information it is understood that excavations for the brick pit were up to -30 m AHD. Since the quarry ceased operation it has subsequently been filled with various landfill materials.

The slope failure was noted on the 5th of May 2015. However, the failure could have occurred prior to this date. The slope failure occurred along the northern boundary of the property, adjacent to an industrial estate off the Princes Highway. An approximate location of the landslip is shown in Figure 1 below.

Figure 1 Site Location and landslip location.

3.0 Observations

3.1 Slope Overview

The slope failure occurred on an embankment near the north western boundary of the site. The embankment is estimated to be 22m high based on survey information from the Westconnex GIS. The surface of the embankment was covered in grasses, shrubs and small trees. The surface materials typically comprised gravel and cobbles of sandstone and bricks in a silty sand matrix. Adjacent to the embankment is a near vertical 17 to19m high siltstone cutting. Above the embankment and siltstone cutting are commercial buildings, an access road and car parking. A photo of the slope failure is shown in Figure 2 below.

The majority of the existing embankment is at a 1H:1V slope. However, based an visual observations it is estimated that the slope angle at the crest of the embankment increases to an angle of between 50° and 70° from horizontal. Undercutting of the slope failure scarp at the embankment crest was also observed beneath the roots of the trees and shrubs

Evidence of surface water runoff was also observed at various locations at the crest of the embankment and down the slope of the embankment. The surface of the embankment was hummocky and saturated in areas. Water was also ponding at the toe of the embankment during both site visits.

Some of the drains along the access road to the north of the embankment were blocked and full of debris.

Immediately above the slope failure is a drainage sump which is understood to drain water from the roof of the adjacent warehouse. The distance between the crest of embankment and the adjacent warehouse is between 1.5m anf 5m.

A sketch of the slope area based on visual observation with typical sections through the embankment have been provided in Attachment A.

Figure 2 Fill embankment looking west showing the landslide (6th May 2015)

3.2 Slope Failure

Based on a visual assessment of the embankment, it is estimated that the size of the slope failure is 6m wide, 6m in length and 0.5 to 2m deep.

The slope failure appears to have travelled approximately 3m to 6m down the embankments. A debris flow was also noted on the northern side of the landslide, however it is unclear if this occured prior to, subsequent to or during the landslide. The general configuration of slope failure is shown in Figure 3 below.

A boulder from the recent landslide, approximately 1m in diameter, was noted 5m from the toe of the slope failure. A photograph of the boulder is shown in Figure 4 below. The landslide materials comprise fill typically containing silty sand, cobbles and boulders of sandstone and bricks.

During the site visit on the 20th of May 2015, tension cracks were observed at the crest of the slope above the slope area, as shown in Figure 5 below, indicating that the embankment may be exhibiting evidence of regression.

Figure 3 Landslide configuration and materials (6th May 2015)

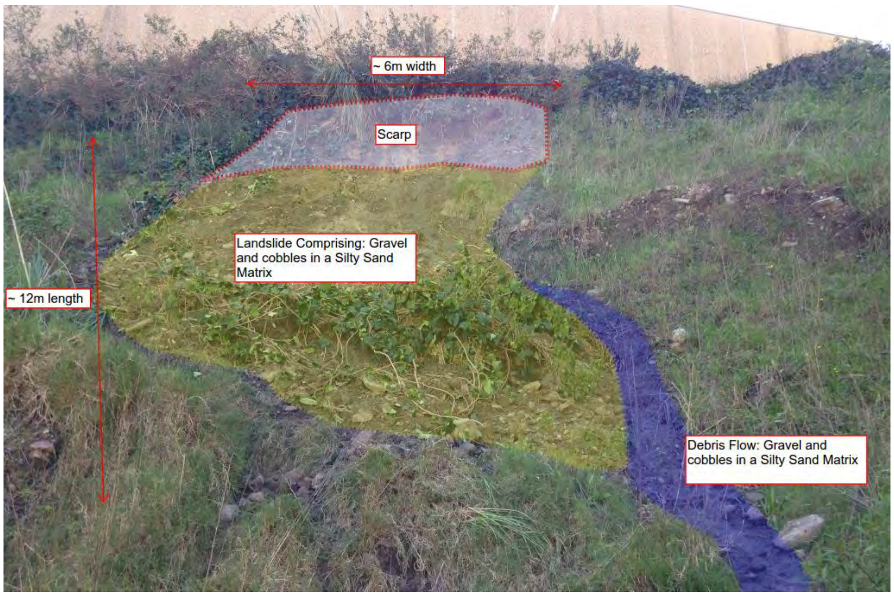


Figure 4 Boulder from Landslide (6th May 2015)

Figure 5 Crest of slope, showing tension cracks and drainage sump and pipe (20th May 2015)

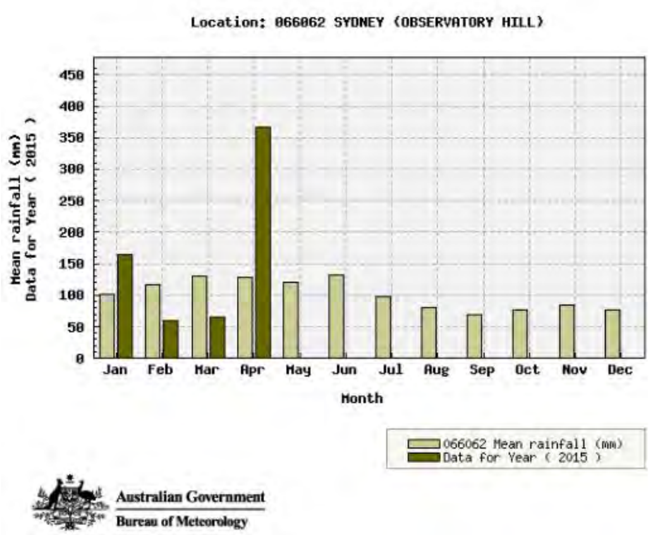
3.3 Potential Triggers

Based on the available information mechanisms that may have contributed to the slope failure are considered to include the following:

- The majority of the existing slope of the embankment is currently at 1H:1V and comprises uncontrolled fill material. Near the crest of the embankment the slope angle increases in places to angles of up to 70°. This batter angle is considered steep for this material.
- Based on records obtained from the Bureau of Meteorology, the total rainfall at Observatory Hill was 366.8mm in April which is nearly 3 times the recorded average of 128.6mm (As shown in Figure 6 below). This rainfall will likely have saturated the slope, resulting in a reduction in strength of the supporting materials.
- Water seepage and saturation of the slope materials, thereby weakening the strength of the soil and reducing the embankments stability. The source of the water may have come from a combination of the following:
    - Damage to the drainage sump and pipe immediately above the slope failure
    - Surface water runoff
    - Blocked drains causing potential runoff down the embankment
- Erosion of the embankment due to surface water run off

There may be additional mechanisms that have contributed to the slope failure however this would require further analysis and investigation.

Figure 6 Monthly average rainfall and recorded rainfall for 2015



4.0 Potential Elements at Risk

Based on a visual assessment of slope the current elements at risk of future settlement

- Potential damage to the road pavement and building structures in the industrial estate at the top of the slope
- Services at the top of the slope including the dewatering system for the former landfill

Vehicles using the access road above the slopes

The is also the potential risk to the safety of people using vehicles on the access road above, people carrying out work at the base of the slope and people within the buildings above the slope.

5.0 Recommendations

Due to the recent slope failure and observations made during the site visits of the potential elements at risk, it is suggested that the Westconnex Delivery Authority (WDA) should carry out the following tasks immediately:

- Cover the top of the slope with plastic to prevent further water ingress to the slope in the vicinity of the failure and tension cracks
- Monitor further ground movements around the slope area daily and any other observable changes

Based on the recent observations, there is considered to be a high probability of the existing slope(s) undergoing further deformation. It is suggested that WDA should carry out immediate temporary stabilization works at the slope, which may include construction of a buttress in the area of the slope failure, subject to further discussion in term logistics and engineering assessment.

It is also recommended that WDA consider carrying out the following additional tasks:

- CCTV inspection of the drainage sump and pipe above the slope failure (it is understood that this work has been organised by WDA);
- Installation of an Inclinometer from the crest of the slope to monitor movements (if safe to do so);
- Slope stability assessment of the existing slope and options for stabilisation of the slope to maintain the existing building stability;
- Slope surveyor monitoring; and
- Dilapidation survey/condition report of the warehouse at the crest of the slope (costs can be provided if requested).

AECOM

6.0 Cost Estimate

6.1 AECOM Rates

AECOM proposes to carry out the proposed work based of cost and materials using our rates listed Table 1 below:

Table 1 AECOM Rates

Role	Rate (Excluding GST)
Industry Director	Redacted
Technical Director	Redacted
Associate Director	Redacted
Principal Engineer	Redacted
Senior Engineer	Redacted
Geotechnical Engineer	Redacted
Graduate Engineer	Redacted
Draftsperson	Redacted
Subcontractors	Redacted

6.2 Drilling investigation

AECOM proposes to drill one borehole at the crest of the embankment immediately adjacent to the slope failure. This information will feed into the stability assessment of the existing structure and slope stability. At the completion of the borehole an inclinometer will be installed to a maximum depth of 10m or 3m into rock to monitor lateral movements of the slope.

Prior to mobilisation of the drilling rig a site visit will be carried out with the drilling contractor out to check access and safety at the proposed drilling location.

Tasks include the following:

- Undertake preliminary activities:
  - Obtain Dial Before You Dig (DBYD) plans and Detailed Services Survey (DSS);
  - Engagement of subcontractors (Service Location Contractor – Vacgroup Pty Limited and Drilling Contractor – Terratest Pty Limited)
  - Prepare Safe Work Method Statements (SWMS) for AECOM site activities; and
  - Collate and review SWMS for subcontractors' site activities.
- Undertake Fieldwork activities:
  - Clearance of underground services so far as is reasonably practicable using a Telstra Accredited services locator using the DBYD;
  - Drill a borehole at the crest of the slope to a maximum depth of 10m below ground surface or 3m into Class III Siltstone;
  - Standard Penetration Testing (SPT) will be carried out at 1.5m depth intervals within soil;
  - When bedrock is encountered, the borehole will be drilled using HQ3 coring techniques to reach the proposed target depths and recover rock core samples for logging and description;
  - Field logging and direction of sampling and in situ strength testing will be undertaken by an AECOM geotechnical engineer/engineering geologist. Field logging will be in general accordance with AS1726-Geotechnical Site Investigations; and
  - At the completion of the testing the excavation will be backfilled using the borehole cuttings.

AECOM

- Office activities
  - Preparations of a geotechnical letter report including outlining the findings of the geotechnical investigation, borehole log, geotechnical parameters for use in a subsequent analysis and stability recommendation.

No allowances have been made for ongoing monitoring of the inclinometer in the cost estimate below.

Table 2 Drilling investigation cost estimate

Item	Unit x Rate	Cost (ex GST)
AECOM Fees		
Project Management (Preparation of contracts, SWMS, DBYD) Principal Geotechnical Engineer Geotechnical Engineer	Redacted	
Site Investigations Geotechnical Engineer		
Reporting (gINTing, Reporting and Review) Geotechnical Engineer Technical Director		
AECOM Fees Subtotal (excl. GST)		Redacted
AECOM Subcontractors		
Service Locating Contactor	Redacted	
Drilling Investigation Contractor Drilling Coreboxes Concrete Loss of circulation material Monument cover Inclinometer		
Geotechnical Laboratory Testing Particle Distribution Testing (PSD) - AS1289 3.6.1 Point Load Index Testing (PLI) - AS4133 4.1.		
Subcontractor(s) fee (excl. mark-up and GST)		Redacted
10% surcharge		Redacted
Overall Fee Estimate (excluding GST)		Redacted
GST		Redacted
Overall Fee Estimate		Redacted

6.3 Slope Stability Assessment and Concept Design

AECOM proposes to carry out a slope stability assessment of one critical section in the area of the slope failure to identify the potential issues and risks to the embankment the stability of the existing slope will be assessed using Slope W or Plaxis software. Following this assessment AECOM will develop two to three remedial concept options to stabilise the slope and prepare a geotechnical letter report outlining the finding of the analysis and proposed concept options.

No allowances have been made for drainage, civil design and preparation of construction drawings.

Table 3 Slope Stability Assessment and Concept Design

Item	Unit x Rate	Cost (ex GST)
AECOM Fees		
Review of available information for Geotechnical Model Industry Director Senior Geotechnical Engineer (per option)	Redacted	
Slope Stability Assessment Senior Geotechnical Engineer		
Development of Remedial measure (per options) Senior Geotechnical Engineer		
Preparation of sketch of concept options Senior Geotechnical Engineer		
Reporting and Review Senior Geotechnical Engineer Industry Director		
Overall Fee Estimate (excluding GST)		Redacted
GST		Redacted
Overall Fee Estimate		Redacted

6.4 Slope surveyor monitoring

As requested AECOM propose to carry out monitoring of the slope using an accredited surveyor (RPS Group). AECOM proposes to place 6 to 7 targets at selected location on the existing building, at the crest of the embankment and if possible on the slope. Once the targets have been installed 3D baseline measurements will be recorded in 3 dimensions.

Ongoing monitoring will be carried out at selected intervals. At this stage it is suggested that measurement is carried out once a day. Depending on the level of movement, AECOM will review the monitoring program in conjunction with WDA and increase or decrease the monitoring program accordingly. Daily monitoring will be carried out at a cost of Redacted per day Redacted

AECOM will provide WDA with the surveyor report once it has been received. No allowance have been made for additional reporting and analysis of the results.

Table 4 Slope surveyor monitoring (Set up)

Item	Unit x Rate	Cost (ex GST)
AECOM Fees		
Project Management (Preparation of contracts, SWMS and survey plan) Principal Geotechnical Engineer Geotechnical Engineer	Redacted	
Supervision of set up Senior Geotechnical Engineer		
AECOM Subcontractors		
Surveyors Set up and Base line measurements		
Subcontractor(s) fee (excl. mark-up and GST)		Redacted
10% surcharge		Redacted
Overall Fee Estimate (excluding GST)		Redacted
GST		Redacted
Overall Fee Estimate		Redacted

Yours faithfully

Peter Plummer
Geotechnical Engineer
peter.plummer@aecom.com

Mobile: +61 401 566 222
Direct Dial: +61 2 8934 0000

John Ashley
Technical Director - Tunnelling
john.ashley@aecom.com

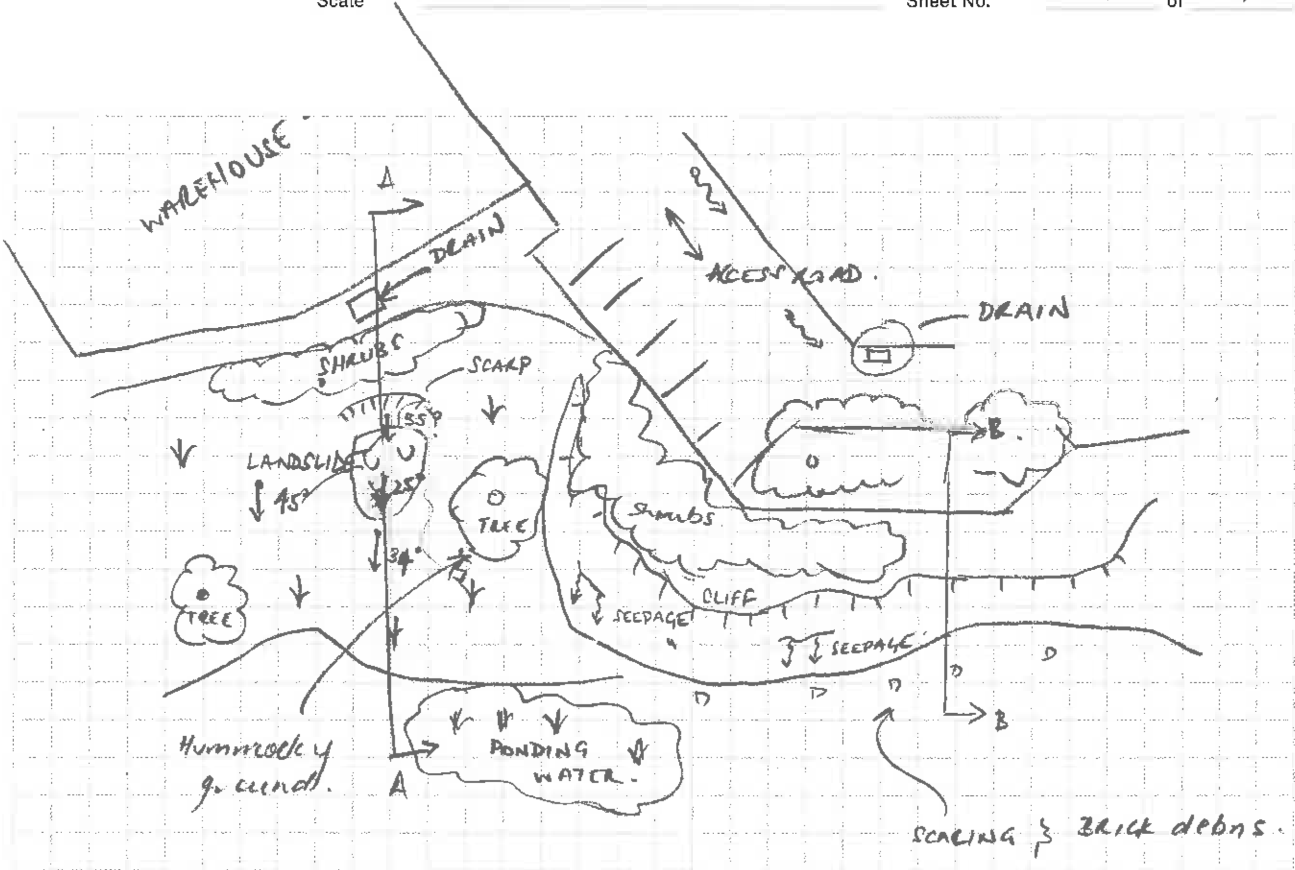
Mobile: +61 412 187 687
Direct Dial: +61 2 8934 0043
Direct Fax: +61 2 8934 0001

cc: Antony Tam

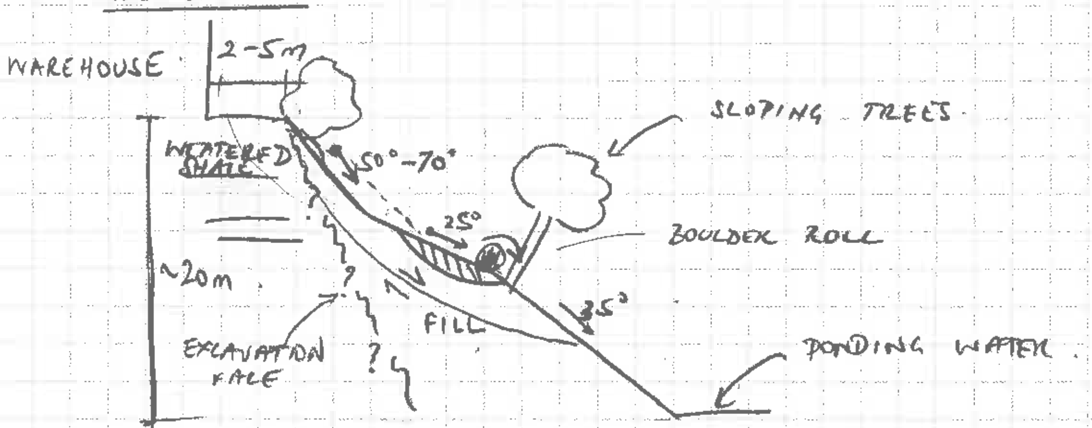
ATTACHMENT A

AECOM

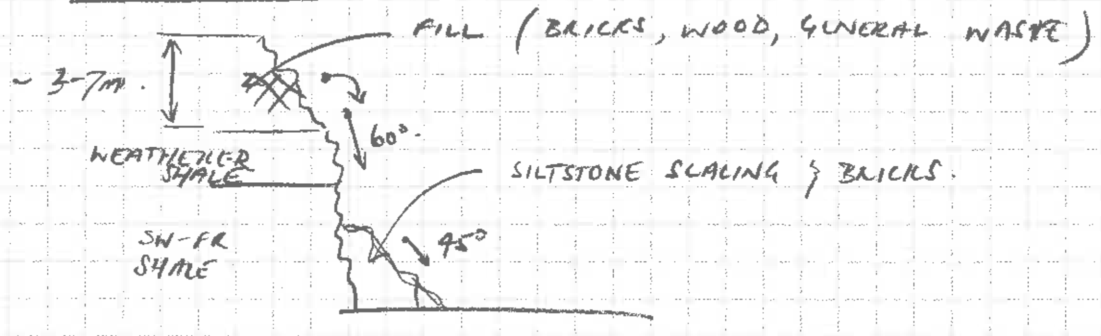
Job Title	WESTCONNEX – ST PETER INTERCHANGE		
Job No.	LANDSLIP.	Calculation No.	—
Originator	P Plummer	Date	6/05/2015
Reviewer	John Ashely	Date	
Scale	NTS	Sheet No.	1 of 1



SECTION A - A.



SECTION B - B.



AECOM Australia Pty Ltd
Level 21, 420 George Street
Sydney NSW 2000
PO Box Q410
QVB Post Office NSW 1230
Australia
www.aecom.com

+61 2 8934 0000 tel
+61 2 8934 0001 fax
ABN 20 093 846 925

18 June 2015

Commercial-in-Confidence

WestConnex Delivery Authority
Locked Bag 928
North Sydney
NSW 2059

Proposed Slope Stabilisation Works - Concept Design St Peter Interchange (SPI)

1.0 Introduction

Further to the slope stability assessment and concept design presented in the AECOM letter of 15 June 2015 , AECOM has been requested to provide further design details and construction recommendations to assist WDA to construct the proposed temporary fill buttress at the SPI site. This letter provides the following information as requested by WDA:

- Specification for imported buttress fill;
- Laboratory test results undertaken on the material samples taken from Stockpiles SP290a and SP365 and comment on the suitability as to be used as fill materials for the proposed fill embankment;
- Preliminary estimate of the buttress fill volume;
- Preliminary drainage design ; and
- Preliminary design drawings of the proposed fill buttress.

2.0 Site Description

The slope section that has suffered instability is located on the northern boundary of the property, adjacent to an industrial/commercial estate located at 300-310 Princes Highway, St Peters as shown in Figure 1.

The site was previously used as a quarry for brick making material and has been used as a landfill. Based on current survey information from the WestConnex GIS portal, current surface levels at the site range from 21m AHD to -11m AHD. Based on historical information, excavations for the brick pit were up to -30 m AHD. Since the quarry ceased operation, it has been filled with various landfill materials. Based on a visual assessment of the material within the slope failure and the surface material on the embankment, the fill is mainly silty sand with cobbles and boulders.

Figure 1 Site Location and landslip location (Not to Scale)

3.0 Concept Design Solution

The proposed slope stabilisation measures recommended by AECOM is to construct a fill buttress over the existing steep fill slope, using compacted fill sourced from various stockpiles within the SPI site or imported fill.

Features of the proposed buttress are summarised below:

- Construct a subsurface drain at the toe of existing slope.
- Construct a drainage layer at the interface between the existing fill slope and the new buttress, linked to the toe drain;
- Form a compacted fill buttress over the existing slope at 1.5H:1V or flatter;
- Grade the fill buttress to have 3m wide berms every change in 7 m vertical height;
- Have a minimum 3 m wide buttress at the crest of the existing slope;

A sketch of the proposed solution is shown in Figure 2.

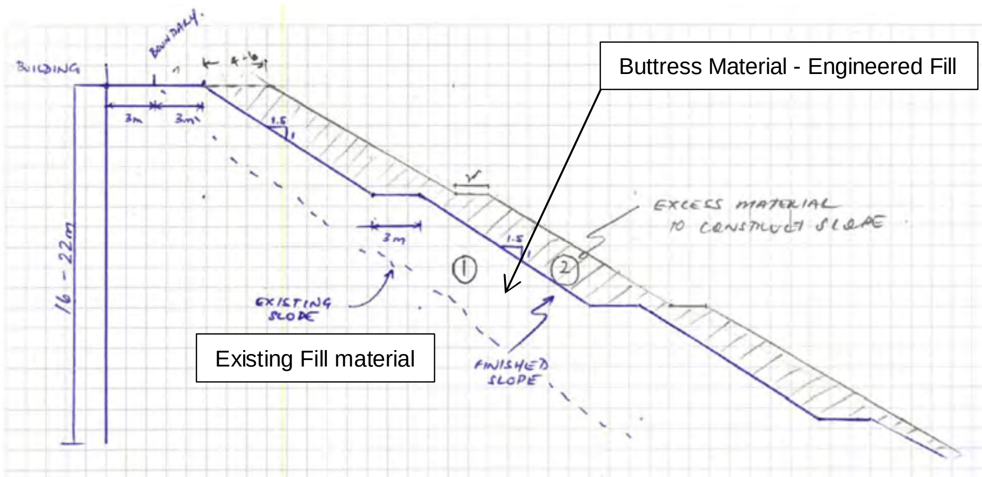


Figure 2 Preliminary Concept Solution Sketch

4.0 Proposed fill material

4.1 Imported fill materials

If imported fill materials are required to be used to form the new buttress, it is suggested that the material be derived from crushed Class IV Sandstone or better or Class III Shale or better. Imported fill shall be relatively free draining with fines content less 15% (material passing the 0.075mm sieve). Fill materials shall also be free of all deleterious material such as tree roots, organic material, wood, plastic, clay lumps and metal.

4.2 Stockpiled materials

The materials from the two existing stockpiles, namely SP290a and SP365, within the site could potentially be used as the buttress fill. A visual assessment of the material indicates that the fill comprises silty sand mixed with crushed sandstone and shale ranging from gravel to boulder size material, with some building debris comprising bricks, clay pipes and concrete fragments.

Materials samples were collected from the surface of the stockpiles on the 5 of June and sent for laboratory testing by a NATA accredited laboratory. Laboratory testing included the following:

- Particle Size distribution testing in accordance with AS 1289 3.6.1;
- Maximum Dry Density testing in accordance with AS 1289.5.1.1

The laboratory testing results have been summarised in Table 1 and the laboratory certificates are included in Attachment A.

Based on site observations and the laboratory testing results these materials could be used to form the proposed buttress, provided all oversize boulders break down to less than 2/3 the compacted layer thickness or are removed.

Figure 3 Stockpile SP290a

Figure 4 Stockpile SP365

Table 1 Summary of Laboratory testing results for Stockpile

Samples ID	Particle Size Distribution (AS1726) Retained in the 63mm sieve	Gravel	Sand	Fines (<0.075mm)	Maximum Dry Density	Optimum Moisture Content
	%	%	%	%	(t/m^3)	%
SP290a – Sample 1	5	34	44	17	1.97	11
SP290a – Sample 2	11	32	41	16		
SP365 – Sample 1	0	41	53	6	1.97	9.5
SP365 – Sample 2	2	28	58	12		

4.3 Earthworks

The proposed buttress shall be formed by fill in horizontal compacted layers less than 300mm in thickness. The maximum particle size shall not exceed 2/3 the compacted layer thickness. Fill material shall be compacted to a ratio of 95% of its maximum dry density (MDD). Testing should be carried out in accordance with AS3798 earthworks guidelines. It is considered that Level 2 supervision of the earthworks is suitable for the proposed works. However, it should be noted that this level of testing is only suitable assuming that the buttress is temporary and will not be required to for permanent engineered fill.

Field density testing should be carried in accordance with AS1289. Testing should be carried out at a minimum frequency of one test every layer or one test per 500 m^3, whichever requires the greater number of tests.

The contractor should develop safe work methods and consider the suitability of plant when undertaking the earthworks. Significant vibrations could trigger further instability and plant may need to be operated in static mode to avoid reduce vibrations.

5.0 Slope Drainage Recommendations

To achieve calculated factors of safety greater than 1.3 the fill buttress should remain unsaturated. Free draining fill should be used if available and drainage should be provided at the slope/buttress interface

Additional surface drainage shall also be provided at the crest of the new buttress to reduce the surface runoff onto the slope. The following drainage elements are recommended:

- A trench drain at the base of the existing slope to collect the water from strip drains and drain the buttress foundation. The trench drain shall be constructed generally in accordance with the Road and Maritime Services (RMS) guidelines, R30 Subsurface Drainage.

  The recommended dimension of the trench drain should be constructed 0.6m deep and 0.3m in width. The trench should be backfilled with F14 aggregate filter material (or similar) in accordance with RMS QA3580 with a 100mm diameter corrugated perforated plastic drainage pipe in the centre of the trench in accordance with RMS QA3552.

  Due to the risk of potential further slop failure of the existing fill embankment, excavation to be undertaken near the toe of existing embankment shall be carried out in a controlled manner and shall not exceed a depth of 1.0m and 10m in length.

- Two-way strip drains or trench drains at 3 m intervals running down the interface of the existing slope and the buttress and linking into the trench drain;

- A shotcrete formed catch drain at crest of the buttress and surface drain along each berm;
- Berms should be graded to collect surface runoff from each slope batter to reduce surface erosion and water infiltration to the fill body. Shotcrete shall be sprayed on each berm to reduce infiltration into the fill buttress.

6.0 Preliminary Drawings

The following concept design drawings and have been provided in Attachment B:

- WCX2-IFD-00-2400-ID588-EW-2015617_LAYOUT1
- WCX2-IFD-00-2400-ID588-EW-2015617_LAYOUT2
- WCX2-IFD-00-2400-ID588-EW-2015617_LSEC_01
- WCX2-IFD-00-2400-ID588-EW-2015617_XSEC_01
- WCX2-IFD-00-2400-ID588-EW-2015617_XSEC_02
- WCX2-IFD-00-2400-ID588-EW-2015617_XSEC_03

7.0 Preliminary estimated volume of final fill embankment

The proposed stabilisation works was estimated using 12D, based on the current concept design the anticipated compacted volume of material required are the following:

- 19,500m^3 buttress material
- 11,500m^3 additional construction material

It should be noted that this additional construction volume is based on advice from Ward Civil Pty Ltd that an additional width of 2 m to create a working platform during construct the fill buttress. From a geotechnical perspective, it should be practicable to form a compacted slope with a lesser width of additional material, subject to safe working requirements.

For and on of AECOM Australia Pty Ltd,

Yours faithfully

Peter Plummer
Geotechnical Engineer
peter.plummer@aecom.com

Mobile: +61 401 566 222+61 401 566 222
Direct Dial: +61 2 8934 0000+61 2 8934 0000

Peter Waddell
Technical Director - Ground Engineering
Peter.Waddell@aecom.comjohn.ashley@aecom.com

Mobile: 0420247972+61 412 187 687
Direct Dial: +61289340116+61 2 8934 0043
Direct Fax: +61289340001+61 2 8934 0001

encl: Attachment A
Attachment BEnclosures

ATTACHMENT A - Laboratory Testing Results

TEST CERTIFICATE

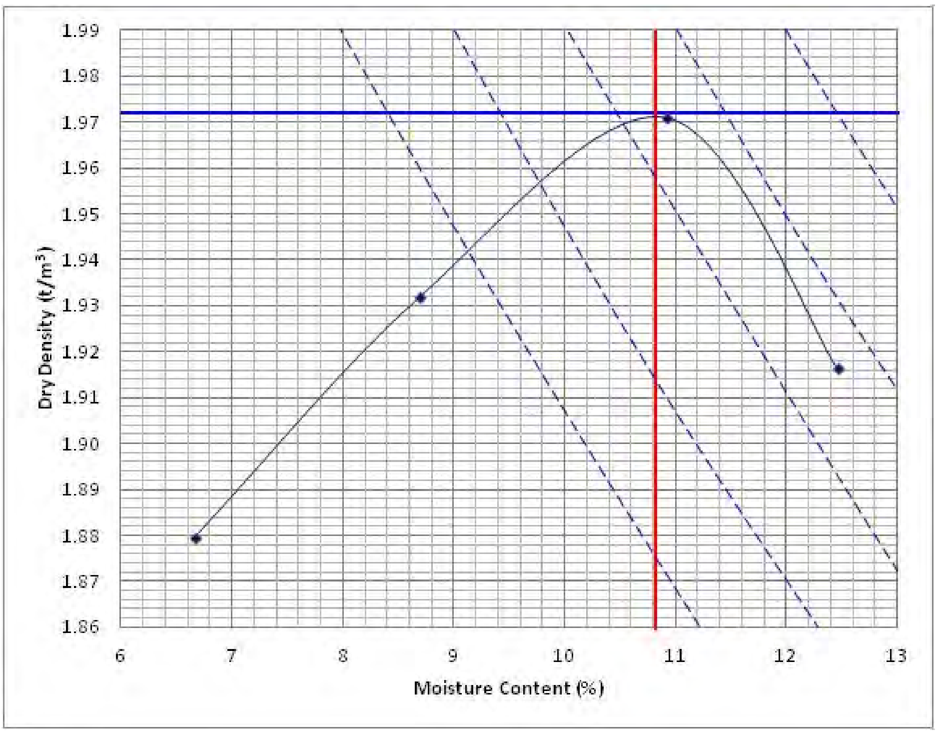
xxxxx.xxxxx@xxx.xxx
ABN: 44 000 964 278
ph: +61 (0)2 8594 0481
fx: +61 (0)2 8594 0499

SGS Australia Pty Ltd
PO Box 6432 Alexandria NSW 2015
Unit 15, 33 Maddox Street
Alexandria NSW 2015

Client:	AECOM Australia Pty Ltd	Client Job No:	
Order No:		Project:	60327128 - West Connex
Tested Date:	12/06/2015	Location:	
SGS Job Number:	15-32-137	Sample No:	15-AC-1238
Lab:	Alexandria CMT	Sample ID:	SP290a Sample 1 and SP290a Sample 2

Dry Density / Moisture Content Relation of a Soil

AS 1289.5.1.1 - Standard Compactive Effort



Sample Description:	CLAYEY SANDY GRAVEL: Brown
Maximum Dry Density:	1.97t/m³
Optimum Moisture Content:	11.0%
Percent Oversize:	18%
Sieve Size:	19.0mm

Note: Sample supplied by client.

Approved Signatory: (Aaron.Lacey, Business Manager) Date: 12/06/2015

Accredited for compliance with ISO/IEC 17025

Accreditation No.: 2418

Site No.: 1452
Cert No.: 15-AC-1238-AN027.1
Form No.PF-AU-INDCMT-GEN-AN-027

Client Address: PO Box 1307 FORTITUDE VALLEY Qld 4006

TEST CERTIFICATE

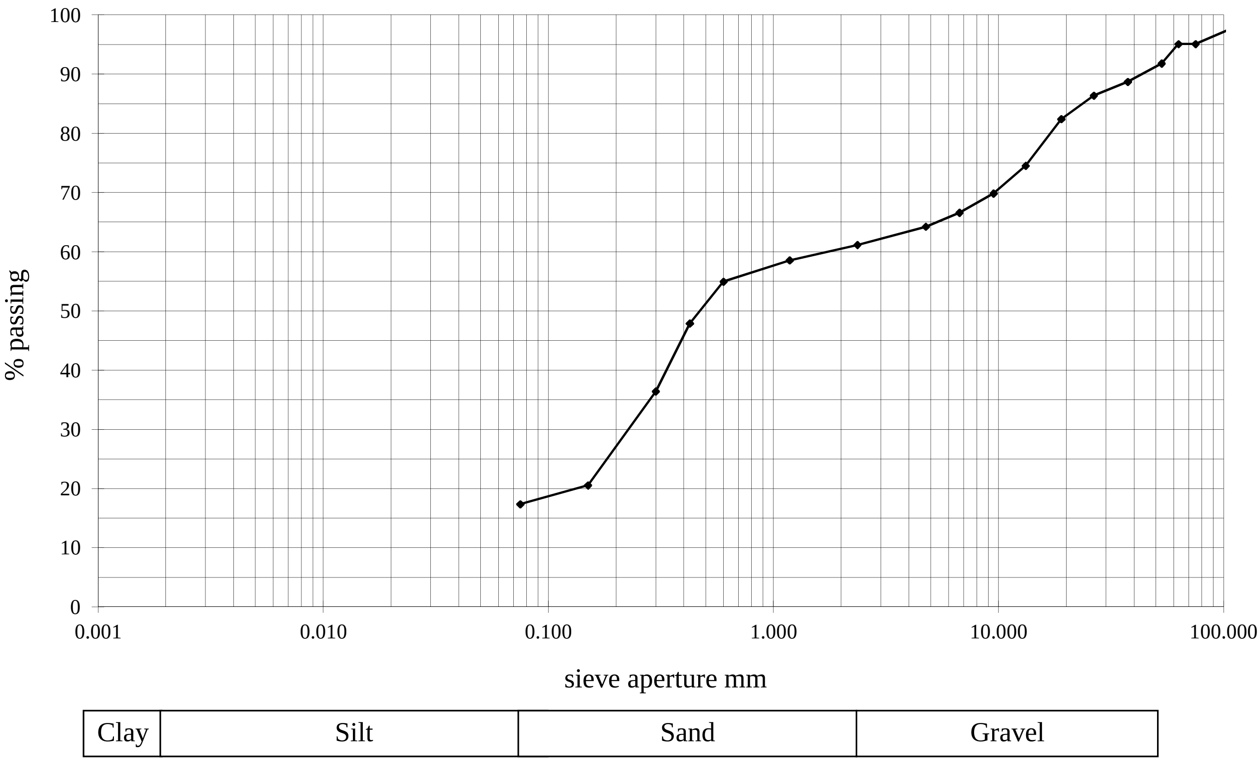
ABN 44 000 964 278
ph: +61 (0)2 8594 0481
fax: +61 (0)2 8594 0499

SGS Australia Pty Ltd
Unit 15, 33 Maddox Street
(PO Box 6432)
Alexandria NSW 2015
Australia

PARTICLE SIZE DISTRIBUTION

Client: **AECOM Australia Pty Ltd**
Address: **PO Box 1307 FORTITUDE VALLEY Qld 4006**
Project: **60327128 - West Connex**
Location:

Test Method: **AS 1289 3.6.1**
Job Number: 15-32-137 | Lab Number: 15-AC-1238
Sample Source: SP290a Sample 1 | Date Tested: 12/06/2015
Sampled By: Client | Checked By: AL



Sample Description: CLAYEY SANDY GRAVEL : Brown

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0	**100**	1.18	**59**
75.0	**95**	0.600	**55**
63.0	**95**	0.425	**48**
53.0	**92**	0.300	**36**
37.5	**89**	0.150	**21**
26.5	**86**	0.075	**17**
19.0	**82**	0.050	
13.2	**75**	0.020	
9.5	**70**	0.010	
6.7	**67**	0.005	
4.75	**64**	0.002	
2.36	**61**		

Hydrometer Type: **N/A**
Dispersant Type: **N/A**
Pretreatment:
Loss on Pretreatment: **None**
Remarks:

Approved Signatory: Aaron Lacey   Date: 12/06/2015

Accredited for Compliance with ISO/IEC 17025

Accreditation No. 2418

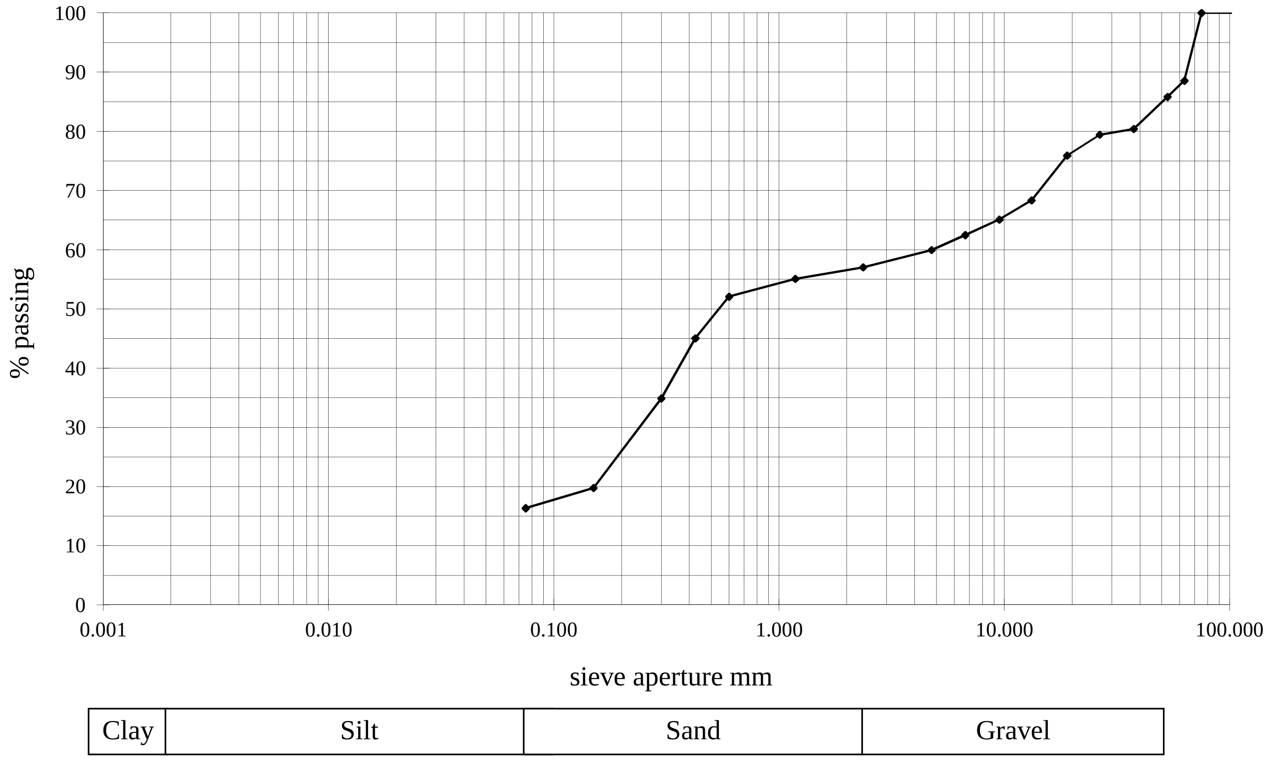
TEST CERTIFICATE

ABN 44 000 964 278
ph: +61 (0)2 8594 0481
fax: +61 (0)2 8594 0499

SGS Australia Pty Ltd
Unit 15, 33 Maddox Street
(PO Box 6432)
Alexandria NSW 2015
Australia

PARTICLE SIZE DISTRIBUTION

Client: **AECOM Australia Pty Ltd**
Address: **PO Box 1307 FORTITUDE VALLEY Qld 4006**
Project: **60327128 - West Connex**
Location:
Test Method: **AS 1289 3.6.1**
Job Number: 15-32-137
Lab Number: 15-AC-1239
Sample Source: SP290a Sample 2
Date Tested: 12/06/2015
Sampled By: Client
Checked By: AL



Sample Description: CLAYEY SANDY GRAVEL : Brown

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	**55**
75.0	**100**	0.600	**52**
63.0	**89**	0.425	**45**
53.0	**86**	0.300	**35**
37.5	**80**	0.150	**20**
26.5	**79**	0.075	**16**
19.0	**76**	0.050	
13.2	**68**	0.020	
9.5	**65**	0.010	
6.7	**62**	0.005	
4.75	**60**	0.002	
2.36	**57**		

Hydrometer Type: **N/A**
Dispersant Type: **N/A**
Pretreatment:
Loss on Pretreatment: **None**
Remarks:

Approved Signatory: Aaron Lacey   Date: 12/06/2015

Accredited for Compliance with ISO/IEC 17025

Accreditation No. 2418

TEST CERTIFICATE

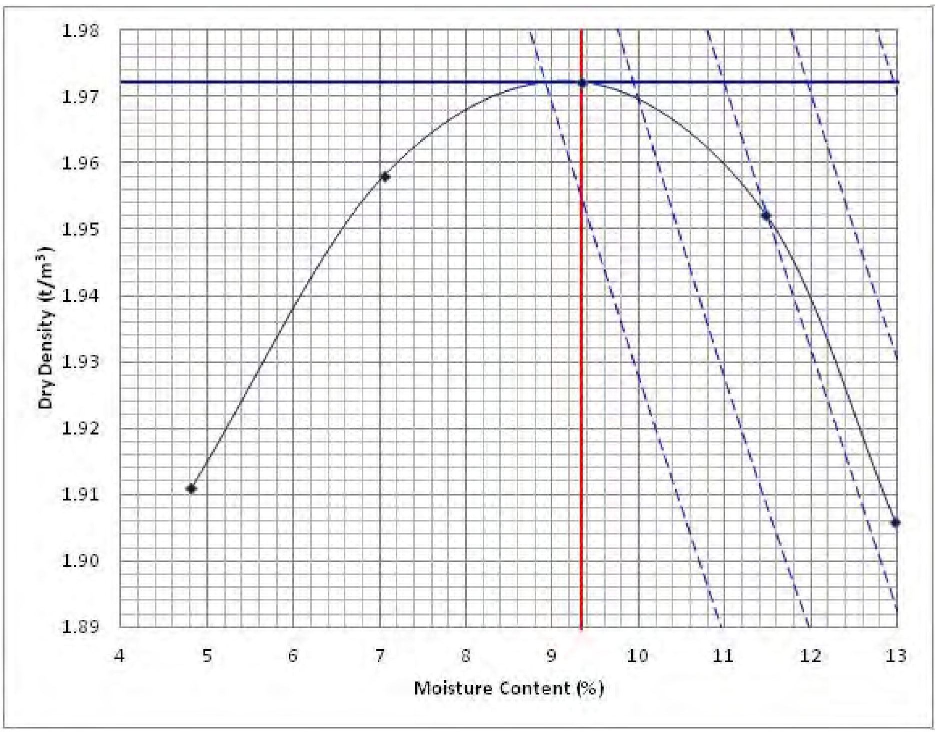
xxxxx.xxxxx@xxx.xxx
ABN: 44 000 964 278
ph: +61 (0)2 8594 0481
fx: +61 (0)2 8594 0499

SGS Australia Pty Ltd
PO Box 6432 Alexandria NSW 2015
Unit 15, 33 Maddox Street
Alexandria NSW 2015

Client:	AECOM Australia Pty Ltd	Client Job No:	
Order No:		Project:	60327128 - West Connex
Tested Date:	12/06/2015	Location:	
SGS Job Number:	15-32-137	Sample No:	15-AC-1241
Lab:	Alexandria CMT	Sample ID:	SP365 Sample 2

Dry Density / Moisture Content Relation of a Soil

AS 1289.5.1.1 - Standard Compactive Effort



Sample Description:	GRAVEL SAND : Yellow Brown
Maximum Dry Density:	1.97t/m³
Optimum Moisture Content:	9.5%
Percent Oversize:	13%
Sieve Size:	19.0mm

Note: Sample supplied by client.

Approved Signatory: (Aaron.Lacey, Business Manager) Date: 12/06/2015

Accredited for compliance with ISO/IEC 17025

Accreditation No.: 2418

Site No.: 1452
Cert No.: 15-AC-1241-AN027.1
Form No.PF-AU-INDCMT-GEN-AN-027

Client Address: PO Box 1307 FORTITUDE VALLEY Qld 4006

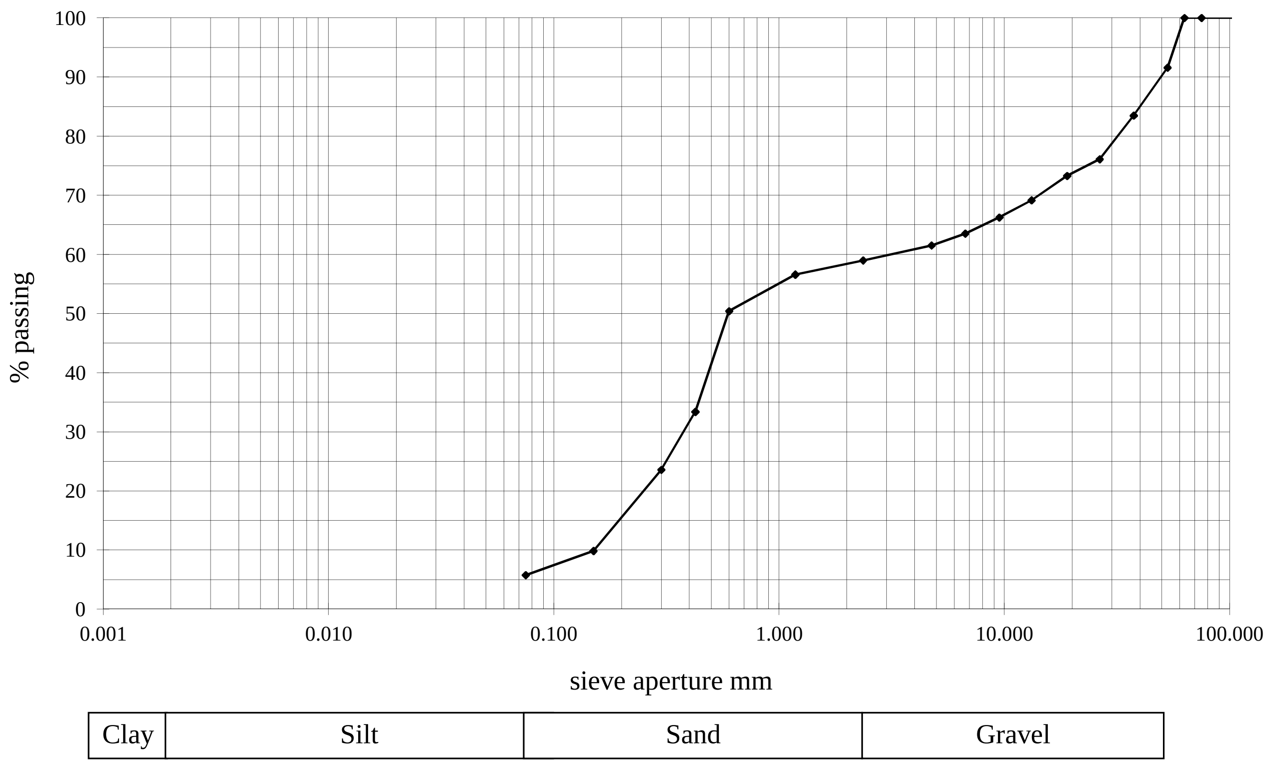
TEST CERTIFICATE

ABN 44 000 964 278
ph: +61 (0)2 8594 0481
fax: +61 (0)2 8594 0499

SGS Australia Pty Ltd
Unit 15, 33 Maddox Street
(PO Box 6432)
Alexandria NSW 2015
Australia

PARTICLE SIZE DISTRIBUTION

Client: **AECOM Australia Pty Ltd**
Address: **PO Box 1307 FORTITUDE VALLEY Qld 4006**
Project: **60327128 - West Connex**
Location:
Test Method: **AS 1289 3.6.1**
Job Number: 15-32-137 Lab Number: 15-AC-1240
Sample Source: SP365 Sample 1 Date Tested: 12/06/2015
Sampled By: Client Checked By: AL



Sample Description: GRAVELLY SAND : Yellow Brown

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	**57**
75.0		0.600	**50**
63.0	**100**	0.425	**33**
53.0	**92**	0.300	**24**
37.5	**83**	0.150	**10**
26.5	**76**	0.075	**6**
19.0	**73**	0.050	
13.2	**69**	0.020	
9.5	**66**	0.010	
6.7	**64**	0.005	
4.75	**62**	0.002	
2.36	**59**		

Hydrometer Type: **N/A**
Dispersant Type: **N/A**
Pretreatment:
Loss on Pretreatment: **None**
Remarks:

Approved Signatory: Aaron Lacey Date: 12/06/2015

Accredited for Compliance with ISO/IEC 17025

Accreditation No. 2418

TEST CERTIFICATE

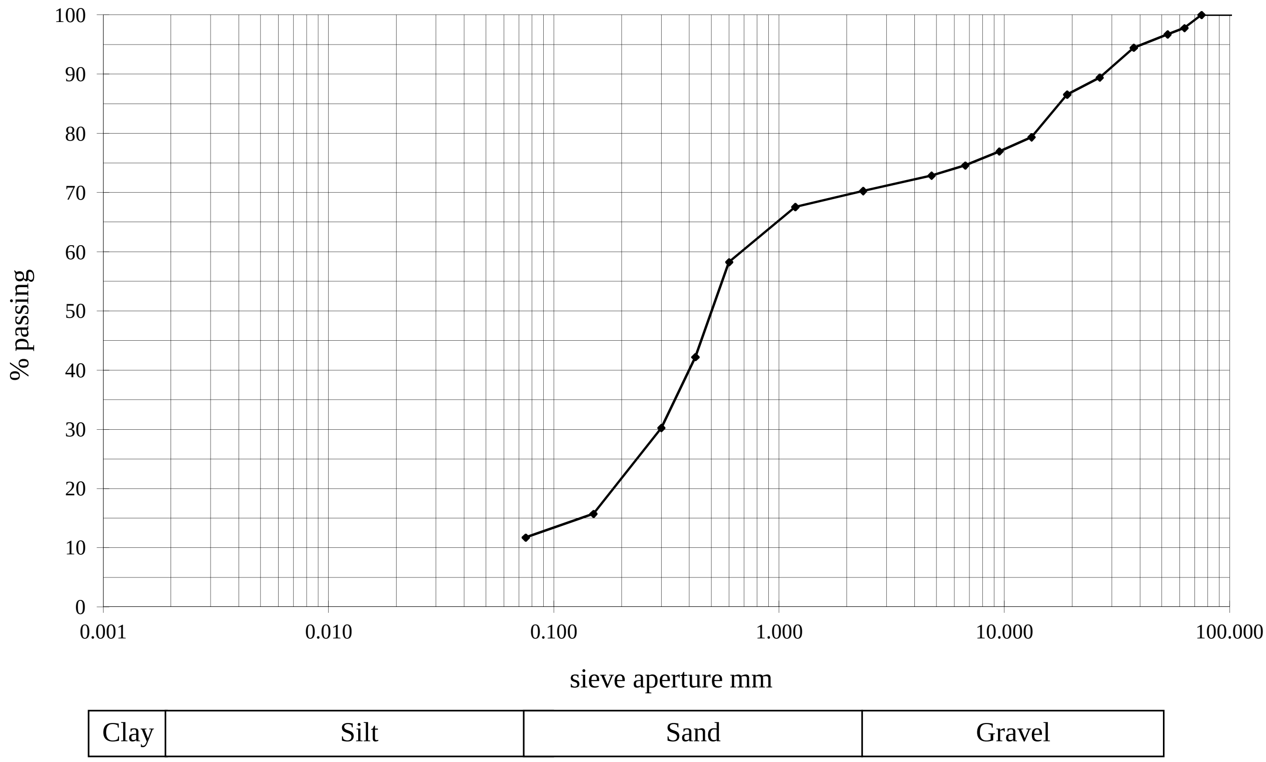
ABN 44 000 964 278
ph: +61 (0)2 8594 0481
fax: +61 (0)2 8594 0499

SGS Australia Pty Ltd
Unit 15, 33 Maddox Street
(PO Box 6432)
Alexandria NSW 2015
Australia

PARTICLE SIZE DISTRIBUTION

Client: **AECOM Australia Pty Ltd**
Address: **PO Box 1307 FORTITUDE VALLEY Qld 4006**
Project: **60327128 - West Connex**
Location:

Test Method: **AS 1289 3.6.1**
Job Number: 15-32-137 Lab Number: 15-AC-1241
Sample Source: SP365 Sample 2 Date Tested: 12/06/2015
Sampled By: Client Checked By: AL



Sample Description: GRAVEL SAND : Yellow Brown

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	**68**
75.0	**100**	0.600	**58**
63.0	**98**	0.425	**42**
53.0	**97**	0.300	**30**
37.5	**94**	0.150	**16**
26.5	**89**	0.075	**12**
19.0	**87**	0.050	
13.2	**79**	0.020	
9.5	**77**	0.010	
6.7	**75**	0.005	
4.75	**73**	0.002	
2.36	**70**		

Hydrometer Type: **N/A**
Dispersant Type: **N/A**
Pretreatment:
Loss on Pretreatment: **None**
Remarks:

Approved Signatory: Aaron Lacey Date: 12/06/2015

Accredited for Compliance with ISO/IEC 17025

RWC-001006 - Information for Release - Page 33 of 218 - PART TWO

Accreditation No. 2418

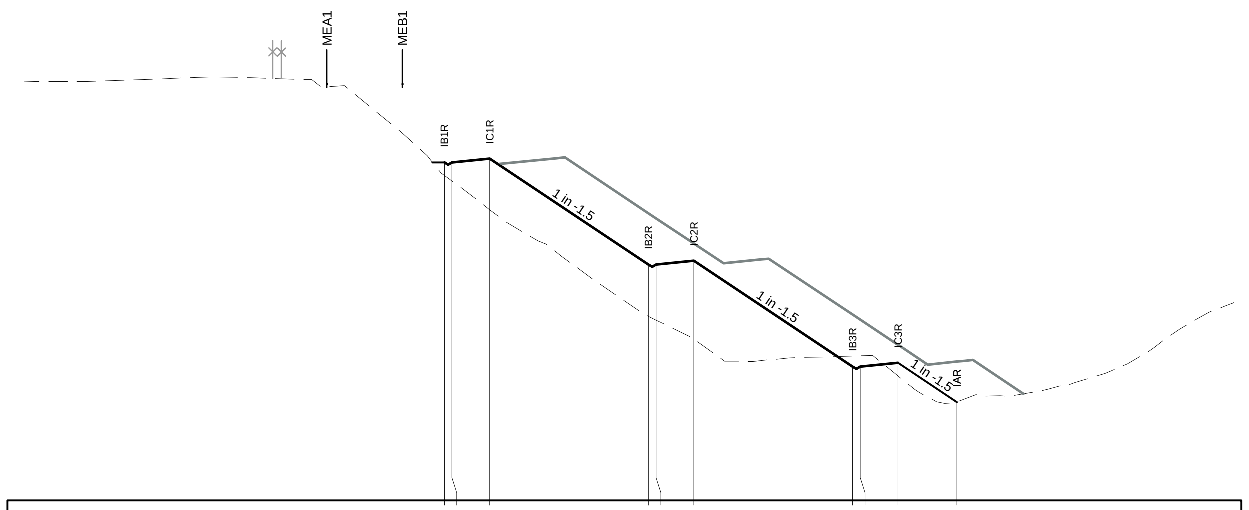
AECOM

ATTACHMENT B - Preliminary Drawings

Cad ref: P:\603X\60327128\5. CAD\06-INFODOCS\WCX2-IFD-00-2400-ID588-EW-20150617_LAYOUT1.dwg Last modified: 17 Jun 15 - 17:37

FOR INFORMATION ONLY

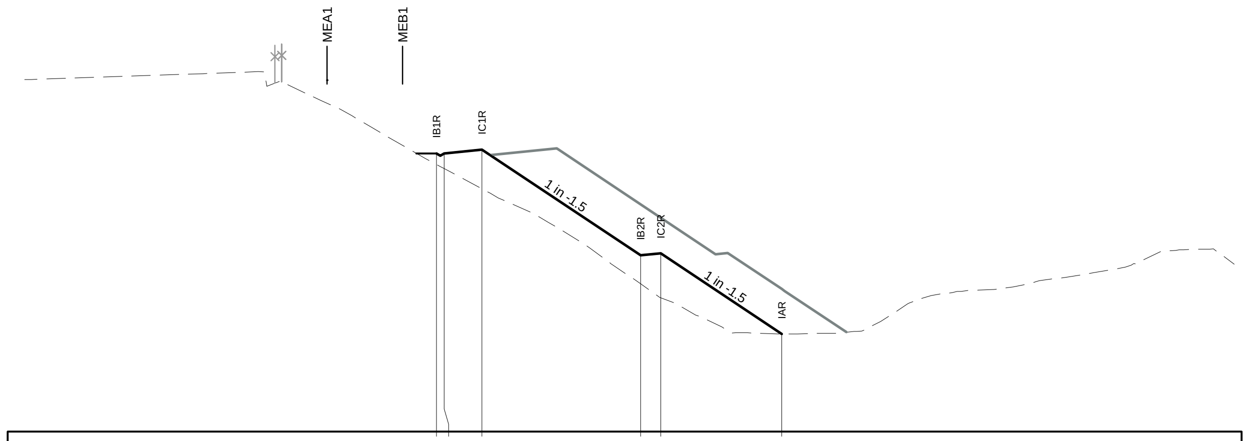
CLIENT:	DESIGNER:		SCALES:			
Transport WestConnex Delivery Authority	AECOM AECOM Australia Pty Ltd A.B.N. 20 093 846 925		2.5 0 2.5 5 7.5m 1 : 500 FULL SIZE A3		M5 WESTCONNEX - ST PETERS INT. CONCEPT DESIGN SLOPE STABILISATION OVERALL LAYOUT	INFORMATION DOCUMENT DOCUMENT NO. PROJECT NO - DOC. TYPE - PROJECT PHASE - DISCIPLINE - DATE (YYYYMMDD) - DESCRIPTION: WCX2-IFD-00-2400-ID588-EW-20150617_LAYOUT1



DATUM -12.000

DESIGN LEVELS	10.354	10.354	10.604	3.604	3.604	3.854	-3.146	-3.146	-2.896	-5.493
EXISTING LEVELS	9.492	9.124	7.222	0.163	-0.080	-1.304	-2.458	-2.444	-3.775	-5.493
DESIGN OFFSETS	7.784	8.284	10.784	21.284	21.784	24.284	34.784	35.284	37.784	41.680

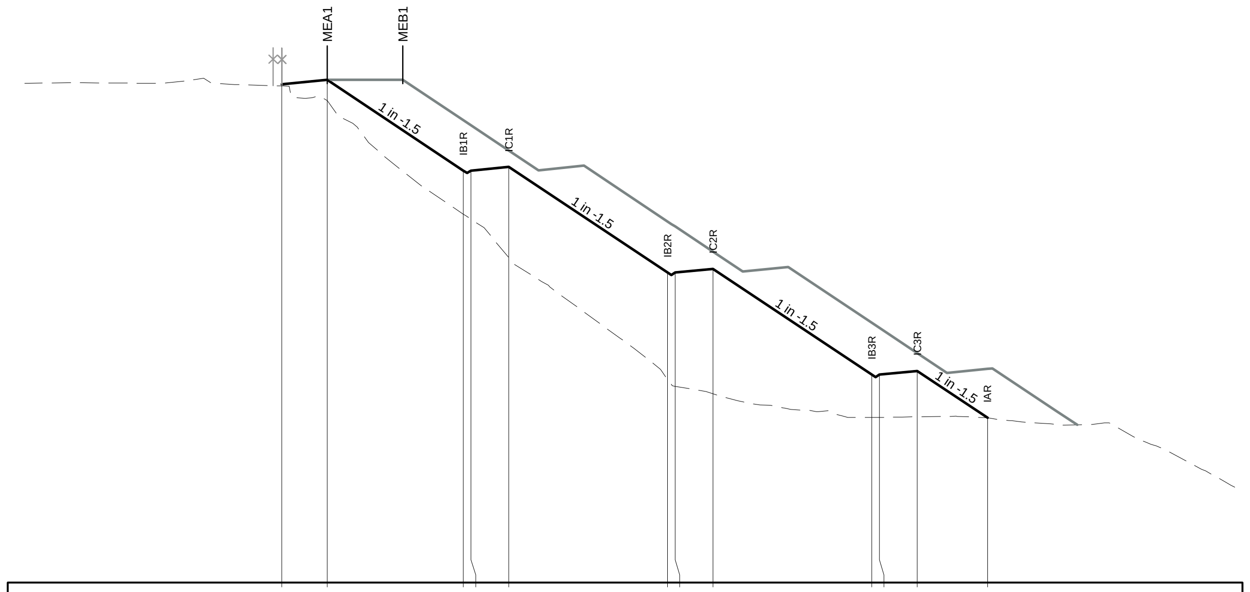
CH 20.000



DATUM -8.000

DESIGN LEVELS	10.404	10.404	10.654	3.654	3.788	-1.543
EXISTING LEVELS	9.667	9.403	8.065	1.785	0.847	-1.543
DESIGN OFFSETS	7.244	7.744	10.244	20.744	22.077	30.073

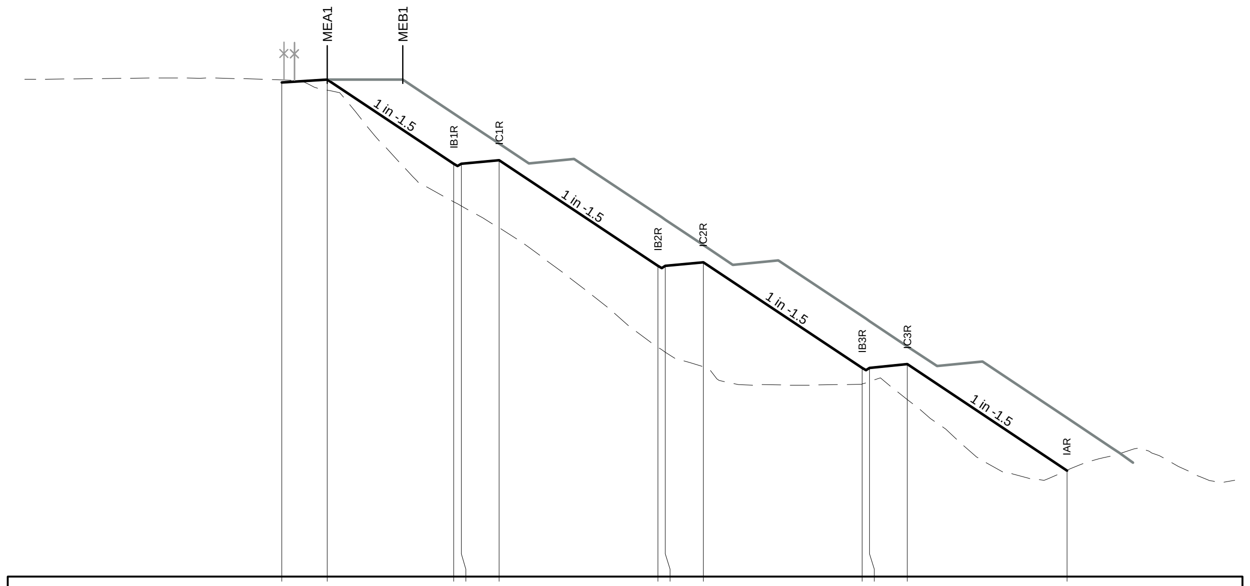
CH 10.000



DATUM -17.000

DESIGN LEVELS	15.936	16.236	10.238	10.238	10.488	3.488	3.488	3.738	-3.262	-3.262	-3.012	-6.114
EXISTING LEVELS	15.832	14.856	7.360	7.028	4.470	-3.566	-4.026	-4.522	-6.083	-6.082	-6.049	-6.114
DESIGN OFFSETS	-3.000	0.001	8.997	9.497	11.997	22.497	22.997	25.497	35.997	36.497	38.997	43.651

CH 40.000



DATUM -17.000

DESIGN LEVELS	15.682	15.868	10.297	10.297	10.547	3.547	3.547	3.797	-3.203	-3.203	-2.953	-9.981
EXISTING LEVELS	15.850	15.178	7.788	7.513	6.063	-1.821	-2.150	-3.125	-4.264	-4.098	-5.294	-9.981
DESIGN OFFSETS	-3.000	0.001	8.358	8.858	11.358	21.858	22.358	24.858	35.358	35.858	38.358	48.899

CH 30.000

FOR INFORMATION ONLY

CLIENT:

Transport WestConnex Delivery Authority

DESIGNER:

AECOM

AECOM Australia Pty Ltd A.B.N. 20 093 846 925

SCALES:

2.5 0 2.5 5 7.5m

1 : 500 FULL SIZE A3

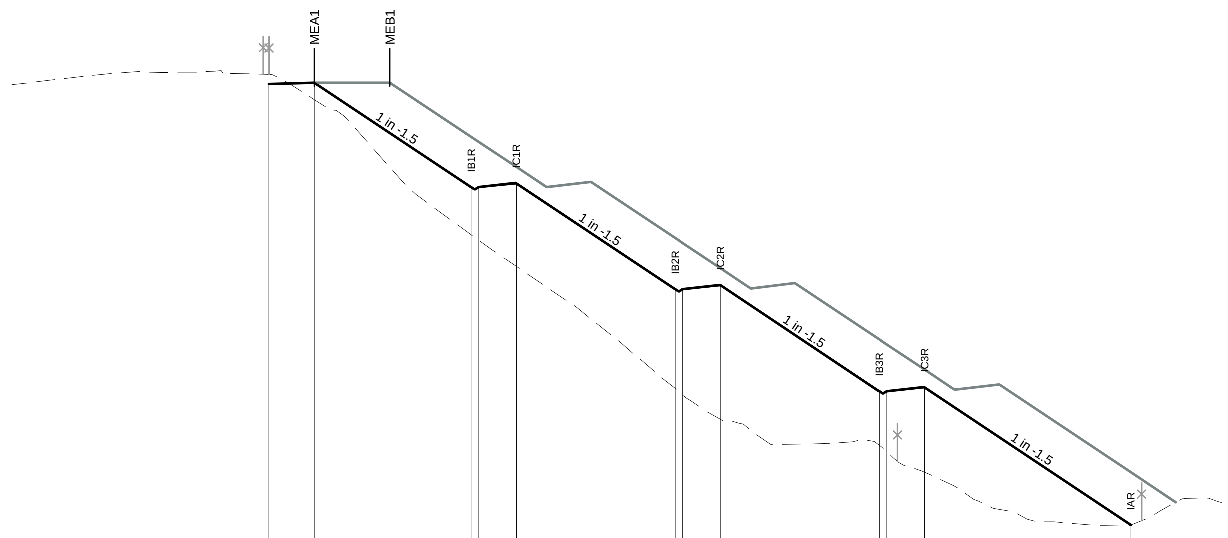
M5 WESTCONNEX - ST PETERS INT.
CONCEPT DESIGN
SLOPE STABILISATION
CROSS SECTIONS - SHEET 1

INFORMATION DOCUMENT

DOCUMENT NO.

PROJECT NO - DOC. TYPE - PROJECT PHASE - DISCIPLINE - DATE (YYYYMMDD) - DESCRIPTION:

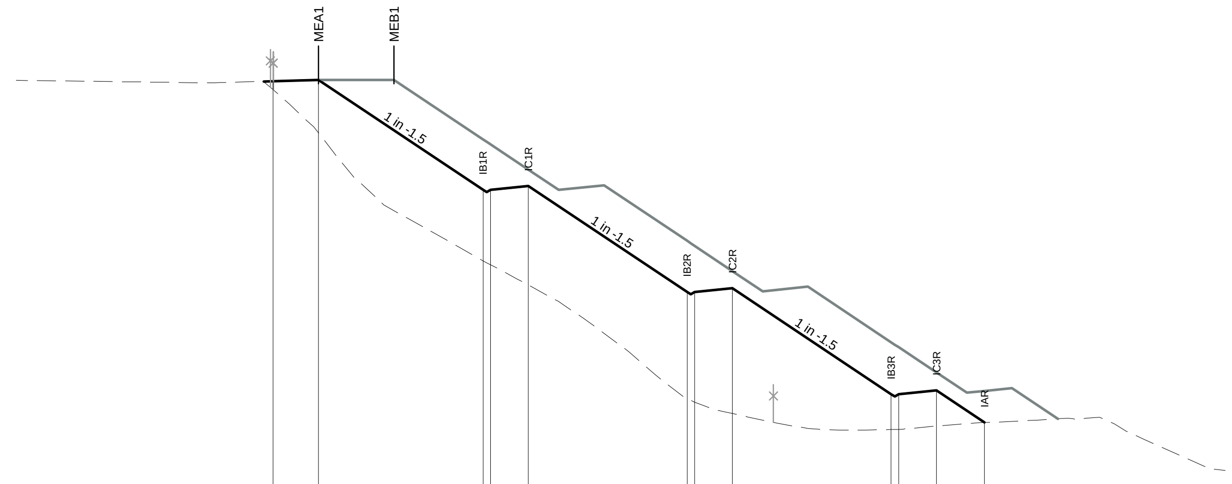
WCX2-IFD-00-2400-ID588-EW-20150617_XSEC_01



DATUM -18.000

DESIGN LEVELS	16.931	17.021	10.107	10.107	10.357	3.357	3.357	3.607	-3.393	-3.393	-3.143	-12.233
EXISTING LEVELS	17.568	15.898	6.957	6.595	4.866	-3.207	-3.639	-5.257	-6.966	-7.366	-8.753	-12.233
DESIGN OFFSETS	-3.000	0.001	10.372	10.872	13.372	23.872	24.372	26.872	37.372	37.872	40.372	54.007

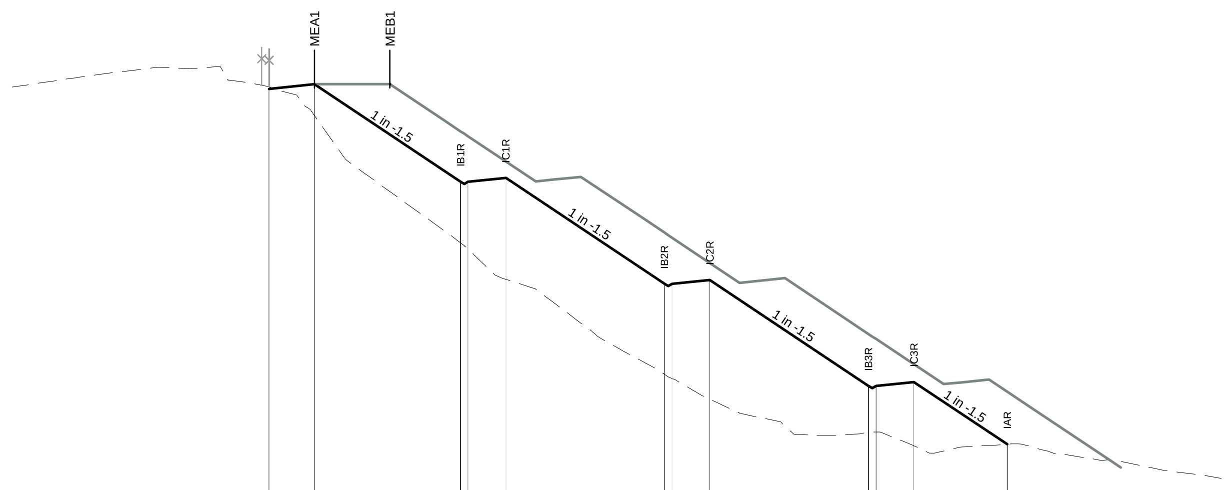
CH 60.000



DATUM -14.000

DESIGN LEVELS	17.376	17.466	10.207	10.207	10.457	3.457	3.457	3.707	-3.293	-3.293	-3.043	-5.164
EXISTING LEVELS	16.828	13.972	5.519	5.254	3.915	-3.616	-3.815	-4.574	-5.627	-5.613	-5.402	-5.164
DESIGN OFFSETS	-3.000	0.001	10.890	11.390	13.890	24.390	24.890	27.390	37.890	38.390	40.890	44.070

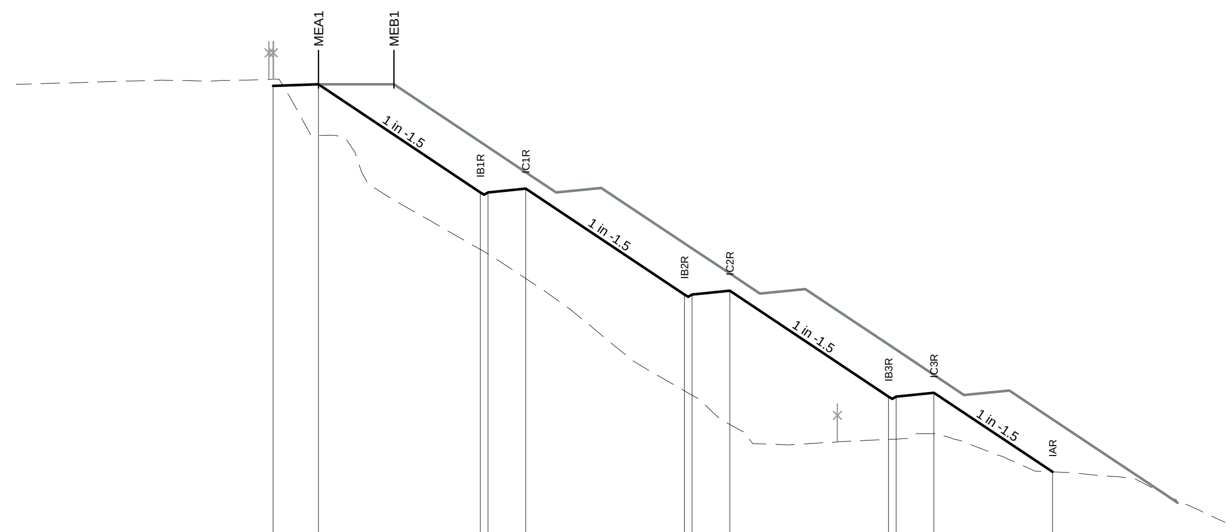
CH 80.000



DATUM -15.000

DESIGN LEVELS	16.335	16.635	10.188	10.188	10.438	3.438	3.438	3.688	-3.312	-3.312	-3.062	-7.176
EXISTING LEVELS	16.473	14.573	6.141	5.765	3.739	-2.551	-2.818	-4.190	-6.377	-6.357	-7.272	-7.176
DESIGN OFFSETS	-3.000	0.001	9.671	10.171	12.671	23.171	23.671	26.171	36.671	37.171	39.671	45.842

CH 50.000



DATUM -18.000

DESIGN LEVELS	17.209	17.299	10.157	10.157	10.407	3.407	3.407	3.657	-3.343	-3.343	-3.093	-8.328
EXISTING LEVELS	17.638	13.908	6.377	6.090	4.457	-2.964	-3.252	-5.194	-6.182	-6.159	-5.810	-8.328
DESIGN OFFSETS	-3.000	0.001	10.714	11.214	13.714	24.214	24.714	27.214	37.714	38.214	40.714	48.566

CH 70.000

FOR INFORMATION ONLY

CLIENT: Transport NSW WestConnex Delivery Authority

DESIGNER: AECOM

AECOM Australia Pty Ltd A.B.N. 20 093 846 925

SCALES: 2.5 0 2.5 5 7.5m 1 : 500 FULL SIZE A3

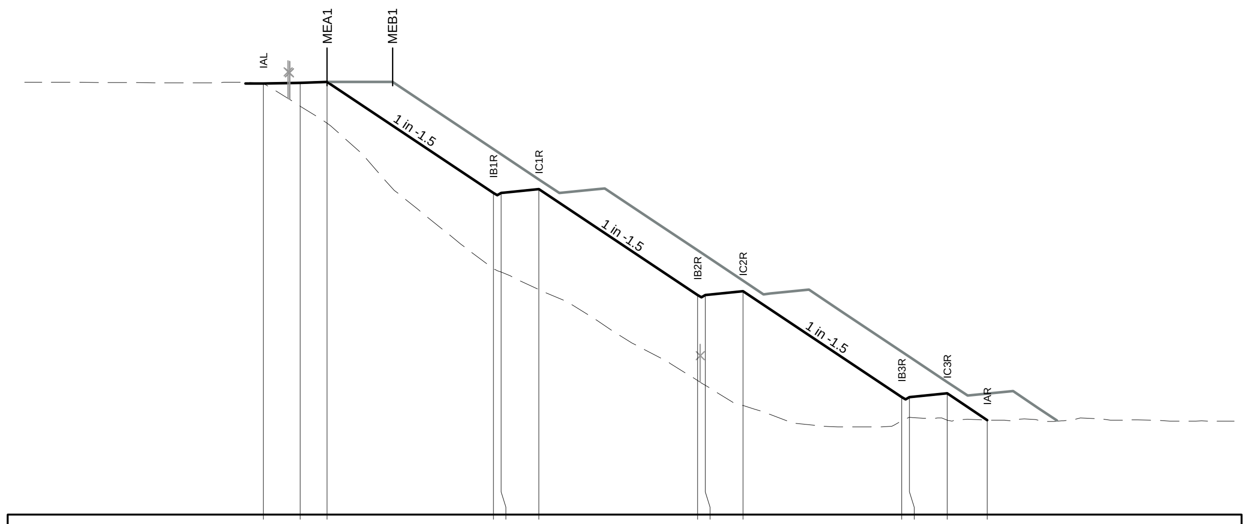
M5 WESTCONNEX - ST PETERS INT.
CONCEPT DESIGN
SLOPE STABILISATION
CROSS SECTIONS - SHEET 2

INFORMATION DOCUMENT

DOCUMENT NO.

PROJECT NO - DOC. TYPE - PROJECT PHASE - DISCIPLINE - DATE (YYYYMMDD) - DESCRIPTION:

WCX2-IFD-00-2400-ID588-EW-20150617_XSEC_02



DATUM -11.000

DESIGN LEVELS	17.514	17.563	17.616	10.270	10.270	10.520	3.520	3.520	3.770	-3.230	-3.230	-2.980	-4.746
EXISTING LEVELS	17.514	16.019	14.896	5.266	5.039	3.876	-2.133	-2.445	-3.789	-4.791	-4.568	-4.750	-4.746
DESIGN OFFSETS	-4.206	-1.765	0.001	11.020	11.520	14.020	24.520	25.020	27.520	38.019	38.519	41.019	43.669

CH 90.000

FOR INFORMATION ONLY

CLIENT: Transport WestConnex Delivery Authority (NSW Government)

DESIGNER: AECOM

AECOM Australia Pty Ltd A.B.N. 20 093 846 925

SCALES:

2.5 0 2.5 5 7.5m

1 : 500 FULL SIZE A3

M5 WESTCONNEX - ST PETERS INT.
DAD SLOPE STABILITY
CONCEPT DESIGN
CROSS SECTIONS - SHEET 3

INFORMATION DOCUMENT

DOCUMENT NO.

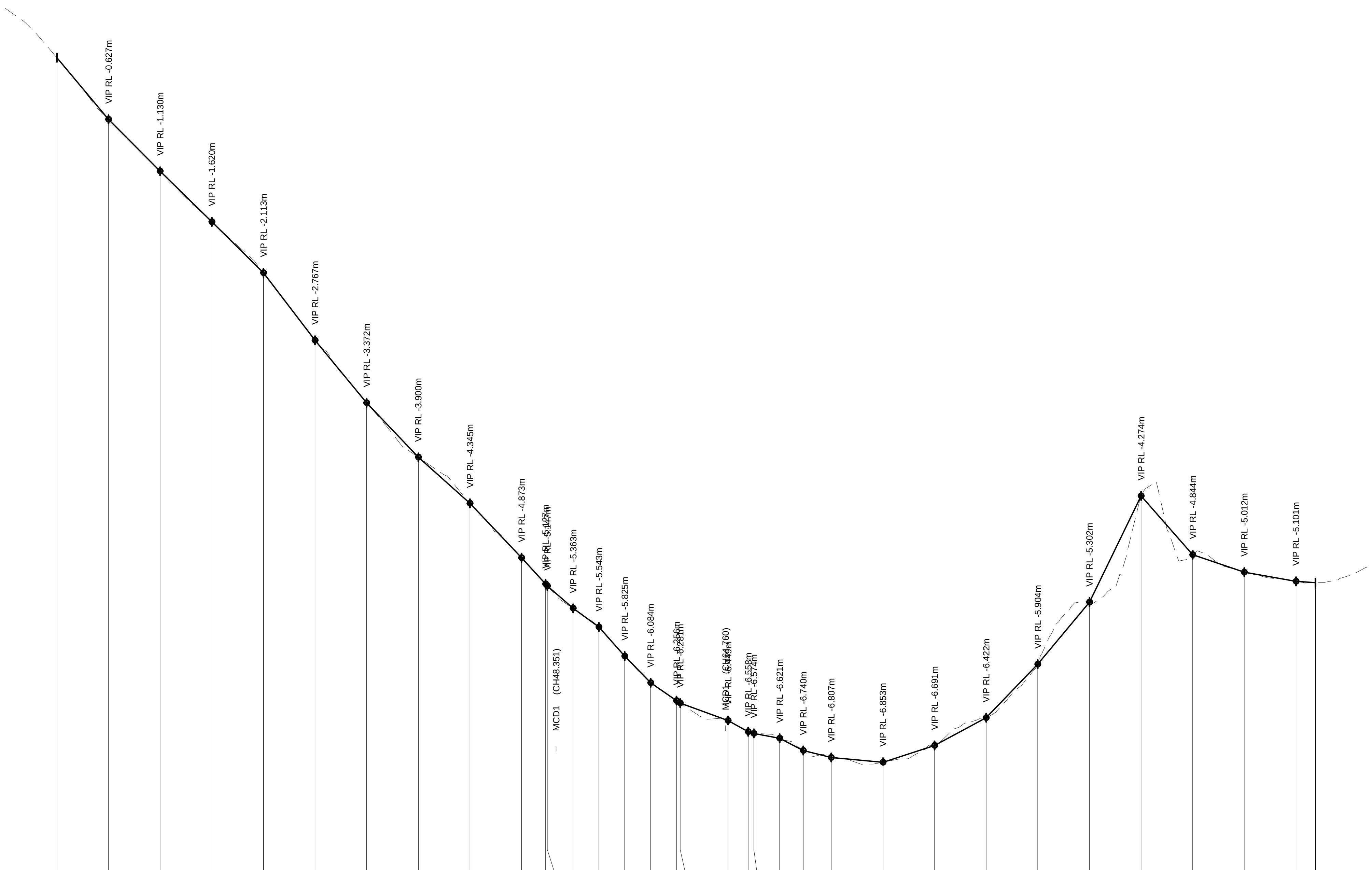
PROJECT NO - DOC. TYPE - PROJECT PHASE - DISCIPLINE - DATE (YYYYMMDD) - DESCRIPTION:

WCX2-IFD-00-2400-ID588-EW-20150617_XSEC_03

Cad ref: C:\pwworking\aecom_au\pricej\dms30306\WCX2-IFD-00-2400-ID588-EW-20150618_LAYOUT2.dwg
Last modified: 18 Jun 15 - 11:00

FOR INFORMATION ONLY

CLIENT:	DESIGNER:		SCALES:			
Transport WestConnex Delivery Authority	AECOM Australia Pty Ltd A.B.N. 20 093 846 925		2.5 0 2.5 5 7.5m 1 : 500 FULL SIZE A3		M5 WESTCONNEX - ST PETERS INT. CONCEPT DESIGN SLOPE STABILISATION OVERALL LAYOUT - EXISTING	INFORMATION DOCUMENT DOCUMENT NO. PROJECT NO - DOC. TYPE - PROJECT PHASE - DISCIPLINE - DATE (YYYYMMDD) - DESCRIPTION: WCX2-IFD-00-2400-ID588-EW-20150618_LAYOUT2



DATUM -8

VERTICAL GEOMETRY: G=-11.92%, G=-10.07%, G=-9.80%, G=-9.87%, G=-13.08%, G=-12.09%, G=-10.57%, G=-8.89%, G=-10.55%, G=-10.99%, G=-10.76%, G=-8.63%, G=-7.22%, G=-11.27%, G=-10.37%, G=-6.87%, G=-6.70%, G=-3.63%, G=-5.60%, G=-2.89%, G=-1.90%, G=-5.21%, G=-2.46%, G=-0.92%, G=3.25%, G=5.37%, G=10.35%, G=12.04%, G=20.56%, G=-11.39%, G=-3.36%, G=-1.78%, G=-0.72%

HORIZONTAL GEOMETRY: R=64.735, R=-15.000, L=6.581, R=30.000, L=49.615

CHAINAGE	DESIGN LEVELS	EXISTING LEVELS
0.000	-0.031	-0.031
5.000	-0.627	-0.627
10.000	-1.130	-1.130
15.000	-1.620	-1.620
20.000	-2.113	-2.113
25.000	-2.767	-2.767
30.000	-3.372	-3.372
35.000	-3.900	-3.900
40.000	-4.345	-4.345
45.000	-4.873	-4.873
47.318	-5.127	-5.127
47.500	-5.147	-5.147
50.000	-5.363	-5.363
52.500	-5.543	-5.543
55.000	-5.825	-5.825
57.500	-6.084	-6.084
60.000	-6.256	-6.256
60.372	-6.281	-6.281
65.000	-6.449	-6.449
66.953	-6.558	-6.558
67.500	-6.574	-6.574
70.000	-6.621	-6.621
72.285	-6.740	-6.740
75.000	-6.807	-6.807
80.000	-6.853	-6.853
85.000	-6.691	-6.691
90.000	-6.422	-6.422
95.000	-5.904	-5.904
100.000	-5.302	-5.302
105.000	-4.274	-4.274
110.000	-4.844	-4.844
115.000	-5.012	-5.012
120.000	-5.101	-5.101
121.900	-5.114	-5.114

LONGITUDINAL SECTION - MCA1

A3 HORIZONTAL SCALE 1:500
A3 VERTICAL SCALE 1:50

FOR INFORMATION ONLY

CLIENT: Transport NSW WestConnex Delivery Authority

DESIGNER: AECOM
AECOM Australia Pty Ltd A.B.N. 20 093 846 925

SCALES: 2.5 0 2.5 5 7.5m
1 : 500 FULL SIZE A3

M5 WESTCONNEX - ST PETERS INT.
CONCEPT DESIGN
SLOPE STABILISATION
ACCESS TRACK LONG SECTION

INFORMATION DOCUMENT

DOCUMENT NO.
PROJECT NO - DOC. TYPE - PROJECT PHASE - DISCIPLINE - DATE (YYYYMMDD) - DESCRIPTION:
WCX2-IFD-00-2400-ID588-EW-20150618_LSEC_01

WestConnex Stage 2
WestConnex Delivery Authority
10-Nov-2015
Doc No. WCX2-20-2400-GT-408A

WestConnex - St Peters Interchange (SPI)

Geotechnical Desktop Study and Slope Risk Assessment

WestConnex - St Peters Interchange (SPI)

Geotechnical Desktop Study and Slope Risk Assessment

Client: WestConnex Delivery Authority

ABN: 33 855 314 176

Prepared by

AECOM Australia Pty Ltd
Level 21, 420 George Street, Sydney NSW 2000, PO Box Q410, QVB Post Office NSW 1230, Australia
T +61 2 8934 0000 F +61 2 8934 0001 www.aecom.com
ABN 20 093 846 925

10-Nov-2015

Job No.: 60327128

AECOM in Australia and New Zealand is certified to the latest version of ISO9001, ISO14001, AS/NZS4801 and OHSAS18001.

Quality Information

Document WestConnex - St Peters Interchange (SPI)

Ref 60327128

Date 10-Nov-2015

Prepared by Peter Plummer

Reviewed by Peter Waddell

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
A	10-Nov-2015	Issued for client review	Simon Tsui Technical Director	

Table of Contents

Executive summary

This report presents the results of the slope risk assessment for selected slopes surrounding the proposed St Peters Interchange (SPI) for the Westconnex Project. This work has been undertaken at the request of the WestConnex Delivery Authority (WDA) in accordance with AECOM proposal dated the 2 June 2015.

The desktop study included review of geotechnical reports, technical papers and studies carried out both within and surrounding the proposed SPI site. The slope risk assessments were carried out in general accordance with RMS slope risk analysis version 4 (Ref 1) and AGS, Quantitative Risk Assessment (QRA) (Ref 2) for six slopes.

The results of the slope risk assessment indicated that that the majority of the slopes were within the ‘As low as reasonably practicable (ALARP) limit. However, Slope 4 is above the acceptable risk criteria for loss of life for all failure mechanisms to pedestrians and people within the adjacent houses. Slope 4 is the masonry wall located along Woodley Street and Campbell lane is currently supporting fill. Due the poor conditions of the masonry wall we recommend that the wall be either demolished or stabilised. Until the wall is demolished or repaired it is suggested that the footpath be temporality closed and pedestrian be redirected.

The risk assessments have been carried out based on limited data. No detailed mapping of the quarry faces has been carried out. Fill slopes are heavily vegetated in places making a detailed assessment of the slopes challenging as potential hazards may have been obscured by vegetation. Detailed assessment of stability of both the fill and the quarry faces will be required prior to construction so that the appropriate mitigation measures can be implemented.

Based on the findings of the desktop study there is significant evidence of past slope instability at the proposed SPI site associated with the excavation of a shale quarry and subsequent landfilling activities. Changes to the SPI site could induce slope failures depending on the location of earthworks. To manage this risk during construction, all slope modifications should be designed and verified by a qualified geotechnical engineer.

Potential remedial works on exposed rock faces include: scaling of loose rock using a long reach excavator, shotcrete and pattern rock bolting, spot rock bolting, draped mesh, horizontal drains and stressed ground anchors.

Two lateral spreads (or large block failures) have been recorded on the northern and southern side of the quarry. Such large scale failures represent a risk to both existing structures surrounding the site and proposed structure at the SPI site. Depending on the geological structures encountered, new works could initiate similar failures. These risks will need to be considered by the designers of the SPI.

Controlling both surface water and groundwater will reduce the risk of failures of the various slopes within the site as groundwater has been a significant factor in previous failures. Surface water should be directed away from the slopes.

1.0 Introduction

AECOM Australia Pty Ltd (AECOM) was commissioned to carry out a geotechnical assessment, comprising a desktop study of available geotechnical information, site visits to observe surface features and slope risk assessment of select slopes at the proposed WestConnex St Peters Interchange (SPI). The assessment has been undertaken at the request of the WestConnex Delivery Authority (WDA) in general accordance with the AECOM proposal dated 2 June 2015.

The assessment was requested following slope instability which occurred in a fill batter on about 5 May 2015, following significant rainfall. Subsequent to the initial failure, another section of the same slope failed after a rainfall event on 18 June 2015.

The objective of the geotechnical assessment was to gather readily available historical geotechnical and geological information and site observations to:

- Develop a geological model at the SPI site
- Identify changes at the site over time and how these have affected the stability of the slopes and surrounding areas
- Identify for assessment slopes which may be subject to instability

From the overall assessment six slopes were identified for more detailed slope risk assessment to:

- Identify potential failure mechanisms
- Rank the six slopes from low to high risk
- Identify potential construction issues and discuss potential slope remedial works that may be required.

These slopes are shown in Figure A2 of Appendix A.

2.0 Methodology

AECOM collated and summarised readily available geotechnical information from public resources and the AECOM and WestConnex Delivery Authority databases. Information on the quarry and landfill obtained from the desk top study of reports and aerial photographs has been used to assess the history of site development and past slope stability issues. A summary of the information gained from previous report and aerial photographs is presented in Appendix B.

Site visits were carried out on various dates between 1 June and 18 June 2015 to visually assess the condition of the slopes and to a collect photographic record of slope conditions. During the site visits a visual assessment was carried out to identify slopes which could potentially be impacted by the removal of Stockpile 21 located in the north western corner and which could impact the general public. During these site visits six slopes were identified for more detailed assessment. These slopes are shown in Figure A2 of Appendix A and described in Section 5.0.

We developed a conceptual geological model for each slope and identified potential failure mechanisms and hazards and these are presented in Section 6.0.

A slope risk assessment was carried out based on the potential failure mechanisms identified for each slope. Elements at risk were identified in general accordance with:

- RMS slope risk analysis version 4 (Ref 1) where instability could potentially impact on road users; or
- AGS, Quantitative Risk Assessment (QRA) outlined in the AGS 2007 (Ref 2) where roads may not be impacted but there is the potential for loss of life.

Other elements at risk include services, infrastructure, roads, commercial building and residential houses that are adjacent to the site. Estimated costs associated with remedial works or potential impacts on services and infrastructure from instability is outside the scope of this report.

The slope risk assessments are presented in Section 6.0 and 7.0.

3.0 General site description and history

The site is located between Alexandria and St Peters, approximately 6km south of the Sydney CBD, as shown is Figure A1 of Appendix A. Canal Road lie to the west, Princes Highway to the north, Campbell Street to the east and Burrows Road to the south. A series of minor residential streets, commercial buildings, residential houses and industrial businesses also border the site.

The site is an irregular shaped property that is a former shale quarry known as the Ralford Pit that was excavated from about 1908 until 1975. After quarrying ceased the site was left abandoned from 1975 to 1988. Since 1988, the site was operated as a landfill and recycling centre. Over time there have been various episodes of instability within the old quarry walls and landfill.

The quarry and landfill will now form part of the proposed Westconnex Stage 2 development, St Peters Interchange. Prior to the site being handed over to a construction contractor, various stockpile materials are required to be removed, including Stockpile 21 which is subject to a clean-up notice issued by the Environmental Protection Agency (EPA). Stockpile 21 is located in the north western corner of the site as shown in Figure 10 of Appendix B

The area of slope subject to recent instability is located on the northern boundary of the property, adjacent to an industrial/commercial estate located at 300-310 Princes Highway, St Peters, as shown in Figure 1.

Figure 1 Site plan showing location of recent slope instability (Not to Scale)

4.0 Geological model

4.1 Regional geology

The *Sydney 1:100,000 Geological Series Sheet 9130* (1983), shows the land surrounding the southern half of the site comprises Quaternary soils overlying Ashfield Shales (Rwa) of the Wianamatta Group. The northern half of the site is underlain by Ashfield Shales (Rwa).

Further detail on the mapped units is provided below based on observations recorded by others (Ref 1 and Ref 7) and AECOM factual geotechnical report (Ref 13), which has been supplemented by observations made during the site visits.

4.2 Recent deposits

4.2.1 Fill

The fill encountered at the site is highly variable comprising various soils (clay, silt, gravel, sand, cobbles and boulders), building refuse and other waste material.

Data from the boreholes drilled within the SPI site indicates that the fill is up to 40.3 m thick (Ref 13, BH053) near the southern boundary of the site. Fill was recorded to a level of RL-34.3m AHD (Ref 13 BH050) near the centre of the site. There is no evidence to suggest that the fill was placed compacted to an engineering specification.

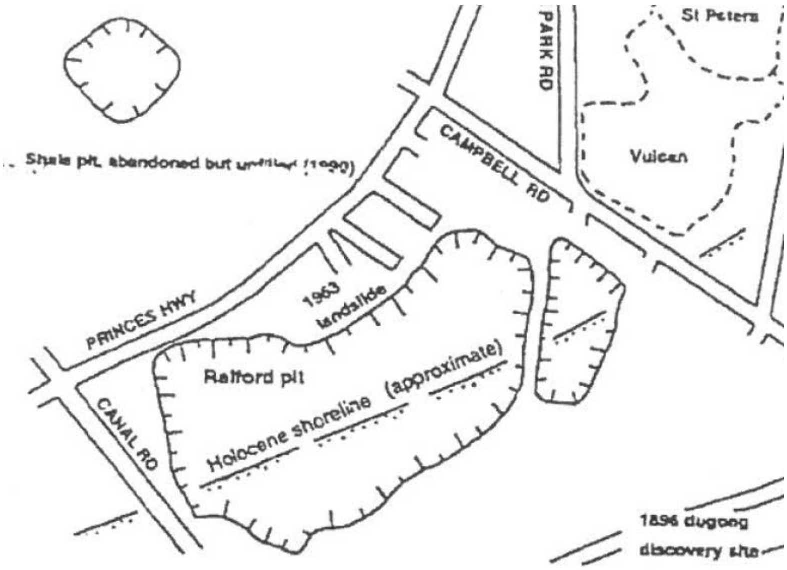
Stockpile 21, that is the subject of an EPA clean up order, comprises silty sand with gravel, cobbles and boulders comprising sandstone, concrete bricks and other building refuse. Whether Stockpile 21 was placed specifically to support the quarry faces or just as part of general landfilling activities is unknown.

4.2.2 Botany Sands

The Quaternary sediments are collectively known as the “Botany Sands” and include fine to medium grained marine sands with podsols (Qhd), likely derived from transgressive dunes, and peats and sandy peats (Qhs) deposited in freshwater swamps and alluvial environments.

The Botany Sands typically comprise sands with variable amounts of silt and clay and occur to depths of up to 13 m along the south eastern boundary of the site. Organic clays, peat and shell horizons were also encountered within the Botany Sands. These materials were typically very loose and soft becoming stiff to medium dense with depth. The historical Holocene shoreline is estimated to run along the south eastern boundary of the quarry parallel to Alexandra Canal. Figure 9 shows the approximate Holocene shoreline along the southern boundary of the site (Ref 7).

Figure 2 Holocene Shoreline - Extract from Ref 5



4.2.3 Residual Soils

The residual soil profile encountered in boreholes was between 1 m to 5 m thick. The soil is derived from the underlying Ashfield Shale. These soils were generally stiff to very stiff with the occasional iron-cemented zones and layers of highly weathered shale.

4.3 Bedrock

4.3.1 Ashfield Shale

Ashfield Shale typically comprises dark grey laminite, siltstone and sideritic siltstone with occasional fine grained sandstone layers. The Ashfield Shale is estimated to be up to 50 m to 60 m thick at the site, overlying Mittagong Formation and Hawkesbury Sandstone. The weathered profile is generally 4 m to 6 m thick and includes lateritic clay zones. Ironstone bands of up to 100 mm thick are also present within the sideritic siltstone. The weathering profile is thickest on the western margin and is almost non-existent on the southern margin of the quarry (Ref 3).

The Shale in the Alexandria Landfill was formerly quarried to RL-32m AHD. This is relatively consistent with the findings of the boreholes carried out within the quarry as part of the AECOM Geotechnical Report (March 2015), which encountered fill to a level of -32.7 m AHD (BH045).

4.3.2 Mittagong Formation

The Mittagong Formation is a transition layer between the Ashfield shale and Hawkesbury Sandstone and consists of interbedded and laminated, fine to medium grained quartz sandstone and black siltstone. It varies up to 6 m thick. Based on boreholes carried out within the quarry as part of the AECOM Geotechnical Report (March 2015), the inferred elevations where Mittagong Formation was encountered ranged from RL-33.4 m AHD to RL-41.5 m AHD.

4.3.3 Hawkesbury Sandstone

Hawkesbury Sandstone typically comprises light grey and brown grey medium to coarse grained quartz sandstone, with occasional shale and laminite beds. Based on boreholes carried out within the quarry as part of the AECOM Geotechnical Report (March 2015), the inferred elevations where Hawkesbury Formation was Geological Structure

Based on information recorded by Branagan, and Norman 1985 (Ref 3) and AECOM geotechnical investigations (Ref 3), the geological structure of the quarry has been summarised below.

4.3.4 Bedrock structure

4.3.4.1 Bedding

The regional dip of the Ashfield shale has been measured at 2° towards Botany Bay, which is located to the south east of the Quarry. Variations of up to 7° were recorded adjacent to faults in the floor of the quarry (Ref 3).

Observation within boreholes at the site typically recorded bedding dipping between 0° to 10°. The dip of laminations and bedding within BH109 and BH119 varied up to 30° between possible shear zones and crushed seams. Sub-horizontal crushed seams were measured up to 0.4 m thick. Extremely weathered seams were typically 10 mm to 50 mm thick.

4.3.4.2 Joints

The most common joint structure identified in the exposed quarry walls comprised two distinct joint sets (Ref 3).

1) A continuous sub-vertical joint set trending 020°, spaced approximately 0.4m

2) A complex, less persistent, secondary set trending from 070° to 110° comprising curved joints with dips varying from 10° to 80°, spaced 0.5m to 2m.

The first joint set deviates from 020° to 010° in the lower section of the quarry. The cause of the deviation in the trend is not clear (Ref 3).

Joints sets recorded within borehole indicated a trend in the sub-vertical joint set typically dipping between 70° to 80° to the horizontal, closely spaced and brecciated in some cases.

4.3.4.3 Faults

Normal and reverse faults with displacements of between 0.02 m and 1.5 m have been observed in the quarry walls and floor (Ref 3). Zones of intense vertical jointing, vertical displacement and brecciation have also been observed. Non-persistent, small displacement normal and reverse faults were observed within the pit and vertical shear zones along the trending NNE joint set were also observed.

Potential faults and shear seams were recorded within some boreholes at the site. Possible fault zones were recorded at the north western boundary at BH119 (approximately 1.9 m thick) and at the north eastern corner of the SPI Site in BH55 (approximately 1.7 m thick). The inferred faults comprised brecciated material and closely spaced joints. Offsets of 5 mm to10 mm within the bedding of the brecciated zones were recorded in BH119.

4.3.4.4 Dykes

According the *Sydney 1:100,000 Geological Series Sheet 9130* (1983) a Dyke crosses the site, which strikes at 105°. There is no evidence of any mapping being undertaken to assess this feature in the available historical information. Dykes in Sydney are typically basalt or dolerite and are up to 6m wide. They may be weathered to clays to considerable depth, and can be conduits for water flow, or impede water flow depending on the composition of the material and amount of fracturing in the dyke and surrounding rock.

4.4 Groundwater

The hydrogeology at the site is complex due to the modifications during quarrying and landfill development, and the interaction with leachate management at the site. Groundwater is present within the fill, Ashfield Shale and the Botany Sands.

Fill leachate is generated as groundwater derived from the Botany Sands, Ashfield Shale and surface water runoff percolated through the fill. The poorly consolidated nature of the fill provides large pore spaces and consequently the hydraulic conductivity is high. Groundwater as leachate is pumped from the pit and treated before being discharged off-site.

Groundwater is present within the Botany Sands as a shallow unconfined aquifer perched on top of the Ashfield Shale. Groundwater levels are variable but would be expected to be at just above sea level in an undisturbed environment. Natural groundwater fluctuations can increase the watertable in the order of 0.5 metres following a high rainfall event and can also be influenced by tidal fluctuations at Alexandra canal. Natural regional groundwater flow within the Botany Sands is towards Botany Bay and locally towards Alexandra Canal. The groundwater depth is also influenced by other local factors such as distance from recharge and discharge areas, local development and dewatering. Recharge is via direct rainfall and local run-off in green spaces such as nearby Sydney Park.

Groundwater quality within the Botany Sands aquifer is of variable quality but is typically of low salinity and moderately acidic. The shallow unconfined aquifer is susceptible to contamination in an urban and industrial environment. Variations in groundwater quality can be attributed to a number of factors including:

- Presence of peaty sediments (elevated sulphide concentrations);
- Local seawater intrusion;
- Industrial development (variety of chemical compounds);

The Ashfield Shale is a semi confined fractured rock aquifer where the dominant groundwater movement is along secondary structural features rather than through the rock mass. Natural groundwater levels would be expected to be close to sea level with regional groundwater flowing to the south. However, groundwater levels at the site are influenced by leachate pumping. Locally groundwater is expected to flow radially towards the leachate pump within the eastern part of the landfill.

Groundwater quality within the shale is typically brackish. Beneficial use of the groundwater from the Ashfield Shale is limited because of the brackish nature of the water. A review of the DPI (Water) groundwater database indicates that within one kilometre of the site there are no boreholes intersecting the shale other than monitoring wells at the site.

McNally and Branagan (Ref 5) presented a conceptual model of the groundwater system within the St Peters quarries. The model indicates the water table at approximately sea level, prior to excavation of the quarries, within the Botany Sands aquifer. According to the model, groundwater from the Botany Sands aquifer and shale fractures would have seeped into the quarry basements prior to filling, causing ponding of the groundwater.

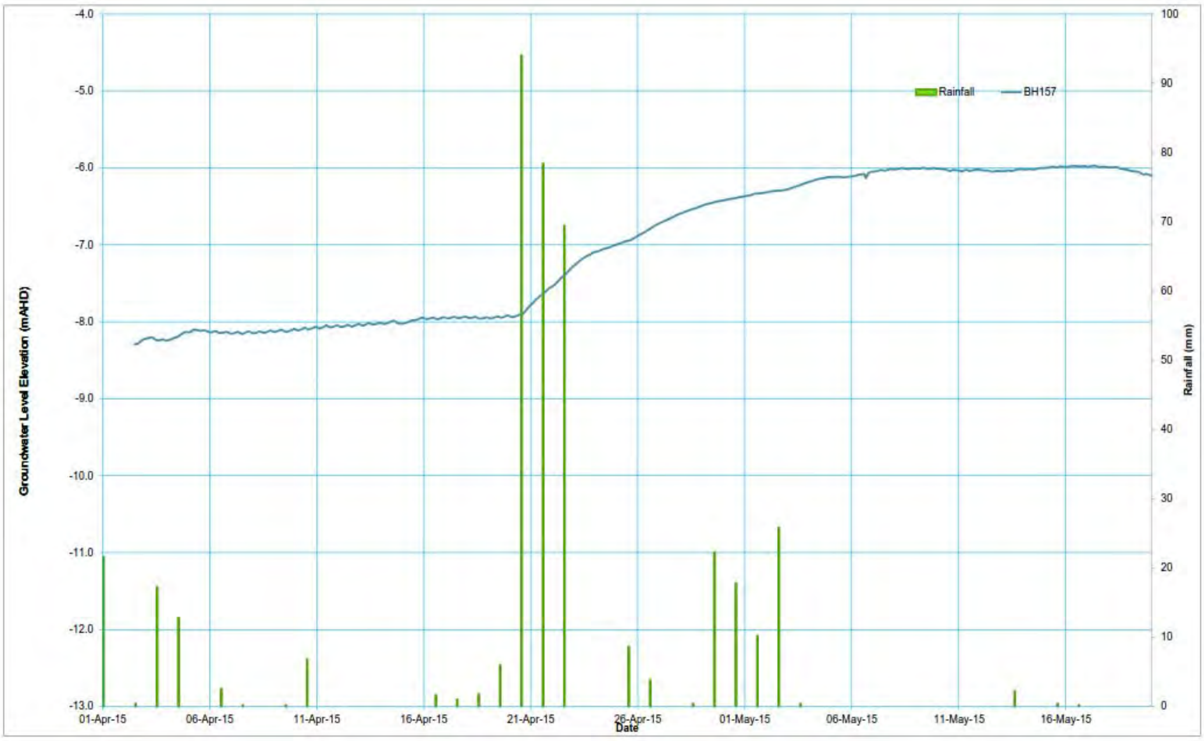
Following filling of the quarry above the level of the boundary with the Quaternary sediments, rainfall, runoff and water infiltration from other sources (e.g. Alexandra Canal) is likely to have caused the leachate in the fill to mound and hydraulically connect the Botany Sands aquifer to the underlying shale aquifer. McNally and Branagan (Ref 5) also noted the following relevant hydrogeological information:

- Five seepages were observed to be discharging at 2.9 L/min to 13.3 L/min in the base of the Ralford Pit;
- Seepages into the pit were visibly polluted with iron and copper salts which were thought to originate from either the northern landfills (possibly the current location of Sydney Park) or from nearby factories;

Based on the well information, shallow groundwater is present in the area in the Botany Sands at depths ranging from 1.8 m to 3 m. Deeper groundwater is present in the shale at depths of approximately 14 mto 15 m.

Groundwater measurements in BH157 (Ref)located on the northern side of the SPI site adjacent to Slope 2 and Slope 3 indicated that groundwater was between RL-8 m AHD and RL-6 m AHD. Groundwater readings from BH157 plotted in Figure 3 illustrate a rise in the water level over a 15 day period following a significant rainfall event.

Figure 3 BH157 Groundwater Level April 2015 to May 2015



5.0 Slope descriptions

Sketches and photos of each of the slopes are provided in Appendix A. Geological conceptual cross sections have also been sketched, illustrating potential failure mechanisms for each slope. Descriptions of each of the slopes are summarised below.

Slope 1 – Princes Highway St Peters, North Western corner of the site

Slope 1 is located at the North West corner of the quarry which abuts the Princes Highway which is 6 lanes wide with a footpath either side. The slope is bounded by Slope 2 to the west and Slope 6 to the east. Slope 1 comprises fill from Stockpile 21, which was placed against the cut face during the period 2005 through to 2014 (Ref 12). Observations of the surface of the fill suggest that it comprises of silty sand with gravel, cobbles and boulders. It is not known if the fill was engineered or compacted during placement.

Slope 1 is about 55 m long, about 9 m high, and has an average slope angle of about 45°. The slope is currently heavily vegetated with grasses, shrubs and scattered trees. There is a gully and access road at the base of the slope, separated by a stockpile approximately 2 m to 3 m in height. Two more batter slopes extend below the access road to the base of the landfill, which was flooded at the time of the site visit. The fill forms a buttress against the original shale quarry face, which is suspected to be near vertical in places and 70° to the horizontal based on historical survey information.

No evidence of previous failures was observed. However, cracking of the pavement and footpath was noted at the top of the slope. It is unclear if this cracking whether this cracking is associated with a failure of the adjacent slope.

Stormwater from the road and footpath grades to a drain located on the western side of the slope. Surface water from the slope is collected in the gully which grades towards a low point on the west side of the slope, where evidence of ponding was observed.

Known infrastructure located at the crest of the slope includes a leachate pipe from the landfill, underground, water, gas, communication lines and overhead power lines. There is a communications tower located at crest on the eastern side of the slope.

Photos of the slope taken during the site visits are shown in Appendix A, Plate 1-1 to Plate 1-4. The locations of the photos are shown on the slope sketches.

Slope 2 – Below commercial buildings at 300 to 310 Princes Highway, St Peters

Slope 2 is located near the North Western corner of the site. The slope is bounded by Slope 1 to the west and Slope 3 to the east. There are commercial buildings at the top of the slope from 300 to 310 Princes Highway, St Peters (Lots 1 & 2/DP788037). Slope 2 comprises fill from Stockpile 21, which was placed against the cut face during the period 2005 through to 2014 (Ref 12). Surficial evidence of the fill suggests that it comprises of silty sand with gravel, cobbles and boulders. It is not known if the fill was engineered or compacted during placement.

Slope 2 suffered recent instability on 5 May and 18 June 2015 following rainfall events. Tension cracks were also apparent behind the recent slope failures, which regressed approximately 0.5 m to 0.8 m further back from the slope crest prior to 18 June 2015. During the site visit evidence of previous slope failure/slumping was apparent including tilting trees, shrubs and scarps both on the slope and at the crest of the slope, similar to observation made letter report carried out (Ref 12) at Slope 2. It is not known when these failures occurred. A temporary stabilisation buttress has been constructed against this slope.

Prior to the modification of Slope 2, the slope was approximately 110m in length and ranged from 12 m to 22 m in height. The slope had an average batter of about 45°. However, the batter at the crest increases to an angle of between 50° and 70° from the horizontal. In the area of the recent instability, undercutting was observed beneath the roots of the trees and shrubs. Access roads and gullies were located at the base of the slope. The surface of the embankment was covered in grasses, shrubs and small trees. The slope is now supported by a buttress battered at 1V:1.5H with a 3 m wide berm at 7 m height intervals.

The 'cliff face' of the quarry is shown on the building footing plan of the commercial building above the slope (Ref 16). The drawings indicate that the 'cliff face' is beyond the boundary of the property of the commercial building located to the east, and within the boundary of the building located to the west. Based on the current edge of the slope it is suggested that the cliff face adjacent to the building may have retreated since the building was constructed. Ref 17 indicates that the existing structure has been designed to accommodate settlement occurring at the edge of the beam should further slope failure occur adjacent to the structure.

Infrastructure located at the crest of the slope includes a leachate pipe from the landfill, stormwater drains and pipes from the commercial building, air conditioning units and communications tower located at the western side of the slope. Drains running along Bishop Street and along car parks on the eastern side of the slope were observed blocked with debris. A disused/blocked drainage pipe was also noted at the base of the slope below the access road along Slope 2.

Evidence of surface water runoff was also observed at various locations at the crest of the slope and down the surface of the slope. The surface of the slope was hummocky and saturated in areas. Water was ponding at the base of the slope between Slopes 2 and 3.

The results of the slope analysis, carried out as part of the stabilisation design for Slope 2, indicated that the stability slope was sensitive to groundwater levels. As part of the temporary stabilisation of the slope, controlling potential water infiltration from the exiting slope and surface water infiltration was important maintaining the stability of the design.

Photos of the slope taken during the site visits are shown in Appendix A, Plate 2-1 to Plate 2-5. The locations of the photos are shown on the sketches of the slope.

Slope 3 – Below car parking area at Bishop Street, St Peters

Slope 3 is an exposed shale quarry cut face along the northern site boundary and abuts Bishop Street and car parking located at the crest of the slope. The cut face is approximately 110 m in length and ranges from 17 m to 23 m in height. The cut face dips at an average of 80° from the horizontal. Sections of the quarry face are overhanging slightly in places. The top of the slope is vegetated with grasses, shrubs, and scattered trees.

The lithological profile of the cut comprises approximately 4 m to 8 m of fill underlain by 4 m to 6 m of residual soil and weathered shale overlying slightly weathered to fresh shale. The crest of the slope could not be observed at the time due to restricted access and safety concerns.

Bricks and fill are held together by vegetation in places at the crest of the slope but have been gradually falling to the base of the slope where there is a collection of talus from fretting of the shale, small shale blocks falls up to 0.2m average dimension and bricks from the overlying fill. At the time of our site visit a 10 m to15 m wide exclusion zone from the quarry face was in place due to instability.

Opening of some of the sub-vertical joints was observed on the exposed shale face which could result in potential toppling failures.

Bishop Street and car parking are approximately 6 m and 10 m from cut face, respectively. Other structures include a stormwater drain and commercial buildings located approximately 20 m to 40 m away from the cut face. It is understood that the leachate pipe from the landfill is also located behind the crest of the quarry face.

Seepage from a number of the exposed shale bedding planes was observed.

Photos of the face taken during the site visits are shown in Appendix A, Plate 3-1 to Plate 3-8. The locations of the photos are shown on the sketches of the slope.

Slope 4 – Masonry Wall along Campbell Lane and Woodley Street, St Peters

Slope 4 is a stockpile of fill colloquially known as “Bradshaw Mountain” located on the eastern side of the site near the main entrance off Albert Street. Historical photographs show the fill appears to have been placed between 1961 and 1978. The stockpile is approximately 200 m long, 100 m wide and 14 m high, with an average batter of 45° and is partly retained by a masonry wall.

The masonry wall is approximately 200 m long and ranges from 1 m to 4 m in height. The wall borders Campbell Lane, Woodley Street and Holland Street. The surface of the slope is covered with vegetation including trees, shrubs, grasses and sandstone boulders up to 2 m in diameter.

Some sections of the masonry wall appear to have either been demolished or may have failed. The masonry wall is displaying signs of distress, including cracking and tilting away from the slope. Some sections of the wall have cracked and are deflecting up to 200 mm.

Infrastructure at the base of the slope includes the local roads, footpath, power lines and houses. The houses and power poles located along Campbell Lane are offset approximately 5 m from edge of the slope.

Photos of the slope taken at during the site visits which are shown in Appendix A, Plate 4-1 to Plate 4-9. The locations of the photos are shown on the sketches of the slope.

Slope 5 – Below commercial buildings at 1-3 Canal Road, St Peters

Slope 5 is a cut face of the quarry with commercial buildings 1-3 Canal Road, St Peters (Lot SP35749) located at the top, adjacent to Canal Road which is a five lane road with a foot path either side. The cut face is approximately 100 m long and is up to 10 m high with a batter ranging from 50° to 70° to the horizontal. The slope is heavily vegetated with grass and low lying shrubs concealing the face. The slope has also been covered with fill from landfilling activities.

We observed evidence of previous cut instability. However, the vegetation could obscure signs of instability.

Infrastructure located at the crest of the slope includes Canal Road, an underground service within canal road, a commercial building, stormwater drains and pipes.

Photos of the slope were taken at during the site visits which are shown in Appendix A, Plate 5-1 to Plate 5-12. The locations of the photos are shown on the sketches of the slope.

Slope 6 – Below commercial buildings at 1-3 Canal Road, St Peters

Slope 6 comprises fill from Stockpile 21 forming a buttress for the cut face of the quarry. Commercial buildings 1-3 Canal Road, St Peters (Lot SP35749) abut the top of the slope which is approximately 110 m long and is covered with scattered vegetation. The slope is relatively flat with stockpiles up to 3 m high in the area. Slope 6 comprises fill from Stockpile 21, which was placed against the cut face during the period 2005 through to 2014 (Ref 12). Fill for these slopes comprise Stockpile 21, surficial evidence of the fill suggests that it comprises of silty sand with gravel, cobbles and boulders. It is not known if the fill was engineered or compacted during placement.

Based on historical survey information between 1999 and 2002, the cut face dips is at 55° to 70° to the horizontal.

Photos of the slope area taken at during the site visits which are shown in Appendix A, Plate 6-1 to Plate 6-3. The locations of the photos are shown on the sketches of the slope.

6.0 Slope risk assessment

6.1 General

Slope risk assessments have been carried in accordance with RMS slope risk analysis version 4 (Ref 1) or AGS, Quantitative Risk Assessment (QRA) outlined in the AGS 2007 (Ref 2) depending potential hazards identified and elements at risk. The potential hazards have been identified using a combination of readily available historical information and observations made during site visits.

The RMS method of slope risk analysis has been carried out for Slope 1, Slope 3 and Slope 4 where failure mechanism/hazards may impact roads to assess an ARL rating for each slope.

The remaining slopes have been assessed in general accordance with the Quantitative Risk Assessment (QRA) outlined in the AGS 2007 for loss of life. Other elements at risk include services, infrastructure, roads, commercial building and residential houses which neighbour the site.

In some cases was not possible to carry out a quantitative slope risk assessment of the slope. As an alternative the slope risk assessment have been based on qualitative values of risk based on visual observations of the potential hazards. Fill slopes are heavily vegetated in places making a detailed assessment of the slopes challenging and potential hazards may have been obscured by vegetation. Detailed assessment of stability of both the fill and the quarry faces will be required prior to construction so that the appropriate mitigation or stabilisation measures can be implemented.

Annual probability of failure has been estimate based on historical information, visual observation, likely trigger mechanisms, geometry and condition of the slope. Annual estimates probability range of failure for the potential failure mechanism have been summarised in Section 6.2.

6.2 Potential landslide hazards

6.2.1 Stockpile 21 (Slopes 1, 2 and 6)

As part of the review of the available historical information and site observation potential landslide hazards at Slope 1, 2 and 6 include:

- Rotational failures (slumps) with an estimate volume of $20m^3$
- Rotational failures with an estimated volume of $250m^3$.

The frequency of these failures has been assessed based on evidence of previous failures since placement and return period of potential trigger events such as rainfall.

The rotation failures that occurred prior to 5 May 2015, has an estimated volume of $250m^3$. As outlined in Section 4.4, there was a prolonged period of rainfall from 21 April to 23 April 2015 where a total of 232.2 mm of rainfall fell over a 72 hour period. Based on the Intensity-Frequency-Duration (IFD) graph developed for the Sydney Airport from the Bureau of Meteorology (BOM) website, this rainfall event has an estimate return period of between 5 years and 10 years. This rainfall event triggered the slope failure was a result of water infiltration into the slope from surface runoff combined with groundwater seepage. Consequently, the estimated frequency of these failures is likely to be within the range of 5 to 10 year.

Based on site observations slump failures with an estimate volume of 20 m^3 are considered have a frequency of between 1 to 10 years.

Slope 1 and 2 are relatively similar geometry and hence the same failure mechanisms/hazards are likely to be present. However the performance of the Slope 1 is likely improved due to surface groundwater control preventing water ingress into the slope such at the footpath, road and stormwater system above the slope.

Slope 6 is relatively flat with fill from Stockpile 21 placed against the quarry face to the same level as the foundation of the adjacent building. In its current condition the slope does not exhibit signs of instability and no obvious potential failure mechanism have been identified. Consequently, failure is considered to be very unlikely. Slope 6 is expected to be essentially unaffected by rainfall and a low probability has been adopted for this slope.

As outlined in Ref 15 and Ref 18, following the slope failure at Slope 2, this slope is currently undergoing stabilisation works. This will reduce the likelihood of failure at Slope 2 as the slope has been flattened and mitigation measures have improved the control groundwater and surface water runoff. The revised risk assessment has also been carried out for both cases to demonstrate the improved performance of Slope 2.

The hazards and probability of occurrence for Slopes 1, 2 and 6 are summarised in Table 1.

Table 1 Slope 1 and 2 Potential Hazards/Failure Mechanism

Slope	Potential Hazards Type	Estimated Volume	Estimated Speed	Trigger	Estimated Annual Probability Range
Slope 1 and 2	Rotational Failure	$250m^3$	5m/sec (Very Rapid)	Rainfall	$2x10^{-1}$ and $1x10^{-2}$
	Rotational Failure (Slump)	$20m^3$	5m/sec (Very Rapid)	Rainfall /Erosion	$1x10^{0}$ and $1x10^{-1}$
Slope 6	Rotational Failure	$250m^3$	5m/sec (Very Rapid)	Rainfall	$1x10^{-5}$
	Rotational Failure (Slump)	$20m^3$	5m/sec (Very Rapid)	Rainfall /Erosion	$1x10^{-5}$
Slope 2 (Post Temporary Stabilisation)	Rotational Failure	$250m^3$	5m/sec (Very Rapid)	Rainfall	$1x10^{-3}$
	Rotational Failure (Slump)	$20m^3$	5m/sec (Very Rapid)	Rainfall /Erosion	$1x10^{-2}$

6.2.2 Exposed quarry faces (Slope 3 and 5)

The likely hazards that have been identified at Slope 3 and 5 include:

- Lateral Spread estimated volume of greater that 1,000 m^3
- Block/Topple (Large) with minimum dimensions of 0.2 m-0.5 m
- Block/Topple (Small) with minimum dimension of 0.1 m
- Rotational failures with an estimate volume of 20 m^3 to 100 m^3

The frequency of the lateral spread has been deduced by frequency of previous events which occurred in 1963 (Ref 7) and 1985 (Ref 4, 5 and 6). However, these mechanisms will be dependent on groundwater controls in place and lateral support of the quarry face such as a buttress or completely landfilling. Landfilling activities and the installation of leachate riser to control groundwater at the site may have reduced the likelihood of these event occurring.

Evidence of frequent block failure failures (topples) have been observed in previous reports and during the site inspections. The frequency of these failures will be influenced by the structure of the rock mass and triggered by surface rainfall and erosion. The frequency of topple and block failure failures is considered high.

Based on the amount of debris at the base of the Slope 3, smaller block/topple failures and rotational failures are considered to be very frequent.

The hazards and probability of occurrence for these slopes is summarised in Table 2.

Table 2 **Potential Hazards/Failure Mechanism of Exposed Quarry Face**

Slope	Potential Hazards Type	Estimated Size	Estimate Speed	Trigger	Estimated Annual Probability Range
Slope 3 and 5	Lateral Spread	<1000m^3	1m/year (Slow) to 5m/s (Very Rapid)	Rainfall/Pore water pressure/Groundwater	1.5x10^{-2} (2 recorded failures, 1963 and 1985)
	Topple (Large)	0.2m-0.5m minimum dimensions	5m/sec (Very Rapid)	surface Erosion as a result of rainfall	1x10^{-1} and 5x10^{-1}
	Topple (Small)	0.1m minimum dimension	5m/sec (Very Rapid)	surface Erosion as a result of rainfall	1x10^{0} and 1x10^{-1}
	Rotational Failure (Slump) of overlying fill	20-100m^3	5m/sec (Very Rapid)	Localised saturation of the slope as a result of rainfall	1x10^{0} and 1x10^{-1}

6.2.3 Masonry Wall (Slope 4)

The potential failure mechanisms that been identified at Slope 4 include:

- Wall overturning
- Boulder Roll
- Global Failure

The wall cross section is not known and hence it is not possible to establish the stability of the wall and a quantitative assessment of this wall is not practical. However, based on the visual inspection of the wall, progress of the mechanisms is evident. These failure mechanisms could be described as evolving and anticipated to occur within a few years to decades.

The hazards and estimate probability of occurrence for these slopes is summarised in Table 3.

Table 3 **Potential Hazards/Failure Mechanism of Slope 4**

Slope	Potential Hazards Type	Estimate Size	Estimate Speed	Trigger	Estimated Annual Probability Range
Slope 4	Wall Overturning	0.5-1.0m minimum dimension	5m/sec (Very Rapid)	Rainfall	1x10^{-2}
	Boulders roll	0.5-1.0m minimum dimension	5m/sec (Very Rapid)	Rainfall/Erosion	1x10^{-2}
	Global Failure	250m^3	5m/sec (Very Rapid)	Rainfall	1x10^{-2}

6.3 Elements at risk

Potential elements at risk for loss of life identified have been summarised in Table 4, based on the various hazards identified in Section 6.2. Other elements at risk include the services, infrastructure, roads, commercial building and houses. The risks from slope instability to construction workers within the SPI site have not been included in this slope risk assessment as these risks should be assessed during construction.

Table 4 Potential elements at Risk

Slope	Elements at Risk - loss of life	Elements at Risk - Property Damage
Slope 1*	• Pedestrians using footpath above the slope • Vehicles on Princes Highway*	• Road (shut down, damage) • Services in the road (communication lines, water, stormwater etc) • Communication tower
Slope 2	• People within the commercial building above the slope	• Commercial building • Services associated with the commercial building • Stormwater pipes
Slope 3	• Vehicles on Bishop Street*	• Road and parking areas
Slope 4*	• Pedestrians using footpath below the slope • Vehicles on Campbell Lane and Woodley Street* • People within the houses on Campbell Lane/Street	• Road (surficial damage) • Residential houses • Retaining wall • Overhead power lines
Slope 5	• People within the commercial building above the slope	• Commercial building • Service associate with commercial building
Slope 6	• People within the commercial building above the slope	• Commercial building • Service associate with commercial building

*RMS slope risk assessment version 4 used to estimate risk

6.4 Quantitative risk assessment (QRA) – Loss of life

The main steps in the QRA process includes hazard assessment, consequence analysis, risk calculation and risk evaluation.

The QRA is essentially a calculation of the

- probability of an event occurring (slope failure),
- probability that someone is within the affected area (spatial probability),
- probability that this person is within the failure zone (temporal probability),
- vulnerability of that person to the event
- number of people affected

The risk calculation outlined in the AGS 2007 calculation for loss of life, the individual risk can be calculated from:

$$\mathbf{R}_{(LoL)} = \mathbf{P}_{(H)} \times \mathbf{P}_{(S:H)} \times \mathbf{P}_{(T:S)} \times \mathbf{V}_{(D:T)}$$

$\mathbf{R}_{(LoL)}$ is the risk (annual probability of loss of life (death) of an individual)

$\mathbf{P}_{(H)}$ is the annual probability of the landslide

$\mathbf{P}_{(S:H)}$ is the probability of spatial impact by the landslide on the property, taking into account the travel distance and direction

$\mathbf{P}_{(T:S)}$ is the temporal spatial probability.

$\mathbf{V}_{(D:T)}$ is the vulnerability of the individual (probability of loss of life of the individual given the impact)

The results of the assessment are summarised in Appendix B.

6.4.1 Probability of the landslide

The annual probability of the landslide has been estimated based on observations, historical information and qualitative measurement of likelihood. The probability of the individual landslide hazards/failure mechanism occurring has been estimated in 6.2.

6.4.2 Probability of spatial impact

The probability of the element at risk is within the area of failure given the size and travel distance of the various landslide hazard/ failure mechanism. This has been estimated for each slope depending on the geometry of the slope and the location of the elements at risk for each of the slopes. Travel distances have been estimate using a combination of the both Hunter and Fell (2002) (Ref 20) and Figure 8 and 9 of RMS slope risk assessment Version 4.

The estimate probability of spatial impact has been summarised in Table 5 for potential impact to people. As outlined above the QRA has been carried out for loss of life. The RMS method of slope risk analysis has been carried out for Slope 1, Slope 3 and Slope 4 where failure mechanism/hazards may impact road/street.

Table 5 Estimated probability of spatial impact

Slope	Hazard	Element at Risk	Probability of spatial impact $P_{(S:H)}$
Slope 1	Rotational Failure	• Pedestrians using footpath • RMS slope risk analysis carried out for people in vehicles	0.1
	Rotational Failure (Slump)	• Unlikely to impact footpath or road above	-
Slope 2	Rotational Failure	• People within the commercial building	0.1
	Rotational Failure (Slump)	• Unlikely to impact commercial building above	-
Slope 3	Large Block Failure/Spread	• RMS slope risk analysis carried out for people in vehicles	-
	Topple (Large)		
	Topple (Small)		
	Rotational Failure (Slump)		
Slope 4	Overturning	• Pedestrians using footpath • Unlikely to impact people within the houses • RMS slope risk analysis carried out for people in vehicles	1.0 - -
	Boulders roll	• Pedestrians using footpath • People within the houses • RMS slope risk analysis carried out for people in vehicles	1.0 0.1 -
	Global Failure	• Pedestrians using footpath • People within the houses • RMS slope risk analysis carried out for people in vehicles	1.0 0.1 -
Slope 5	Large Block Failure/Spread	• People within the commercial building	1.0
	Topple (Large)	• People within the commercial building	0.1
	Topple (Small)	• Unlikely to impact people within the commercial building	-
	Rotational Failure (Slump)	• People within the commercial building	N/A
Slope 6	Potential slope failure/hazards considered very unlikely		

**prior to temporary stabilisation*

6.4.3 Temporal probability

The temporal spatial probability has been estimate for the following elements at risk:

- people within houses
- people within commercial buildings
- pedestrian on the footpath

The following assumptions have been made to determine the temporal probability.

People within houses

Four people live in each of the houses at risk. One of those is in the house 20 hours per day 7 days a week, whilst the others three are there for 12hrs per day 7 days a week.

$P_{(T:S)}$ *for Single person most at risk = 0.83*

$P_{(T:S)}$ *for other three people at risk is = 0.50*

People within commercial buildings

Five people work in each of the commercial building for 8 hours per day 5 days a week.

$P_{(T:S)}$ = *0.24*

Pedestrians on the footpath

The temporal probability of a person occupying the footpath assuming that the number of people using the footpath is estimated to be 100 per day, occupying 100m section of footpath is $P_{(T:S)}$ = *0.08*

6.4.4 Vulnerability

Vulnerability $V_{(D:T)}$ may be thought of as the probability of loss of life/serious injury of the hazard impacting the person. The vulnerability is dependent on the size and velocity of the landslide. Rapid failures will have a high vulnerability when compared to slower moving failure. Large volumes of material are more likely to inundate/bury a person when compared to smaller slump failures.

The recommended vulnerabilities for loss of life for the various hazards identified has been summarised in Table 6. The vulnerabilities which are based on the recommended values outlined in Appendix F of the AGS Landslide Risk Management 2007, adapted from Finlay, Mostyn and Fell (1999) (Ref 19).

Table 6 Summary of vulnerabilities for the various hazards

Hazard	Vulnerability	Comment/Assumptions
Vulnerability Person in the Open		
Rotational Failure	1.0	Person likely to be buried by debris
Rotational Failure	0.1	Person not considered likely to be buried. High chance of survival
Large Block Failure/Spread*	0.01	This failure mechanism is likely slow moving and will likely allow time for people to evade. However, the speed of the failure could increase suddenly.
Topple (Large)	1.0	Person struck by debris likely to result in death
Topple (Small)	0.5	Maybe injured, but unlikely to cause death
Overturning	1.0	Person struck by debris likely to result in death
Boulders roll	0.7	May result in injury of death
Global Failure	1.0	Person likely to be buried by debris
Vulnerability Person in building		
Boulders roll	0.05	The houses are offset approximately 4m from the slope which near edge of the estimated travel distance
Global Failure	0.05	The houses are offset approximately 4m from the slope which near edge of the estimated travel distance
Rotational Failure	0.05	Virtually no damage considered likely to building
Topple (Large)	0.05	Virtually no damage considered likely to building above the quarry face

*Adjusted value to account for the speed of movement

6.5 RMS slope risk analysis

The RMS method of slope risk analysis has been carried out for Slope 1, Slope 3 and Slope 4 where failure mechanism/hazards may impact roads. The assessments for each of the slopes are provided in Appendix C.

The traffic data used for Slope 1 is based on RTA traffic model M0131 which is estimate to be 21,267 per day heading south across three lanes, resulting is a T2 temporal rating for the slope. There was no data available for roads near Slope 3 and Slope 4. It has been estimated that volume of traffic using these roads is between 30 and 270 per lane resulting is a T4 temporal rating for the slope.

7.0 Risk evaluation

7.1 Quantitative risk assessment

The results of the QRA have been summarised in Appendix C. The values represent the highest annual risk to life of a person current annual risk to and ranked as follows:

1) Slope 4 with an estimate $8.0x10^{-4}$ annual risk to life to pedestrians
2) Slope 2 with an estimate $2.4x10^{-4}$ annual risk to life to people within the commercial building above the slope prior to placement of the buttress (estimate to be reduced to $1.2x10^{-5}$ following temporary stabilisation)
3) Slope 5 with an estimate $6.0x10^{-5}$ annual risk to life to people within the commercial building above the slope
4) Slope 1 with an estimate $8.0x10^{-6}$ annual risk to life to pedestrians

5) Slope 6 with an estimate 2.4×10^{-8} annual risk to life to people within the commercial building above the slope prior to placement of the buttress

6) RMS Slope risk analysis carried out for Slope 3

The AGS Landslide Risk Management 2007 guide suggests the following risk values for tolerable loss of life for the person most at risk:

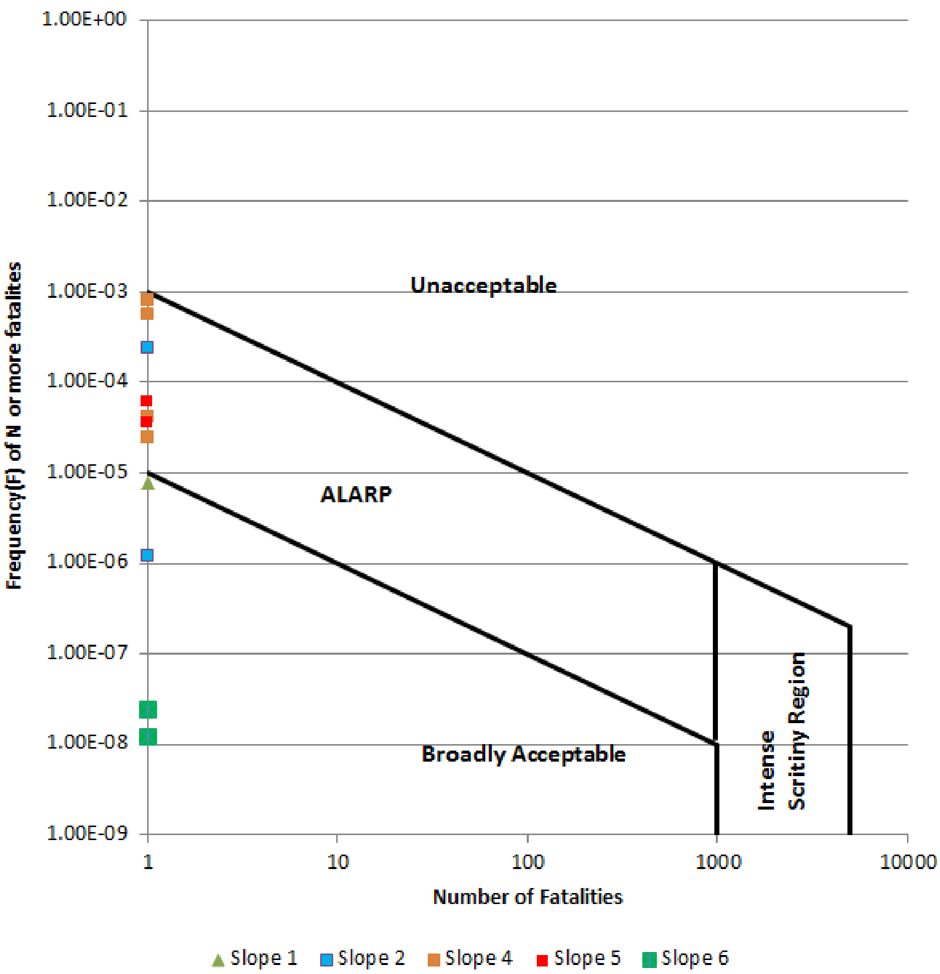
- Existing slope/existing development 10^{-4}
- New Constructed slope/New development/Existing landslide 10^{-5}

Based on the criteria outlined above, the results of the slope risk assessment indicate the following:

- Slope 4 - above the acceptable risk criteria for loss of life for all failure mechanisms to pedestrians
- Slope 2 - was above the acceptable risk criteria for loss of life for people within the commercial building above, prior to temporary stabilisation of the slope;
- Slope 5 - was within the acceptable criteria for loss of life; and
- Slope 6 - was within the acceptable criteria for loss of life.
- Slope 1 - was within the acceptable criteria for loss of life.

The results of the assessment have been plotted in Figure 4 against the tolerable societal risk to loss of life. The majority of the results are in the ALARP level (as low as reasonably practicable). Slope 2 and Slope 4 was above the acceptable risk criteria for loss of life, prior to temporary stabilisation of the slope. Recommendations to manage the potential hazards are summarised in Section 8.0.

Figure 4 Societal Tolerable risk to loss of life



7.2 RMS slope risk analysis

The results of the RMS slope risk analysis slope risk analysis have been summarised in Table 7 and are provided in Appendix C. The results of the assessment indicated that the risk to people in vehicles was between an ARL4 and 5, which is considered to be relatively low risk.

Table 7 ARL Rating

Slope	Failure Mechanism	Likelihood	Consequence Class	ARL
Slope 1	Rotational Large	L4	C3	ARL5
	Rotational Small	L4	C3	ARL5
Slope 3	Rotational	L4	C5	ARL5
Slope 4	Overturning	L2	C5	ARL4
	Global Failure	L2	C5	ARL4
	Boulder Roll	L2	C5	ARL4

8.0 Conclusions and recommendations

Based results of this assessment there is significant evidence of past slope instability at the proposed SPI site associated with the excavation of the shale quarry and subsequent landfilling activities. The slope risk assessments presented in this report relate to risks to the public and property on adjacent sites and do not address the stability during earthworks for construction of the SPI.

To manage slope risk during construction, all slope modifications should be assessed by an experienced geotechnical practitioner during design and construction. Detailed assessment of stability of both the fill and the quarry faces will be required prior to construction so that monitoring and mitigation measures can be implemented and verified.

Potential mitigation measures to manage the potential landslide hazards identified in Section 6.2 are summarized below.

Masonry Wall – Slope 4

The masonry wall located along Woodley Street and Campbell Lane supports fill. The walls show signs of deterioration and it is unlikely to have been designed to support fill. Due the poor conditions of the masonry wall we recommend that it be either demolished or stabilised. The wall could be potential be stabilised by placing a series of bracing elements such as a post and panel wall. Until the wall is demolished or repaired it is suggested that the footpath be temporality closed and pedestrian be redirected.

Stockpile 21 (Landfill) – Slope 1, 2 and 6)

Stockpile 21 fill is highly variable, comprising various soil types (clay, silt, gravel, sand, cobbles and boulders), building refuse and other waste material. We recommend that the fill could be temporally cut at a batter of 1V:1.5H, subject to geotechnical assessment during excavation. If groundwater seepage is encountered within the stockpile it may be necessary to flatten the batter.

The condition of the old quarry face behind Stockpile 21 is unknown and the assessment of this quarry face is beyond the scope of this assessment.

Exposed Quarry Faces (Slope 3 and 5)

Fretting of exposed quarry faces could be controlled by measures such as shotcrete and pattern rock bolts or draped mesh. Small and large block failures could be supported by spot bolting and using stressed ground anchors. Potential failures could also be removed by controlled scaled of the quarry face using a long reach excavator. Mesh could be draped and bolted onto the quarry face to restrict movement of smaller block failures away from the quarry face.

Fill at the top of Slope 3 is currently falling from overlying fill material. This fill needs to be flattened or treating the slope using a combination shotcrete and soil nails to mitigate ongoing instability.

Hydrostatic pressures along various joints, faults and fractures can triggered block failures at the quarry. Controlling both surface water and groundwater will reduce the potential risk of failure. Surface water should be directed away from the slopes. Horizontal drains could be installed to reduce the risk of groundwater pressures inducing failures.

Lateral Spreads

Two lateral spreads (or large block failures) have been recorded on the both the northern and southern side of the quarry in 1963 and prior to 1985 respectively. The cause of these failures was attributed to be due to a combination of the hydrostatic pressures and stress relief due to excavation of the quarry. However these mechanisms are relatively unknown and subject to further investigation.

Such large scale failures represent a risk to both existing structures surrounding the site and proposed structure at the SPI site. Depending on the size of potential failure masses it may not be practicable to support them with anchoring. Groundwater control and fill buttresses are likely to more effective than anchoring.

The approximate location of the previous large scale failures are shown in Figure A2 in Appendix A. However, depending on the geological structures encountered, new works could initiate similar failures in other locations. These risks will need to be considered by the designers of the SPI.

9.0 Limitations

AECOM (Australia) Pty Ltd does not represent that the information or interpretation contained in this report addresses all of the existing features, as-built construction, subsurface conditions or ground behaviour on the subject site. This is because the ground is a product of continuing natural and man-made processes and therefore exhibits characteristics and properties which vary from place to place and can change with time. Geotechnical engineering involves the gathering and assimilating of the limited facts about these characteristics and properties in order to better understand or predict the behaviour of the ground on a particular site for certain conditions.

The data reported in this document may have been obtained by observation, excavation, probing, sampling, testing or other means of investigation. They are directly relevant only to the ground at the place where and time when the investigation was carried out and are believed to be reported accurately. Any interpretation or recommendation given in this report is based on judgement and experience and not on greater knowledge of the facts than the reported investigation may imply.

10.0 References

RTA Guide to Slope Risk Analysis, Version 4 – Reference 1 (Ref 1)

Practice Note Guideline for Landslide Risk Management 2007, Journal and New of the Australian Geomechanics Society, Volume 42 No1 March 2007 – Reference 2 (Ref 2)

St Peters Brick-Shale Quarry, Canal Road, Geology and Alternative Rehabilitation Proposal, Branagan, D.F. and Norman, A.R. May 1985 (Ref 3)

Department of Main Roads (DMR), Materials Division, F5 Southern Western Freeway. Fairford Road, Padstow to Euston Road, St Peters. Second Supplementary Stability Assessment of Quarry Face – Austral Brick CO. Warren Gash, D.J. February 1987. Reference 4 (Ref 4)

Department of Main Road (DMR), Materials Service Section, F5 Southern Western Freeway. Construction between Princes Highway at Tempe and Campbell Road at St Peters. Stability at St Peters Brick Pit. Warren Gash, D.J. April 1989. Reference 5 (Ref 5)

Dames and Moore, Stability of St Peters Brick Pit Adjacent to the proposed F5 South-Western Freeway Campbell Road to Canal Road, St Peters. Barry McMahon, April 1989. Reference 6 (Ref 6)

The St Peters Brickpits: Their Geology, Operation and Reclamation, and the adjacent Quaternary shoreline. McNally, G.H. and Branagan, D.F., 1998, Environmental Geology of the Botany Basin. Reference 7 (Ref 7)

Assessment of Landslip – Stormwater Pipeline St Peters, Douglas Partners, January 2000. Reference 8 (Ref 8)

Slope Failure, Waste Transfer Station, Albert St, St Peters, Review of Documents – Draft Report, Geotechnique to City of Sydney Council, January 2001. Reference 9 (Ref 9).

Gravity Storm Drain, Waste Transfer Station, St Peters – Geotechnical Investigation Report, Geotechnique to City of Sydney Council, 28 February 2001. Reference 10 (Ref 10).

Geotechnical Opinion 238-310 Princes Highway St Peters, NSW, J&K Pty Ltd to Rocca Building Pty Ltd, November 2005. Reference 11 (Ref 11):

Geotechnical Opinion 238-310 Princes Highway St Peters, NSW, J&K Pty Ltd to Rocca Building Pty Ltd, 13 March 2014. Reference 12 (Ref 12):

Factual Geotechnical Investigation report, WestConnex Stage 2, AECOM to the WestConnex Delivery Authority, 27 March 2015. Reference 13 (Ref13):

AECOM Memorandum Alexandria Landfill: Volumetric Survey Data and EPL Compliance - 2002 to 2015, 8 March 2015, AECOM. Reference 14 (Ref 14):

Letter to Westconnex Delivery Authority, Proposed Slope Stabilisation Works - Concept Design St Peter Interchange (SPI), 2 July 2015, AECOM Reference 15 (Ref 15)

Drawings for *"Proposed Sydney Park Business Centre", T.C Plunnett and Associates Pty Ltd for Walker Development Pty Ltd. 1987 Reference 16 (Ref 16)*

Letter to Westconnex Delivery Authority, Structural Assessment - 300 Princes Highway adjacent to St Peters Interchange, 16 June 2015, AECOM Reference 17 (Ref 17)

Letter to Westconnex Delivery Authority, Slope Stability Assessment and Final Design - Westconnex - St Peters Interchange (SPI), 25 June 2015, AECOM Reference 18 (Ref 18)

Finlay, P.J, Mostyn,G.R and Fell, R Landslides: Prediction of Travel Distance and Guideline for Vulnerability of Persons, Australian Geomechanics, June 1999 Reference 19 (Ref 19)

Hunter, G. and Fell, R., Estimation of Travel Distance for Landslides in Soil Slopes, Australian Geomechnics, May 2002 Reference 20 (Ref 20)

Appendix A

Summary of information from desk top study

Appendix A Site Location Plan, Photos and Sketches

Figure – A1 – Site Location Plan

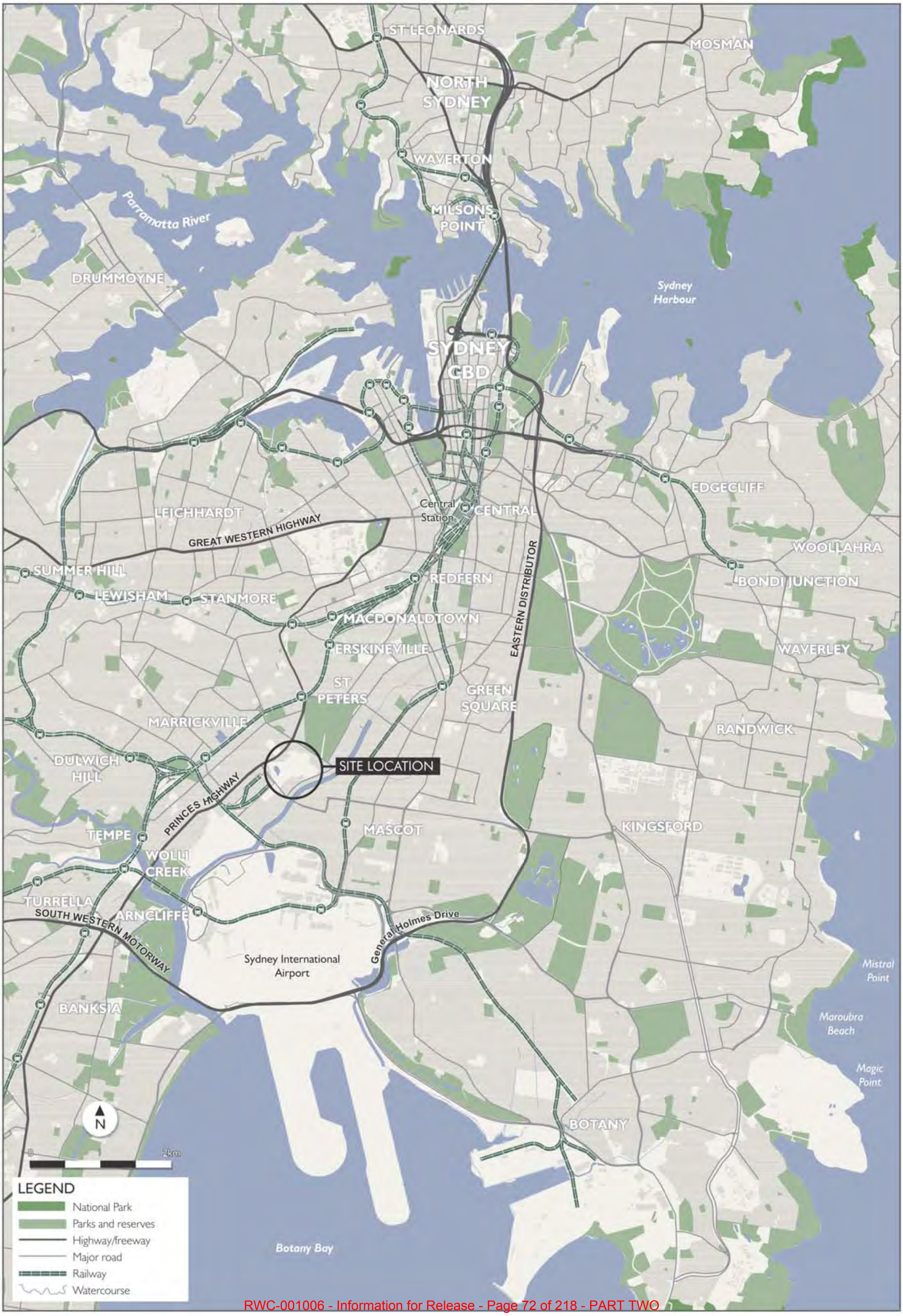
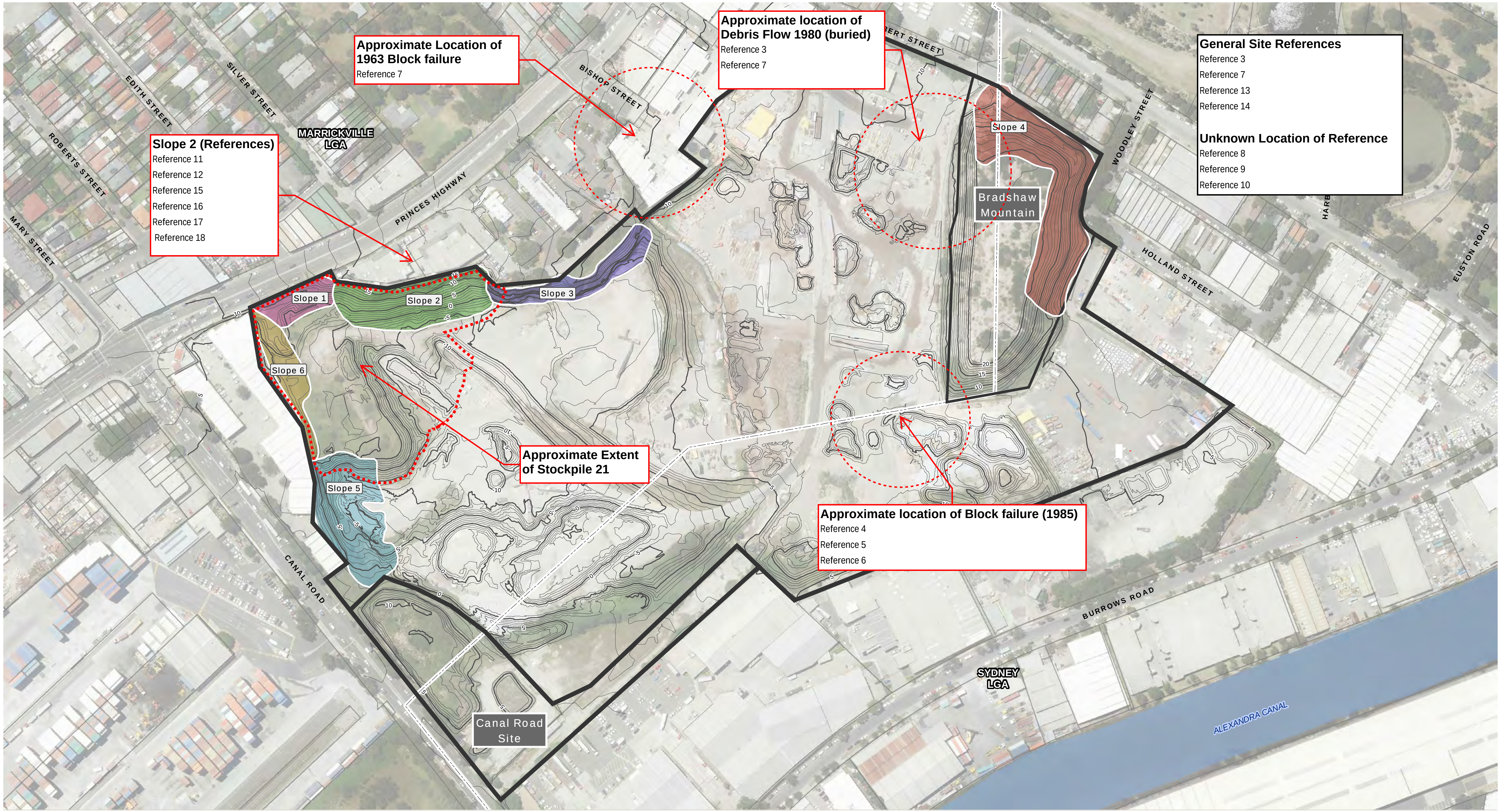

ST LEONARDS
MOSMAN
NORTH SYDNEY
WAVERTON
MILSONS POINT
Parramatta River
DRUMMOYNE
Sydney Harbour
SYDNEY CBD
EDGECLIFF
LEICHHARDT
GREAT WESTERN HIGHWAY
Central Station
CENTRAL
WOOLLAHRA
SUMMER HILL
LEWISHAM
STANMORE
REDFERN
BONDI JUNCTION
MACDONALDTOWN
EASTERN DISTRIBUTOR
ERSKINEVILLE
WAVERLEY
ST PETERS
GREEN SQUARE
MARRICKVILLE
RANDWICK
DULWICH HILL
SITE LOCATION
PRINCES HIGHWAY
MASCOT
KINGSFORD
TEMPE
WOLLI CREEK
TURRELLA
ARNCLIFFE
SOUTH WESTERN MOTORWAY
General Holmes Drive
Sydney International Airport
Mistral Point
BANKSIA
Maroubra Beach
Magic Point
N
BOTANY
0
2km
LEGEND
National Park
Parks and reserves
Highway/freeway
Major road
Railway
Watercourse
Botany Bay

Figure –A2 - Overall Site Plan



AECOM GIS Printed Date: 28/05/2015 \\ausyd1fp001\Projects\603X\60327128\4. Tech work area\4.99 GIS\02_Maps\AECOM\G156_01_60327128_A3L_WCX_DADI_SLOPES_Analyses_20150528.mxd

KEY

Alexandria Landfill Site Boundary

0 50 100 m

Disclaimer

Map produced by AECOM on behalf of WestConnex Development Authority.

Map data copyright 2014 WestConnex Delivery Authority, NSW. Spatial data used under licence from Land and Property Management Authority, NSW © 2014.

AECOM/WDA makes no representations or warranties of any kind, about the accuracy, reliability, completeness, suitability or fitness for purpose in relation to the map content.

CONFIDENTIAL GIS MAP

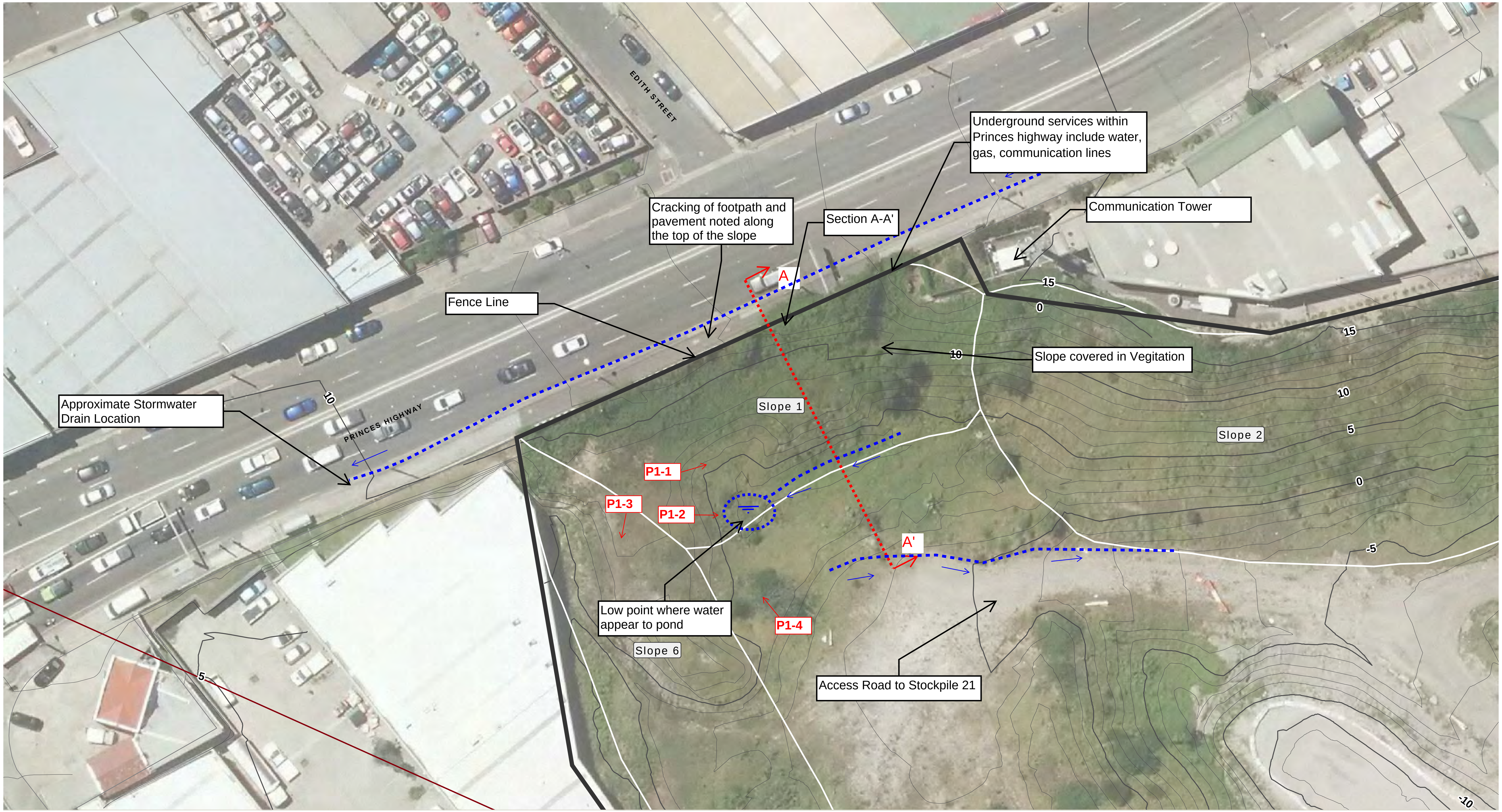
SCALE 1:2,750	A3
SHEET 1 of 1	COORDINATE SYSTEM GDA 1994 MGA Zone 56
TITLE WestConnex Motorway	
Figure : Preliminary Slopes Assessment	
PROJECT WESTCONNEX STAGE 2 TA	
CLIENT WESTCONNEX DELIVERY AUTHORITY	
DRAWN DN	PROJECT # 60327128
CHECK	DATE 28/05/2015
MAP # REV Project	G156 01 60327128

WestConnex
Building for the future

AECOM

Slope Photos and Sketches

Slope 1 - Overall Plan



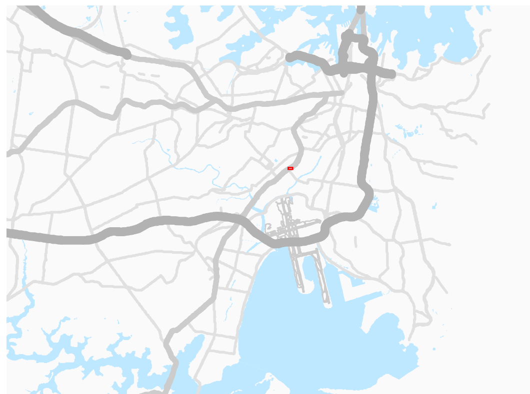
KEY

- Alexandria Landfill Site Boundary
- Dyke
- PX-X Photo Location, number and direction
- Surface groundwater

0 10 20 m

Disclaimer

Map produced by AECOM on behalf of WestConnex Development Authority.



CONFIDENTIAL GIS MAP

SCALE 1:500 A3

SHEET 1 of 1 COORDINATE SYSTEM GDA 1994 MGA Zone 56

TITLE WestConnex Motorway

Figure 1: Preliminary Slope 1 Assessment

PROJECT

WESTCONNEX STAGE 2 TA

CLIENT

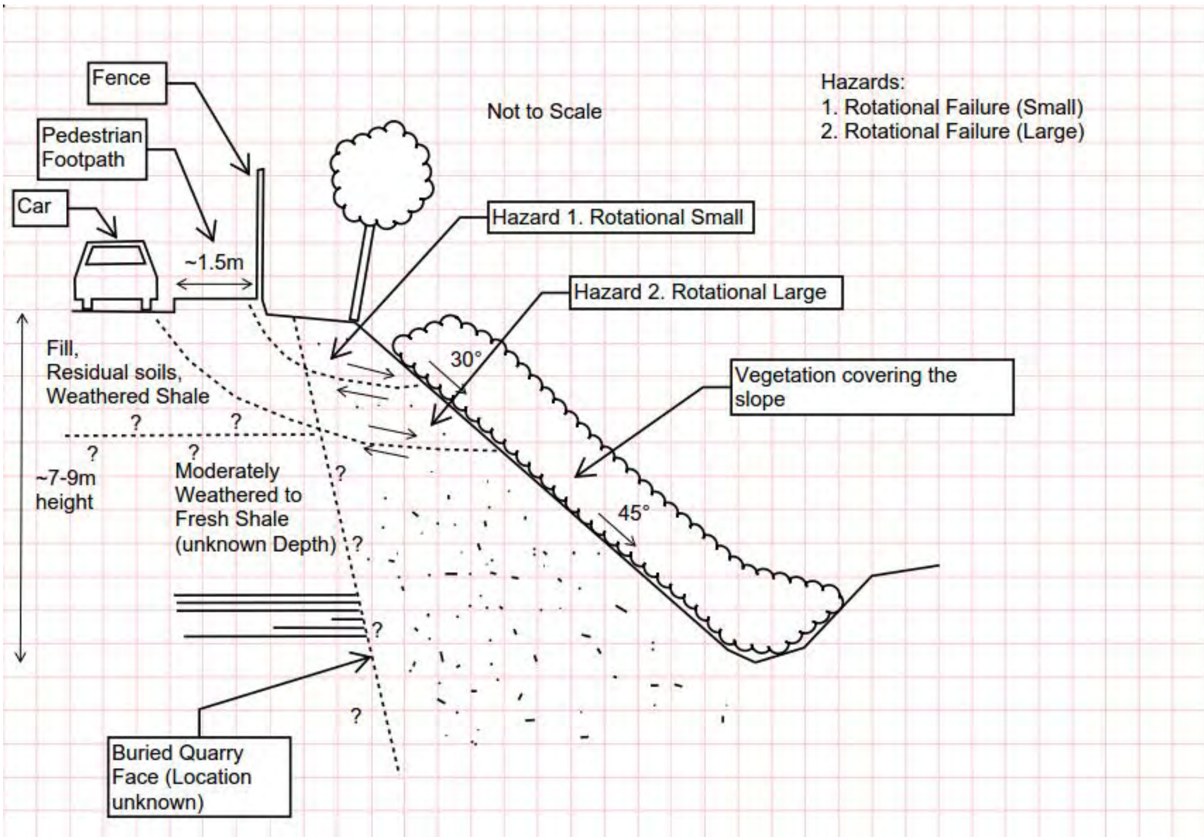
WESTCONNEX DELIVERY AUTHORITY

DRAWN	SG	PROJECT # 60327128	MAP #	REV	Project
CHECK		DATE 22/10/2015	G199 01 60327128		

WestConnex
Building for the future

AECOM

Slope 1 – Section A-A'



Slope 1

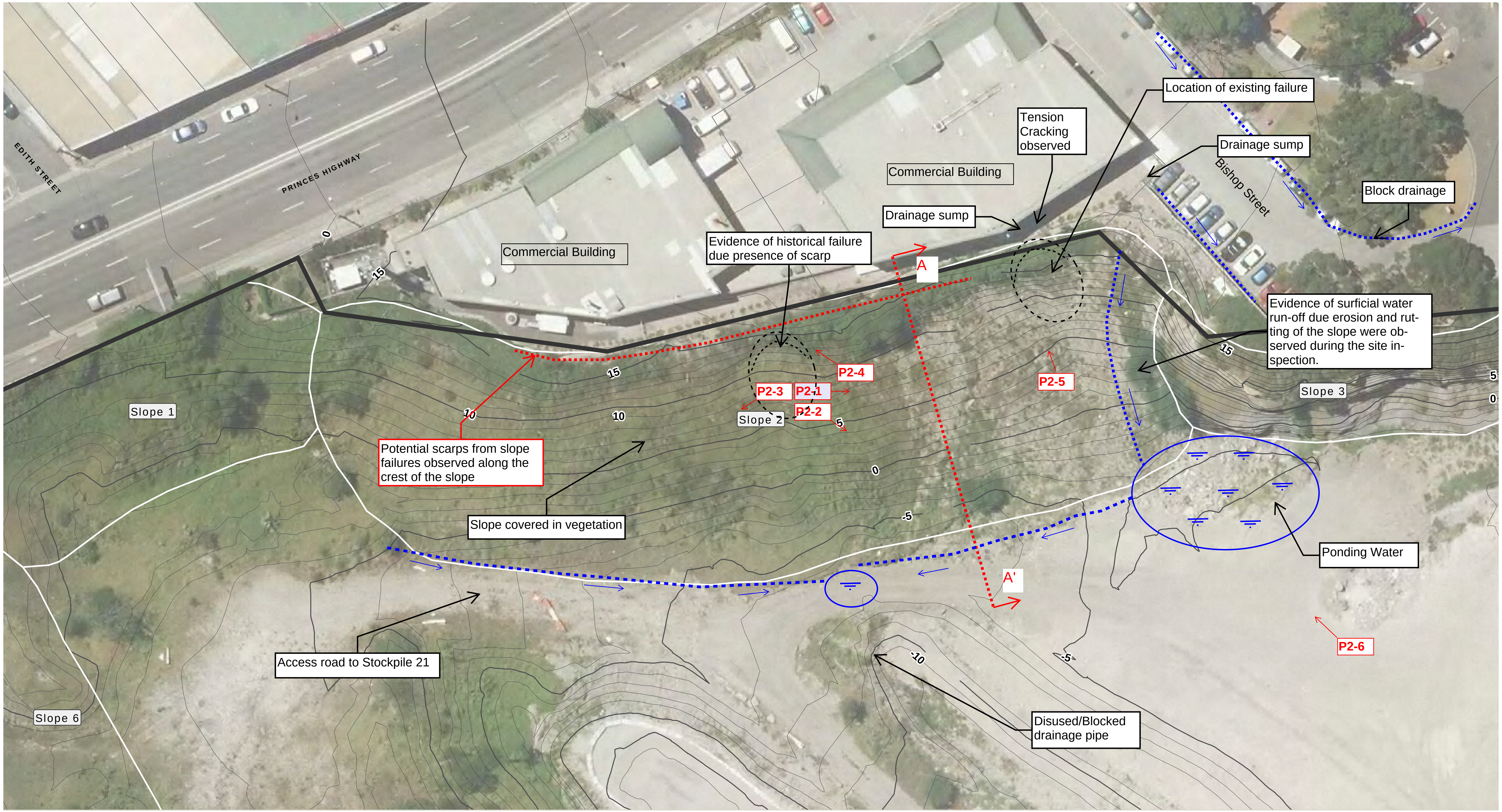
Plate 1-1 - View looking north east along the slope face (slope obscured by vegetation)

Plate 1-2 - Low point of the slope, evidence of ponding water

Plate 1-3 - View looking south west adjacent to the existing warehouse

Plate 1-4 - View looking north at slope face

Slope 2 - Overall Plan



KEY

- Alexandria Landfill Site Boundary
- Dyke
- PX-X Photo Location, number and direction
- Surface groundwater

0 10 20 m

N

Disclaimer

Map produced by AECOM on behalf of WestConnex Development Authority.

Map data copyright 2014 WestConnex Delivery Authority, NSW. Spatial data used under licence from Land and Property Management Authority, NSW © 2014.

AECOM/WDA makes no representations or warranties of any kind, about the accuracy, reliability, completeness, suitability or fitness for purpose in relation to the map content.

CONFIDENTIAL GIS MAP

SCALE 1:500 A3

SHEET 1 of 1 COORDINATE SYSTEM GDA 1994 MGA Zone 56

TITLE WestConnex Motorway

Figure 2: Preliminary Slope 2 Assessment

PROJECT WESTCONNEX STAGE 2 TA

CLIENT WESTCONNEX DELIVERY AUTHORITY

DRAWN SG PROJECT # 60327128 MAP # REV Project

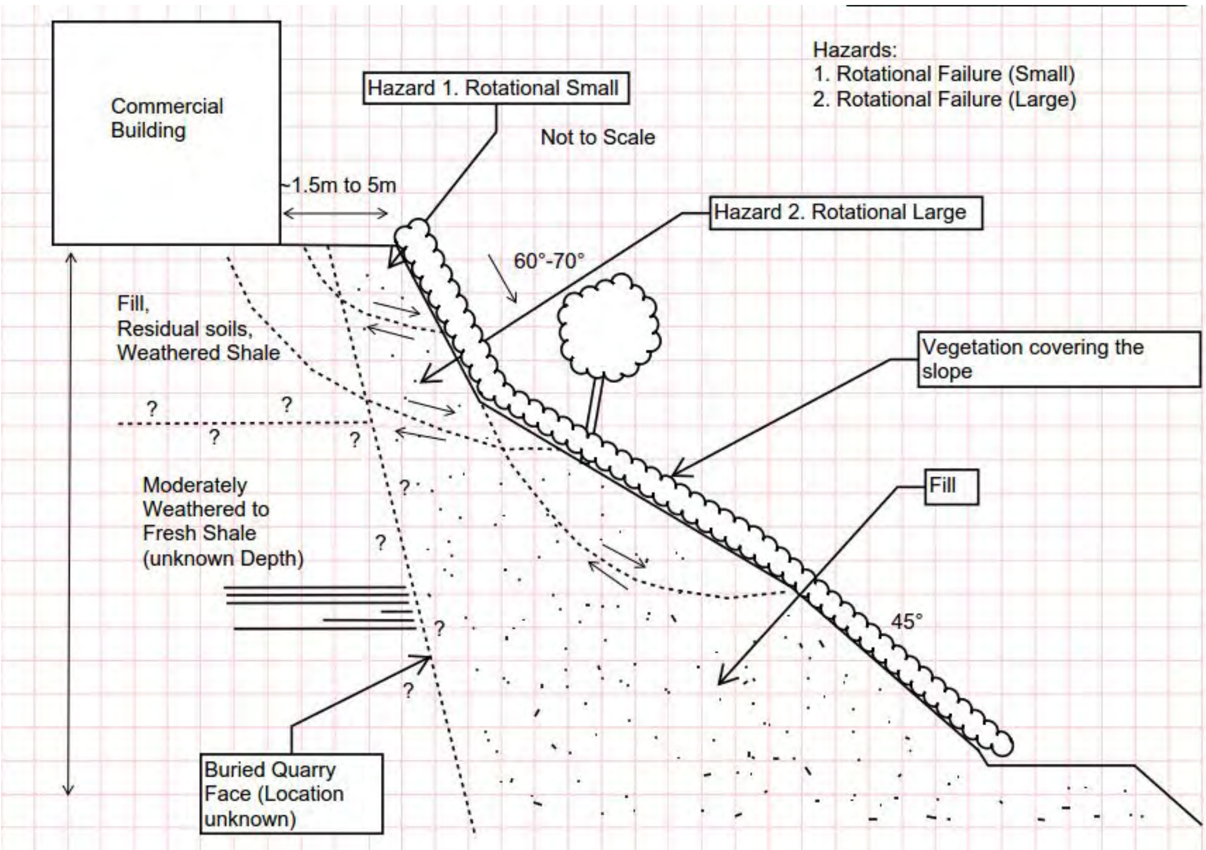
CHECK DATE 22/10/2015 G199 01 60327128

WestConnex
Building for the future

AECOM

AECOM GIS Printed Date: 22/10/2015 P:\603X\60327128\4. Tech work area\4.99 GIS\02_Maps\AECOM\G199_01_60327128_A3L_DDP_WCX_DAD_SLOPES_Analyses_20151022.mxd

Slope 2 – Section A-A'



Slope 2

Plate 2-1 - View looking east along the slope face (slope obscured by vegetation)

Plate 2-2 - View looking south east along the slope face to the access road at base of the slope

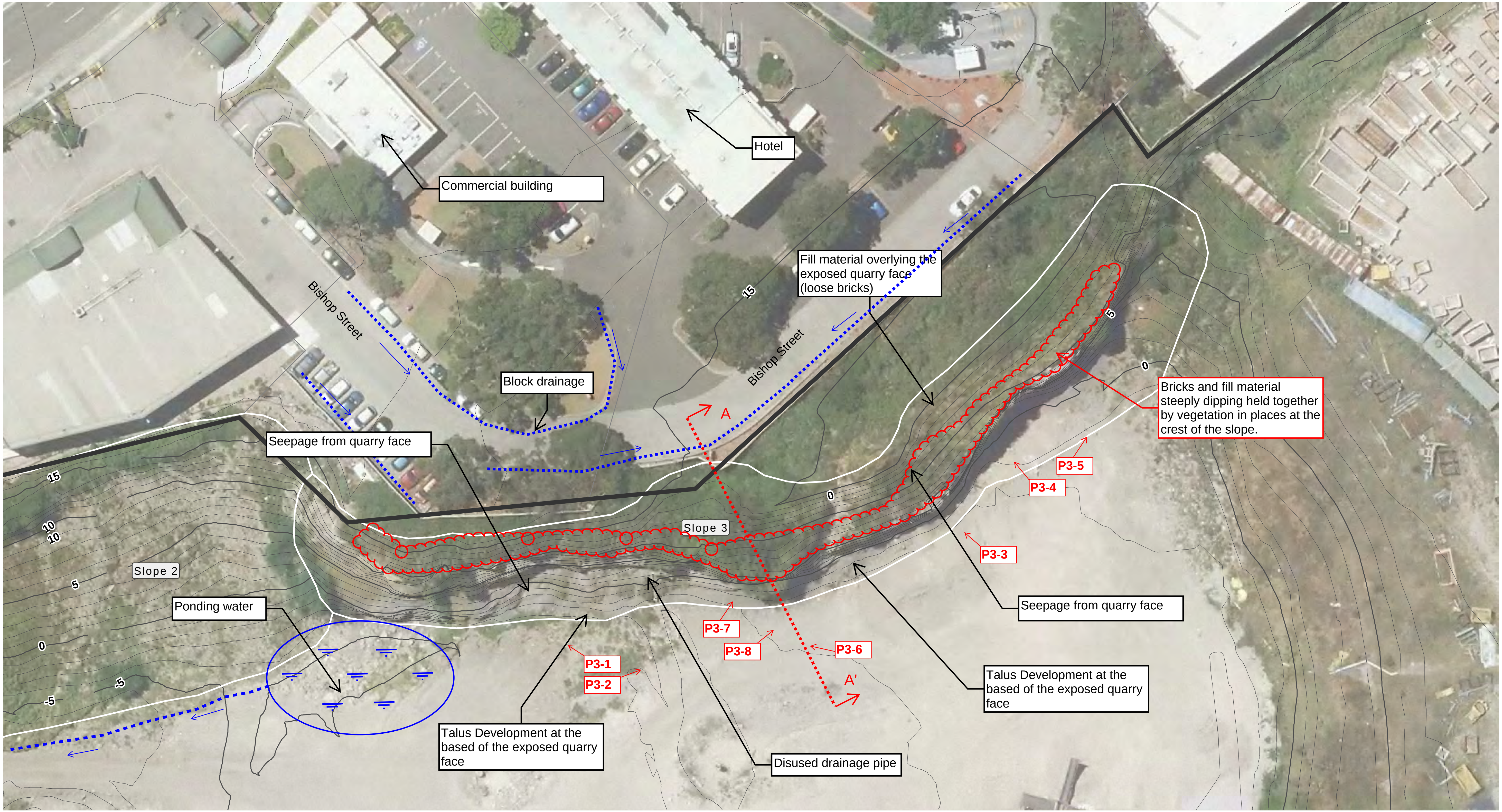
Plate 2-3 - View looking West along the slope face

Plate 2-4 - View looking North West along the slope face at potential historical failure

Plate 2-5 – View looking North at slope failure above the existing warehouse/commercial building

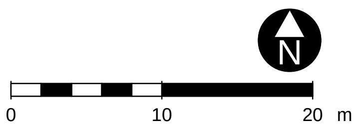
Plate 2-6 – View looking North at slope failure

Slope 3 - Overall Plan



KEY

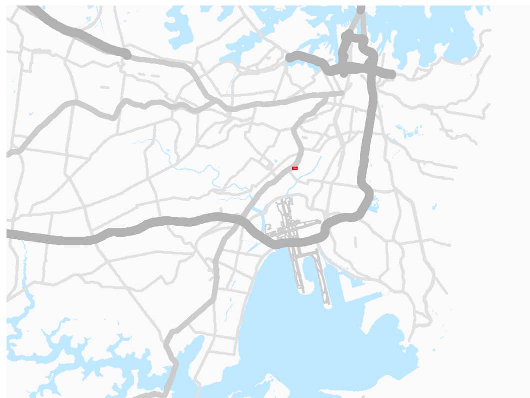
- Alexandria Landfill Site Boundary
- Dyke
- PX-X Photo Location, number and direction
- Surface groundwater



Disclaimer

Map produced by AECOM on behalf of WestConnex Development Authority.

AECOM/WDA makes no representations or warranties of any kind, about the accuracy, reliability, completeness, suitability or fitness for purpose in relation to the map content.

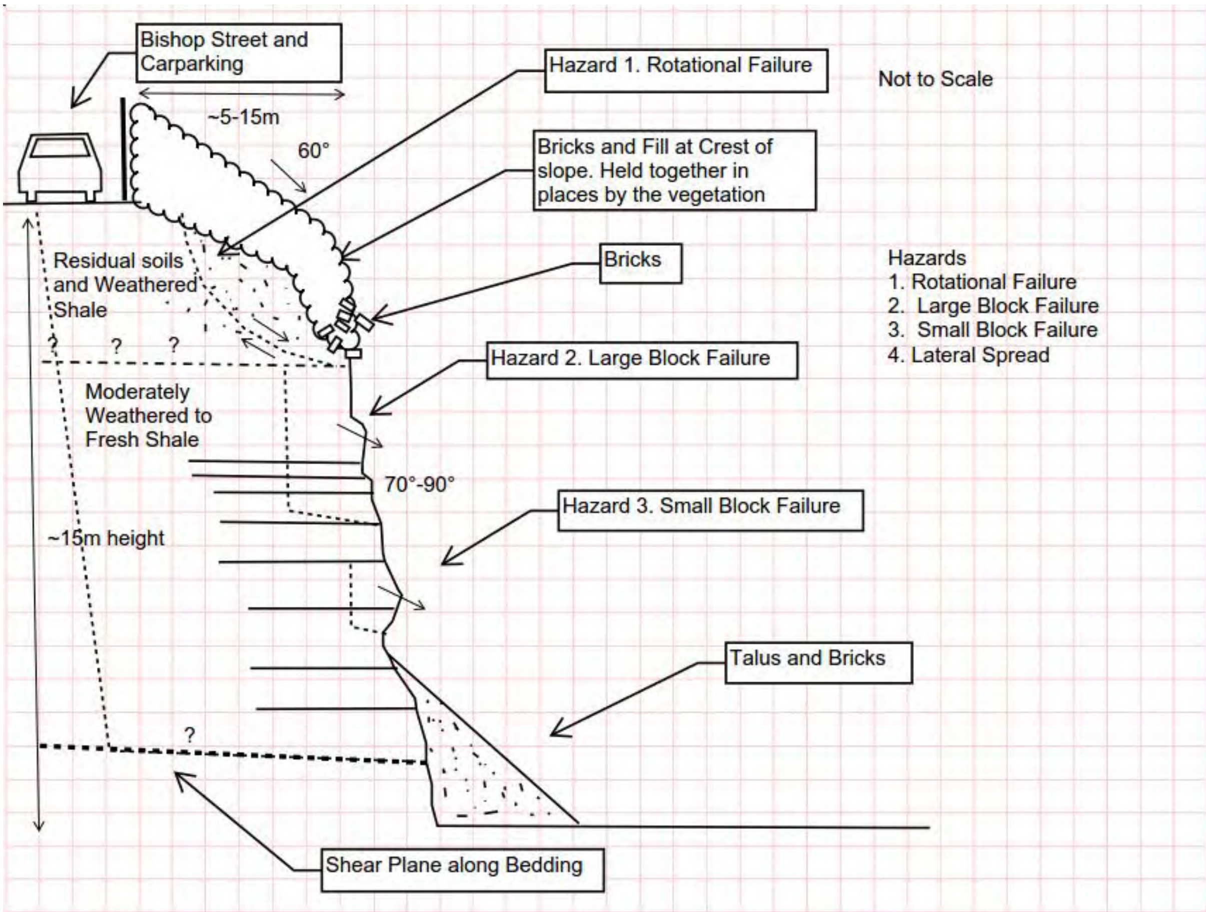


CONFIDENTIAL GIS MAP

SCALE 1:500	A3
SHEET 1 of 1	COORDINATE SYSTEM GDA 1994 MGA Zone 56
TITLE WestConnex Motorway	
Figure 3: Preliminary Slope 3 Assessment	
PROJECT WESTCONNEX STAGE 2 TA	
CLIENT WESTCONNEX DELIVERY AUTHORITY	
DRAWN SG	PROJECT # 60327128
CHECK	DATE 22/10/2015
	G199 01 60327128

WestConnex
Building for the future

Slope 3 – Section A-A'



Slope 3

Plate 3-1 - View looking west along the overall exposed quarry face

Plate 3-2 - View looking east along the overall exposed quarry face

Plate 3-3 - View looking north at exposed quarry face with fill overlying the weathered shale and seepage from bedding

Plate 3-4 – Talus build-up and fill (bricks) at the base of the slope

Plate 3-5 - View looking east along the overall slope

Plate 3-6 - View looking west along the overall slope

Plate 3-7 – Overhanging section of exposed cut face where previous small block has fallen out

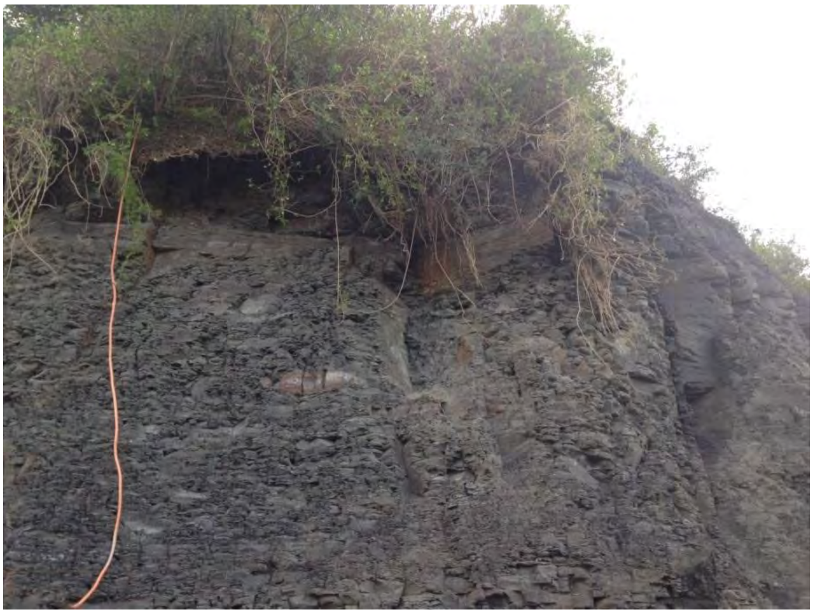
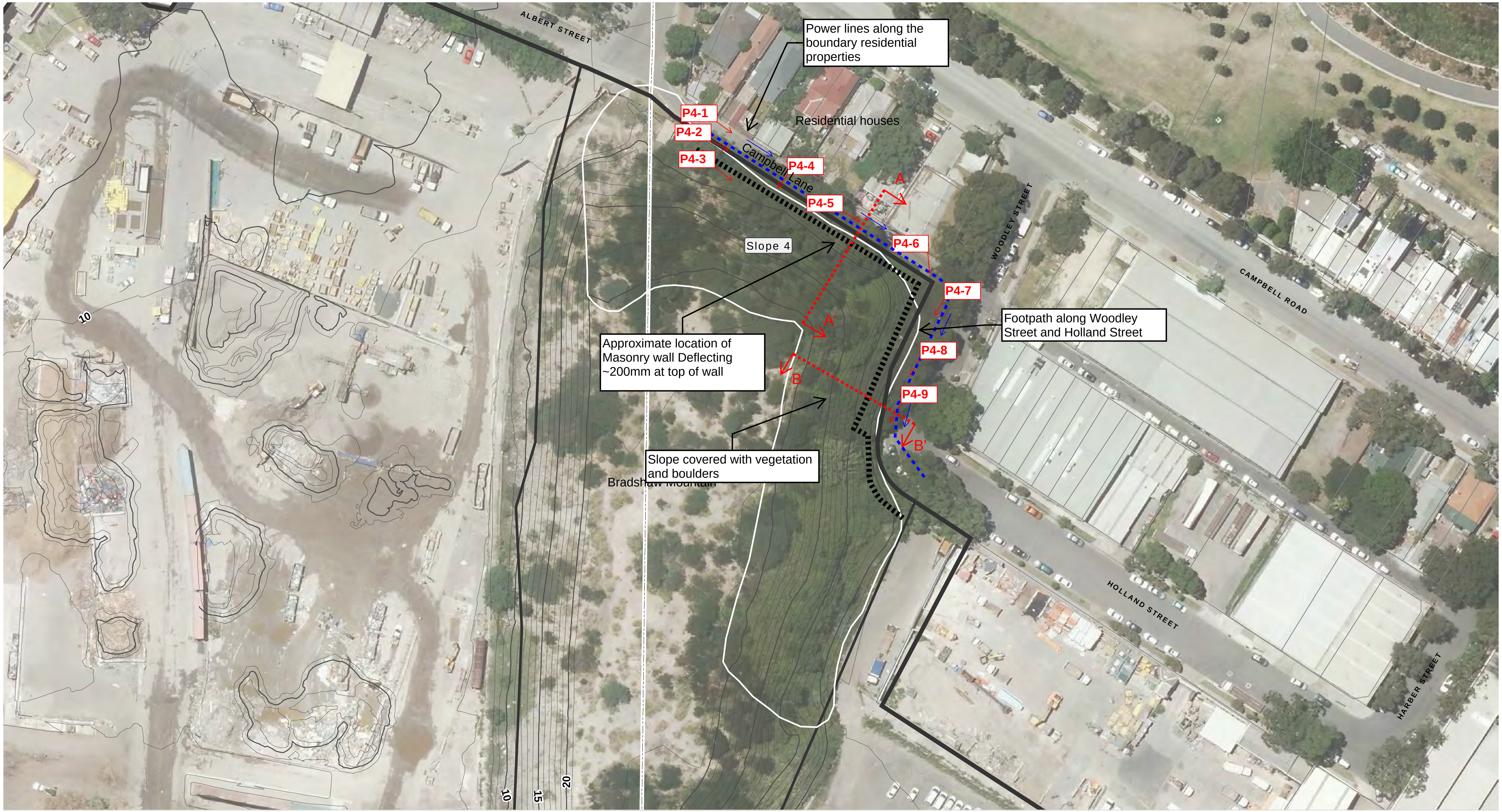


Plate 3-8 – Talus build-up (spalling, small blocks and bricks)

Slope 4 - Overall Plan



KEY

- Alexandria Landfill Site Boundary
- Dyke
- PX-X Photo Location, number and direction
- Surface groundwater

0 10 20 m

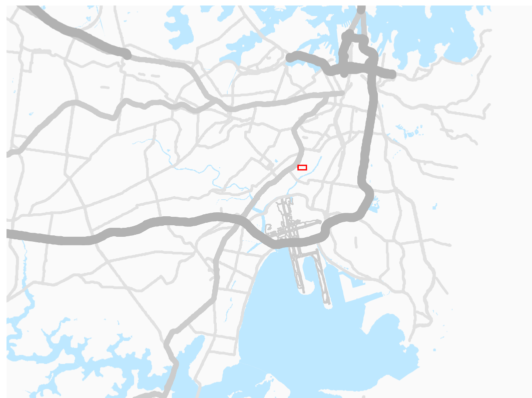
Disclaimer

Map produced by AECOM on behalf of WestConnex Development Authority.

AECOM/WDA makes no representations or warranties of any kind, about the accuracy, reliability, completeness, suitability or fitness for purpose in relation to the map content.

WestConnex
Building for the future

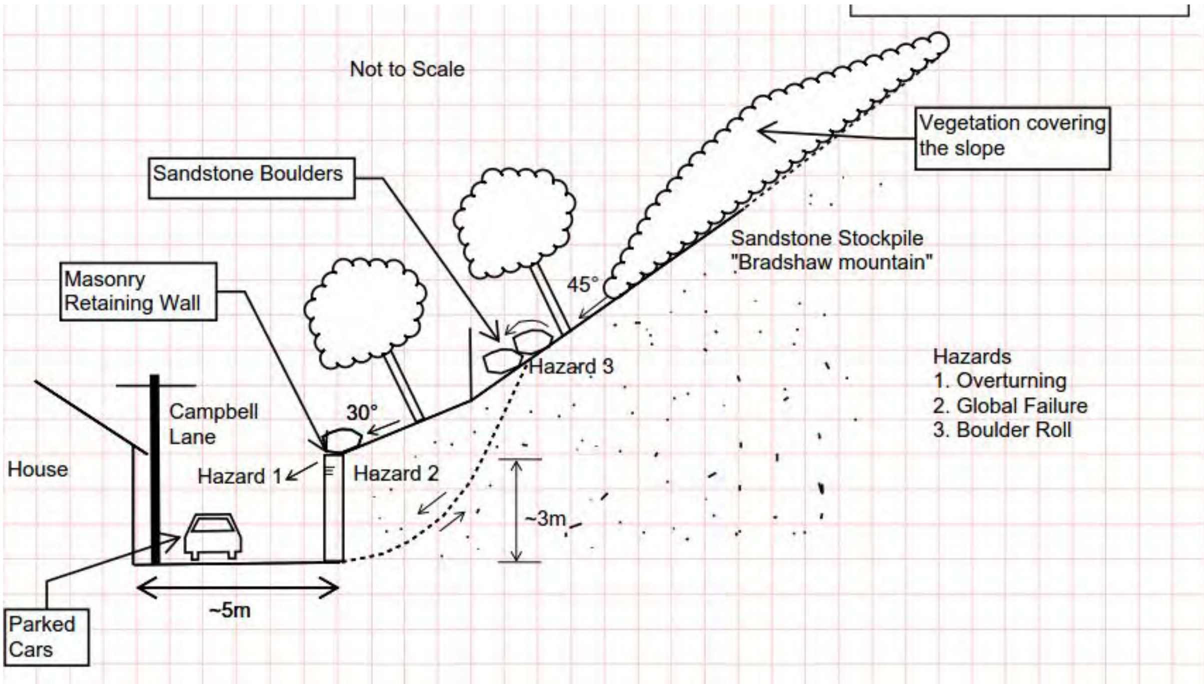
AECOM



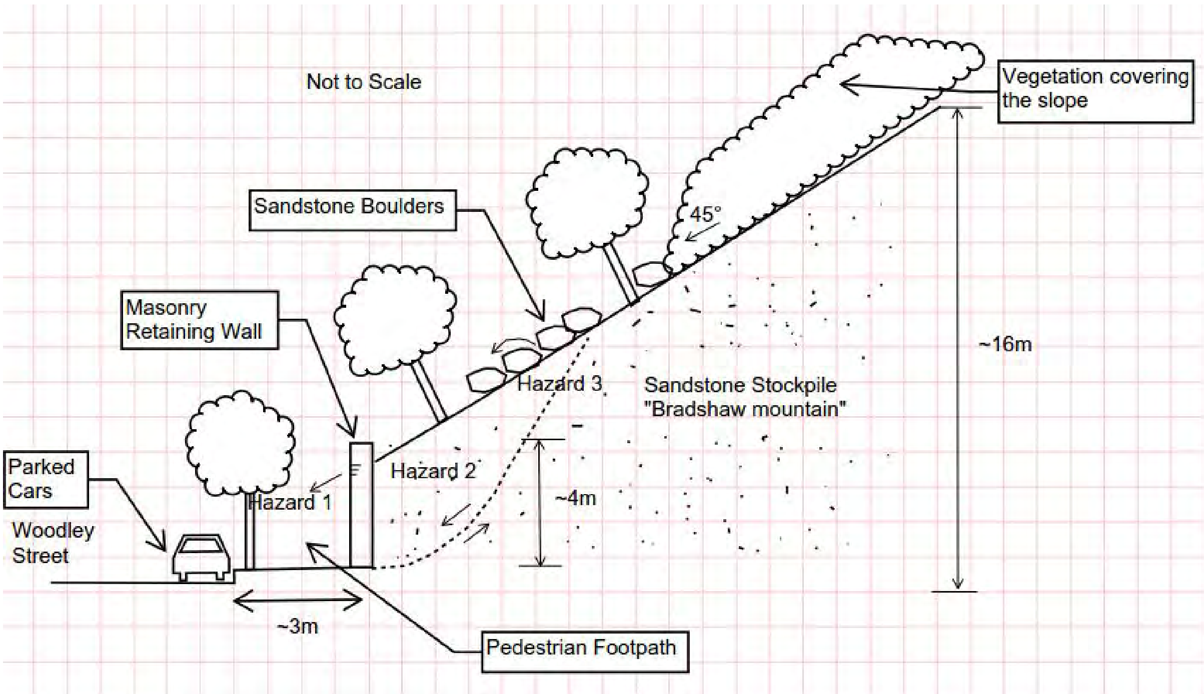
CONFIDENTIAL GIS MAP

SCALE 1:1,000 A3
SHEET 1 of 1
COORDINATE SYSTEM GDA 1994 MGA Zone 56
TITLE WestConnex Motorway
Figure 4: Preliminary Slope 4 Assessment
PROJECT
WESTCONNEX STAGE 2 TA
CLIENT
WESTCONNEX DELIVERY AUTHORITY
DRAWN SG PROJECT # 60327128 MAP # REV Project
CHECK DATE 22/10/2015 G199 01 60327128

Slope 4 – Section A-A'



Slope 4 – Section B-B'



Slope 4

Plate 4-1 - View looking east at gravity wall and boulders

Plate 4-2 - View looking east at leaning gravity wall down Campbell Lane

Plate 4-3 - View looking east at vegetation growth on top of the gravity wall down Campbell Lane

Plate 4-4 - View looking boulders just above the gravity wall on Campbell Lane

Plate 4-5 - View looking boulders just above the gravity wall on Campbell Lane

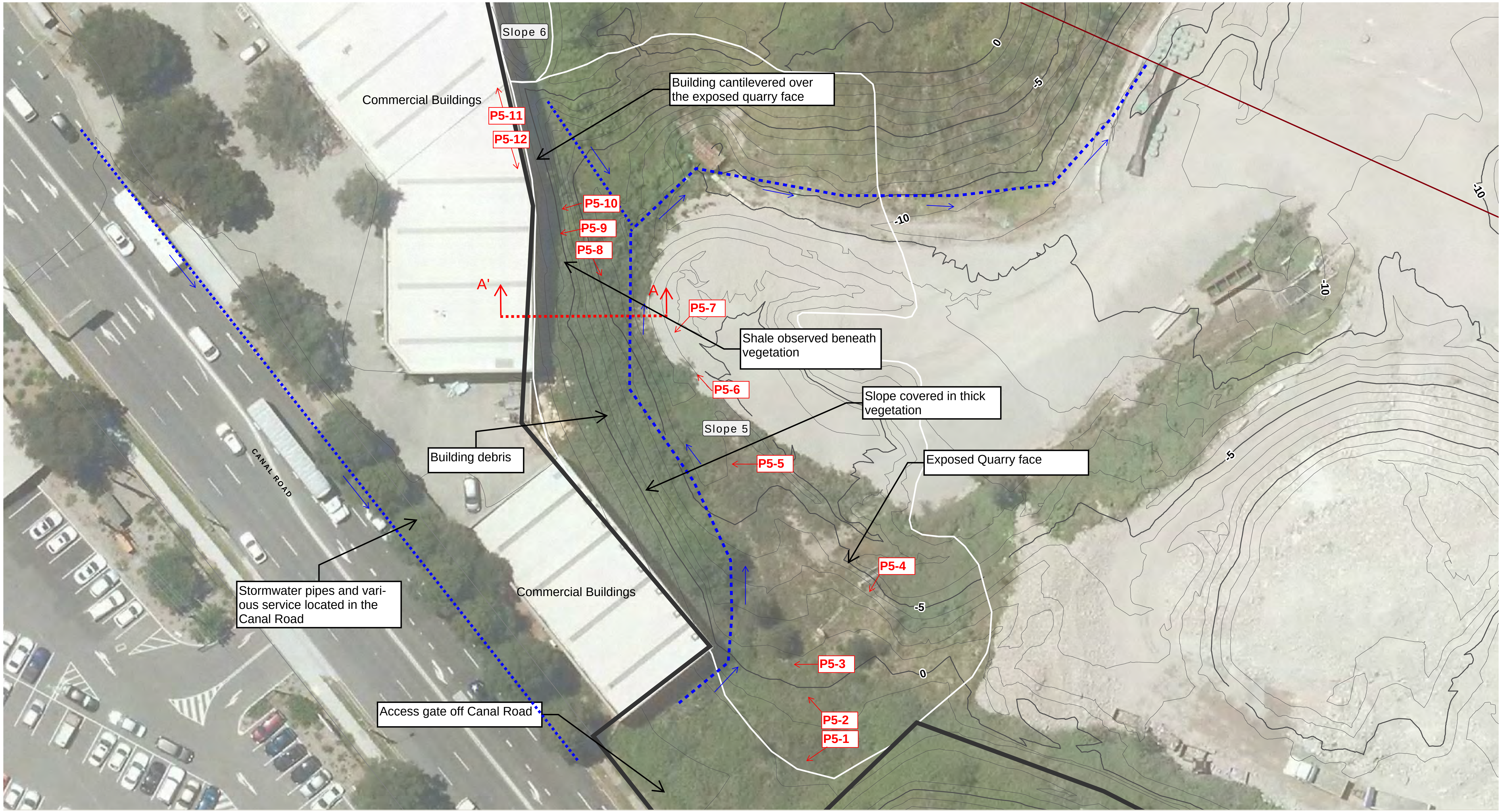
Plate 4-6 - View looking East down Campbell Lane towards Woodley Street

Plate 4-7 - View looking South down Woodley Street at gravity wall

Plate 4-8 - View looking South down Woodley Street at gravity wall

Plate 4-9 - View looking South at Corner Woodley Street and Holland Road l

Slope 5 - Overall Plan



AECOM GIS Printed:Date: 22/10/2015 P:\603X\60327128\4. Tech work area\4.99 GIS\02_Maps\AECOM\G199_01_60327128_A3L_DDP_WCX_DADI_SLOPES_Analyses_20151022.mxd

KEY

- Alexandria Landfill Site Boundary
- Dyke
- PX-X Photo Location, number and direction
- Surface groundwater

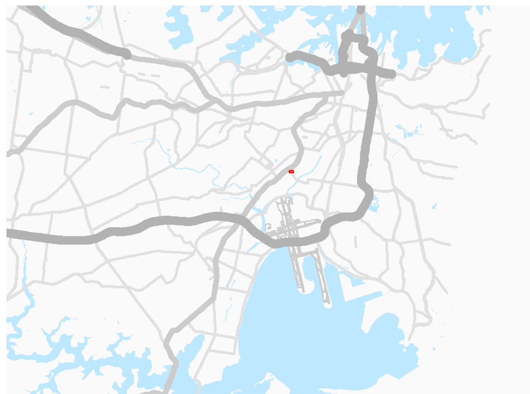
0 10 20 m

N

Disclaimer

Map produced by AECOM on behalf of WestConnex Development Authority.

AECOM/WDA makes no representations or warranties of any kind, about the accuracy, reliability, completeness, suitability or fitness for purpose in relation to the map content.



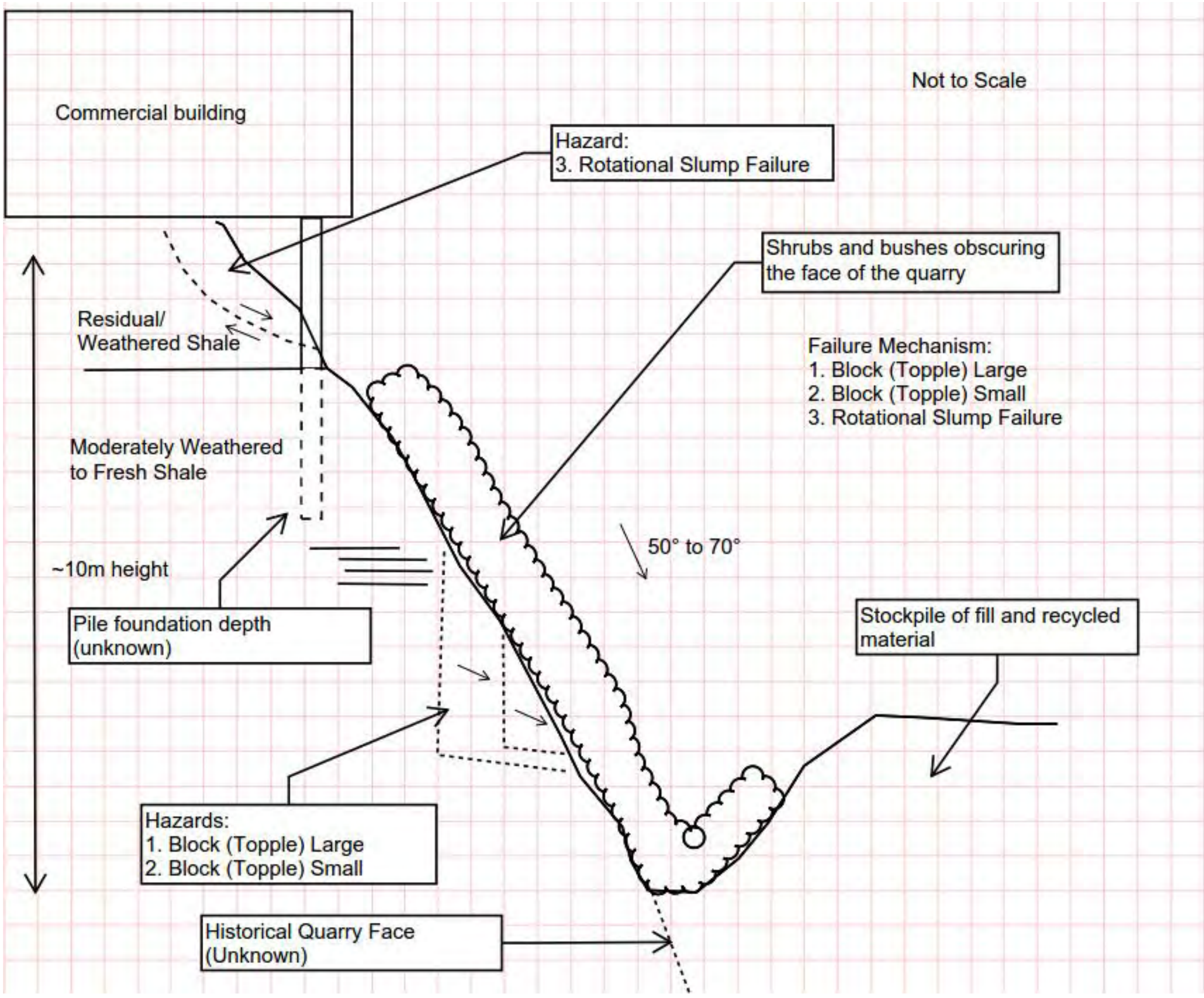
CONFIDENTIAL GIS MAP

SCALE 1:500	A3
SHEET 1 of 1	COORDINATE SYSTEM GDA 1994 MGA Zone 56
TITLE WestConnex Motorway	
Figure 5: Preliminary Slope 5 Assessment	
PROJECT WESTCONNEX STAGE 2 TA	
CLIENT WESTCONNEX DELIVERY AUTHORITY	
DRAWN SG	PROJECT # 60327128
CHECK	DATE 22/10/2015
MAP #	REV
Project	G199 01 60327128

WestConnex
Building for the future

AECOM

Slope 5 – Section A-A'



Slope 5

Plate 5-1 - View looking West at access gate to Canal Road

Plate 5-2 - View looking North along access track from Canal Road to base of the landfill

Plate 5-3 - View looking North at commercial building from access track at the crest of the slope

Plate 5-4 – Services into the landfill from Canal Road (likely for Leachate Riser), Exposed quarry face

Plate 5-5 – View looking West at overall slope, slope obscured by dense vegetation, illegal dumping into the site also noted on the slope.

Plate 5-6 – View looking North at overall slope, slope obscured by dense vegetation

Plate 5-7 – View looking North at overall slope, slope obscured by dense vegetation

Plate 5-8 – View looking south at overall slope, slope obscured by dense vegetation

Plate 5-9 – Exposed Siltstone quarry face observed in dense vegetation

Plate 5-10 – View looking west at the underside of the commercial building from base of the landfill on Canal Road

Plate 5-11 – View looking North at the underside of the commercial building above the landfill on Canal Road

Plate 5-12 – View looking South at the underside of the commercial building above the landfill on Canal Road

Slope 6 - Overall Plan

AECOM GIS Printed:Date: 22/10/2015 P:\603X\60327128\4. Tech work area\4.99 GIS\02_Maps\AECOM\G199_01_60327128_A3L_DDP_WCX_DADI_SLOPES_Analyses_20151022.mxd

KEY

- Alexandria Landfill Site Boundary
- Dyke
- PX-X Photo Location, number and direction
- Surface groundwater

0 10 20 m

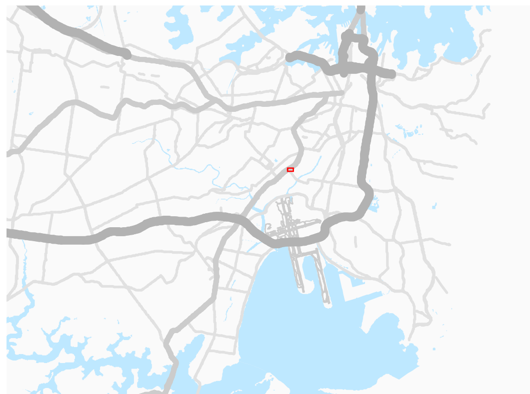
N

Disclaimer

Map produced by AECOM on behalf of WestConnex Development Authority.

Map data copyright 2014 WestConnex Delivery Authority, NSW. Spatial data used under licence from Land and Property Management Authority, NSW © 2014.

AECOM/WDA makes no representations or warranties of any kind, about the accuracy, reliability, completeness, suitability or fitness for purpose in relation to the map content.



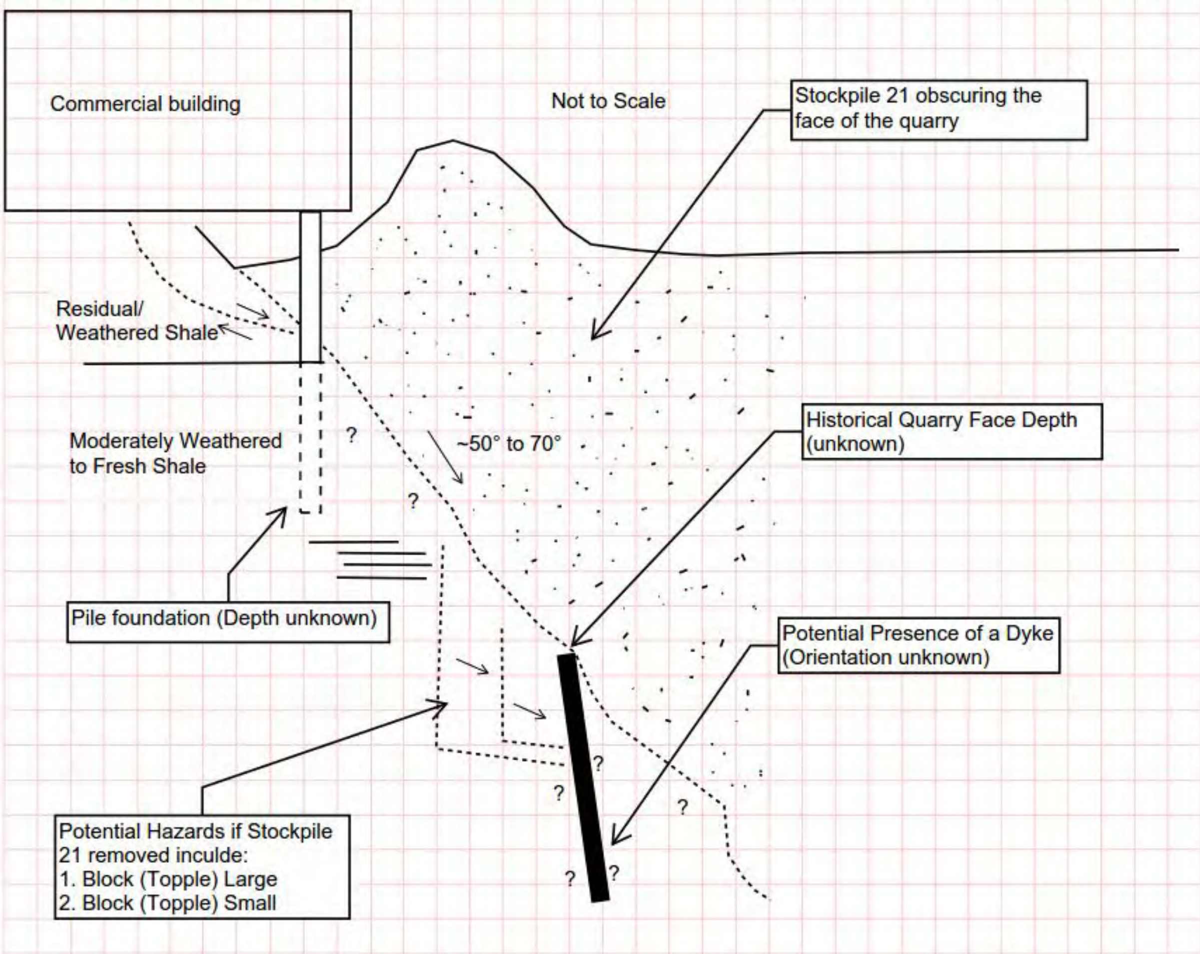
CONFIDENTIAL GIS MAP

SCALE 1:750	A3
SHEET 1 of 1	COORDINATE SYSTEM GDA 1994 MGA Zone 56
TITLE WestConnex Motorway	
Figure 6: Preliminary Slope 6 Assessment	
PROJECT WESTCONNEX STAGE 2 TA	
CLIENT WESTCONNEX DELIVERY AUTHORITY	
DRAWN SG	PROJECT # 60327128
CHECK	DATE 22/10/2015
MAP # REV Project	G199 01 60327128

WestConnex
Building for the future

AECOM

Slope 6 – Section A-A'



Slope 6

Plate 6-1 - View looking South along the top of Stockpile 21

Plate 6-2 - View looking North along the top of Stockpile 21

Plate 6-3 - View looking North along the top of Stockpile 21 and commercial building

Appendix B

Summary of information from desk top study