Transport Roads & Maritime Services

QA SPECIFICATION PS331

GEOTECHNICAL INVESTIGATION AND DESIGN

IC-QA-PS331

VERSION FOR: ***Macquarie Park Bus Priority and Capacity Improvement Project - Stage 2***
DATE: ***December 2018 (Addendum 2)***

CONTENTS

CLAUSE **PAGE**

FOREWORD

ROADS AND MARITIME SERVICES COPYRIGHT AND USE OF THIS DOCUMENT

When this document forms part of a contract

This document should be read with all the documents forming the Contract.

PROJECT SPECIFIC CHANGES

Any project specific changes have been indicated in the following manner:

(a) Text which is additional to the base document and which is included in the Specification is shown in bold italics e.g. ***Additional Text***.

(b) Text which has been deleted from the base document and which is not included in the Specification is shown struck out e.g. ~~Deleted Text~~.

RMS SPECIFICATION PS331

GEOTECHNICAL INVESTIGATION AND DESIGN

1 INTRODUCTION

1.1 PROFESSIONAL SERVICES SPECIFICATION

This specification is one of a set of Professional Services Specifications for detailed design. Refer to PS301 for Professional Service Scope and Requirements.

1.2 SCOPE & PROJECT DESCRIPTION

This Specification sets out the requirements for an aspect of detailed design. It requires C72 Panel Deed for Professional Services or equivalent Professional Services Conditions of Contract.

1.2.1 Project Specific Requirements

Refer to Annexure PS331/A for Project Specific Requirements for Geotechnical Investigation and Design.

1.3 PROJECT INTRODUCTION

Refer to PS301 - Professional Service Scope and Requirements for Project Introduction details.

1.4 STRUCTURE OF THE SPECIFICATION

1.4.1 Schedules of HOLD POINTS, WITNESS POINTS, DELIVERABLES AND WORKSHOPS.

The schedules in Annexure PS331/C list the **HOLD POINTS, WITNESS POINTS, DELIVERABLES AND WORKSHOPS** that must be produced / observed. Refer to specification PS301 - Professional Service Scope and Requirements for definitions of **HOLD POINTS**.

1.4.2 Additional Design Reference Documents and Support Information.

The schedules in Annexure PS331/M list the **REFERENCE DOCUMENTS** & **SUPPORTING INFORMATION** that apply to this Specification.

Unless otherwise specified the applicable issue of a referenced document, other than a Roads and Maritime Specification, is the issue current at the date one week before the closing date for tenders, or where no issue is current at that date, the most recent issue.

2 GEOTECHNICAL SERVICES

2.1 INTRODUCTION

This specification provides the technical requirements for detailed stage geotechnical investigation and design for a new or existing site.

2.2 OBJECTIVE

The objectives of geotechnical investigations and designs for detailed stage are:

(i) To provide sufficient detailed geotechnical information for the preparation of representative geological and geotechnical models for the development of the detailed design and construction and tender documentation.

(ii) To undertake a detailed geotechnical study that includes the following activities:

a. Review of previous geotechnical investigations, identify the scope of further investigations and undertake the investigations upon concurrence with RMS.

b. Physical investigations, materials testing and data collation as outlined in Annexure PS331/E. Minimum requirements for geotechnical investigations shall comply with Section 3.8 "Minimum Scope of Investigation for Detailed Design".

c. Analysis, interpretation and commentary on all aspects of the investigations, taking into account the findings from both previous and current investigations.

d. Development of representative geological and geotechnical models for the entire project.

e. To consider detailed design options for all geotechnical structures, including but not limited to cuttings, embankments, bridge, culverts, retaining walls, , pavements, earthwork, other structure foundations and ground treatment if it is required (For Geotechnical Investigation and Design for Tunnels refer to PS333).

f. Selection of preferred options for the geotechnical structures of (e) above and provide details to enable an accurate assessment of geotechnical risks which will impact on the planning, options selection, design, construction and costing of the project.

g. Where required, preparation of environmental assessments (refer to the RMS's Environmental Assessment Procedures for Routine and Minor Works EIA-P051 and consult Environment Branch) and accompanying environmental management plan (EMP) for any field investigations which have not been assessed under the main project REF prepared for the project during the concept design phase.

(iii) The investigations must also provide enough information for a designer to:

a. Produce a pavement options report with the selection of preferred pavements - refer to PS 341 - Pavement Investigation and Design.

b. Produce Structures Detailed Option Reports, Design Proposal Form 62 and Design Report – refer to PS361 - Bridge and Structure Design.

c. Produce detailed designs for drainage and water quality structures - refer to PS371 - Hydrology and Drainage Design.

d. Provide details of utility and property impacts - refer to PS321 - Detailed Survey and Utility Adjustment and PS351 - Road Design.

(iv) Where required in Annexure PS331/A6, produce geotechnical reports and drawings including but not limited to:

a. Geotechnical Investigation Proposal Plan .

b. Geotechnical Factual Report.

c. Geotechnical Interpretive Report.

d. Geotechnical Design Statement Report.

e. Geotechnical Design Option Report.

f. Geotechnical Design Report.

g. Geotechnical Detailed Design Drawings

h. Earthworks and Batter Management Report

~~i. Acid sulfate Soils Management Plan~~

~~j. Contaminated Soils Remedial Action Plan~~

Details of the above reports are given Sections 5 and 7.1. The requirements of submission of these individual reports is to follow the project specific schedule in PS331/A7, and in accordance with the hold points outlined in Annexure PS331/C1 unless prior agreement is obtained with RMS. For specific projects, some of these reports could be combined as specified in Annexure PS331/C1.

2.3 CONSIDERATIONS

2.3.1 Purpose of Geotechnical Investigations and Designs

The geotechnical investigations must be undertaken with consideration to its purpose with respect to the proposed geotechnical infrastructure, including but not limited to cuttings, embankments, bridge, culverts, retaining walls, pavements, earthwork, other structure foundations and ground treatment if it is required. The PSC must undertake the investigation noting the specific design requirements in section 3.

2.3.2 Topography, Geology and Climate

Geotechnical descriptions relating to topography, geology, soils and climate should be consistent with AS 1726 – Geotechnical Site Investigations.

2.3.3 Outline of Ground Conditions

The outline of ground conditions must consist of a summary of the geotechnical model and must include:

a. Unit descriptions and properties (including rock mass properties)

b. Unit depths and levels

c. Unit thicknesses

2.3.4 Groundwater

Where groundwater may pose impacts on the project, investigations are required to supplement existing groundwater information and to assist with design. Groundwater quality and groundwater level monitoring must be included in the investigations.

The dewatering potential for any deep cuttings or culvert/tunnel structures (if applicable) is to be considered. Monitoring bores must be provided to monitor water quality and level to provide information for the detailed design and construction phase of the project.

2.4 APPLICABLE STANDARDS

The applicable standards/reference document are as follows but not limited to:

(In the event of the design standard/reference document quoted being not the most appropriate document, the PSC must acquire and use most appropriate/latest version for the design with the approval of the RMS Representative).

(i) Australian Standard AS 1726: Geotechnical Site Investigation

(ii) Australian Standard AS 5100: Bridge Design

(iii) Australian Standard AS 2159: Piling –Design and Installation Australian Standard AS 5100:2-2004: Vehicle design loading

(iv) Australian Standard AS 1597.2-1996: Box culverts

(v) Managing Urban Stormwater Soils and Construction Volume 2D, Main road construction, Department of Environment and Climate Change, NSW, 2008

(vi) RMS Geotechnical Technical Direction GTD2012/001- Excavation Adjacent to RMS Infrastructure

(vii) RMS Geotechnical Technical Direction GTD2015/001- Use of New Geotechnical Products or Technique on Roads Maritime Projects.

3 GEOTECHNICAL INVESTIGATION GENERAL REQUIREMENTS

3.1 GEOTECHNICAL INVESTIGATIONS REF AND EMP

Any Geotechnical investigations Review of Environmental Factors (REF) required for geotechnical investigations will be undertaken by RMS and is exclude from the PSC scope of work.

~~A Review of Environmental Factors (REF) report will be required for any geotechnical investigations to be carried out ahead of determination of the main project REF, or that have not been assessed as part of the main project REF - Refer to PS311 - Environmental Assessment~~

~~The REF is to be accompanied by an Environmental Management Plan (EMP) which will address the relevant environmental issues, the impacts of, and ameliorative measures required, for the investigation works.~~

~~Refer to RMS Environmental Assessment Procedures for Routine and Minor Works EIA-P051 and consult RMS Environment Branch.~~

~~The REF and or EMP will be primarily required to address the following site works:~~

~~(i) Investigations to be undertaken within the SEPP14 wetlands.~~

~~(ii) Investigations to be undertaken within creek and foreshores areas if any.~~

~~(iii) Investigations that require clearing for the construction of access tracks where threatened flora species may be encountered.~~

~~The REF and EMP should determine the requirements for:~~

~~(i) Site rehabilitation.~~

~~(ii) Grouting of boreholes and backfilling of test holes etc.~~

~~(iii) Installation and removal of access tracks.~~

~~(iv) Disposal of waste water, drilling mud etc.~~

~~The REF and EMP will be subject to RMS approval and the work is to include all necessary changes and revisions. Unless agreed prior, the Pro-forma for the Environmental Management Plan will be provided at the project inception meeting.~~

~~HOLD POINT~~	
~~Process held:~~	~~Field geotechnical investigation work~~
~~Submission details:~~	~~Draft and final REF and EMP~~
~~Release of hold point~~	~~RMS's representative will release the hold point following approval of the PSC's REF and EMP (specifically for geotechnical investigations)~~

~~Refer to Annexure PS331/A for the report and plan review requirements.~~

3.2 LEGAL ACCESS AND APPROVALS

Any site access approvals required for additional geotechnical investigations will be undertaken by RMS and is exclude from the PSC scope of work.

~~Site access must be fully addressed in the REF/EMP. All access tracks and investigation sites are to include the environmental controls identified in the REF/EMP.~~

~~Construction of access tracks is likely to require imported material.~~

~~Where clearing is required for the construction of access tracks and investigation sites, the construction and investigation crews are to be accompanied by a qualified Ecologist (approved by the RMS's Representative) to ensure minimal disturbance to rare and threatened flora species, environmental controls for sedimentation etc.~~

~~The conduct of negotiations with land holders is a matter of great importance to the RMS as it influences to a large extent the programming of works and also the public acceptance of RMS proposals. The PSC's field personnel must contact the owners and/or occupiers prior to entry to inform them of the nature and extent of the activities and confirm in writing an agreement to access. If entry is refused, the matter should be immediately referred to the RMS.~~

3.3 SERVICE AUTHORITIES

The PSC must liaise with relevant authorities where investigation activities may impact on any services. The PSC must ensure that all work on site is undertaken without interference to services or utilities in the area. The PSC must make all enquires necessary and obtain all necessary clearances prior to undertaking any work that may interfere with utilities or services. All costs associated with the required supervision by services authorities are to be included in the rates. Refer to PS321 - Detailed Survey and Utility Adjustments.

3.4 PROTECTION OF PROPERTY

The geotechnical team must carry out the investigations in an environmentally sensitive manner and must avoid causing damage to property. Any claims for damages associated with the work will be the responsibility of the PSC. A record of any damage caused and compensation made should be prepared and signed off by the owners and/or occupiers prior to being forwarded to the RMS in a property damages/compensation report. Refer to PS301 - Professional Service Scope and Requirements.

3.5 ROAD OCCUPANCY

Where the PSC's work will, or is likely to, obstruct or have the effect of restricting, closing, interfering with or obstructing the free flow of traffic on any lane or shoulder of the existing road or intersection, the PSC must lodge with the RMS, 14 days prior to the work:

A request for a road occupancy licence providing all relevant details of the proposed work.

A traffic control plan prepared in accordance with the requirements of RMS's Traffic Control at Work Sites Manual (2010) and RMS Specification G10 Traffic Management.

3.6 SITE RE-INSTATEMENT

The PSC is to address all site re-instatement requirements and conditions contained in the REF/EMP.

All road test holes are to be repaired in a manner acceptable to relevant Roads and Maritime maintenance requirements (refer to RMS Asset for RMS requirements and local council for council requirements) prior to reopening to traffic. The road surface is to be re-instated as soon as possible thereafter.

Refer to PS351 - Road Design for the requirements related to road user delay management.

3.7 GEOTECHNICAL INVESTIGATION STANDARDS AND REQUIREMENTS

Refer to Annexure E for geotechnical investigation standards and technical requirements.

3.8 MINIMUM SCOPE OF INVESTIGATION FOR DETAILED DESIGN

If required, the PSC must identify in detail all proposed investigation methods which will be used to 'ground truth' and define the geotechnical conditions for all road formation structures. The following planning information is required for review by RMS:

(i) Site map that shows the proposed locations of the investigation sites

(ii) Breakup of project alignment into sections detailing the proposed construction, field investigations (e.g. drilling, test pits, CPT, seismic, laboratory testing etc.)

(iii) Geotechnical field instrumentation required for design purposes such as piezometers, settlement gauges, inclinometers etc.

Boreholes and test pits should not be located at regular intervals or on a grid unless it is appropriate to do so. Location of boreholes must be carefully located to identify, delimit and characterise geological units which will impact on the design and construction process. It is recognised that geotechnical conditions will differ for each project. The PSC will accordingly tailor the investigations for the particular project site conditions.

Notwithstanding the information that follows, the PSC must ensure that the amount and type of investigations undertaken can achieve the requirement of the Geotechnical Design General Requirements in Section 4 and Project Specific Geotechnical Requirements in Annexure PS331/A. This may involve obtaining further information as the need arises. To this end the PSC is to provide, with the tender proposal, a schedule of rates covering all anticipated investigations and testing activities likely to be undertaken.

It is noted that property access, environmental and public utility issues may result in a number of the investigation sites requiring relocation from planned locations.

The following Table PS331.1 – "Minimum Geotechnical Investigation Requirements for Detailed Stage Road Design" maybe used as a guide for scoping geotechnical site investigations.

Field and Laboratory Testing Requirements

Additional specialised testing (in situ or laboratory based) on retrieved materials may be proposed by the PSC to characterise their engineering behaviour for design purposes of each geotechnical structure at specific locations.

Table PS331.2 – "Field and Laboratory Testing Requirements from Geotechnical Sampling" maybe used as a guide for scoping field and laboratory testing.

Table PS331.1 - Minimum Geotechnical Investigation Requirements for Detailed Stage Road Design

Road Formation Structure	Boreholes (NB Average number of holes to be located to identify, define & characterise geological units)	Test Pits	Other Investigation Methods
Cuttings	One BH every 80 m along c/l and staggered across the edge of cutting, including deepest part of larger cuts; drilling depth to at least 6 m below proposed grade line NB; For steeply dipping strata inclined drilling must be included in the investigation Large diameter borehole sampling (selected cuttings)	One TP every 100m along c/l One TP over each proposed batter at 100m intervals	Seismic traverse along c/l longitudinally for larger cuts Seismic traverse perpendicular to c/l or bedding strike in deepest section of the cut; spacing of traverses 100 to 150m.
Fill Embankments	One BH every 100 m on c/l and staggered across the footprint of the embankment, targeting the deepest part of fill; drilling to stiff stratum or rock if TP does not provide adequate information	One TP every 100 m to 200m along c/l. One TP at toe or proposed fill batters at 200m intervals. One TP for each sedimentation basin	
On grade sections		One TP every 50 m along c/l	

Existing Pavement	For flexible pavements consider one 300 mm (min) diameter solid flight auger hole every 50 to 100 m located outside main wheel paths (shoulder preferred). Log existing pavement materials. DCP test the subgrade and collect sufficient subgrade sample for CBR and classification testing (suggest min. 20 kg).		For rigid pavements consider saw cut test pit every 50 to 100 m avoiding main wheel paths where possible (shoulder preferred). Log existing pavement materials. DCP test the subgrade and collect sufficient subgrade sample for CBR and classification testing (suggest min. 20 kg). Reinstatement of rigid pavement to consider dowelling and reinforcement required.
Embankments on soft ground sections	One BH at 50 to 100 m intervals on c/l and staggered across the footprint of the embankment, drilling depth to stiff stratum or bedrock Vane shear testing and piston sampling of soft soils every at 1.5 m intervals for boreholes located staggered around c/l NB U75 undisturbed sampling is required. Piston sampling method is preferred over tube sampler	One TP every 50 m along c/l	CPT Friction Cone Test at 50 m intervals covering the footprint of the embankment to the base level of the firm stratum; pore water dissipation tests every 1.5m down each hole – tested next to BH's Continuous sampling of soft soils at representative locations

~~**Bridge Foundations**~~	~~One BH must be drilled within 2 m from the centreline of each pier location .~~ ~~Where the width of the top of a pier or abutment is greater than 12 m measured along the pier or abutment centreline, a minimum of two BH's is to be drilled within 2 m of the centreline and 5 m along the long axis from each pier or abutment. The two BHs should not be on the same side of these lines and should be within the footprint of the bridge.~~ ~~Twin bridge must be treated as two separate bridges.~~ ~~BHs are to be drilled at least 6 m into medium strength bedrock or 5 times the pile diameter below the pile founding level, whichever is the deeper; 3 m below pad footing founding levels. If hard/dense stratum is encountered (i.e. with SPT > 30) the boreholes are to be terminated 9 m into such a stratum, or 5 times the pile diameter below the pile founding level or 3 times the width of the pad footing below the footing founding level, whichever is the shallower.~~ ~~Sufficient core must be recovered from the boreholes for assessment of design parameters.~~	~~NA~~	
~~**Bridge Abutments**~~	~~As per Bridge Foundations.~~ ~~In addition, one BH located 30 m back from each abutment on the centreline;~~	~~One TP per abutment~~	

~~**Arch Structures (concrete or large steel arch)**~~	~~If BHs are required instead of test pits due to deep soft/soil profile, the BH requirements are the same as "Embankment on Soft Ground Sections" above, with the BH interval not more than 30 m along the arch structure alignment and positioned evenly not more than 20m laterally at each abutment.~~	~~BH may be omitted if bedrock is within 1 m below the ground surface level. If this is the case then one TP at each end of the abutments, and intermediate ones at not more than 20m intervals along the width of the arch structure. Termination criteria 1 m into hard stratum or bucket refusal on bedrock.~~	
Culvert Structures	If BHs are required instead of test pit due to deep soft/soil profile then boreholes are to be located at not more than 30 m apart measured along the structure alignment and staggered within 2 m of the centre line. A minimum of two boreholes are needed. The BHs are to be drilled to 5 times the pile diameter below the pile founding level.	One TP at each end and intermediate locations at not more than 30 m intervals measured along the culvert alignment, into very stiff stratum or bedrock	
Gravity Retaining structures (including RSW structural counterfort walls)	Two BH' if wall length < 30 m BH's at both ends and intermediate locations not more than 30m intervals staggered at both sides of the wall alignment into stiff stratum or rock .	One TP every 25m as an alternative, if stiff strata or rock within 2m of surface. (NB. TP spacing may be varied depending on variability of ground conditions)	

Structural cantilever pile walls with or without anchors	One BH at 15m intervals along proposed length, staggered within min 3 m of the wall foot print and drilled into stiff stratum or bedrock to allow adequate definition of the ground condition for design of the retaining walls . BHs are to be drilled to at least 5 m into medium strength bedrock or hard/dense strata. If hard/dense stratum encountered (i.e. with SPT > 30) the hole is to be terminated at least 7 m into such strata For anchored pile walls; one BH every 15m in anchorage zone drilled to very stiff strata or bedrock.	NA	
~~**Pre-existing landslide sites**~~	~~One BH at the head, middle and toe of the landslide zone drilled to stiff/dense stratum or bedrock.~~ ~~Boreholes to cover lateral extent dependant on landslide geometry and complexity.~~ ~~Installation of inclinometers and piezometers are to be considered in these borcholes.~~	~~Four TP within landslide zone to characterise ground conditions~~	~~Seismic traverses along the axis of the landslide to determine subsurface profiles~~
~~**Pre-existing old fill tip sites (e.g. waste dumps)**~~	~~One BH every 30 to 50m interval drilled to the floor of the pit on the c/l and at the edge of the road formation to determine lateral extent, depth and characteristics.~~	~~TP at 30m intervals on c/l~~	~~Seismic traverses along c/l of tip site and every 30m traverse to c'l to determine subsurface profile.~~
~~**Areas affected by shallow mine workings**~~	~~One BH at 25m to 50m interval both at the c'l and at edge of proposed road formation drilled to 3 m below the level of workings, plus camera inspections. The location of these boreholes should be guided by the past mine working records/drawings.~~ ~~Consideration given to probe drilling (e.g.. Air track) on a regular grid pattern to define goaf areas and extent of old mine workings.~~	~~TP at 100 m intervals on c/l~~	~~Geophysical Electromagnetic Induced Polarisation survey on c/l.~~ ~~Ground Penetrating Radar for shallow workings less than 15m below ground; Traverse spacing at 50m depending on mine subsidence complexity.~~

Table PS331.2 Field and Laboratory Testing Requirements from Geotechnical Sampling

Test Type	Cuts	C/F Transition & Shallow Embankment	Fills	Soft Ground	Bridge and structure Foundations	Pavement
Field Moisture Contents.	√	√	√	√	√	√
Particle Size Distribution and hydrometer	√	√	√	√	√	√
Atterberg Limits testing	√	√	√	√	√	√
Field Vane Shear Test (insitu)				√		
Hand Vane shear test (on tube samples)				√		
Triaxial – Consolidated Undrained & Drained tests				√		
Consolidation Test (7 stage)				√		
MDD and CBR testing	√	√				√
Point load/UCS testing on recovered rock cores	√				√	
Modulus testing on rock core						
Emerson Crumb Testing	√	√	√	√		
Insitu Density of Existing Subgrade.						√
Bulking Factors of Cut Material	√					
Hand Dynamic Cone Penetration Test	√	√	√		√	√
Soil and groundwater aggression testing (durability testing) (chlorides, sulphates, pH, resistivity)	√			√	√	
Standpipe or piezometer (+/- water data logger)	√			√	√	
Cone Penetrometer CPT testing – including dissipation tests				√	√	
Acid Sulfate Soils/ Rock testing.	~~√~~			~~√~~	~~√~~	
Other Tests						
Aggregate tests	√					
Downhole geophysical logging						
Borehole Imaging	√					
Packer testing of rock						
Insitu Stress Testing of rock						

3.9 SURVEY OF GEOTECHNICAL INVESTIGATIONS

The PSC must carry out a coordinate survey of all investigation sites including:

All boreholes, test pits, seismic survey spreads, piezocone/cone penetrometer sites, other sampling locations and any other significant features relevant to the geological site model should be adequately marked in the field and recorded by coordinate survey. Refer to PS321 - Detailed Survey and Utility Adjustment.

A copy of the coordinate locations must be included in the geotechnical report and all such locations should be clearly shown on plan diagrams and relevant detail design drawings.

Note that payment will not be made for any investigations works not surveyed.

4 GEOTECHNICAL DESIGN GENERAL REQUIREMENTS

4.1 OBJECTIVES

The objectives are to produce detailed designs for all the key elements to suit the requirements of the project. The design must be feasible, durable, constructable, safely maintainable and satisfy the project constraints and requirements.

The designed structures must not adversely impact on adjacent infrastructure, existing structures or utilities. In case that these structures are affected adversely, the design must address and mitigate these impacts adequately and satisfactorily.

The drawings produced associated with the designs must contain sufficient details to allow costing.

The project may include the following elements:

(i) embankments

(ii) cuttings

(iii) retaining structures

(iv) drainage structures including culverts

(v) pavements

(vi) bridge and other structure foundations, including ground improvements to support them where considered necessary

(vii) earthworks

The geotechnical design of each of the above element must meet the requirements of:

(i) relevant design standard and codes of practices

(ii) General Requirements are listed in this Section 4,

(iii) Geotechnical Design and Performance Requirements in Annexure PS331/E7, and

(iv) Project Specific Geotechnical Requirements in Annexure PS331/A.

The PSC may request additional investigation noting the above design requirements.

4.2 EMBANKMENTS

4.2.1 General

The geotechnical design must assess and provide:

(i) Foundation and slope stability to support the proposed embankment and all associated road infrastructures. Undertake detailed, and where required, staged assessments on fill batter slopes with consideration to slope stability, erosion control, vegetation cover requirements, surface treatments and subsurface drainage needs.

(ii) Where batters require stabilisation treatment, the PSC must review and develop the recommended options in the concept report to a detailed design. The details of the design are to be included in the geotechnical design report along with the adopted design parameters.

(iii) the requirements of urban design, drainage, maintenance and safety in the design.

(iv) CBR strengths for pavement subgrade.

(v) presence and quantity of unsuitable material ~~and extent of acid sulfate soil and contaminated soils~~.

(vi) the need for special construction techniques and sequences.

(vii) the need for ground improvement to enable adequate deformation performance of the subgrade and the lower layers of embankments.

(viii) potential construction problems and resolution, such as access difficulties during wet conditions and loss of subgrade strength on saturation.

(ix) Impact assessment and predicted movements and stability on both new and/or existing structures, earthworks and services. And appropriate mitigation measures to suit Instrumentation and monitoring plan needs to be designed where required.

(x) the need for drainage and/or bridging layers with details on material types, grading and thickness of layers.

(xi) assessment of the availability of required materials, drainage/bridging layers, from within the project boundaries and if necessary from external sources with details of sources, quality and quantity.

4.2.2 Embankments Proposed on Soft Ground

The geotechnical design must assess the following in addition to all the consideration listed in section 4.2.1:

(i) the need for trial embankments and/or staging of earthworks.

(ii) embankment stability, deformation performance for pavement durability and road user safety.

(iii) treatment or removal of low strength zones, and provide advice on ground improvement options, and confirm the recommendation in concept design on an optimised ground improvement solution for each embankment.

(iv) necessity for ground improvements for approach embankments to bridges, retaining structures or adjacent structures to ensure the structures perform adequately and without distress, and to allow the embankments completed within the project time frame.

(v) Estimation of settlements and rates of settlement that could occur to the critical embankments and to provide detailed design for the optimised ground improvement solutions including staged construction to ensure timely delivery of the project.

(vi) analysis of settlement at culvert sites and design of satisfactory ground improvement/settlement mitigation measures at these sites.

(vii) where appropriate provide design and advice on settlement/stability monitoring of embankments.

4.2.3 Embankment construction and staging of works

Provide recommendations and design on construction aspects of embankments with respect to:

(i) the need for, and details of, ground reinforcing with geogrids or geotextiles.

(ii) recommendations on need, extent and duration of each stage of embankment construction.

(iii) recommend on necessary specialist foundation improvement options.

(iv) materials requiring removal from embankment foundations.

(v) the need for drainage and/or bridging layers with details on material types, grading and thickness of layers.

4.3 CUTTINGS

4.3.1 General

The PSC must provide an assessment on:

(i) slope stability of batters in soil or rock based on detailed synthesis of geological data, materials testing results and soil/rock mechanics analysis.

(ii) effects of cut excavation on batter stability, other structures or adjacent infrastructure (e.g. gas, water pipelines or heritage listed items etc.)

(iii) bulk properties, excavation conditions, rippability and quantities of various types of materials to be excavated.

(iv) advice on suitability and quantity of the excavated materials as construction materials for the project. This will include bulk testing to determine compaction characteristics (e.g. optimum moisture and density), workability of materials and breakdown characteristics.

(v) definition of any unsuitable materials from cuttings such as clays/claystones. The clay mineralogy type (e.g. halloysites) must be determined with discussion on any particular problems that may be associated with such clays with respect to field moisture content, drying, laboratory testing, workability and field compaction.

(vi) occurrence, extent, location and sizes of any cobbles and boulders (e.g. Basalt), and comment on appropriate methods of excavation and possible uses.

(vii) subgrade CBRs for the floor areas.

(viii) the need for drainage layers in cutting floors. It should be noted that reliance on only site inspection by geotechnical personnel during construction is not adequate. The PSC must examine the hydrogeology and other associated topographic and environmental factors to determine the need in the design.

(ix) the need for bridging layers in cuttings with details of material types, grading and thickness of layers.

(x) the PSC must prepare a batter durability and protection protocol that identifies all of the batter conditions to be encountered in the project, and this protocol should address the following:

a. geotechnical conditions;

b. slope drainages (surface and sub-surface);

c. stabilisation treatments;

d. batter protection requirements, and

e. durability, maintenance and safety issues;

4.3.2 Cut Batter Slope Design

(i) Batter slope design for cuttings must meet the performance requirements and design criteria given in Annexure PS331/E7.

(ii) Undertake detailed, and where required, staged assessments on cut batter slopes with consideration to slope stability, vegetation cover requirements, surface treatments and subsurface drainage needs.

(iii) Where batters require stabilisation treatment, the PSC must review and develop the recommended options in the concept report to a detailed design. The details of the design are to be included in the geotechnical design report along with the adopted design parameters.

(iv) New batter slopes and existing batter slopes within the project must achieve an Assessed Risk Level (ARL) ranking of 5, but not less than 4 when assessed in accordance with the RMS 'Guide to Slope Risk Analysis'.

4.4 FOUNDATIONS FOR BRIDGE, CULVERT, RETAINING WALL AND OTHER STRUCTURES

Geotechnical design must consider the foundations for bridge, culvert, retaining wall and other structures.

(i) Bridge, retaining wall and other structure locations must be identified during the detailed design stage.

(ii) Where soft soil issues have been identified along the alignment but have not been adequately investigated due to previous site access constraints, the PSC must address this in the appraisal stage and undertake further investigations once the site access becomes available.

(iii) Boreholes and test pits must be carried out to determine the full foundation conditions that could impact on the structures. The minimum investigation requirements must comply with Section 3.8.

(iv) Review the chemical environment at all structure sites to determine any long term impacts on concrete and structural components (including concrete, steel, timber, geosynthetic materials and the like) and determine the durability requirements for these structures and potential protective measures. The analysis and assessment must be included in the detailed design report.

(v) If consolidation settlement of bridge and culvert approaches is likely then the design must provide an impact assessment on the substructures of all affected structures, together with an analysis of rate, magnitude and timeframes of any settlement with respect to the construction program, with an aim to provide durability and integrity to all structures concerned. Refer to Annexure PS331\ E7 for technical requirements.

(vi) Recommendations and design of foundations for all structures must be included in the design report along with comments and advice on all site aspects likely to impact on construction, such as the bridging structures.

(vii) Assessment and documentation of the effects on nearby residences / structures / services, from construction of the proposed foundation with respect to ground and groundwater movements, and other environmental effects such as noise, dust or vibration.

4.5 DURABILITY TESTING AND ASSESSMENT FOR STRUCTURES

Chemical testing and assessment are to be undertaken on soil and water samples from all bridge/other structures, culvert and retaining wall sites, and an analysis performed to consider any long term impacts on structural components (including concrete, steel and timber) and to determine the durability requirements for structures (concrete, steel and timber) and potential protective measures. The analysis and assessment must be included in the detailed design report.

As a minimum, the testing needs to include the following durability testing:

(i) soil, rock and ground water analysis for chlorides, sulphates, sulphites, magnesium ions, resistivity, dissolved solids and pH.

(ii) soil and rock analysis for the presence of sulphides.

(iii) soil and rock analysis for the presence of sulphur oxidising bacteria.

(iv) soil and rock analysis for the presence of sulphate reducing bacteria.

(v) soil and rock permeability (horizontal and vertical).

(vi) stream water needs to be analysed for pH, hardness, chlorides, sulfates and magnesium ions. Sampling needs to take account of water level fluctuations, including tidal variations.

4.6 EARTHWORKS

4.6.1 Selected Material Assessment

Design must consider the types of material present in cuttings and determine:

(i) suitability and available quantities of excavated material for use as selected material (CBR > 19 and CBR > 33), upper zone of formation (CBR > 8) and pavement materials. Significant sampling (e.g. heavy bucket augering or Pengo boring), testing and modelling will be required to determine the location, quality and extent of these materials.

(ii) the need for importing selected materials as necessary, including details of sources, quality and quantity.

4.6.2 Unsuitable Materials Assessment

Design must consider and characterise the types of materials present and determine:

(i) The occurrence and extent of poor quality unsuitable materials (e.g. those with soaked CBR (10 day) less than 4, those with high insitu moisture contents which at the time of construction may cause problems and any other poor quality materials requiring spoiling).

4.6.3 Cut / Fill Interface Area

Particular attention must be placed on investigations and design in this area to determine requirements for cut/fill interface treatments

4.7 PAVEMENTS

4.7.1 Existing pavements/formations investigations

Where existing pavements and road formations either impact on, or are to be incorporated into new roadways/pavements, appropriate investigations and testing are to be carried out. The work should include:

(i) consultation with the pavement designer to determine and define all requirements.

(ii) inspection and evaluation of investigation details for inclusion in the geotechnical investigations proposal plan including evaluation of:

a. general location of test holes to be excavated (divide length into homogeneous sections if applicable).

b. a deflection survey of existing pavement to be retained and rehabilitated. Refer Annexure PS341/A2 if deflection testing is to be undertaken by the PSC or provided by RMS.

c. extent and description of existing failures.

d. evidence of drainage issues.

e. equipment requirements to carry out the investigations.

f. safety, traffic control and delay management requirements.

(iii) sufficient site investigation to characterise existing pavements, their materials, structure and subgrade. It is important that a sufficient number of samples and investigation methods be used so that the strength and character of all materials encountered can be evaluated for the purposes of pavement design.

(iv) establish the reasons for any failures of the existing pavement (where applicable) to determine whether the pavement can be incorporated into the proposed work.

(v) determine the strength of subgrade materials in each excavated test hole using both CBR testing of remoulded samples and field dynamic cone penetrometer testing.

(vi) consideration of drainage issues with identification of any source of water ingress and its possible management. This should include determination of the existing moisture and drainage conditions to allow for widening/overlay of existing road embankments.

(vii) sampling and testing to determine UCS strength with various binders where insitu stabilisation of the existing pavement is likely.

The pavement investigations report (included in the Geotechnical Report) should include:

(i) test hole logs.

(ii) photographs (colour) of test holes and other relevant detail.

(iii) all laboratory test reports.

(iv) survey location of all investigation sites.

(v) discussion of all results.

(vi) all other relevant detail required by the pavement designer.

4.7.2 Proposed pavements

Refer pavement investigation requirements to Section 3.8.

The design report must provide advice on geotechnical aspects for all pavements required for the project including, but not limited to:

(i) consultation with the pavements designer to determine and define all requirements.

(ii) determination of appropriate design subgrade CBR values for all required pavements.

(iii) advice on specific issues relevant to pavement design including drainage requirements, subgrade support, need for bridging layers, specific requirements for fill material (including upper zone of formation), and swell/shrink characteristics of underlying materials.

(iv) an assessment of the impact of expected residual and differential settlement of any supporting foundation and its effect on the pavement choice, design and timing of construction.

(v) advice on alternatives, including stabilisation and the effect of high moisture content on the performance of flexible pavements including temporary pavements, tie-in areas etc.

(vi) advice on the suitability of the existing embankment to support the new pavement where existing road formations are to be retained.

(vii) advice on the suitability of the existing embankment and pavement material for incorporation into other areas of the work.

(viii) consideration of sources of materials required for the main carriageway upgrade, service, local and temporary roads in view of the demands of adjacent projects.

5 GEOTECHNICAL REPORTING GENERAL REQUIREMENTS

The schedule and details of geotechnical reports for a specific project is listed in Annexure PS331/ A6 and A7.

The design report including the geotechnical data must be documented both in hard copy and electronically in accordance with the requirements of Section 5.10. The drawing documentation should be drafted in accordance with RMS structural Drafting and Detailing Manual.

The general requirements on the content of various reports are outlined below.

5.1 GEOTECHNICAL INVESTIGATION FACTUAL REPORT

This report must include:

(i) An overview or synopsis that clearly sets out the structure of the report sections and volumes.

(ii) A description of the work carried out.

(iii) Copies of all factual data, laboratory test results and collected information from the geotechnical investigations.

(iv) All information specified in Sections 4 and 5.1 relevant to the geotechnical investigation factual report.

This report must be suitable for use by PSC for the detailed design, environmental assessment (REF) and for use in the RMS project construction tender documents as a document for the convenience of the construction contractor. The report must present the factual geotechnical information as described above and must exclude interpretative content, such as that outlined in Section 5.2. The interpretative content must be excluded so that all risks from interpretation of the factual data is transferred to the construction contractor.

The investigation report including the geotechnical data must be documented both in hard copy and electronically in accordance with the requirements of Section 5.10.

HOLD POINT	
Process held:	Final geotechnical investigation factual report
Submission details:	Submission of draft geotechnical investigation factual report
Release of hold point	RMS's representative will release the hold point following review of the draft geotechnical investigation factual report, and acceptance of comments by the PSC

Refer to Section 6 of PS331 for the report and plan review requirements.

5.2 GEOTECHNICAL INTERPRETIVE REPORT

The geotechnical interpretive report presents an assessment of the geotechnical and geological conditions based on the factual information obtained during site investigations. The report is used in project

management, detailed design, tender assessment and overall understanding of the project. The geotechnical interpretive report must be prepared with engineering design input and must include:

(i) Presentation of interpreted geological / geotechnical models for detailed design of all geotechnical/structural elements.

(ii) All information and advice specified in Section 4 and this section, relevant to the geotechnical interpretive report.

(iii) Groundwater, hydrology, hydrogeology and engineering geomorphology.

(iv) Earthworks materials planning and management.

(v) Analysis and commentary on all aspects of the investigations, including interpretations, predictions and construction strategies, and taking into account the findings from both previous and current investigations.

(vi) Recommendations on all design geotechnical parameters.

(vii) Design options for all proposed structures unless otherwise covered by the Geotechnical Detailed Design Option Report.

HOLD POINT	
Process held:	Final geotechnical investigations interpretative report
Submission details:	Submission of draft geotechnical investigations interpretative report
Release of hold point	RMS's representative will release the hold point following review of the draft geotechnical investigations interpretative report, and acceptance of comments by the PSC

Refer to Section 6 PS331 for the report and plan review requirements.

5.3 GEOTECHNICAL DESIGN STATEMENT REPORT

The geotechnical design statement report sets out project specifications and reference documents, design methodologies, loading and load cases, design models and geotechnical parameters. Specifically, the report is to include:

(i) Presentation of the design methodologies adopted in detail for design of each type of geotechnical element including design software.

(ii) Standards, specifications and reference documents in relation to the proposed structures, and relevant design and performance criteria that are to be adopted. Design integration and safety in design should also be included.

(iii) Loadings and load cases imposed on the design elements as agreed with RMS's Representative or as specified in the design brief and appropriate to the intended use of the structure and design life.

(iv) Design and performance criteria for each type of geotechnical element and as outlined in Annexure PS331/E.7

(v) Geotechnical models and parameters along the alignment of the project. In developing the geotechnical models the PSC must assess the engineering properties of all relevant soil and rock materials encountered within the project sites. The design groundwater conditions are also to be assessed and presented. Adopted parameters that are different to those recommended in the geotechnical interpretive report should be stated and justified with reasons. The PSC must:

a. Review all site geotechnical data and include information gathered from the site appraisal and site investigation to ensure that the quantum and methods of site investigation are appropriate for the structures to be adequately and economically designed.

b. Ensure that the geological/geotechnical models developed for the site are consistent with the site investigation findings.

c. Ensure that sufficient soil and rock testing are carried out to define material design parameters.

d. Ensure assumptions made in the design are based on substantiated test data from the site investigations phase which is verifiable and accurate.

e. Confirm design flood levels, design scour depths and design protection measures with RMS's Representative in the case that a structure may be exposed to flooding.

f. List all assumptions for conformance check at a later stage.

(vi) For complex problems or when ground deformation is critical to the design, numerical modelling techniques (e.g. Finite Element Method or Finite Difference Method) should be considered. For complex and variable ground conditions where a single geotechnical model might not be most representative, sensitivity studies should be undertaken to provide robustness to the design.

The above items need to be considered in relation to each geotechnical element, including but not limited to cuttings, embankments, retaining walls and reinforced slopes, bridge foundations, culvert foundations, ground improvements, , over/underpasses, subsurface drainage, earthworks and water detention ponds.

The PSC should also liaise with RMS's Representative and relevant stakeholders to define/confirm the constraints that the project could be subjected to, whether from design, construction, maintenance or other points of view. The PSC requires integration of interdisciplinary objectives, such as functionality, durability, maintenance, aesthetics and safety into the design.

HOLD POINT	
Process held:	Commencement of detailed Design Option Report
Submission details:	Submission of draft geotechnical design statement report
Release of hold point	RMS's representative will release the hold point following review of the draft geotechnical design statement report, and acceptance of comments by the PSC

Refer to Section 6 for the report and plan review requirements.

5.4 GEOTECHNICAL DESIGN OPTION REPORT

The design option report presents and discusses feasible options or review and confirm the preferred concept option from concept design stage, for all geotechnical elements, including but not limited to poor ground treatments, batter stabilisation, foundation options for bridges, culverts, retaining structures and other structures. The options are to compare construction costs, evaluate advantages and disadvantages and to identify or confirm a preferred option for detailed design, which is to be consistent with the structural design option report and satisfies all the project constraints.

The geotechnical design option report must include:

(i) Project constraints.

(ii) Design assumptions.

(iii) Interpretations of the geotechnical information.

(iv) Development of the geological/geotechnical models including consideration of relevant geological defects and structures, insitu stresses, design groundwater conditions and flood conditions.

(v) Presentation of design options for all design elements.

(vi) Discussion of detailed design options, identification of the preferred options and justification for the preferred option(s) supported by analysis and calculations.

The design option report should be sufficiently detailed to allow a clear identification of the preferred options, and for progression to the detailed design and drawing preparation.

HOLD POINT	
Process held:	Commencement of detailed geotechnical analysis and design
Submission details:	Submission of draft geotechnical design option report
Release of hold point	RMS's representative will release the hold point following review of the draft geotechnical design option report, and acceptance of comments by the PSC

Refer to Section 6 for the report and plan review requirements.

If agreed with RMS, the Geotechnical Option Report could be combined with the Geotechnical Detailed Design Report below.

5.5 GEOTECHNICAL DETAILED DESIGN REPORT

The geotechnical detailed design report must present and discuss the analysis and results of the detailed design, document calculations and analysis on all aspects of the designs, taking into account of the findings from both previous and current investigations. The design and documentation need to include all the geotechnical elements in the project such as embankments, cuttings, pavements, bridge foundations, culverts, and over/underpasses, and other structures. Sensitivity of the designs to critical parameters is to be reported.

The analysis should cover all typical and non-typical cross sections and should be adequate to permit detailed design drawing preparation. The designs should be sufficient to allow progression and dovetail to other civil/structural designs.

Durability needs to be considered to comply with the minimum design life requirements as given in PS301 – Professional Service Scope and Requirements. The design output must meet the project requirements and should be fully presented. The PSC is responsible for documentation of the design report and that may include but not limited to:

(i) Appreciation of the project

(ii) when and where departures from the geotechnical design statement report occur, present such departures which may include design criteria, design standards, design methodology and software used.

(iii) Compliance with the Project Brief

(iv) Conformance to all RMS technical requirements outlined in Annexure PS331/E.7.

(v) Documentation of the adopted geological/geotechnical models, design parameters, design assumptions and limitations

(vi) Calculations and analysis of the design elements. The analysis should cover all typical and non-typical cross sections and should be adequate to permit detailed design drawing preparation and costing.

(vii) Calculations associated with stability and settlement, including total settlement; total residual settlement; differential settlement; tilt, rotation, and lateral deformations etc.

(viii) Foundation designs, including foundations and other ground improvement designs, are to include assessments of the geotechnical capacities, all load induced movements on affected structures and utilities to demonstrate design conformance.

(ix) Consideration of durability, constructability, operation and maintenance in the design.

(x) Integration of safety in design for the construction, operation and maintenance of the structures.

(xi) For each structure site, a separate geotechnical investigation report or an extract from it must be included as part of the design documentation in accordance with Chief Bridge Engineer Circular, CBE 2000/09. The geotechnical investigation report must be prepared by a recognised geotechnical and foundation engineer and must contain assessment of foundation conditions, design criteria, design calculations, geotechnical models, and recommendations of design parameters for the design of foundations for geotechnical structures. The design strength parameters of soil and rock must be characteristic values as defined in AS5100.3.

(xii) The design drawing documentation of all bridge and associated works must make reference to the relevant geotechnical investigation report.

(xiii) Where considered necessary, documentation of a construction monitoring and trigger level response plan to validate the design conformance.

(xiv) Recording the changes from the previously submitted stages and stating the reasons for the changes.

(xv) Responses to comments on earlier submissions from RMS Representative, Proof Engineer or the Project Verifier. Discussion and recommendations, including responses to requests by RMS's Representative.

(xvi) Preparation of detailed design drawings and other supporting documentation

5.6 GEOTECHNICAL DETAILED DESIGN DRAWINGS

The PSC must prepare the design drawings at an appropriate stage. The drawings need to be developed with sufficient details and dimensions to define all of the significant cost items associated with each geotechnical structures. Provision for maintenance and safety must also be considered in the drawings.

The geotechnical detailed design drawings for earthworks, embankments, cuttings, retaining structures and foundation of structures must show the following details as a minimum:

(i) Slopes of batters and benches including changes in slope and slope transitions.

(ii) Proposed batter treatments.

(iii) Proposed ground and earthwork foundation treatments.

(iv) Proposed foundation system for structures, including bridge abutment and pier, culverts and retaining walls.

(v) Details of retaining walls types, principal dimensions and their lateral and longitudinal extent, subsoil drainage, and backfill materials and their geometry.

(vi) Critical design assumptions requiring geotechnical verification by competent and experienced geotechnical personnel

(vii) Instrumentation and monitoring plan with trigger and action measures, where necessary.

(viii) Key construction sequence, staging and constraints

(ix) In consultation with RMS representative, an identification number must be obtained for each new geotechnical structure and included in the respective drawing for easy reference in future maintenance.

The drawing documentation should be drafted in accordance with RMS Structural Drafting and Detailing Manual.

HOLD POINT	
Process held:	Final draft geotechnical detailed design report and drawings
Submission details:	Submission of draft geotechnical detailed design report and drawings
Release of hold point	RMS's representative will release the hold point following review of the draft geotechnical detailed design report and drawings, and acceptance of comments by the PSC

Refer to Sections 6 for the report and plan review requirements.

5.7 EARTHWORKS AND BATTER MANAGEMENT REPORT

The earthworks and batter management report sets out the project requirements for earthwork material management and batter management. This report should be developed on the basis of interpretations of the site geotechnical/geological conditions, using data obtained from boreholes and trial pits carried out on the sites. The data should be used to develop longitudinal and cross-sectional geological models based on the latest road design alignment. This report should be treated as a live document and updated regularly as additional information becomes available.

Specifically, the report is to include:

(i) Summary of the geotechnical design requirements set out in the Project Brief

(ii) Summary of the geological setting and main earthworks features of the proposed alignment

(iii) An outline and definition of materials currently available on site which will be won during the excavation of cuttings, and a summary of potential applications for reuse based on material properties.

(iv) Outline of the earthworks material management including but not limited to the following;

a. Estimation of cut and fill quantities;

b. Assessment of suitability and quantity of materials won from the project, or those nominated by RMS representative, for road construction application along the length of the proposed project alignment

c. Assessment of shortfalls of the type and quantity of materials, identification of suitable quarries etc.

d. Discussion of the types of earthwork foundation treatment required in accordance with R44 for cuts, embankments fills, transition zones and sloping embankments.

e. An idealised work schedule and material movement plan based on geotechnical information to date.

f. A consideration of site won material quantities in terms of material proportion (%) by inferring available geotechnical information for each cut section.

g. Requirements on material types – (i) topsoil (ii) unsuitable materials (iii) select material zone (iv) verge material and (v) upper zone of formation other than select material.

h. A summary of fill type and quantity needed for different structures such as earth fill embankments, bridge abutments, gravity walls and the like.

i. Details of material specifications required in accordance with RTA QA Specifications.

j. Details of additional conformity requirements during earthworks e.g. placement, compaction, moisture content, sampling and testing frequency, if not yet specified elsewhere.

k. A Summary of all earthworks construction and testing requirements.

l. The embankment batter management strategy

m. The embankment batter and cut batter stability, drainage and durability assessment

n. Assessment of batter erosion in accordance with the Department of Housing publication

(v) Geotechnical consideration and design assumptions for embankments and culverts

HOLD POINT	
Process held:	Final draft earthworks and batter management report
Submission details:	Submission of final draft earthworks and batter management report
Release of hold point	RMS's representative will release the hold point following consideration of the draft earthworks and batter management report and acceptance/incorporation of RMS comments by the PSC

5.8 ~~ACID SULFATE SOILS MANAGEMENT PLAN~~

~~Investigations are required to supplement existing acid sulfate soils survey (if these are available) with analysis of all low lying ground areas (areas less than 5m AHD) that are to be disturbed by the proposal.~~

~~The survey (including sampling and laboratory testing programme) is to be carried out in accordance with Guidelines for the Management of Acid Sulfate materials, Acid Sulfate Soils, Acid Sulfate Rock and Monosulphide Black Ooze (RTA 2005) and the ASSMAC Acid Sulfate Soil Manual, 1998.~~

~~Develop an Acid Sulfate Soil Management Plan to the satisfaction of Office of Environment and Heritage (if appropriate). The plan is to be prepared in accordance with the Acid Sulfate Manual (ASSMAC, 1998). The plan must include inter alia:~~

~~(i) Reference to the water quality monitoring program contained in the Soil and Water Quality Management Sub-plan (if this exists, refer to PS371 Hydrology and Drainage Design).~~

~~(ii) A procedure for sampling and testing for the presence of acid sulfate soils during construction.~~

~~(iii) A procedure for the handling and treatment of expected acid sulfate soils.~~

~~(iv) Management of the banks and the beds of creeks~~

~~(v) A contingency plan to deal with the unexpected discovery of actual or potential acid sulfate soils.~~

~~Advice and recommendations for the management of acid sulfate soils including their impact on structural components such as bridge piles, foundations and culvert base slabs.~~

HOLD POINT	
Process held:	Finalisation of acid sulfate soils management plan
Submission details:	Draft acid sulfate soil management plan
Release of hold point	RMS's representative will release the hold point following consideration of the draft acid sulfate soils management plan and incorporation of RMS comments by the PSC

Refer to Annexure Section 6 for the report and plan review requirements.

5.9 CONTAMINATED SOILS REMEDIAL ACTION PLAN

The PSC is required to:

(i) Undertake a desk top study and produce a contaminated soils investigation report. The study is to be in consultation with an appropriate environmental expert and other studies, including a review of RMS contaminated sites investigations (if available), to increase confidence from the environmental assessment and subsequent studies to meet the requirements of the Department of Planning and Infrastructure, NSW (if appropriate) and to identify if and what further investigations are required.

Sampling and laboratory testing for contaminated soils is to be carried out in accordance with:

(i) "Assessment and Management of Contaminated Sites" (ANZECC/NHMRC, 1992).

(ii) "Service Station Sites. Assessment and Remediation", Office of Environment and Heritage.

(iii) "Guidelines for Consultants Reporting on Contaminated Sites", EPA 1997.

(iv) EPA Contaminated Sites Section publications on assessing cattle dips site and assessing former banana plantations (if applicable).

HOLD POINT	
Process held:	Field contaminated soils investigation work
Submission details:	Contaminated soils investigation report
Release of hold point	RMS's representative will consider the submitted study prior to releasing the hold point

Refer to Section 6 for the report and plan review requirements.

The PSC is required to:

(i) Undertake appropriate investigations, in areas found likely to be contaminated, to determine the nature and extent of any contamination.

(ii) Prepare a Contamination Investigation Report to the satisfaction of the Office of Environment and Heritage (if required) to confirm the nature, extent and degree of contamination. This report must detail the results of site investigations and provide an assessment of potential risks posed by contaminants to health and to the environment and indicate whether remediation is required.

(iii) Based on the findings of the Contamination Investigation Report, develop a Contaminated Soils Remedial Action Plan in consultation with Office of Environment and Heritage (if required) and Department of Planning and Infrastructure NSW (if required). The plan is to include inter alia:

a. Identify the location and nature of remedial action(s) proposed.

b. Detail proposed methods to identify, classify, store and if necessary, dispose of contaminated soil.

c. Refer to Office of Environment and Heritage's Environmental Guidelines: Assessment, Classification and Management of Liquid and Non-Liquid Wastes in the development of the Action Plan.

d. Include reference to the water quality monitoring program contained in the project Soil and Water Quality Management Sub-Plan (if this exists, refer to refer to PS371 Hydrology and Drainage Design).

e. Identify all construction activities likely to disturb contaminated sediments and contaminated soils.

f. Clearly explain how the mitigation of any disturbed sediments or soils will be controlled during construction.

g. Include a detailed contingency plan to deal with the unexpected discovery of contaminated sediments, prepared to the satisfaction of the Office of Environment and Heritage (if required) and in consultation with the Department of Planning and Infrastructure, NSW (if required).

h. Demonstrate how mitigation measures will successfully manage contaminated sediments during construction, especially arsenic, copper, lead and benzo-a-pyrene.

i. Identify any stockpiling locations for contaminated material.

j. Describe disposal methods and make reference to the Office of Environment and Heritage's waste classification.

k. Maps to identify transport routes and locations of disposal sites for contaminated spoil.

HOLD POINT	
Process held:	Finalisation of contaminated soils remedial action plan
Submission details:	Draft contaminated soils remedial action plan
Release of hold point	RMS's representative will release the hold point following consideration of the draft contaminated soils remedial action plan, and incorporation of RMS comments by the PSC

Refer to Section 6 for the report and plan review requirements.

5.10 ELECTRONIC FORMAT OF DATA AND DOCUMENTATION

The PSC must make available, when requested, electronic copies of all data and documentation for review by RMS Representative. Final copies / presentations of all data and documentation are to be provided to RMS on flash memory stick or external hard drive.

Electronic copies of data and documentation must be compatible with RMS's software and systems. Electronic systems for all subcontract and specialist reports must comply with this requirement. Electronic copies of reports must be submitted in Microsoft Word 2007 and pdf format.

All borehole logs, test pit logs, CPT logs, insitu testing, field testing, laboratory testing and monitoring data (including installation details) must be provided to RMS in the following electronic formats:-

(i) .pdf; and

(ii) ASCII data file in the latest RTA AGS format as defined on http://www.rms.nsw.gov.au/business-industry/partners-suppliers/design-documents/geotechnical-information.html

Further information on RTA AGS can be obtained at http://www.datgel.com/AGSRTAFormat.aspx

Data must be entered under the individual field headings for all fields, including the GORA, GORB, GOSA, GOSB and DISC fields of AGS RTA groups. For example the GORA field includes separate headings for rock name (3 headings), colour (1 heading), grainsize (3 headings), texture, fabric, structure, odour, staining, additional remarks etc. Data that is not entered in the correct fields and under the correct headings will not be accepted by RMS until it has been correctly entered.

The most recent RMS gINT library and template can be obtained on request from the RMS Pavements and Geotechnical Section for data entry.

(i) All GIS data produced for the project must be supplied to the RMS in ESRI ArcGIS10 format Map Package (MPK). This is to be projected in MGA coordinate system in the appropriate zone. As a minimum data this data must include test site locations and the geology map. All spatial information obtained as part of the investigations must be included.

(ii) All drawings, cross sections, GIS plans etc. must also be submitted in .pdf format.

(iii) All design software electronic files are to be made available to the RMS upon request, including but not limited to commercial software and spreadsheets used in design.

6 GEOTECHNICAL REVIEW

6.1 REVIEW BY ROADS AND MARITIME

A design review must be carried out by the PSC at an appropriate stage to ensure that the work is proceeding within the scope of the project and in accordance with the requirements specified by RMS's Representative. Should there be changes to the design requirement initiated either by RMS's Representative or other authorities, the PSC must review accordingly to ensure that all changes are dealt with adequately.

The PSC is responsible for the following and shall submit the items identified below to RMS for review :

(i) all design input, either in the form of document and/or electronic data.

(ii) The PSC is responsible for checking the design plans and drawings for consistency and accuracy, which are to be forwarded to the project reviewer for approval.

(iii) The PSC must provide their program to RMS for review and, where possible, avoid submitting design packages concurrently to allow timely review and release of hold points by RMS Representative.

(iv) When submitting any design reports outlined herein, the PSC must include a summary of all site investigation, laboratory test data and any other inputs used in the development of the design. All input data are to be referenced such that the reviewer could easily find and verify them during the review.

(v) The PSC must consider the review timing requirements mentioned in Annexure PS331/A10.

6.2 REVIEW BY INDEPENDENT VERIFIER

~~Where required,~~ Reports are also to be forwarded to an independent geotechnical contractor (proposed by the PSC with concurrence by the RMS) for an overall review of the geotechnical investigations, the geotechnical reports and drawings. The timing of the independent verification report and review period is shown in Annexure PS331/A10.

7 GEOTECHNICAL SERVICES PRICING INSTRUCTIONS

7.1 GEOTECHNICAL INVESTIGATION PROPOSAL PLAN

The PSC must review the existing ***Macquarie Park Stage*** 1 ***Geotechnical Interpretative Report and Macquarie Park Bus Priority Program (Stage 2) Factual Report - Geotechnical Investigation and the concept design documentation*** ~~geotechnical information~~ and identify what additional geotechnical investigation is required to complete the requirements of this Brief Specification. The PSC needs to produce a geotechnical investigation proposal plan based on the requirements of this Specification. The geotechnical investigation proposal plan is to include a strategy on how the PSC will achieve the project outcomes with respect to the additional geotechnical investigations. The geotechnical investigations must be carried out in accordance with the requirements outlined in Section 3.8 (Minimum scope of Investigation for Detailed Design) and Annexure PS331/E1 (Geotechnical Investigation Methods).

The geotechnical investigation proposal plan is to address as a minimum, the following:

(i) Desk top study of relevant background data and review of geotechnical works carried out to date.

(ii) Extent of geotechnical investigations including a plan of the proposed geotechnical investigation sites and access arrangements.

(iii) Methodology and extent for assessing the impact of constructing the proposed new works on the existing infrastructure, particularly bridges and current road formation.

(iv) Methodology and equipment for field sampling, testing and investigations.

(v) Highlighting of any particular areas of concern relating to stability, settlement, unsuitable material, contaminated soils, embankment materials, foundation conditions and ground water.

(vi) Provision of necessary input and recommendations to the road, pavement and structures design.

(vii) Consider a seismic refraction investigation (or alternative geophysical investigation technique) as required by Annexure PS331/E.

(viii) Survey of locations - refer to PS321 Detailed Survey and Utility Adjustment.

(ix) Consultation with services authorities.

(x) Provision for internal review and independent verification of the geotechnical report - refer to Section 6 and Annexure PS331/A10.

(xi) Presentation of collected data.

(xii) Transfer of data.

(xiii) Road occupancy/traffic control

7.2 PRICING OF GEOTECHNICAL SERVICES

All geotechnical design, reviews, reporting, management, etc costs to comply with this specification must be priced and included in the Tender submission except for:

- ***Any additional geotechnical investigations identified and required for the design will be procured and undertaken by the PSC with the costs being priced and agreed to by RMS and funded from the Provisional Sum. Refer PS301 for Provisional Sum allowed.***

For pricing purposes ***of additional geotechnical investigations***, the works have been broken up into tasks as described below.

For each task the PSC should:

(i) Price the minimum investigation, testing, interpreting , analysing and produce geotechnical design and documentations required to meet the performance and technical requirements of this Brief.

(ii) Where relevant the PSC is to separately identify and price any investigations considered additional to the minimum requirements that have potential to add further value or minimisation of risk to the project.

The final scope of investigations will result from the Geotechnical Investigations Proposal Plan. This plan will be agreed between the PSC and the RMS. The tasks include:

~~**7.2.1 REF/EMP**~~

~~Pricing of works required by this task must include all costs associated with the development, preparation, gaining of approval and implementation of the REF and EMP refer to Clause 2.4.1 - 'Geotechnical Investigations – REF and EMP.~~

7.2.2 Planning, Preparation and Project Management

Pricing of works required by this task must include all costs associated with all preparation, planning and project management for the works and will include the geotechnical investigations proposal plan, liaison with authorities, consultations, obtaining of licences (where applicable) and general project management. All WHS requirements must be identified, and the associated costs, included in the pricing – refer to PS301 Professional Service Scope and Requirements.

7.2.3 Geotechnical Investigation and Testing

Pricing of works required by this task must include all costs associated with undertaking the investigations and testing. Pricing is to be inclusive of all associated costs including but not limited to: site establishment and set-up, field supervision and logging, standby time, provision of site access (including access tracks and over water access), equipment and plant (e.g. vehicles, water cart, barges etc.), implementation of environmental controls generally and as required by the REF/EMP, grouting of boreholes, neutralisation of drill cuttings, site re-instatement, ground water instrument installation and monitoring, all expenses, and all other ancillary tasks, activities and requirements.

7.2.4 Survey

Costs for this work include all the costs associated with surveying investigation sites to the required accuracy including the survey location of previous investigation sites that have been marked on the ground - refer to PS321 Detailed Survey and Utility Adjustment.

~~**7.2.5 Contaminated Soils and Acid Sulfate Soil Investigations**~~

~~Costs for this task include: a desk top study, environmental input, sampling, testing, interpretation/analysis and reporting including the development of a Contamination Investigation Report and a Remedial Action Plan and an Acid Sulfate Soils Management Plan.~~

7.2.6 Investigation Reporting, Design Documentation and Ongoing Design Support

Pricing of works required by this task must include all costs associated with the following:

(i) Development of geological/geotechnical models.

(ii) Interpretation of geological and geotechnical data.

(iii) Provision of advice and ongoing design support, including inter-disciplinary liaison for comprehensive and satisfactory completion of this Brief.

(iv) Undertake the detailed geotechnical design ~~and environmental assessment (REF).~~

(v) Recommendations for additional geotechnical investigations or testing.

(vi) Production of geotechnical reports and drawings as listed in PS331/A6 and A7 to satisfy the general requirements in Sections 4, 5 and 6 and Project specific requirements in PS331/A .

(vii) Management and meeting with RMS Peer Reviewer.

(viii) Input and participation at workshops including risk management and value engineering with RMS - refer to PS301 Professional Service Scope and Requirements.

(ix) Direct input and support for detailed design including the progressive and timely release of data.

(x) Ongoing consultation in the project throughout the detailed design and environmental assessment process including attendance at technical meetings as required.

.

HOLD POINT	
Process held:	Commencement of field geotechnical investigations
Submission details:	Report on the existing geotechnical information and a detailed geotechnical investigations proposal plan (with pricing) based on the requirements of this Brief.
Release of hold point	RMS's representative will release the hold point following consideration of, and agreement between RMS and the PSC to the report on the existing geotechnical information and the detailed geotechnical investigations proposal plan (with pricing) based on the requirements of this brief

Refer to Annexure PS331/A6 and A10 for the report and plan review requirements.

ANNEXURE PS331/A – PROJECT SPECIFIC GEOTECHNICAL REQUIREMENTS

A1 PROJECT DETAILS

Table PS331.A1 – Project Details

Project Name	***Macquarie Park Bus Priority and Capacity Improvement Project - Stage 2***
Project Number	***P.0023019***
Location	***Epping Road, Herring Road, Waterloo Road and Lane Cove Road, Macquarie Park***
Local Council	***Ryde Council***
Length (size) of the project	***MR 373 Epping Road to MR 162 Lane Cove Road via Herring Road (7486) and Waterloo Road at Macquarie Park and MR 162 Lane Cove Road from Waterloo Road to Epping Road.*** ***Project length approximately 2.8km.***
Project features	• ***Upgrade of the state and local road network in the Macquarie Park precinct to improve travel times and reliability for buses and for other road users*** • ***3 new signalised intersections and upgrades to the existing signalised intersections*** • ***Installation of bus lanes and road widening with improved pedestrian and cyclist crossing facilities at signalised intersections*** • ***Partial (strip) property acquisitions along Herring Rd, Waterloo Road, Byfield St, Khartoum Rd and Lane Cove Rd to enable the road widening and intersection upgrade works*** • ***Service relocations to allow kerb relocation and lane widening***

Refer PS301: Professional Services for Detailed Design Scope and Requirements, Annexure PS301/A for project details, background and project specific requirements.

A2 PROPOSED WORKS

The geotechnical investigation in general consists of:

- ***undertake a review of the existing Macquarie Park Stage 1 Geotechnical Interpretative Report and Macquarie Park Bus Priority Program (Stage 2) Factual Report - Geotechnical Investigation to identify if additional geotechnical investigation is required to complete the requirements of this Macquarie Park Stage 2 Specification.***
- ***Develop a scope of work and price for the additional geotechnical investigations required***
- ***Undertake the additional geotechnical investigations required***
- ***Provide a report on the results of the additional geotechnical investigations required***
- ***Provide geotechnical design, reporting, management as required under this specification during the detailed design***

A3 DESCRIPTION OF THE SITE

Refer to:

- ***PS301: Professional Services for Detailed Design Scope and Requirements, Annexure PS301/A for project details, background and project specific requirements.***
- ***the Macquarie Park Stage 1 Geotechnical Interpretative Report and Macquarie Park Bus Priority Program (Stage 2) Factual Report - Geotechnical Investigation for geotechnical specific information***

A4 DESCRIPTION OF THE GEOLOGY AND GROUND CONDITIONS

Refer to the Macquarie Park Stage 1 Geotechnical Interpretative Report and Macquarie Park Bus Priority Program (Stage 2) Factual Report - Geotechnical Investigation

A5 GEOTECHNICAL INVESTIGATION AND DESIGN - SCOPE OF WORK

A5/2 Defined by PSC

If additional geotechnical investigation is required in order to complete detailed design, the scope is to be defined by the PSC and undertaken as per this specification. Refer to Sections 3.8 and 7 for scope and pricing instructions respectively.

A6 GEOTECHNICAL REPORTS REQUIRED

The following geotechnical reports and design are required and must be prepared in accordance with Sections 4 and 5 of this specification..

Section	Description	Requirements (Y/N)
7.1	Geotechnical Investigations Proposal Plan	***Within 20 working days of the detailed design being awarded***
5.1	Geotechnical Investigation Factual Report	***PSC to advise dates as part of proposal.***
5.2	Geotechnical Interpretative Report	***PSC to advise dates as part of proposal.***
5.3	Geotechnical Design Statement Report	***PSC to advise dates as part of proposal.***
5.4	Geotechnical Detailed Design Option Report	***PSC to advise dates as part of proposal.***
5.5	Geotechnical Detailed Design Report	***PSC to advise dates as part of proposal.***
5.6	Geotechnical Detailed Design Drawings	***PSC to advise dates as part of proposal.***
5.7	Earthworks and Batter Management Report	***PSC to advise dates as part of proposal.***
5.8	Acid Sulfate Soils Management Plan	***N***

5.9	Contaminated Soils Remedial Action Plan	***N***

A7 PROGRAM OF GEOTECHNICAL DELIVERABLES

As part of tender submission, the PSC must develop a program to chart progress of the geotechnical investigation, laboratory testing and reporting requirements, including report review time required. The program must be shown on a Gantt chart and be generated in such a way that it can be easily modified to suit program changes. ***The geotechnical program must be included in the overall concept design and detailed design program and linked to the dependant concept design and detailed design tasks as required.***

A8 MINIMUM STAFFING LEVELS AND EXPERIENCE

It is expected that all investigation logs are checked against samples and the RMS Logging Explanatory Notes prior to report submission. All personnel who check investigation logs must be an engineering geologist or geotechnical engineer having a minimum of 10 years relevant industry experience, including 3 years on work in the Sydney Basin.

Personnel who check the Geotechnical Factual Report and Geotechnical Interpretation Report must be an engineering geologist or geotechnical engineer having a minimum of 15 years relevant industry experience, including 3 years on work in the Sydney Basin.

It is expected that the persons nominated within your tender, particularly those in key positions, will be the people who undertake the work described within this documentation. Changes to staffing will need to be accepted by the RMS Representative in writing).

A9 PROJECT SPECIFIC TECHNICAL REQUIREMENTS

Some proposed works will be within the exclusion zone of the existing Epping to Chatswood Rail Link (ECRL) tunnels. Approval to conduct work at these locations will be required from Sydney Trains and/or Sydney Metro. Depth of boreholes within the exclusion zone of the existing Epping to Chatswood Rail Link (ECRL) tunnels will have to be confirmed with Sydney Trains and/or Sydney Metro.

A10 REVIEW OF REPORTS

In reference to Section 6, the review must be carried out by RMS ***and an*** Independent Verifier and the timing of the verification report and review period duration is shown below. Unless mentioned elsewhere all reports must be reviewed.

Review by:	**Submission of verification report/documents (prior to end of review)**	**Review Period Duration**
RMS Geotechnical	10 working days	10 working days
Independent reviewer	10 working days	10 working days

ANNEXURE PS331/B – PAYMENT

Payment will be made for all costs associated with completing the work detailed in this Specification in accordance with the Pay Item(s) in **PS301 - Professional Services Scope and Requirements**.

Where no specific pay items are provided for a particular item of work, the costs associated with that item of work are deemed to be included in the rates and prices generally for the works.

ANNEXURE PS331/C- SCHEDULES OF HOLD POINTS, WITNESS POINTS, DELIVERABLES AND WORKSHOPS

C1 SCHEDULE OF HOLD POINTS AND WITNESS POINTS

The PSC must give the RMS's Representative at least five working days written notice prior to reaching any hold point for which a release by the RMS's Representative is required. Only items with a **Y** are required for this project.

Table PS331.C1 – Hold Point Requirements

Section	Type	Description	Required (Y/N)
~~3.1~~	~~Hold~~	~~Field geotechnical investigation work~~	***N***
5.1	Hold	Final Geotechnical Investigations Factual Report	***Y***
5.2	Hold	Final Geotechnical Interpretive Report	***Y***
5.3	Hold	Commencement of detailed Design Option report.	***Y***
5.4	Hold	Commencement of detailed geotechnical analysis and design	***Y***
5.6	Hold	Final Draft Geotechnical Detailed Design Report and Drawings	***Y***
5.7	Hold	Final draft earthworks and batter management report	***Y***
5.8	Hold	Finalisation of acid sulfate soils management plan	***N***
5.9	Hold	Field contaminated soils investigation work	***N***
5.9	Hold	Finalisation of contaminated soils remedial action plan	***Y***
7.2.6	Hold	Commencement of field geotechnical investigations	***Y***

C2 SCHEDULE OF DELIVERABLES AND SUBMISSION DETAILS

The PSC must give the RMS's Representative at least ten working days to review all deliverables identified in the table below. Only items with an **Y** are required for this project.

Table PS331.C2 – Deliverables and Submission Details

Section	Description of Deliverable	Delivery timeframe	Required (Y/N)
7.1	Geotechnical Investigations Proposal Plan	***Within 20 working days of the detailed design being awarded***	Y
5.1	Geotechnical Investigation Factual Report	To be included in the 50% Design submission	***Y***

		onwards	
5.2	Geotechnical Interpretative Report	To be included in the 50% Design submission onwards	***Y***
5.3	Geotechnical Design Statement Report	To be included in the 50% Design submission onwards	***Y***
5.4	Geotechnical Detailed Design Option Report	To be included in the 50% Design submission onwards	***Y***
5.5	Geotechnical Detailed Design Report	To be included in the 50% Design submission onwards	***Y***
5.6	Geotechnical Detailed Design Drawings	To be included in the 50% Design submission onwards	***Y***
5.7	Earthworks and Batter Management Report	To be included in the 50% Design submission onwards	***Y***
5.8	Acid Sulfate Soils Management Plan	To be included in the 50% Design submission onwards	***N***
5.9	Contaminated Soils Remedial Action Plan	To be included in the 50% Design submission onwards	***N***

C3 SCHEDULE OF WORKSHOPS REQUIRED

Refer to PS301/A and PS301/C for meeting and workshop requirements.

Table PS331.C3 – Workshop Requirements

Section	Description of Workshops	Required (Y/N)	Location	Minimum Expected Duration
7.2.6	HSiD &Risk management Workshop	Y	PSC or RMS Offices	***Refer PS201/C***
~~7.2.6~~	~~Value Engineering workshop~~	N	~~RMS Offices~~	~~7hrs~~

C4 SCHEDULE OF MEETINGS REQUIRED

Refer to PS301/A and PS301/C for meeting and workshop requirements.

Table PS211.C3 – Meetings Required

Section	Description of Meetings Required	Required?	Timing	Location	Expected Duration
7.2.6	Technical Meetings	Y	As required	RMS office, Parramatta	As required

ANNEXURE PS331/D – NOT USED

ANNEXURE PS331/E – GEOTECHNICAL SPECIFICATION

E1 GEOTECHNICAL INVESTIGATION METHODS

E1.1 Test pits

Test pits are to be excavated either by backhoe or excavator to determine the nature of the near surface materials. The proposed test pit depth and nature of materials will determine the excavation method used.

The minimum depth of test pits must be 3.0 metres depending on subsurface materials. Deep (5m+) excavator test pits are required at locations such as deep cuttings to obtain bulk samples for laboratory testing. These test pits are required to be excavated with a large excavator (minimum weight 20 tonne) equipped with a single tine ripper for additional penetration and rippability assessment.

All excavations are to be logged, colour photographed, tested to record insitu conditions and sampled for subsequent laboratory testing. Testing must include dynamic cone penetrometer and hand penetrometer.

Sampling must be representative of all major material types along the route to record variability in the ground conditions. The sample residues are to be stored for the duration of this Contract at the laboratory undertaking the testing.

E1.1.1 Logging of test pits

Unless otherwise approved, the information recorded must be, as a minimum that recorded on standard RMS excavation log sheets. The information recorded must be complete, including:

(i) logged by and checked by

(ii) equipment type

(iii) method

(iv) penetration

(v) support

(vi) ground water levels

(vii) samples and tests

(viii) soil classification symbol

(ix) moisture and relative density / consistency

(x) hand penetrometer tests and log

(xi) rock type, weathering, strength and defects

Standard RMS excavation log sheets are available on request from the RMS Geotechnical Science Section.

All pits are to be logged and photographed. An uncontaminated sample must be retrieved from each soil/rock layer. Depth records for each layer must be measured from the vertical sides of the test pit.

Hand penetrometer tests are to be conducted on all cohesive (i.e. clay) soil layers. At depth hand, penetrometer tests may be carried out on relatively undisturbed samples of material. In this instance the log is to note "not insitu" next to the test result. If required, test pits must be located at the following sites given in Table PS331/E1.

Table PS331/E1 Geotechnical information required from test pitting

Road Formation Structure or Geological Feature	Geotechnical Information to be obtained (NB – Typical features to be recorded)
Proposed Cuttings	Soil strata & strength Higher strength material at depth that may be suitable for select fill Presence of boulders or high strength rock that may affect excavation methods.
Proposed cut / fill intersection	Soil strata & strength; clay or silt layers for CBR determination affecting pavement design; water table or seepage zones Soft or loose material which may require removal as unsuitable material Boulders or high strength rock that may affect excavation methods.
Proposed fill embankments	Soil strata & strength Soft or loose material that may need to be removed as unsuitable material Requirement for bridging layers during construction
Bridge abutments /footings	Soil strata & strength ; Rock type, strength and defects
Arch or culvert structures	Soil strata & strength ; Rock type, strength and defects
Retaining structures	Soil strata and strength : Rock type, strength and defects Seepage zones/
Landslip areas	Slip failure surfaces & geometry Seepage zones Tension cracks
Old fill tip sites	Depth of fill areas Nature of tip materials (putrescible/ non-putrescible) Odours, possible toxicity of waste materials and asbestos building materials
Old mine workings (shallow)	Extent of mine workings Subsidence features; goafing (mine roof collapse / stability)

E1.1.3 Test Pit Photography

A representative face of each test pit must be photographed after excavation and logging. Excavated material may require photography to record the nature of soil/rock strata such as the presence of boulders or high strength material.

(i) The following good practice is required to accurately record field information.

(ii) Test pit photos must include a peg board to clearly identify the project, test pit number and location (e.g. chainage & offset) and other data (e.g. date)

(iii) Photographs of test pit faces must be carried out on faces of excavation which are not smeared during the excavation process and where soil/rock stratigraphy are clearly visible.

(iv) Test pit faces must be properly illuminated to ensure clear images.

(v) Each photo must record the full depth of the test pit face or in composite vertical sections if this is not possible.

(vi) Photos must include a clearly marked vertical scale (either tape or rigid scale) with 0.1 metre graduations over the full depth of the pit face.

E1.2 Non-core drilling

Boreholes in low-lying ground are to be targeted in relevant areas to assess potential for ground settlement and instability under fill embankments. Adequate undisturbed samples are to be taken for this assessment. The Contractor should note the possibility of encountering gravels and/or cobbles, when considering drilling techniques.

E1.2.1 Default Drilling Methods, Sampling Rates and Testing Rates

Unless the purpose of a borehole requires otherwise, drilling must be carried out in the following manner:

(i) In soils above the water table use continuous flight augers with a V bit.

(ii) In soils below the water table use wash boring techniques. This may be done with a cruciform tungsten bit or a rock roller. Provision is to be made for the borehole to be supported by casing.

(iii) In unconsolidated strata, SPT testing is to be carried out at 1.5 metre intervals and undisturbed (U75) samples taken where appropriate to represent each discrete layer. The undisturbed samples are to be taken immediately above SPT tests

(iv) In soft clays, carry out vane shear testing. (generally restricted to in situ shear strengths < 50 kPa)

(v) Where driven piles are likely to be used ensure a minimum of 8 metres of SPT > 30

(vi) On reaching V bit refusal or encountering rock whilst wash boring, start coring using NMLC equipment, drilling in accordance with the requirements of E1.3.1

(vii) Install standpipe piezometers as required. Water levels are to be measured after installation, at the conclusion of the drilling programme and thereafter at a maximum of three monthly intervals.

(viii) Analyse the chemical environment at proposed structures to determine any long term impacts on concrete and structural components. Testing for this analysis is to include pH, resistivity and dissolved solids.

E1.2.2 Subsidiary Procedures

The following procedures must be recorded if carried out during the drilling/logging work:

(i) Determination of the Penetration Resistance of a soil: Standard Method (SPT) Australian Standard AS 1289.6.3.1

(ii) Determination of the Shear Strength of a soil: Vane Shear - Australian Standard AS 1289.6.2.1

(iii) Hand Penetrometer - This test is generally done on the exposed ends of an undisturbed sample or an SPT sample.

(iv) Disturbed Sampling - The disturbed samples most commonly taken from boreholes are those obtained from standard penetration tests. These are to be logged, placed in a plastic bag, effectively sealed and labelled (i.e. job number, borehole number and depth interval details).

(v) Disturbed samples can be taken from cuttings that come to the surfacing during the auger process. Samples taken from the auger bit on removal are more accurate with respect to depth. Disturbed samples may be taken from the flights of the augers only when the material being penetrated is of a uniform nature.

(vi) The origin and sampling method for any disturbed sample must be recorded.

(vii) Thin walled Tube Sampling (U50 and U75) - Undisturbed samples are to be taken in accordance with Site Investigation code AS 1289.1.3.1. Seventy-five millimetre diameter, U75 tubes, are to be used to take undisturbed samples. A U50 tube may only be used if recovery is not possible with a U75 tube.

When U75 / U50 tubes are recovered, consistency tests using a hand penetrometer are to be performed before sealing. Tubes are to be sealed using a rubber "O" ring plug. The tubes must be clearly marked with Job No., Bore Hole No., Depth and any other relevant information.

The following precautions must be followed to ensure that samples are not compressed:

(i) Measure the distance between the cutting head of the tube and the bottom of the adaptor and push the tube in approximately 5 cm less than this distance to ensure there is no compression of the sample.

(ii) After taking a sample, inspect the top of the tube for signs of compressed material, for example a small lump indicates that material has been forced up into the ball bearing valve in the adaptor

(iii) If the soil sample has been compressed, another sample must be taken.

(iv) Water Sampling - If there are requirements for maximum time between sampling and testing and / or sample storage temperature, ensure that these requirements are met.

The following procedures are required in order to minimise the probability of contamination by drilling chemicals, polymer etc. :

(i) Blow the standpipe out with compressed air, trying to force water up the sides of the tube to flush the sides of the hole (so that ground water that flows in is relatively uncontaminated) OR.

(ii) use a bailer or pump to flush the hole.

Clean sample bottles are to be used with proper labelling (i.e. date, job number, borehole number and depth).

E1.2.3 Continuous Sampling Requirements for Soft Soils

Continuous sampling should be undertaken at selected locations in soft alluvial/estuarine material. The purpose of obtaining the continuous soil profile is:

(i) to ascertain the nature of sand lenses/beds within soft clay soils

(ii) to confirm and correlate material type interpretations for nearby CPTs.

(iii) to provide an alternative sample source for PASS testing and Durability testing

Where the soil material is not encased in plastic during the sampling process, the sampled soil should be encased in plastic wrapping immediately upon extrusion to preserve the natural moisture content. Where samples of the soil are to be used for PASS and/or Durability tests the relevant cold storage procedures must be applied.

Samples should be logged on "Non-Core" drilling log sheets in accordance with Section E1.3.2 "Rock Description and Logging"

Samples should be stored in a manner that permits later inspection. This may require cutting of the sample into 1.0m sections and storing in a core box of appropriate dimensions. Core boxes should be labelled in accordance with "Section E1.3.1 – Core packing, labelling, handling and storage".

E1.2.4 Large Diameter Borehole Sampling Requirements for Cuttings

General

Recovery of material for destructive testing (e.g. CBR testing, Wet/Dry Strength Variation) from deeper zones of proposed cuttings may be undertaken by one of the following methods:

(i) Large diameter coring (HQ or larger)

(ii) Heavy bucket augering

(iii) Pengo augering

The locations selected for large diameter coring/boring at a proposed cutting should be determined following the completion of the core drilling program at that site. Large diameter coring/boring is to be undertaken adjacent to selected existing boreholes. A distance of 1m to 2m from an existing logged borehole is considered appropriate. Large diameter coring/boring should not be undertaken adjacent to boreholes equipped with standpipes. The drilling method selected:

(i) will be dependent upon the rock type and rock strength identified in the previously logged boreholes

(ii) must produce a material suitable for the proposed testing

(iii) will partially be dependent upon the volume required

It should not be necessary to log the holes producing material for destructive testing, however any discrepancies between the material encountered and the logged adjacent borehole must be noted on the borehole log for the adjacent logged borehole.

Large diameter core holes must be either backfilled or capped. Large diameter augered boreholes must be backfilled to existing ground level and be compacted such that they will not settle over time.

Samples should be stored core boxes of appropriate dimensions. Core boxes should be labelled as per "Section E1.3.1 – Core packing, labelling, handling and storage"

Material for Wet/Dry Strength Variation

Higher strength rock which is to be tested for Wet/Dry strength variation is best recovered using large diameter coring techniques and then subsequently crushed to an appropriate size. The limitation of this method is production of adequate volumes for testing. As a rough guide, 5m of HQ core of higher strength rock, crushed in a jaw crusher, will produce approximately 20kgs of material suitable for one Wet/Dry test (20kgs). Rock material that is foliated or laminated may not produce material suitable for testing.

Heavy bucket augers are capable of producing large volumes of material, however in higher strength rock they may not produce material of appropriate size. Pengo rigs are unlikely to be able to sample higher strength materials.

Material for CBR and PI Tests

Rock which is to be tested for CBR and PI values to determine suitability for Upper Zone of Formation and/or Selected Material may be recovered by either large diameter coring or one of the two augering methods.

Where large diameter coring is used in lower strength materials care must be taken to minimise core loss. As a rough guide, 5m of HQ core, will produce sufficient material for tests required for determination of CBR and the Plasticity Index. Higher strength rock may need to be crushed in a jaw crusher.

Where one of the two augering methods is used, it will be necessary to monitor the size of fragments within the material recovered to ensure that it is representative of material fragment size that is likely to be placed in the Upper Zone of Formation and/or the Selected Material Zone. Pengo drilling rigs may not be able to produce suitable material if rock strengths increase above low strength. This will depend partly upon foliation or laminations of the rock mass.

E1.3 Core Drilling

E1.3.1 Default Drilling Methods, Sampling Rates and Testing Rates

Cuttings

Boreholes in proposed cuttings are required to define geological strata and the engineering properties of all major stratigraphic units. Holes must be drilled to a depth of at least 6m below finished surface level (FSL) of the pavement. Emphasis is to be placed on the recovery of core as a permanent record of the geological strata encountered.

Listed below are the main drilling requirements:

(i) Use NMLC triple tube coring method from the surface. If coring is not possible, obtain samples of all soils by continuous SPT testing. (NB Some projects may require larger diameter drill coring such as HX triple tube methods as directed by the RMS Representative)

(ii) Point load tests must be performed on representative rock core and include different weathering grades where necessary.

(iii) UCS (Unconfined Compressive Strength) samples must be taken from representative rock core of all strengths, including VH and EH strength rock.

(iv) Additional core samples are to be taken for petrographic examination.

(v) Standpipe piezometers are to be installed as required to determine water table hydrology. Water levels must be measured a) shortly after installation b) 2 weeks after installation c) at 3 monthly intervals. Water sampling and testing must be carried out if aggressive or contaminated ground water is suspected.

Structures

(i) Use NMLC triple tube coring method from the surface. If coring is not possible, obtain samples of all soils by continuous SPT testing.

(ii) Boreholes must be drilled to an appropriate depth (at least 3 metres) below the base of foundations.

(iii) Point load tests must be performed on representative rock core and include different weathering grades where necessary.

(iv) UCS (Unconfined Compressive Strength) samples must be taken from representative rock core particularly from the stronger intervals of rock (especially VH and EH rock).

(v) Standpipe piezometers are required to be installed as required to determine water table hydrology. Water levels are required to be measured a) shortly after installation b) 2 weeks after installation c) at

3 monthly intervals. Water sampling and testing must be carried out if aggressive or contaminated ground water is suspected.

Core Drilling

The object of coring is to recover the maximum amount of sample as possible until termination at the specified depth.

All drilling investigations are to comply with the Water Act 1912. In this regard consultations will be required comply with DLWC regarding:

(i) licensing requirements; and

(ii) requirements for sealing/grouting of boreholes.

Logging of Boreholes

Unless otherwise approved, the information recorded must be, as a minimum that recorded on standard RMS non-core and cored logging sheets. The information recorded must be complete, including:

(i) logged by and checked by

(ii) rig type and mounting

(iii) drilling method and casing

(iv) drilling penetration rate including the depth at which any variation in drilling rate occurs (e.g.. Sudden drops, fast drill advance)

(v) drilling fluid type, additives and loss

(vi) ground water levels

(vii) soil classification symbol

(viii) moisture and relative density / consistency

(ix) weathering, strength and natural fracture spacing

(x) visual column

(xi) details of each rock defect

Standard RMS non-core and cored logging sheets are available on request from the RMS Geotechnical Science Section.

Measuring and Core Loss

Calculate the current depth of the hole by subtracting the "stick-up" from the total length of the core barrel and rods.

If there is core loss the core is to be carefully inspected for a possible core loss location. If the core loss location cannot be determined the core loss is to be placed at the bottom of the run.

A core loss sections in the core box must be represented by a strip of polystyrene foam inserted at the appropriate location and marked accordingly.

Core Packing, Labelling, Handling and Storage

The core boxes used should have five divisions, be 1.05 metres long, be designed to closely fit NMLC core and have "v" sections underneath to aid lifting.

When boxing and labelling drill core, the following field procedures are required:

(i) All core must be boxed immediately on removal from the core barrel after logging of natural fractures.

(ii) A 50 mm length of polystyrene must be inserted at the left end of each division in the core box and labelled in metre units. For example, if the core commenced at 2.6 metres, the first division would contain 0.6 m of polystyrene then 0.4 m core, and the subsequent 50 mm polystyrene at the left end of divisions would be labelled 3 m, 4 m, 5m etc.

(iii) If the first division in the first core box is not completely filled, then polystyrene must be inserted where the core is absent (0.6 m in the above example). This length of polystyrene is labelled with the borehole number, the job number and the depth at which coring was started.

(iv) Rock cores must be placed in core boxes so that the core depth increases from left to right, and from the top of the box to the bottom of the box.

(v) Each core box must be labelled on the outside left end (same end as the depth markers inside) clearly stating :

a. The job number and borehole number on the left side (job number on top)

b. The depth: From x.xx m - To x.xx m (in the middle)

c. Box (number) of (total number for hole) on the right side.

Boxes of core must be stored only in a secure area and in conditions where the core, boxes and labelling are safe from damage or deterioration.

Photography

Good quality photographs of boxed core are required to be taken in the field after completion of each box. This applied particularly if core in the box is fractured. Such photos are a record of the core in its least disturbed state after being taken out of the core barrel sampler.

The following procedures are recommended:

(i) Cores are required to be wetted (e.g. using a fine sprayer) prior to photography.

(ii) Use of a high definition digital camera with a zoom lens and good flash.

(iii) A pegboard is required in the photo to label clear and concise information of the project. Information such as project description, Job No., BH number, drill run depths must be clearly stated.

(iv) Core boxes must be photographed under good even lighting conditions to minimise shadowing or distortion

(v) A colour chart must accompany the peg board details during photography. The colour bar must include the following colours (Pantone - Process Yellow, 335, Process Cyan and 192 colours)

(vi) Core box photographs must be in a line perpendicular to the centre of the core box to minimise distortion due to parallax. A zoom lens may be used to minimise distortion.

(vii) Photos must have a uniform clear background behind the core boxes

Sampling

Core samples are to be taken from the box after photographing, wrapped in plastic to retain moisture and labelled appropriately. Core sections taken from the boxed core are to be replaced by white strips of polystyrene marked ”Sample”

Core samples for UCS testing must be wrapped in plastic such as “Gladwrap”, or similar when:

(i) cores do not need to be soaked, and/or

(ii) cores are likely to change properties with drying (e.g. shale, laminite)

Logging and Checking

All borehole logs must be logged by or checked in detail against the core by a suitably qualified and experienced geologist or engineer, including non-core samples in accordance with AS 1726. Logging descriptions must comply with the requirements in this document.

Point Load Strength Testing must be in accordance with RMS Test Method T223: (Determination of Point Load Strength of Rock Specimen).

When the rock is such that its properties could change significantly in the core boxes, the logs are to be checked against the core as soon as practical after drilling

Surveying

All boreholes must be surveyed after drilling, even if the proposed location was surveyed prior to drilling. Minimum survey accuracy is to be 0.01 m vertically and 0.1 m horizontally.

On Completion of Drilling

Boreholes must be sealed to prevent injury to the public, animal stock or fauna.

Survey pegs are to be replaced and marked with spray paint.

The site must be restored in accordance with the approved EMP requirements.

E1.3.2 Rock Descriptions and Logging

Core logging descriptions are generally in accordance with AS1726 - 1993, except for descriptions of weathering which are enhanced by RMS geotechnical requirements. The differences in the terms used for weathering are discussed below. This section includes information on the preferred style of logging where ambiguity exists.

Weathering Terms

AS 1726 provides the following weathering terminology and their definitions as follows:

(i) Fresh (Fr) - Rock substance unaffected by weathering.

(ii) Slightly Weathered (SW) - Rock substance partly stained or discoloured. Colour and texture of fresh rock recognisable.

(iii) Moderately Weathered (MW) - Staining or discolouration extends throughout rock substance. Fresh rock colour not recognisable

(iv) Highly Weathered (HW) - Stained or discoloured throughout. Signs of physical or chemical alteration. Rock texture retained.

(v) Extremely Weathered (EW) - Rock texture evident but material has soil properties and can be remoulded.

The RMS system is based on changes to the colour of the rock, with an effort being made, as far as possible, to exclude strength from the classification. Suggested boundaries between classes are given below:

(i) Fresh - Completely unaffected by weathering, visually.

(ii) Fr to SW - Onset of discolouration along joints or bedding, extending into the rock substance (i.e. not a lining or coating on defects), discoloured patches in otherwise fresh rock or selective breakdown of

some minerals, leaving the remainder of the rock unaffected. There will often be a slightly "bleached" zone on the fresh side of the obviously discoloured material - the edge of this will mark the boundary to "Fresh" on the log.

(iii) SW to MW - Discolouration generally extends throughout the rock substance but it is still possible to detect the original colour of the rock. The rock substance is intact.

(iv) MW to HW - Similar to the above, but discolouration is so intense that it is no longer possible to determine the original colour of the rock. The rock substance is on the verge of break down i.e. becomes friable.

(v) HW to EW - Development of soil properties i.e. the rock is remouldable, as distinct from friable, but rock texture is still present and can be seen on freshly broken surfaces.

(vi) EW to Soil - Rock texture is no longer present on freshly broken surfaces.

Multiple terms may be used to describe the rock core where appropriate e.g. "MW/HW" or "MW to HW" which could apply for cases where the rock is transitioning between weathering grades.

Special care is required in logging cemented or indurated layers within (mostly) residual soils.

Strength Terms

Strength logs are to be based on interpolation between point load tests. In general the higher numerical Is(50) value between axial and diametral point load tests governs. Judgement is required where sections of core change strength. The logged strength must be consistent with the point load test results, unless there is an abnormality in the test which could cause the result to be invalid. The strength log is to be very detailed. Even narrow stronger or weaker bands may be very important.

Point load tests must be carried out immediately after the core is recovered. If testing is carried out at a later date this information is to be recorded on the log sheet noting the time and rock core conditions at the time of test.

The point load testing is performed on rock core with Is(50) less than 10 MPa for practical safety reasons. If the rock has strengths higher than this value, the log must indicate this fact as "> 10 MPa". Results of tests which are terminated at lower strengths before test break load failure of the core occurs are to be shown in a similar manner.

If the strength is consistently on or very close to a class boundary, mark-up of Is(50) result on the boundary line of such strength columns is permitted on the logs. The log must only show strengths over two or more columns if the rock is extremely variable as it is not practical to log the variations separately. If this is the case a comment is to be placed in the description column.

Defect Descriptions

Descriptions are based on AS1726 Table A10, which gives a comprehensive guide to defect explanations. Standard abbreviations are available for most features which are likely to be encountered. The remainder of this section deals with defect logging of drill core.

Defect ("fracture") logging is probably still the most difficult aspect of core logging and very open to subjective interpretation. The following notes are provided to enable consistency in defect ('fracture") logging of rock core.

For the description column in the log:

(i) angle to the plane normal to the core axis is to be recorded for each defect

(ii) use the standard abbreviations where possible

(iii) if most of the defects are of the same type, and quantity, it is acceptable to say "unless otherwise indicated, defects are ...". However, all exceptions are to be logged and all angles are to be logged individually.

(iv) EW rock (soil properties) must use "N/A" except under special circumstances.

The following information is provided to distinguishing natural and artificial breaks in rock core. There are a number of possibilities which cause such breaks:

(i) the break occurred during removal from the splits or afterwards. This is a handling induced break. Include in description as "handling break" (or "handling break on ..." if the core breaks on a cemented joint, cleavage or bedding parting, etc.). In the latter case the break is represented on the "visual" log as a dashed line.

(ii) clean breaks through the rock substance are almost certainly drilling induced and described as such. A dotted line is used to describe this break in the "visual" log.

(iii) breaks parallel to bedding planes, "bedding partings" or cleavage, where the opposite surfaces "match", are probably drilling induced, especially if (say) Fe-staining only partially covers the surface. A dashed line is used to represent the break in the visual log in this case.

(iv) "cemented" breaks (again, surfaces are to "match" and are completely covered by the cementing agent) are described as natural defects if they are broken when the splits are open. If they stay closed, the "visual" log must represent this condition as a dashed line and described as "closed" (e.g. "Jt 60° Fe closed").

(v) unground "non-matching" surfaces are logged as natural breaks. These are usually Fe stained and are likely to represent open defects in the rock mass.

(vi) "ground" surfaces (i.e. where core has spun inside the barrel and abraded the fracture surface) are noted as such and any available evidence used to decide what they originally represented. It may not be possible to describe the break with the above terminology in which case the term "origin uncertain" must be used.

(vii) "infilled" defects (i.e. containing soil e.g. clay, not EW rock) are logged as natural breaks whether they are open or not.

The "visual" log is to show all the logged defects, as indicated above, with their relative orientations and relationships being shown as far as practical. Traces are to go right across the column if the defect goes right across the core.

The "natural fracture spacing" log is interpretive. The log is to be based on defects interpreted as open insitu. It should be completed after the other parts of the defect log are finished and all the breaks in the core have been classified.

The spacing log should indicate lengths of core with an apparently similar fracture state. A section of core logged as one class can include isolated pieces of core which are one class longer or shorter than the rest. Such core must not be logged individually for spacing. If the core is broken into pieces on a class boundary the log must centre the column on the class boundary. If the core is broken into alternating lengths which are several classes different, it may be necessary to show the range of spacing and provide explanatory notes on the logs.

Where steeply dipping defects are encountered, spacing is measured along the core axis, not perpendicular to the defects.

The "natural" fracture spacing may be significantly affected by the quality of the drilling. Where the drilling process or drilling advance is a problem (e.g. drill string vibration etc.) this must be noted on the log to enable a better understanding and interpretation of the drill logs.

Changes in Core Properties

The information recorded is to represent the core as recovered. If significant changes occur after recovery but prior to core box storage, such changes are to be recorded as a note at the foot of the log or in the "comments" column adjacent to the affected length. Changes could include core drying, discing of laminate layers, rock breakdown, core colour changes on exposure etc. These changes may be critical for design, specification or contractual decisions.

E1.4 Sampling

Sampling must be carried out in accordance with Sections E1.1, E1.2 and E1.3

E1.5 Sonic Drilling

Under development. Adopt industry best practice.

E2 INSITU TESTING METHODS

E2.1 Dynamic Cone Penetration

In accordance with AS1289 cl6.3.2.

E2.2 Cone Penetration Testing

An investigation of low lying ground prone to settlement or instability under proposed fill embankments with particular emphasis on bridge approaches must be carried out using electric-friction static or piezocone cone penetrometer (termed CPT) probing (with appropriate dissipation testing).

The minimum number of CPT test locations is given in PS331 Section 3.8 "Minimum Scope of Investigations for Detailed Design". Sufficient test sites are required to fully investigate and define the extent of such areas and to allow data to be analysed in conjunction with the undisturbed sample test data from the drilling investigation.

Should this investigation identify the need for more intensive work in areas of high settlement potential, a further program of work to address this situation should then be recommended.

E2.3 Permeability testing

Under development. Adopt industry best practice.

E2.4 Insitu Stress Testing

Under development. Adopt industry best practice.

E2.5 CPTU Testing

E2.5.1 General

Scope

The technical requirements of the CPTU testing covers the determination of end bearing, pore water pressure and side friction developed during the steady slow penetration of electrical piezo-cone penetrometers into the soil and the monitoring of the dissipation of the excess pore water pressure generated at regular depth intervals. The CPTU testing must be in accordance with the Australian Standard

designation: AS 1289.6.5.1—1999 and Recommended Standard for Cone penetration Test, SGF Report 1:93E, Swedish Geotechnical Society June 15 , 1992, unless otherwise specified herein.

Safety

Refer to the project Work Health and Safety Management Plan Safety Plan for project specific requirements.

Particular care must be paid to the presence of overhead and underground utilities as outlined in the Work Health and Safety Management Plan

Ensure that traffic control is implemented in accordance with project requirements.

Environmental Considerations

Refer to the project Environmental Management Plan for project specific environmental controls.

When probing and drilling near a creek that feeds into a local water supply, take precaution to minimise the amount of drilling water reaching the creek. Also take particular care with fuels and oils.

At all sites, care is to be taken of indigenous vegetation and the clearing of trees and bushes. Where possible, test locations should be adjusted to account for mature trees or any sensitive vegetation. Clearing of vegetation is only permitted where specifically addressed within the project Environmental Management Plan.

E2.5.2 Apparatus

Selection of Cone

The cone is to be appropriate to the strata being tested:

(i) A high capacity cone (typically 100 MPa) is able to penetrate through stiffer / denser strata, but provides lower resolution for true “soft soils” – They are usually of inadequate resolution for accurate determination of shear strength in soft soils;

(ii) A lower capacity cone (5 to 25 MPa) will reach refusal in medium dense or dense sands and stiff clays, but provides more accurate data in “soft soils”. These soft soils commonly govern stability and settlement and require more accurate definition. A well calibrated 25 MPa cone will usually be of sufficient resolution for most soils except some very soft sediments.

A combination of two (or more) cone types may be required within a project subject to the direction of the RMS Representative.

Equipment Specification and Calibration

The penetrometer tip must have the basic configuration of the electric cone penetrometer with a friction sleeve and a filter element. The cone must have a 60 degree point angle and a nominal base diameter of 35.7 mm resulting in a projected area of 10 cm^2. The friction sleeve must have the same outside diameter as the base of the cone and a surface area of 150 cm^3. The filter element used for measuring the pore water pressure must be located immediately above the conical part of the tip. The cone must have a net area correction ratio no greater than 0.78 and no net sleeve correction.

The outer push rods must be made of suitable steel and must have a section adequate to sustain, without buckling, the thrust required to advance the penetrometer tip. They must have an outside diameter not greater than the diameter of the base of the cone for a length of at least 0.3 m above the top of the friction sleeve. They must screw or attach together to bear against each other and to form a rigid-jointed string of rods with a continuous, straight axis. The deviation from the axis should not exceed 4% for the lower five push rods of the series and 8% for the remainder.

The thrust machine must be capable of proving a continuous stroke over a distance greater than one rod length at a constant rate of 20 ± 5 mm/s. It must be able to exert a thrust of at least 25 kN.

The CPTU cone apparatus and measuring system must be regularly calibrated between each testing project and during large test programmes, at least every third month. The calibration must be in accordance with the requirements from manufacturer and the procedures of NATA.

The sensing devices for measuring the cone resistance, the pore water pressure and the friction resistance must be designed in such a way that eccentricity of these resistances and ambient temperature cannot influence the readings. The precisions of these sensing devices must be limited to the values in Table PS331/E2 and must be verified by regular calibration.

Table PS331/E2 CPTU calibration values

Cone Capacity (MPa)	Tip Resistance (kPa)	Friction Resistance (kPa)	Pore Water Pressure (kPa)
5 to 25	20	2	1
100	100	10	10

Taking into account of all possible sources of error (parasite frictions, errors of measuring devices, eccentricity of the loads on the cone and the sleeve, temperature effects, etc.) , the accuracy must be better than:

(i) ±2% of the typical measured value (the average value) for any of the soil layers (in thick homogeneous soil layers, this refers to 1 m thick depth intervals) , in which the results are to be interpreted in terms of classification and soil properties

(ii) ±1% of the measured values for static pore pressures.

E2.6 Prior to Commencing Testing

If testing is to be carried out on private property, approval must have been obtained (in writing) prior to commencing fieldwork. Ensure that all follow up actions and access requirements are adhered to.

(i) Determine exact position of CPTU.

(ii) Confirm the required probe resolution or requirements for side-by-side testing;

(iii) If testing cannot be carried out at designated position, note position of selected alternative site in relation to the original site.

(iv) If underground services exist and their position cannot be accurately determined, the location must be excavated with a hand auger or shovel to the appropriate depth to ensure no danger exists of services being damaged by drilling.

Prior to the commencement of testing, CPTU contractor must submit the details of equipment used and method statement for the specific testing, including programme, together with all cone and measuring system calibration documentation within the last 12 months.

E2.7 Procedures

E2.7.1 Setup

The thrust machine should be set up so as to obtain a thrust direction as near as possible to vertical. The deviation of the initial thrust direction from vertical should not exceed 2 degrees and push rods should be checked for straightness.

Zero Load Compensation

The filter element used for measuring pore water pressure must be thoroughly de-aired prior to testing. During the assembly of the cone before each test, the filter element and all fluid spaces of the piezo-cone must be fully filled with light motor oil or another suitable fluid. Precautions must be taken to maintain full saturation of the filter and the other spaces of the measuring system after assembly and during the execution of the piezo-cone penetration tests.

After the piezo-cone is assembled, the probe must be completely submerged in water. It must then be connected to the data-logger and must be left to stabilise for a minimum of 15 minutes.

A set of initial readings with the penetrometer tip hanging freely in the water, out of direct sunlight, and after the initial stabilising period must be recorded.

The output of the sensors at zero load can be sensitive to changes in temperature. Zero load readings are to be recorded both at the start and end of each CPT.

The final set of zero load compensation readings are undertaken at the end of a sounding and after extracting the cone from the test hole. These are undertaken as for readings prior to testing. The final set of datum readings is to be as at the outset and compare the initial and final datum readings. The test readings must be corrected using the after test datum readings if the difference between the two sets of datum readings is greater than 10% of the initial set.

Pre-drilling

Advancing the piezo-cone with the de-aired filter element through the upper layers of the unsaturated soils without pre-drilling must be avoided. If the upper portion of the hole does not remain open, then temporary casing must be used to ensure that the cone can be safely inserted to water table while maintaining saturation (using a plastic sheath to cover the tip during insertion). If measurement is required for the upper crust layers, a solid cone without the piezo-element should be used.

For penetration in fills or hard soils it may also be necessary to pre-drill in order to avoid damaging the cone. Pre-drilling, in certain cases, may be replaced by first pre-punching a hole through the upper problem material with a solid steel dummy probe with a diameter slightly larger than the cone.

Cone Penetration

The testing procedure must be that of continuous penetration testing, in which the measurements are made while all elements of the penetrometer tip have the same rate of penetration. The standard rate of penetration is 20 mm/s. Readings intervals to be no more than 200 mm. Data is to be collected at intervals not exceeding 25 mm.

The information obtained during penetration must include the cone resistance, pore water pressure, friction resistance, and inclination of the cone, penetration depth and the time. The readings must be recorded digitally on the data logger or a computer.

Pore Water Pressure Dissipation Monitoring

Dissipation testing is used to measure the decay of excess pore water pressure over time. Excess pore water pressures are induced around the cone during testing. When testing is paused the excess pore water pressures will dissipate. Eventually the initial or hydrostatic pore water pressure will be restored. This can be almost instantaneous (sandy soils) or take several hours (high plasticity clays). The information that dissipation tests provide are consolidation coefficients and permeability parameters.

Dissipation testing must be undertaken at locations within clay soils. Dissipation test locations must be untaken either:

(i) At predetermined depths based on nearby investigation data (with confirmation of suitable strata during test progress); OR

(ii) On the basis of conditions encountered during the testing:

If no specific test requirements have been provided, two dissipation tests are to be undertaken at each CPTU location (subject to suitable conditions being encountered). Dissipation depths should be staggered between adjacent test locations.

During dissipation tests a plot of excess pore pressure versus log time is to be monitored (either via digital display or hand plotting if required). The dissipation test is to continue until the plot "turns" (excess pore pressure decay rate slows down on log time scale). The dissipation monitoring at each level must not be terminated prior to 50% of the excess pore water pressure has been dissipated, unless instructed by the RMS Representative.

Final Datum Readings

At the end of a sounding and after extracting the cone from the test hole, obtain a final set of datum readings as at the outset and compare the initial and final datum readings. The test readings must be corrected using the after test datum readings if the difference between the two sets of datum readings is greater than 10% of the initial set.

Test Termination

The cone penetration test terminated once the probe reaches refusal, when the rods behind the cone cannot be advanced further due to resistance developed along the rods or when the rig reaction limit has been obtained (either due to lifting of the rig, or limit of hydraulic thrust). The probe is then withdrawn from the ground and a series of zero datum readings are recorded.

Ensure that the test location is pegged and clearly labelled for subsequent survey.

Photography

Photographs are to be recorded of each test site, illustrating the location of the test site relative to the general surrounding topography and features, and condition of the site upon rehabilitation (as required).

E2.8 Report

Recorded data for the cone penetration will be presented in the form of graphs and tables of, cone resistance (qc), friction resistance (fs), pore water pressure (u), corrected total tip resistance (qt), pore pressure parameter ratio(Bq) and friction ratio (Rf%),versus depth in metres together with a graphical log showing the classification of the soils encountered . The combined plots must be presented with depth in metres in one sheet. (A3 size). The soil classification must be in accordance with the method adopted in Robertson, P.K. (1990)," Soil classification using the cone penetration test" Canadian Geotechnical Journal, 27(1)151-8.

The pore water pressure dissipation monitoring data will be presented in the form of graphs as pore water pressure versus square root of time and as percentage of dissipation versus log time. The depth of the dissipation test and the hydrostatic groundwater table level should also be recorded.

Apart from the graphical and tabulated presentation of the test results, all test data must be provided digitally in both Excel spreadsheet file as well as stored in AGS format suitable to be retrieved for plotting using gINT version 7 or above. The digitized test data must be clearly labelled and tabulated.

AGS Digital Format must be a data format that complies with Appendix 1 of the third edition (1999) of the Association of Geotechnical Specialists (AGS) publication 'Electronic Transfer of Geotechnical Data from

Ground Investigations'. Each copy of the report, including the Master Copy, must contain in an AGS and Excel data disk.

The test report must be submitted within 2 week after the field test completed and must also include:-

(i) Name and location of the job.

(ii) Date of sounding and sounding number.

(iii) Elevation and co-ordinates of sounding position if available.

(iv) Elevation of the natural water table.

(v) Any other pertinent details. (particularly observations of adjacent ground conditions, topography and surface water)

E3 GEOPHYSICAL INVESTIGATION METHODS

E3.1 Seismic Refraction

Seismic lines will be used to investigate proposed road cutting locations, but may be used for other design items, for example embankments or bridge foundations. Some seismic line locations may be adjacent to the existing main carriageway/highway, either within the road reserve or close by, in adjacent properties.

In general seismic lines would be set out parallel to the proposed road alignment with transverse lines which may be perpendicular to the proposed road alignment or parallel and perpendicular to the geological strike. Site restrictions may mean that these ideals may not apply at all locations. In some cases seismic lines may be set out parallel and perpendicular only to the geological strike.

Minimum lengths of lines would be half a 24 channel spread (12 channels) at 55 m for a 5 m geophone spacing (33 m for a 3 m geophone spacing), but mostly minimum one 24 channel spread (115 m and 69 m for 5 m and 3 m geophone spacing respectively). The lengths of individual lines may be restricted by:

(i) the extent of the investigation area (proposed cutting) in the orientation tested.

(ii) site constraints.

curvature of the alignment necessitating adjoining of short straight seismic line segments.

E3.2 Gravity and Micro-Gravity

Under development. Adopt industry best practice.

E3.3 Multispectral analysis of Surface Waves

Under development. Adopt industry best practice.

E3.4 Down-hole Survey

Under development. Adopt industry best practice.

E3.5 Acoustic Televiewer

Under development. Adopt industry best practice.

E3.6 Optical Televiewer

Under development. Adopt industry best practice.

E4 INSTRUMENTATION AND MONITORING

Under development. Adopt industry best practice.

E4.1 Standpipes

E4.2 Settlement

E4.3 Inclinometers

E4.4 Extensometers

E5 LOGGING AND DESCRIPTION OF GEOTECHNICAL MATERIALS

Refer to Section E1.3.2 for rocks and Section E1.1 for soils.

E6 LABORATORY TESTING

Unless already specified in this specification, adopt RMS test methods in the first instance, then Australian Standard test methods then industry best practice.

E6.1 Classification

E6.2 Earthworks

E6.3 Soil Strength and Compressibility

E6.4 Rock Strength

E6.5 ASS/ASR

E7 GEOTECHNICAL DESIGN AND PERFORMANCE REQUIREMENTS

The design of new slopes and new geotechnical structures must satisfy the geotechnical design and performance requirements in Figure PS331/E1. The following diagram shows which geotechnical works are covered in this annexure. For tunnel projects, specific geotechnical design and performance requirements refer to PS333 Geotechnical Investigation and Design for Tunnels.

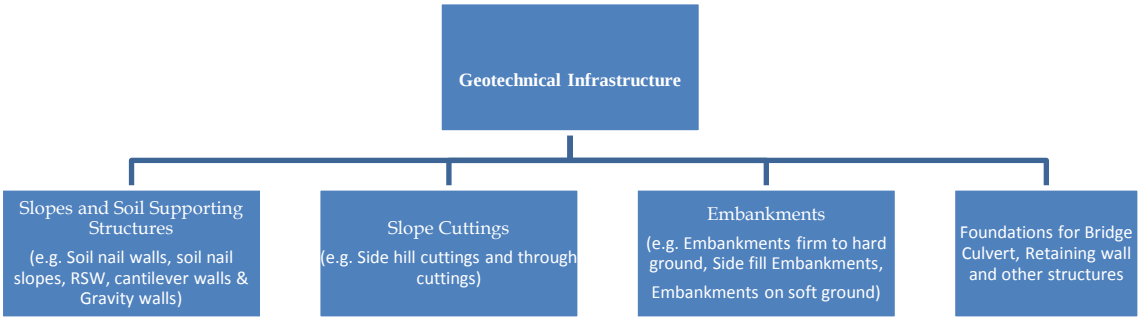

Figure PS331/E1 Geotechnical design covered in Annexure PS331/E

E7.1 General

The effects of the designed structure must not adversely impact on adjacent infrastructure, existing structures (e.g. buildings, dwellings) or utilities (telecommunications, gas, water etc.).

E7.1.1 General Design requirements

The standards, specifications and other relevant engineering design documents used in the design should be documented. Generally these may include the following, in decreasing order of priority:

(i) RMS documents (This specification, Technical Directions, RMS QA Specifications and the like)

(ii) Australian Standards

(iii) Relevant national and international practices

The PSC should also liaise with RMS's Representative and relevant stakeholder to define/confirm the constraints that the project could be subjected to, whether from design, construction, maintenance or other points of view.

The PSC requires integration of interdisciplinary objectives, such as functionality, durability, maintenance, aesthetics and safety into the design.

All design assumptions are to be included in the drawings for appropriate verification during construction by suitably qualified personnel.

E7.1.2 Loads and load combinations

The imposed loading on the design elements should be agreed with RMS's Representative, or as specified in this specification, and appropriate to the intended use of the structure and design life.

The geotechnical loading should be estimated in accordance with the assessed material parameters, support conditions and problem geometries. Appropriate water pressures, piezometric pressures and phreatic design levels should be established from the site investigation, monitoring results or similar.

The load combinations should be defined for the various design conditions. For example, for maximum bearing loads on the foundation of gravity L-shaped retaining walls the live/construction loads should extend to above the top of the walls, whereas for maximum slide force on the wall bases these loads directly above the wall base should be omitted.

Designs for the long and short term conditions are different and these must be considered.

E7.2 Soil and slope supporting structures

Soil and slope supporting structures include but not limited to soil nail walls and slopes, reinforced soil walls, gravity retaining walls, cantilever retaining walls, anchored walls, reinforced soil slopes, unreinforced soil slopes and embankments on soft ground.

E7.2.1 General

(i) Reinforced earth wall structures must be designed in accordance with RMS R57.

(ii) Basal reinforced embankments, including piled embankments on poor ground consisting of firm or weak soil layers, must be designed in accordance with BS 8006 (2010). Refer to Section PS331\E7.5

(iii) The maximum foundation settlement is to be limited to 50 mm for retaining walls.

(iv) The maximum deflection of retaining walls is to be limited to 1/150 of retaining wall height.

(v) Where existing retaining structures are affected, their stability and deformation must be assessed and documented, and where required strengthening measures are to be designed to conform to the performance requirements of this annexure.

(vi) Unprotected gabion walls are not to be used within 4 m of the carriageway. The design must consider the need to restrict public access and prevent vandalism.

(vii) Type F safety barrier must not be used as a retaining structure.

E7.2.2 Loading

(i) For soil supporting structures other than those referred in E7.2.1(i), the following limit state load combinations must be considered:

a. Load Combination A

- permanent effects and nominal live load.

b. Load Combination B

- permanent effects and the most critical transient load (i.e. only 1 transient load at any time);

- transient loads include, but not limited to, earthquake load with annual probability of exceedance of 1 in 500, traffic impact load, traffic braking load, wind load and rapid drawdown load.

(ii) A minimum nominal vertical live load of 20 kPa for strength and stability and 10 kPa for settlement calculations (over the carriageway) must be allowed for in the design soil and slope structures. Where soil and slope structures neither retain road embankments nor support structures and where there is no possibility of these being constructed in the future, the minimum nominal loading allowed for in the design for strength and stability may be reduced to 10 kPa and zero for settlement calculations.

Construction loads are to be considered separately where necessary. Beneficial effects of traffic loads must be excluded in the design.

(iii) Vehicle impact loading should be considered in the design when applicable, and must conform to AS5100 for the various crash barrier systems.

E7.2.3 Design Mechanisms

The design of soil and slope structures must consider and address, but not be limited to, the following geotechnical failure mechanisms, both internal and external to the structures:

a. Ultimate Limit States:

- bearing failure;
- sliding failure;
- rotational failure; and
- global slip failure.

b. Serviceability Limit State:

- settlement and lateral movement;
- tilting and rotation;
- differential settlement.
- Eccentricity should be limited to the middle third of the wall base for soil foundations and middle half for rock foundations

E7.2.4 Design Criteria

(i) Soil and slope supporting structures, other than those referred to in section E7.2.1 (i) and (ii) must be designed and constructed in accordance with AS5100 except that:

a. the geotechnical strength reduction factors for all load combinations for strength and stability design must comply with Table PS331/E2 instead of Table 13.3.1(A) of AS5100.3, except stated otherwise in the Table.

b. the acceleration coefficient ‘a’ referred to in AS 5100.2 must be replaced by the Hazard Factor ‘Z‘ as defined in AS 1170.4.

c. wall frictional angles and adhesion should be considered with the design demonstrated to be conservative. The PSC may refer to section 5.11 of the “Guide to Retaining Wall Design, 1993, published by the Hong Kong Government” for guidance on these values.

d. base shear resistance should be considered with the design demonstrated to be conservative. The PSC may refer to section 5.12 of the “Guide to Retaining Wall Design, 1993, published by the Hong Kong Government” for guidance on this value.

e. calculations of earth pressure must comply with Section 6 of the “Guide to Retaining Wall Design, 1993, published by the Hong Kong Government”.

f. the design ground water level must be one which has a return period of 1 in 10 years, except as outlined below. The determination of the design ground water level must consider storm response as well as seasonal response. The design ground water level , where information is available, must be one of the following cases, whichever is more critical:

- a 1 in 10 year return period storm rise added to a typical wet season ground water level , or;
- a typical storm rise added to a 1 in 10 year return period seasonal rise;

Alternatively, the design groundwater table may be taken as one at least 2m above the maximum observed ground water table or at one third of the retaining height as a minimum, whichever is the more conservative.

Where applicable, the PSC should consider the effect of an accidental flood case in the event where localised high pressure utilities have become compromised and have induced rapid flooding.

When checking stability during rapid drawdown, the water table within soil and slope structures must correspond to a 1 in 100 year event. Where a flood case needs to be considered for design, the PSC must establish the design flood level based on available data for the return flood period and as agreed to by the client.

g. AS 5100.3 Clause 13.3.1 on provision of over-excavation is to apply only to bored pile type of cantilever retaining walls, not to L-shape cantilever or other gravity retaining structures.

h. unless otherwise specified, provision for future utility excavation at the toe of the structures is not required. Appropriate notes in the drawings to ensure stability of these structures are to be included when such excavation by others is needed.

i. for gravity retaining walls, the beneficial effect of passive earth pressures exerted on the walls must be excluded in the check against sliding stability.

j. slip surface analyses must be carried out to identify the most critical slip surface for each design load combination specified in Clause 22.3 of AS5100.2 and:

- the design geotechnical shear strength along the complete slip surface must be determined using the ultimate geotechnical shear strength multiplied by the relevant geotechnical strength reduction factor in Table PS331/E2;
- the design geotechnical pull-out strength of soil reinforcements and ground anchors must be determined using the ultimate strength and the corresponding geotechnical strength reduction factor;
- the design structural strength of geosynthetic reinforcements must be determined in accordance with Section 5.3.3, Annexure A and Annexure D of BS 8006 (1995);
- the design strength of soil reinforcements or ground anchors must be the lower of the design geotechnical pull-out strength and the design structural strength;
- the combined design geotechnical shear strength along the slip surface and design strength of soil reinforcements/ground anchors must be capable of maintaining all the critical slip surfaces in a stable condition;
- simultaneous occurrence of more than 1 transient effect is not required to be considered in the slip surface analyses.

(ii) Stability of soil slope structures during construction must be considered. A maximum Geotechnical Strength Reduction Factor (ϕg) of 0.83, equivalent of minimum factor of safety (FOS) of 1.20 may be deemed to be satisfactory for intermediate construction stages, however, the minimum acceptance criteria should include the consideration of the nature, extent and duration of the immediate stages, the consequence of failure, details and extent of risk management with contingency plan, degree of emergency and other factors. A set of appropriate acceptance criteria for each intermediate construction stage, taking into account all relevant facts must be established and stated in the Design Documentation.

(iii) Structures affected by the soil and slope structures must be designed to accommodate all movements associated with these structures over their design life. The maximum movements of all soil and soil supporting structures supporting traffic must be the smaller of 0.5% of the retained height of the

structure or those deformation criteria stipulated for road pavement designs and/or road embankments applicable under the serviceability limit state criteria specified elsewhere in the this Specification.

(iv) Assessment of foundation conditions, design criteria, design calculations, geotechnical models, geotechnical investigation report and geotechnical interpretation report must be presented in the design documentation.

Table PS331/E2 - Range of Values of Geotechnical Strength Reduction Factor (ϕ_g) for Soil and Slope Structures

Load Combination Case	Range of values[1] of ϕ_g			
	Bearing and passive capacity	**Restoring moment contributed by gravity force and non-passive pressure**	**Shear strength in sliding and slip surface analyses.**	**Pull-out strength of soil reinforcement (excluding ground anchors)**
A	0.35-0.50	0.50	0.65	0.5
B	0.30-0.65	0.65	0.80	0.65

Notes: (1) If designing for a bridge structure, then use Table 13.3.1(A) of AS 5100.3. The adopted ϕg values need to be addressed clearly in the Design Statement Report

E7.2.5 Drainage considerations

(i) The design of soil and slope structures must address all drainage issues associated with the structures, including provisions for cleaning and maintenance of the drainage infrastructure. Drainage must be provided behind any facing panels provided on soil and slope structures.

(ii) Soil and slope structures must be provided with suitable free draining backfill and / or drainage systems to ensure there is no build-up of water pressure behind the structure. Full width geotextile must be provided behind the facing panels provided on soil and slope structures where the base of these structures is below the level of the design flood event.

(iii) All earth retaining structures carrying water mains or similar utilities within their influence zones are to consider the effect of accidental rupture of such utilities.

(iv) Where a gravity retaining wall abuts hillside or is located in an area where water may enter the structure from behind and water pressure is neglected in the design :

a. a full height drainage layer must be provided at the back of the structure.

b. where the height of the structure is greater than 3 m the drainage layer must comprise a suitable granular filter material complying with Cl 5.4 of RMS R57 wrapped with a synthetic filter and separation fabric complying with RMS R63;

c. where the height of the structure is 3 metres or less the drainage layer must comprise either:

- a suitable granular filter material complying with Cl 5.4 of RMS R57 wrapped with a synthetic filter and separation fabric complying with RMS R63; or
- a prefabricated cellular material wrapped with a synthetic filter and separation fabric complying with RMS R63.

d. surface water must be collected and discharged by a separate surface water drainage system, which must discharge to the stormwater drainage system.

(v) The drainage systems should be designed to be primarily self-cleaning with minimum maintenance and with provision for maintenance and flushing where considered necessary.

E7.2.6 Unreinforced Slopes

(i) Unreinforced soil slopes and extremely low / very low strength weathered rock slopes must be designed for stability with the maximum Geotechnical Strength Reduction Factors (ϕg) of 0.65 (equivalent of minimum factor of safety (FOS) of 1.50) and 0.80 (equivalent of minimum FOS of 1.25) for Load Combinations A and B respectively as per Section E7.2.2 (i), unless otherwise agreed with RMS. The design ground water level must be determined in accordance with Section E7.2.4 (i) (f).

(ii) The extremely low /very low strength weathered rocks could be susceptible to surface erosion and the design must include consideration for durability and for suitable surface protection to conform to the design life requirement of the structures.

E7.3 Cuttings

A cut or cutting could be made in natural or man-made materials.

E7.3.1 Design Requirements

(xi) The geotechnical design must address the key issues for formation of the cuttings during the design, construction and for safe and easy maintenance throughout their design life, and these issues include but not limited to:

a. cutting geometry, benching and stability;

b. slopes adjacent to cuttings;

c. presence of landslides including the existence of landslide debris;

d. weathering (both on the cutting surface and at depth)

e. fracture, slippage and rock falls;

f. unplanned tree growth;

g. rock/cut face stabilisation and batter treatment provisions;

h. erosion, scour and scour protection;

i. drainage around, into, within and out of the cuttings; springs and groundwater (including stability of cuttings, water quality, drawdown

ground water recharge); and impacts on water resources;

j. traffic/construction loads;

k. traffic safety;

l. excavatability and constructability;

m. monitoring and validating that the predicted ground movements meet the performance requirements; and

n. maintenance requirements and safe access provisions.

(xii) Batters in cuttings must be designed to satisfy the following criteria:

a. The overall batter slope must be stable with no foreseeable possibility of failure involving the whole or a major part of the slope;

b. slope stability in soil or rock must be based on detailed synthesis of geological/geotechnical data, materials testing and soil/rock mechanics analysis. For soil and weathered rock slopes, the stability is to be designed in accordance with the requirements of Section E7.2.6. The various critical cut slope failure mechanisms must be assessed in the design and documented in the design report.

c. Batters must be designed so that materials which may become detached is prevented from reaching the road shoulder. Appropriate batter stabilisation treatment should be provided where required.

(xiii) Benches must be provided on batter slopes in accordance with the requirements of Table PS331/E3, to restrict the length of unbroken batter face and to minimise erosion of soil and weathered materials. Ponding on the slope benches must be avoided. Where ponding is possible and the slope materials are subjected to softening from excessive soaking then appropriate protection of these materials must be provided to facilitate drainage and to avoid slope instability.

(xiv) Bench widths must be designed to accommodate safe access for maintenance plant items and to control runoff.

Table PS331/E3 Bench requirements on cut batters

Batter Slope	Vertical Spacing Between Batters	Bench Width
Steeper than 2:1 H:V	Maximum 7 m	Minimum 4.5 m
2:1 H:V or flatter	Maximum 10 m	Minimum 4.5 m

(xv) Designs for cutting batters must include:

a. Logic for selection and application of batter protection for:

i. soft seams;

ii. shattered, fractured or jointed rock;

iii. degradable rock; and

iv. stress release in rock cuts.

b. A schedule of estimated quantities for the various cutting batter protection systems proposed.

c. Details on drainage provisions

(xvi) Cut batter designs must detail the required surface condition and roughness of cut batters and include:

a. details on measures to control water flow and runoff and to minimise erosion of soil and weathered materials; and

b. methodologies to apply and retain topsoil and seed.

(xvii) Cutting batter designs must detail measures to prevent erosion of material from the seams in cuttings that are prone to rapid weathering

(xviii) Except for transitions at the ends of cuts, batter slopes must not lie between 0.75:1 (H:V) and 1.5:1 (H:V).

(xix) An appropriate rock catch fence to RMS standard must be provided on the lowest bench in cuttings where the batter above the lowest bench is steeper than 1.5H:1V.

(xx) Cut batters must be laid back and curved at the ends, for a minimum 50m length, to reflect the influence of the subsurface profile and to blend in with adjacent slopes.

(xxi) Except where identified otherwise in the Detailed Design Drawings cut batter slopes must be 2H:1V or flatter.

(xxii) The batter durability and protection protocol must be used in determining the requirements for batter protection and stabilisation treatments.

E7.3.2 Performance Requirements

Batters must be constructed to conform to the design requirements and the batter tolerances in RMS R44. The Contractor must undertake a survey of the completed batters within 4 weeks of completion of construction of the adjacent section of pavement and provide a baseline batter profile against which to monitor batter changes.

Cut batters must be designed so that localised deviations, movements and changes in the batter surfaces, over any area do not exceed the batter limits detailed in Table PS331/E4 during the Design Life of the batters.

Table PS331/E4 Cut batter limits

Year After the Date of Construction Completion	Maximum limit of localised deviations, movements and changes in batters (relative to the baseline batter profile)
1	100 mm
2	125 mm
3	150 mm
4	175 mm
10	200 mm
100	300 mm

E7.4 Embankments

This section on embankments applies to fill embankments constructed on generally firm to hard ground, side fill embankments adjacent to hillsides or steep terrain and side fill embankments adjacent to existing road embankments (i.e. road widening). For design and performance requirements for embankments constructed on compressible foundation materials and foundations for other structures, refer to Sections E7.5 and E7.6 respectively.

E7.4.1 Design Requirements

(i) The geotechnical design will consider and address all the issues that will affect or be affected by the embankments during the construction and operation of the structures over the design life of the works, and these include but not limited to the following:

a. embankment heights and stability;

b. slopes/structures affected by the proposed embankments;

c. surface water and groundwater impacts;

d. embankment foundations and settlements;

e. sub-surface drainages on side slopes, subgrade, cut to fill transitions and surface drainages;

f. materials and internal compression;

g. moisture conditions;

h. erosion, scour and scour protection;

i. maintenance requirements and access provisions;

j. traffic/construction loads.

(ii) The geotechnical design of embankments must design:

a. to be globally and locally stable with no foreseeable possibility of a failure involving the whole or a major part of the embankment, and it must satisfy all requirements specified in this Section. The design will detail the proposed methods for the treatment of all embankment foundations, including requirements to key into side slopes and at cut to fill transitions;

b. batter slopes and benches stability in accordance with Section E7.2;

c. to have a minimum embankment height for main carriageways and ramp embankments, from the natural surface to the underside of pavement of 1 m, except for cut to fill transition zones which must be treated in accordance with RMS R44, and for embankments over Compressible Foundation Materials, as defined in section E7.5.1(i), which must have a minimum embankment height from the natural surface to the underside of pavement of 1.5 m;

d. except for rockfill batters or on rock-faced embankment batters, to provide benches on all embankment batters in accordance with the requirements in Table PS331/E5. The benches must be designed to satisfy the requirements of the proposed maintenance methodology.

e. all embankment batter slopes are to be 2:1 (H:V) or flatter. The exceptions are rock protected batters and abutment spill through batters, which requires rigorous stability analysis.

Table PS331/E5 Bench requirements on embankment batters

Batter Slope	Vertical Spacing Between Batters	Bench Width
Steeper than 2:1 H:V	Maximum 7 m	Minimum 4.0 m
2:1 H:V or flatter	Maximum 10 m	Minimum 4.0 m

f. the settlement and lateral deformation of embankments for pavement performance only, including predictions of:

i. Total Settlement which is defined as the total amount of settlement of the embankment, at any location on the embankment, that occurs in the period from the commencement of embankment construction until the date which is the minimum Design Life of the pavement after the Date of Construction Completion;

ii. Total Residual Settlement which is defined as the total amount of settlement of the pavement, at any location on the pavement surface, that occurs in the period from the completion of pavement construction until the date which is the minimum Design Life of the pavement after the Date of Construction Completion;

iii. Differential Settlement which is defined as the total change in grade of the pavement over any distance, at any location on the pavement surface, that occurs in the period from the completion of pavement construction until the date which is the minimum Design Life of the pavement after the Date of Construction Completion; and

iv. Lateral deformation of embankments and foundations at the interface with all structures affected by embankments, including:

- Total Lateral Deformation which is defined as the total amount of lateral movement of the embankment or foundation, at the affected structure, that occurs in the period from the commencement of embankment construction until the date which is the minimum Design Life of the structure; and
- Total Residual Lateral Deformation which is defined as the total amount of lateral movement of the embankment or foundation, at the affected structure, that occurs in the period from the commencement of structure construction until the date which is the minimum Design Life of the structure after the Date of Construction Completion.

g. the strain rate for evaulatimg internal compression of compacted embankment fill shall be taken to be minimum of 0.15% of the thickness of embankment fill per log cycle of the time, unless otherwise justified;

h. the assessment of options and design the solution for limiting or accelerating settlement;

i. the methodology for verifying, monitoring and validating that predicted residual settlements, differential settlements and lateral movements meet the performance requirements;

j. surface, subsurface and batter drainage, including where embankments are designed to settle, measures and methodologies proposed to maintain drainage capacities and efficiencies;

k. erosion and scour protection and stabilisation;

l. intervention levels for maintenance and/or repair; and

m. access provisions for safe maintenance and repair.

n. the impacts of embankment materials, dewatering, drainage and pore water pressures on embankment foundations. It must be noted that reliance on site inspections by geotechnical personnel to determine drainage requirements is not acceptable. The designer must determine and specify the drainage requirements on the drawings following rigorous study of the site topography, geology, hydrogeology and the location of the proposed embankments.

E7.4.2 Performance Requirements

(i) Level and shape changes in the pavements and embankment are to be limited to the following, including all those resulting from settlements of the embankment foundations, changes in moisture conditions and internal compression of fill materials within the embankments:

a. no increase in level after the construction of the pavements;

b. decrease in level following the construction of the pavements to a maximum of 20 mm over any twelve month period;

c. decrease in level following the construction of the pavements to a maximum of the greater of 50 mm or 0.35 % of the embankment heights measured at carriageway centrelines; and

d. differential settlements in any direction of a maximumof 0.3 %.

e. Satisfy the design flood immunity requirements

f. The total lateral ground deformation conforms to the structural requirements of structures

g. The total and differential settlements conforms to the surface and subsoil drainage design requirements

(ii) Where considered necessary, monitoring plan for verifying and validating the predicted residual settlements, differential settlements and lateral movements is to be included in the design reports and drawings.

E7.5 Embankments on Compressible Foundation Materials

E7.5.1 Design Requirements

(i) Embankments on compressible foundation materials where anyone of the requirements in Section E7.4.2(i) is not met without the application of specific embankment foundation improvement techniques then:

a. assess foundation improvement options in accordance with the Geotechnical Design Statement Report and the Option Report, whenever available, that optimises the road pavements and other design elements with regard to their types and maintenance requirements; and

b. estimate the predicted total, residual, differential and lateral deformations

c. comply with the performance requirements of section E7.5.2

(ii) The overall stability of embankments is to be assessed as embankments on normal ground as outlined in Section E7.2. The failure mechanisms of foundation extrusion and lateral sliding have to be assessed in accordance with Section 8 of BS8006 (2010).

(iii) All ground improvement design including piled embankments on compressible foundation materials must be designed in accordance with BS 8006 (2010). In addition to the loads specified therein, a nominal earthquake loading with an annual probability of exceedance of 1 in 500 must be included and addressed in the design. For earthquake load cases, the partial load factor for external live load may be reduced to 0.6.

(iv) All ground improvement design must consider the installation effect and ensure the integrity of the installed structural elements. In the design of foundations for piled embankments, the enhancing effect of the sliding resistance of the foundation soils may be utilised as described in Section 8.3.3.3(b) of BS 8006 (2010). Potential pile displacement in any direction due to soil displacement resulted from subsequent pile installation must be allowed for in the design. The amount of allowable pile displacement in any direction must be specified in the design drawings and verified upon completion of all pile installation.

(v) Notwithstanding of the aforementioned Standard for design, the design strength and anchorage of geosynthetic soil reinforcement must be determined in accordance with BS 8006 (1995).

E7.5.2 Performance Requirements

(i) Main Carriageway and Ramp embankments constructed on top of compressible foundation materials, as defined in Section E7.5.1 (i) above, must comply with the pavement performance criteria in Table PS331/E6 including pavement drainage, road geometry, ride quality, except for the section of bridge approach slabs where the settlement is to be limited to 50 mm.

(ii) The bridge approach slabs must be a minimum of 6m long.

Table PS331/E6 Pavement performance criteria

Pavement Type	Maximum Total residual Settlement	Maximum change of grade in any direction
Concrete Pavement	100mm in 40 years	0.3% over 40 years
Heavy Duty Flexible	200mm in 40 years	0.5% over 40 years

(iii) Notwithstanding the pavement performance criteria in Table PS331/E6 above, the design must also:

a. limit the total residual settlement within 20 m of the bridge abutments to 50 mm in 40 years.

b. Where the length of pavement constructed above compressible foundation materials is less than 50 m then the differential settlement is to be limited to a maximum of 0.3 % and the total residual settlement limited to a maximum of 50 mm.

c. Refer to E7.4.2(i) e, f and g.

E7.5.3 Design of bridge abutments affected by embankments

(i) Where depth of soft soils exceeds 3 metres at the bridge abutments, raking piles must not be used to support the abutments.

(ii) Down drag (negative skin friction) effects due to settlement on piles must be considered for in the design. The total residual lateral soil movements must not be greater, at any point during the design life of the piles, than those designed for this effect.

(iii) Where structures or utilities exist within the influence zone of these embankments the design must assess the impacts of ground movements and construction on such structures or utilities, and design mitigation measures when these impacts are excessive. The impact statement and acceptable tolerances for such structures and utilities must be developed in liaison with the relevant stakeholders.

(iv) The total settlement, residual settlement, differential settlement and lateral movement as described in E7.4.1 at any point along the structures shall be defined to occur within the period from the commencement of structure construction until the date which is the minimum design life of the structure; and these movements/settlements, including those induced by nearby embankments, must be compatible with the respective structure serviceability limits which must be stated in the design report.

E7.5.4 Instrumentation Monitoring Requirements

(i) Main Carriageway and Ramp embankments constructed above compressible foundation materials, as defined in Section E7.5 above, or at sites affecting structures or utilities, or at other locations as requested by the Client, will include instrumentation to measure the internal settlement, external settlement, pore water pressure and lateral movement of the ground and embankments, and the deformation of the utilities and affected structures

(ii) The PSC must provide a plan that details the scope of monitoring on settlement and stability of the embankments above compressible foundation materials or other locations as requested by RMS. The monitoring plan must include, but not limited to, the extent and type of instrumentation, their construction details, monitoring frequency, interpretation and reporting requirements. Trigger levels for each type of instrumentation and associated responsive actions are also to be included for each instrumented embankment.

(iii) Upon RMS request, the PSC, must review the monitoring data, confirm, and amend with corrective actions on, where necessary, the performance predictions documented in the Design Report.

a. the instrumentation monitoring plan must consider the following: appropriate instrumentation at spacing of less than 100 m along the embankment axis, and at the structure/utility sites along their centreline and within ten metres of both sides of the structures, is needed. Settlement monitoring instrumentation will include at least three settlement plates and a hydrostatic profile gauge (HPG) at where the predicted total settlement exceeds 100mm and or the predicted total residual settlement exceeds 50mm; HPG can be omitted if the predicted settlements are less than these limits.

b. in addition to the above, the PSC must include in the design drawings showing survey measurement pins:

- at 10 m intervals along the nearside edge line of both north and south bound carriageways within 100m of the bridge abutments ; or along the centre line of and within 10m of both sides of the culvert, and
- at each location where settlement plates are present

c. the monitoring plan must document baseline surveys and measurements to be completed within 4 weeks of the completion of construction of the pavement. Survey and measurements must be undertaken thereafter at 6 monthly intervals until the Date of Construction Completion, or until three successive measurements confirming the design requirements are met, whichever is the later.

d. the monitoring plan must document that all instrumentation installed for monitoring of the settlements of the embankments and pavements must be maintained by the monitoring Contractor until the Date of Construction Completion, or until three successive measurements confirming the design requirements are met, whichever is the later, and

e. provide RMS with an up to date monitoring and interpretation results and recommendation

E7.6 Foundations for Bridge, Culvert, Retaining Wall and other Structures

This section provides specific geotechnical design requirements for bridges, culverts, retaining walls and other structures. The design must address on the following:

(i) identify and include all information available in the design for each new structure, and for protecting all existing structures and utilities.

(ii) consider the structural adequacy, long term deformation and durability of the foundation,

(iii) design the foundations to suit the performance requirements of the structures.

(iv) All structures constructed within the compressible materials as defined in E7.5 must have a monitoring plan as per E7.5.4.

E7.6.1 Design Requirements

The geotechnical design for structure foundations must consider the following:

(i) unless otherwise stated the designs must be in accordance with AS5100,

(ii) Identify and assess any aggressive ground or groundwater conditions that may be potentially harmful to the foundation and its structural elements to achieve the required design life.

(iii) Where the soil and soil supporting structures are susceptible to damage by tree root actions, the design must eliminate the growth of such trees within the active zone of the structures.

(iv) Where the structures are subjected to the influence of compressible foundation materials the design requirement as listed in Section E7.5.3 must be used.

E7.6.2 Pile Caps and Footings

The top of pile caps and footings must be located at a minimum depth of 0.5 m below the finished ground level.

E7.6.3 Pile Foundation Analysis and Design

The geotechnical design where appropriate, must include the following design elements:

(i) Presentation of relevant structural and geotechnical loadings and load cases

The PSC must consider both the serviceability and ultimate limit state loads and load cases in the design.

(ii) Geotechnical Models

Geotechnical models are to be developed for each foundation site based on all the findings including site investigations, field and laboratory tests. Where appropriate, models for both longitudinal and transverse directions, or any suitable orientations, may be needed to suit the design for analysis.

(iii) Selection of Pile Types

The PSC must critically review the feasible pile options in the Option Report. Where such options are not available rigorous development of a most suitable pile type is to be undertaken to suit the requirements of the site conditions and be compatible with the superstructure requirements, and other site and project constraints.

(iv) Calculation of Pile Ultimate Capacities

The PSC must determine the ultimate geotechnical capacities for the chosen piles, appropriate for the loads and ground conditions, and consider them in the geotechnical design in terms of R_{ug} consistent with the nomenclature of AS 5100, Bridge design, and $R_{d,ug}$ as in AS 2159, Piling – Design and installation. Where appropriate to the ground conditions and/or the structure requirements, loads such as uplift or negative skin friction may also need to the considered in the derivation of these capacities. Where pile buckling is deemed to be a concern, this must be communicated to the structural engineers for further studies and evaluation.

The adopted geotechnical reduction factor values of Φg in the derivation of the above capacities must be in accordance with AS 2159, and stated in the design.

In selecting the geotechnical reduction factors for design of the pile capacities, the designer must consider their compatibility with a proposed construction and pile wall support method. It should be pointed out that deviation from this assumption may significantly affect the pile capacity design. This assumption must be stated in the construction drawing for verification.

(v) Trial Pile or Pile Group Geometry

The PSC must recommend, in consultation with the structural engineer, a suitable pile arrangement for each pile group for analysis and for selection of trial piles for testing.

(vi) Analysis of Piles or Pile Groups

The PSC must analyse the piles or pile groups for the adverse ultimate limit state load combinations to determine the pile design action effects.

(vii) Determination of Pile and Pile Cap Deflections

The PSC must determine the total and differential deflections of piles and pile groups, at any location and direction, under the serviceability load cases and checked against allowable values for compatibility. The calculated results together with the allowable values must be included in the geotechnical design for review and verification.

(viii) Geotechnical and Structural Assessment of Piles and Pile/Pile Cap Connections

The PSC must use adverse load combinations to determine the geotechnical and structural design action effects on the piles to ensure that the piles can withstand the ultimate design action effects. Due consideration must also be given to piles which could be subjected to scour.

(ix) Geotechnical and Structural Design of Pile Caps

The PSC must use adverse ultimate limit state pile load combinations to determine the design action effects on the pile caps by using soil/rock parameters appropriate to the ground conditions. The results are to be communicated to the structural engineer for structural design. Iterations between the structural and geotechnical calculations may be needed for optimisation purposes.

(x) Driveability and Capacity Assessment of Pile – Driven Piles

The PSC must determine the pile types, pile geometries and then ascertain that the piles can be driven to the proposed founding levels without compromising the pile integrity. The PSC must also ensure

that the required pile capacities and deformation performance could be achieved at such levels. Where complication exists, the PSC must specify the installation requirements to overcome the complications and to suit the ground conditions. Test piles should be considered in such instances. The PSC must also specify the pile driving parameters associated with the proposed piling equipment.

(xi) Pile Tests

For piles other than driven preformed piles, consideration should also be given to the need for pile testing to confirm pile capacity and/or integrity. The PSC is to refer to AS 2159 for various types of pile load testing.

Testing of bored cast-in-place concrete piles for integrity and geotechnical strength must comply with the requirements of Bridge Technical Direction BTD 2011/08.

E7.6.4 Precast arch structures

(i) The design of precast arch structures must assess and address foundation stability, settlements, including differential settlements, and foundation treatment requirements, where required.

(ii) The design must also assess and address loads that could be induced during the construction of the arch structures, such as differential loading due to variation of backfill levels, asymmetric construction traffic loading and the like.

E7.6.5 Noise barrier structures

Noise barriers and support systems must comply with RMS R271, Design and Construction of Noise Walls. Concrete work must be in accordance with the requirements of RMS B80, Concrete Work for Bridges. Steel components must comply with the requirements of RMS B241, Manufacture of Minor Steel Items, and be hot dip galvanised in accordance with the requirements of RMS B220, Protective Treatment of Steelwork.

E7.6.6 Culvert

(i) The PSC is to ensure there are adequate and relevant site investigation information for assessment and design of the culvert foundation. Where this condition is not satisfactory, additional site investigation must be undertaken prior to the detailed design.

(ii) The design of culvert structures must assess and address foundation stability, settlements, including differential settlements, and foundation treatment requirements.

(iii) The differential settlement have to be assessed and designed to suit the long term structural and drainage performance in accordance with AS5100 and relevant part of the project Brief.

(iv) The construction sequence, including the backfill sequence, must be specified to ensure that the structural and drainage capacities are not compromised over the culvert design life.

(v) Culvert constructed in compressible materials as per E7.5, the residual settlement as defined in E7.6.1 at any point along the culvert at the design invert level must be limited to 100 mm over 100 years after construction. The differential settlement must be limited to the design structural or hydraulic tolerances, whichever is more stringent.

(vi) For culvert located over soft ground, ground treatment may be required and the design must conform to the requirements given in E7.5 above. Monitoring plan for the ground and the structure in the vicinity of the culvert is required as stipulated in E7.5.4.

ANNEXURES PS331/F - L – NOT USED

ANNEXURE PS331/M – REFERENCE DOCUMENTS & SUPPORTING INFORMATION

M1 DESIGN REFERENCE DOCUMENTS

Roads and Maritime Technical Directions and Quality Alerts

Roads and Maritime Design Guides

Roads and Maritime Standard Drawings

Roads and Maritime Specifications

Austroads Guides

Australian Standards

Urban Design

Software Programs

M2 REFERENCE DOCUMENTS

M3 SUPPORTING INFORMATION

1. *Macquarie Park Stage 1 Geotechnical Interpretative Report*
2. *Macquarie Park Bus Priority Program (Stage 2) Factual Report - Geotechnical Investigation*