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Acid Sulphate Soils and Groundwater Assessment

Cobaki Estate - Concept Plan (MP06_0316 Mod 8) SEAR Response

Prepared for LEDA Manorstead Pty Ltd
27 September 2018

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SMEC Company Details

Approved by:	JON ALEXANDER		
Address:	Level 1, 832 Southport-Nerang Rd, Nerang, QLD, 4211, Australia		
Signature:			
Tel:	(07) 5578 0200	Fax:	-
Email:	Jon.alexander@smec.com	Website:	www.smec.com

Cover Photo: Cobaki Estate taken from proposed Precinct 5 looking South towards Precincts 6,7 and 8.

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1 Introduction

1.1 Background

Leda Manorstead have applied for a modification of the existing Concept Approval of the Cobaki Estate (MP 06_0316 MOD 8). The proposed modification would involve the following modification to the Concept Plan and Height Controls Plan approved under Concept Approval 06_0316:

- Reduced town centre in Precinct 5 with:
  - Portion south of approved connector road retained; and
  - Portion north of approved connector road replaced with residential uses.
- Amended height controls to enable development with maximum height not to exceed height of finished level of:
  - In Precinct 5: Adjoining ridgeline/knoll in land zoned Environmental Protection Area to the north.
  - In Precincts 11, 12, 15 and 17: Adjoining ridgeline/knoll in land zoned Environmental Protection Area to the west.

The NSW Department of Planning and Environment have issued the Secretary's Environmental Assessment Requirements (SEARs) in response to the initial application. This report is a specific response to the following sections of the SEARs:

Requirement 15

Provide updated:

- *Acid Sulphate Assessment and Management Plan; and*
- *Groundwater Assessment*

Requirement 9

- *Consider consequences for, and incorporate actions to, complement the ongoing management of the saltmarsh rehabilitation areas located within the development precinct.*

The location of precincts within the site is illustrated in **Figure 1.**

1.2 Previous Studies and Management Plans

Detailed Acid Sulphate Soil (ASS) investigation have been undertaken across the majority of the Cobaki Estate site which is below 5m AHD. These investigations were undertaken to support ASS Management plans delivered as a requirement of various approval conditions relating to the development. These plans have been assessed and approved by Tweed Shire Council. Relevant plans are:

- ASS Investigation and Management Plan for Precincts 1,2,6 and the Central Open Space Area. (SMEC, 2012)
- ASS Investigation and Management Plan for Precincts 7-12 (SMEC 2016)

Similarly, Groundwater Investigations have also been undertaken and Management Plan prepared. These include:

- Groundwater Investigation and Management Plan for Precincts 1,2,6 and the Central Open Space Area. (SMEC, 2012)
- Groundwater Investigation and Management Plan for Precincts 7-12 (SMEC 2016)

Copies of these approved plans have been lodged previously with the NSW Dept of Planning as part of various Mod applications.

These plans are provided for reference in **Attachments 1 and 2**.

Figure 1 - Development Precinct Layout

2 Impacts of the Proposed Modification

The proposed modification has two distinct components:

- The reduction of the size of "Town Centre" within Precinct 5 and a conversion of the landuse in this area to residential development, and
- Amended height controls to permit taller construction in some areas of the site.

The impacts these proposed changes on may have on ASS and Groundwater are discrete and are addressed separately in the following sections.

2.1 Precinct 5 Landuse Changes

The changes proposed with regard to this aspect of the modification application are largely related to changes in the nature of the final development form from commercial to residential. This change may ultimately see a reduction in the amount of commercial buildings constructed and an increase in residential construction. This part of the modification appears highly unlikely to result in any significant change in the previously identified potential impacts on ASS and groundwater. Potential impacts are generally associated with direct disturbance during construction, particularly during bulk earthworks.

Correspondingly the management actions proposed in the already approved plans are still considered the most suitable approach for management of ASS and Groundwater.

2.2 Changes to Height Limits

Changes to height limits are proposed in a number of precincts; these are noted in Section 1.1 and illustrated in **Figure 2**.

Many of the areas proposed for changes are topographically elevated. This factor limits the potential for these areas to have potential for the presence of ASS and for future works to intercept groundwater. The approximate elevations are summarised in **Table 1** below.

Table 1 - Approximate Elevation of Height Control Areas

PRECINCT	APPROXIMATE AVERAGE ELEVATION (METRES AHD)	POTENTIAL FOR ASS	POTENTIAL FOR GROUNDWATER INTERCEPTION
9	13m	Low	Low
13	86m	Nil	Nil
16	74m	Nil	Nil
15	13m	Low	Low
17	12m	Low	Low
5	7m	Moderate	Moderate
4	30m	Nil	Low

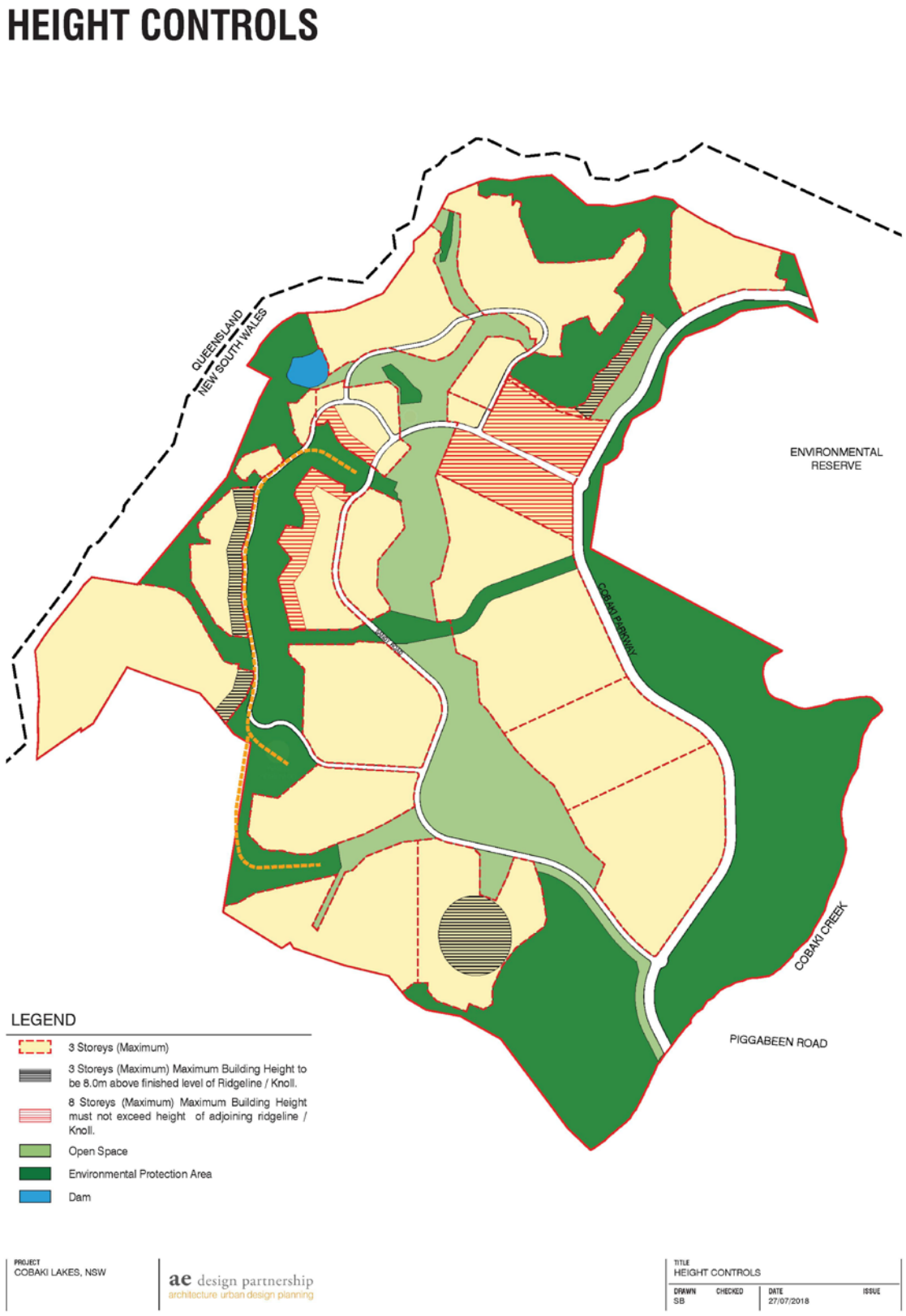

Figure 2. Areas of proposed change to Height Controls

Based on the elevations of the proposed height control areas the only area which may have any potential for impacts to ASS and Groundwater would be the lower lying areas of Precinct 5. Potential impacts in this area would only be associated with construction related excavation which went below 5m AHD. It should be noted that the lower lying areas of Precinct 5 have been previously assessed for ASS and Groundwater impacts as part of the preparation of the previously discussed ASS and Groundwater Management Plans (Section 1.2)

As this modification application calls for a broad landuse change and does not propose any specific structures or detailed design it is not possible to assess specific impacts which could occur as part of future construction at this point. However, the management actions proposed in the existing approved ASS and Groundwater Management plans are considered appropriate for the management of any future construction phase issues with ASS and Groundwater.

2.3 Impacts on Saltmarsh

The proposed modification generally relates to areas at the Northern end of the site with a separation of at least a kilometre from the nearest point of the Saltmarsh rehabilitation area. The proposed modification to the concept plan in these areas (Precincts -13,15,16,17, 4 and 5) is highly unlikely to have any influence on the ecological function of the Saltmarsh rehabilitation area. The area within development Precinct 9 which is subject to the modification application immediately adjoins the North West boundary of the Saltmarsh rehabilitation area.

The proposed changes appear unlikely to result in a net increase in the amount of impervious surface in the Cobaki Estate and correspondingly any changes in stormwater runoff are considered likely to be minor. Any potential increase in stormwater volumes would be managed through adjustment to the design of the stormwater treatment chain. Development Precinct 9 is elevated to a level that would be highly unlikely to contain ASS or to have groundwater flows which would have a hydrologic influence on the Saltmarsh Rehabilitation Area. The proposal to increase building height to 3 storeys in Precinct 9 is considered highly unlikely to have any influence of the ecological function or rehabilitation of the Saltmarsh rehabilitation area.

3 Conclusion

The changes proposed by the modification application are highly unlikely to result in any impacts to ASS and Groundwater that have not been assessed and addressed through previously approved management plans. The changes proposed are changes to built form and development zoning (Commercial to residential). These changes will still see development in areas previously approved for that purpose, albeit in a different form.

Most of the areas proposed for modification are outside areas which contain ASS or are likely to have groundwater flows close to the surface which could be influenced by construction. The proposed modification application does not propose changes which would introduce new impacts that have not been previously addressed.

Appendix A ASS Management Plans

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Cobaki Estate
Acid Sulfate Soil Management Plan

Precincts 7-12

April 2016

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1. INTRODUCTION

This Acid Sulfate Soils Investigation and Management Plan (ASSMP) has been prepared by SMEC Pty Ltd for LEDA Manorstead Pty Ltd for Precincts 7, 8, 9,10,11 and 12 within the proposed development known as the Cobaki Estate. The Cobaki Estate Development is located west of the Tugun Bypass and Gold Coast Airport, Tweed Heads. The proposed development is bound by the Queensland and New South Wales border to the north and west and Piggabean Road to the south. The site adjoins Cobaki Creek and Cobaki Broadwater to the east.

The site exists in its current state as a large portion of cleared land, which was previously cleared for agricultural purposes (cattle grazing), and scatterings of native vegetation communities.

This report specifically pertains to Development Precincts 7, 8 , 9, 10, 11 and 12. These precincts occur in the southern portion of the Cobaki site and consist of land described as Lot 1 DP 562222, Lot 1 DP 570077, Lot 2 DP 566529, Lot 1 DP 823679, Lots 46, 54, 55, 228 & 305 DP 755740. Precincts 7 – 12 cover a total area of approximately 132 hectares (33 ha, 17 ha, 22.6 ha, 22 ha, 15ha and 22 ha respectively).

The location of Development Precincts 7-12 with respect to the Cobaki site is shown in Figure 1.

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1.1. Acid Sulfate Soils

ASS are a characteristic feature of low lying coastal environments in eastern Australia, particularly where landform elevations are below 5m AHD. ASS are comprised of iron sulfides generally in the form of pyritic material that is a product of the natural interaction between iron rich organic matter and sulfate rich seawater present in anaerobic low energy estuarine environments. Undisturbed, these soils are generally present in an anaerobic state within the subsurface profile (below the water table) of Holocene marine muds and sands in the form of potential acid sulfate soil (PASS). Actual acid sulfate soils (AASS) are the oxidised (disturbed) form, which may occur as the result of natural or anthropogenic disturbance from changes in groundwater levels and/or exposure to oxygen.

ASS in an undisturbed environment may have a pH of neutral or slightly alkaline and no visual appearances indicating its acidic potential. However, when exposed to air either by direct excavation or by indirect changes to the surrounding water table, pyritic material inherent in the soil matrix is oxidised by sulfur oxidising bacteria leading to the formation of sulfuric acid. Following rainfall, sulfuric acid associated with soil oxidation can then be released into surface runoff and receiving waters and mobilised in groundwater, resulting in mortality of aquatic flora and fauna and deterioration in ecosystem health as well as impacts on structures and existing infrastructure.

In addition to acidification of receiving waters, the acidic environment of the soils and/or receiving waters have the potential to mobilise metal contaminants (particularly aluminium and iron). These metals become soluble under acidic conditions and are readily leached from the soil profile by catchment runoff or groundwater flows. Therefore runoff or drainage water from uncontrolled or inadequately managed exposed acid sulfate soils has the potential to significantly impact upon flora, fauna and ecosystem health.

1.2. Scope of Works

This report provides an assessment of the acid sulfate soils (ASS) investigation undertaken at the site and management guidelines for the excavation of or the construction over ASS and PASS where present within the project Development Precincts 7, 8 and 9.

Figure 1 – Locality Plan

2. METHODOLOGY

2.1. Desktop Analysis

The desktop assessment consisted of:

- Review existing Acid Sulfate Soils Risk Mapping, completed by Department of Infrastructure, Planning and Natural Resources, NSW;
- Reference of NSW Planning and Assessment Guidelines (1998);
- Reference to NSW Acid Sulfate Soils Manual (1998);
- Assessment of the topographical and geological characteristics of the study area; and
- Assessment of the risk of intercepting ASS during construction;
- Review of National Acid Sulfate Soils Mapping by ASRIS (2007); and
- Review of site survey undertaken by Michel Group Services 16/7/2015.

2.2. Field Investigations

To determine the extent of ASS within the project area, 96 boreholes (AS136-AS234) in precincts 7 and 8 and 5 boreholes (AS115 to AS119) in precinct 9 were drilled using Jacro 200 4WD mounted drilling rig. The boreholes were drilled to 2m where natural materials were encountered at surface and samples were taken at 0.25m intervals over the depth of the borehole. Where existing filling was encountered on the site boreholes were extended to at least 1m below the existing filling and samples were taken at 0.25m to 1m below the fill/natural transition. Where residual clays/extremely weathered rock was intersected sample were not taken. The stratigraphy of the boreholes was logged, noting changes, colour of differing strata along with other relevant properties.

Fieldwork was carried out during the months of October and November 2013 (Precinct 9) and July and August/Sept 2015 (Precincts 7- 12) under the supervision of an experienced geotechnical professional from SMEC. The investigations were carried out in general accordance with the following documents and policies:

- AS1726-1993 Geotechnical Site Investigations, and,
- New South Wales (NSW) Acid Sulfate Soils Management Advisory Committee, Acid Sulfate Soils Planning Guidelines, 1998.

All soils samples recovered during the fieldwork were stored in a chilled cooler box for transport to the laboratory. Acid Sulfate borehole logs are contained in Appendix B.

2.3. Laboratory Analysis

All samples (646 no.) from the 101 boreholes were collected and sent for laboratory analysis. Analysis included:

- pH_f and pH_{fox}, and,
- Chromium Reducible Sulfur (CRS).

3. RESULTS

3.1. Desktop Analysis findings

3.1.1. General

A review of existing mapping from Australian Soils Resource Information System (ASRIS) Google Earth Plugin (Updated 20/07/07) and the 9541S1 Bilambil Acid Sulfate Soil Risk Map Edition 2 (1997) published by Department of Natural Resources NSW from shows variation in the probability of occurrence of ASS or PASS is likely to be present across the site. *Figure 2* and *Figure 3* show the proposed precinct boundaries overlain on the ASRIS and Bilambil Maps respectively.

Additionally site survey was undertaken by Michel Group Services which mapped all surface contours across the site where surface RLs are less than 5m AHD.

3.1.1. Precinct 7

Precinct 7 is shown as being almost entirely within the Low Probability of occurrence of ASS or PASS with some areas of High Probability at the southern boundary in both *Figure 2* and *Figure 3*. The site survey undertaken shows that the entire precinct is below RL5m AHD.

3.1.2. Precinct 8

Precinct 8 is shown as having Low Probability of occurrence of ASS or PASS over the western half with High Probability of occurrence over the eastern half, and southern portion in the case of *Figure 2* only. The site survey shows that the entire precinct is below RL5m AHD.

3.1.3. Precinct 9

Figure 2 generally shows approximately 45% of large portion of Precinct 9 is generally located in terrain where ASS or PASS are not expected. And approximately 45% in areas with Low Probability in the north-west corner of the precinct, and very small amounts of High Probability areas around the north east and east precinct perimeter.

Figure 3 shows that the majority of the precinct is in an area where ASS or PASS are not expected with small amounts of the precinct boundaries encroaching on Low Probability to the north west and High Probability of occurrence to the north east and east.

Based on the site contours the refinement of this areas is possible due site observations and the elevations being above RL5m AHD which is generally consistent with the Bilambil map. The underlying geology is the basement rocks underlying the Tweed Shire, described as the Neranleigh-Fernvale Beds (1:250,000 Geological Sheet SH 56-3, Tweed, 1972). This is the material observed currently being removed from the Precinct 9 as borrow material.

3.1.4. Precinct 10

Precinct 10 is shown as being almost entirely within the Low Probability of occurrence of ASS or PASS with some areas of Higher Probability at the northern end of the precinct in both *Figure 2* and *Figure 3*.

3.1.5. Precinct 11

Precinct 11 is shown as being almost entirely within the Low Probability of occurrence of ASS or PASS with some areas of Higher Probability at the eastern end of the precinct in both *Figure 2* and *Figure 3*. The site is generally above 5m AHD with the exception of the section to the east of "Sandy Lane"

3.1.6. Precinct 12

Similarly, Precinct 12share an almost identical topography with Precinct 11 and is shown as being almost entirely within the Low Probability of occurrence of ASS or PASS with some areas of Higher Probability at the eastern end of the precinct in both *Figure 2* and *Figure 3*. The site is generally above 5m AHD with the exception of the section to the east of "Sandy Lane"

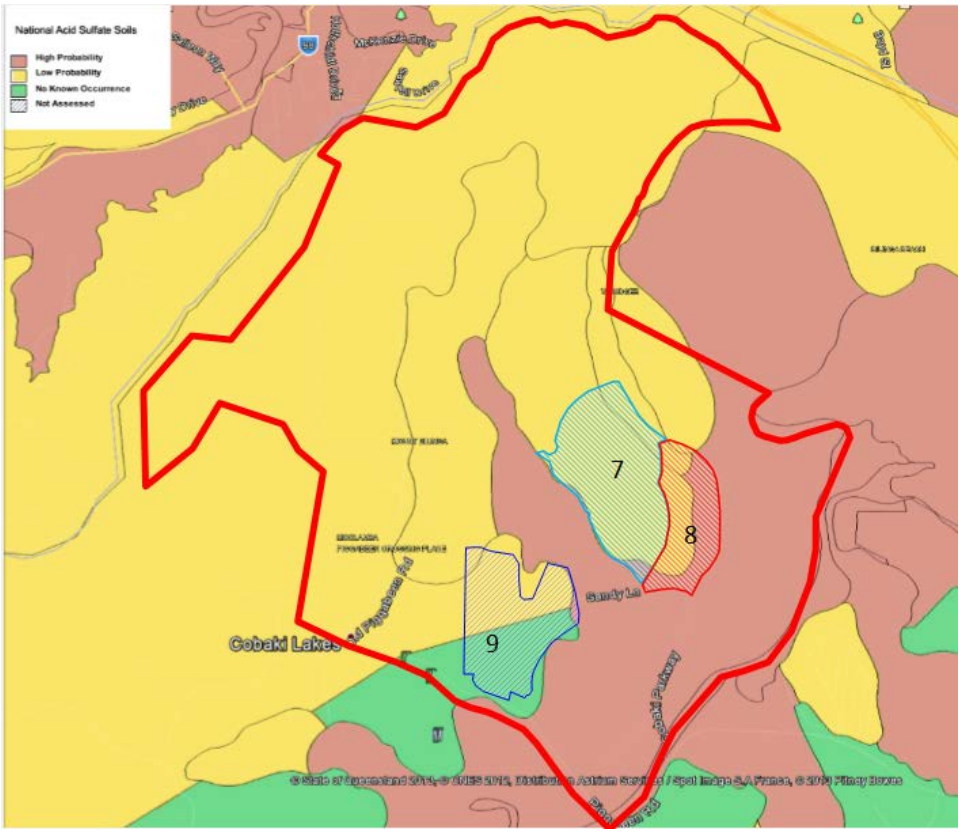

Figure 2 – Acid Sulfate Soil Risk Distribution - ASRIS 2007

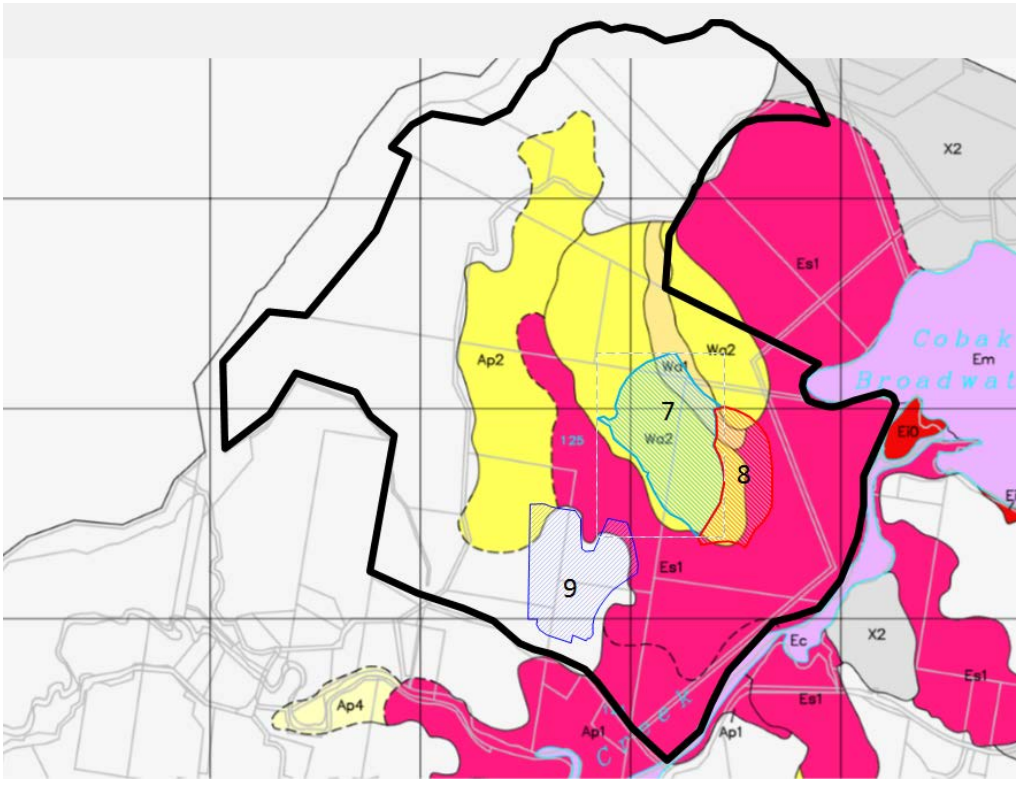

Figure 3 – Acid Sulfate Soil Risk Distribution - Bilambil Edition 2 1997

3.2. Laboratory Test Results

3.2.1. Soil Testing

The soil samples were sent to the laboratory, Bio-Track Pty Ltd for a staged testing program. Qualitative testing (pH_f and pH_{fox}) was undertaken on samples collected at 0.25m intervals. Quantitative testing (CRS) was subsequently carried out on samples collected at 0.5m intervals.

The action criteria triggering management plans for ASS and PASS disturbance are presented in Table 1.

Table 1 – Action Criteria Triggering Management Plans for ASS and PASS Disturbance

Texture/ Soil type	Clay Content (%)	1-1000 Tonnes Disturbed Soil		>1000 Tonnes Disturbed Soil	
		Sulfur Trail (%S)	Acid Trail (M H+/t)	Sulfur Trail (%S)	Acid Trail (M H+/t)
Coarse – Sands/Loamy Sands	<5.0	0.03	18	0.03	18
Medium – Sandy Loams/Light Clays	5-40	0.06	36	0.03	18
Fine – Medium – heavy Clays/Silty Clays	>40	0.10	62	0.03	18

Field Screening

Filed screening test results are assessed against pH levels to indicate the presence of Actual Acid Sulfate Soil (AASS) and Potential Acid Sulfate Soil (PASS). These indicator levels are as follows:

- pH field (pH_f) <4.0 indicates Actual ASS (AASS);and
- pH oxidised (pH_{fox}) < 3.0 indicates Potential ASS (PASS).

The field screening test results included:

- pH field (pH_f) ranged from 3.4 to 7.4
- pH oxidised (pH_{fox}) ranged from 1.0 to 6.3

These results indicate that some Potential Acid Sulfate Soils (PASS) and some Actual Acid Sulfate Soils (AASS) may be present on the site.

Quantitative Analyses

CRS suite testing and analyses were subsequently undertaken to quantify the potential and acid hazard within selected samples. The levels that trigger the requirement for appropriate management plans are presented in Table 1. With reference to this table, the extent of earthworks proposed within Precinct 7, 8 and 9 exceeds 1000 tonnes of disturbed soil, hence the following triggering levels:

- Net Acidity (%S) > 0.03%
- Total Actual Acidity (M H^+/t) >18

The quantitative results included:

- Actual Sulfide (S_{Cr}) levels ranged from below the Limit of Reporting (LOR) (<0.01 %S) to 0.71%S,.
- Total Actual Acidity ranged from below laboratory detection limits (<1 moles H^+/t) to 131 moles H^+/t, and was 25.24 moles H^+/t on average.

A summary of the quantitative testing can be found below in Table 2, Table 3 and Table 4. Laboratory test certificates for all screening and analytical testing are presented in Appendix C.

Table 2 – Acid Sulfate Soil Analysis Summary Laboratory Test Results Precinct 7

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS136	250	500	0	<0.01	0.001
AS136	750	1000	0	<0.01	0.002
AS136	1250	1500	10	<0.01	0.018
AS136	1750	2000	**73**	<0.01	**0.12**
AS137	0	250	**25**	<0.01	**0.045**
AS137	500	750	1	<0.01	0.003
AS137	1000	1250	**54**	<0.01	**0.09**
AS137	1500	1750	**29**	<0.01	**0.051**
AS138	250	500	0	<0.01	0.002
AS138	750	1000	0	<0.01	0
AS138	1250	1500	**29**	<0.01	**0.05**
AS138	1750	2000	**67**	<0.01	**0.113**
AS139	0	250	11	<0.01	0.022
AS139	500	750	0	<0.01	0.002
AS139	1000	1250	0	<0.01	0.002
AS139	1500	1750	0	<0.01	0.003
AS140	1850	2100	**24**	<0.01	**0.038**
AS140	2350	2600	**43**	<0.01	**0.074**
AS141	250	500	8	<0.01	0.017
AS141	750	1000	1	<0.01	0.006
AS141	1250	1500	**51**	<0.01	**0.087**
AS141	1750	2000	**42**	<0.01	**0.072**
AS142	0	250	8	<0.01	0.014
AS142	500	750	0	<0.01	0.001
AS142	1000	1250	**46**	<0.01	**0.079**

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS142	1500	1750	**23**	<0.01	**0.041**
AS143	250	500	0	<0.01	0.002
AS143	750	1000	12	<0.01	0.02
AS143	1250	1500	10	<0.01	0.02
AS143	1750	2000	**58**	<0.01	**0.093**
AS144	250	500	1	<0.01	0.002
AS144	750	1000	0	<0.01	0
AS144	1250	1500	4	<0.01	0.006
AS144	1750	2000	**48**	<0.01	**0.08**
AS145	1500	1750	**19**	<0.01	**0.034**
AS145	2000	2250	**72**	<0.01	**0.12**
AS146	0	250	**48**	<0.01	**0.08**
AS146	500	750	5	<0.01	0.01
AS146	1000	1250	5	<0.01	0.009
AS146	1500	1750	**67**	<0.01	**0.115**
AS147	0	250	15	<0.01	**0.027**
AS147	500	750	0	<0.01	0.002
AS147	1000	1250	0	<0.01	0.001
AS147	1500	1750	**45**	<0.01	**0.074**
AS148	250	500	0	<0.01	0
AS148	750	1000	3	<0.01	0.005
AS148	1250	1500	**77**	<0.01	**0.126**
AS148	1750	2000	**95**	<0.01	**0.154**
AS149	250	500	0	<0.01	0
AS149	750	1000	0	<0.01	0
AS149	1250	1500	15	<0.01	**0.027**

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS149	1750	2000	14	<0.01	**0.026**
AS150	0	250	**20**	0.02	**0.052**
AS150	500	750	0	<0.01	0.001
AS150	1000	1250	0	<0.01	0
AS150	1500	1750	7	<0.01	0.011
AS151	1600	1850	0	<0.01	0
AS151	2100	2350	**22**	<0.01	**0.036**
AS152	1250	1500	**54**	<0.01	**0.093**
AS152	1750	2000	**58**	<0.01	**0.096**
AS152	250	500	6	<0.01	0.012
AS152	750	1000	1	<0.01	0.01
AS152	250	500	6	<0.01	0.012
AS152	750	1000	1	<0.01	0.01
AS152	1250	1500	**54**	<0.01	**0.093**
AS152	1750	2000	**58**	<0.01	**0.096**
AS153	0	250	5	<0.01	0.012
AS153	500	750	**115**	<0.01	**0.189**
AS153	1000	1250	**82**	<0.01	**0.14**
AS153	1500	1750	**61**	<0.01	**0.098**
AS154	0	250	3	<0.01	0.007
AS154	500	750	2	<0.01	0.008
AS154	1000	1250	**34**	<0.01	**0.055**
AS154	1500	1750	**45**	<0.01	**0.077**
AS155	0	250	15	<0.01	0.028
AS155	500	750	8	<0.01	0.015
AS155	1000	1250	10	<0.01	0.017

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS155	1500	1750	**77**	<0.01	**0.134**
AS156	250	500	9	<0.01	0.018
AS156	750	1000	2	<0.01	0.006
AS156	1250	1500	**25**	<0.01	**0.044**
AS156	1750	2000	**37**	<0.01	**0.065**
AS157	250	500	5	<0.01	0.008
AS157	750	1000	0	<0.01	0.001
AS157	1250	1500	16	<0.01	**0.027**
AS157	1750	2000	31	<0.01	**0.05**
AS158	0	250	**35**	<0.01	**0.057**
AS158	500	750	5	<0.01	0.008
AS158	1000	1250	**36**	<0.01	**0.061**
AS158	1500	1750	16	<0.01	**0.028**
AS159	1750	2000	**58**	<0.01	**0.103**
AS159	2250	2500	**52**	<0.01	**0.09**
AS160	250	500	9	<0.01	0.018
AS160	750	1000	2	<0.01	0.003
AS160	1250	1500	**66**	<0.01	**0.11**
AS160	1750	2000	**60**	<0.01	**0.1**
AS161	250	500	10	<0.01	0.019
AS161	750	1000	1	<0.01	0.004
AS161	1250	1500	22	<0.01	**0.039**
AS161	1750	2000	39	<0.01	**0.066**
AS162	250	500	5	<0.01	0.011
AS162	750	1000	6	<0.01	0.013
AS162	1250	1500	**48**	<0.01	**0.082**

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS162	1750	2000	**42**	<0.01	**0.07**
AS163	250	500	1	<0.01	0.004
AS163	750	1000	4	<0.01	0.013
AS163	1250	1500	**52**	<0.01	**0.085**
AS163	1750	2000	**59**	<0.01	**0.1**
AS164	0	250	**20**	<0.01	**0.033**
AS164	500	750	2	<0.01	0.004
AS164	1000	1250	2	<0.01	0.004
AS164	1500	1750	**60**	<0.01	**0.098**
AS165	250	500	5	<0.01	0.008
AS165	750	1000	6	<0.01	0.01
AS165	1250	1500	6	<0.01	0.01
AS165	1750	2000	**64**	<0.01	**0.105**
AS166	250	500	6	<0.01	0.012
AS166	750	1000	4	<0.01	0.008
AS166	1250	1500	13	<0.01	0.022
AS166	1750	2000	**43**	<0.01	**0.07**
AS167	1350	1600	1	<0.01	0.002
AS167	1850	2100	**45**	<0.01	**0.073**
AS168	1750	2000	**89**	<0.01	**0.15**
AS168	2250	2500	**66**	<0.01	**0.113**
AS169	2050	2300	**25**	<0.01	**0.043**
AS169	2550	2800	**43**	<0.01	**0.073**
AS170	250	500	3	<0.01	0.014
AS170	750	1000	1	<0.01	0.009
AS170	1250	1500	**92**	0.01	**0.158**

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS170	1750	2000	**71**	<0.01	**0.121**
AS171	250	500	4	<0.01	0.008
AS171	750	1000	6	<0.01	0.011
AS171	1250	1500	**66**	<0.01	**0.107**
AS171	1750	2000	**79**	<0.01	**0.13**
AS172	250	500	6	<0.01	0.011
AS172	750	1000	**37**	<0.01	**0.062**
AS172	1250	1500	**48**	<0.01	**0.085**
AS172	1750	2000	**75**	<0.01	**0.126**
AS173	0	250	**50**	<0.01	**0.084**
AS173	500	750	5	<0.01	0.008
AS173	1000	1250	9	<0.01	0.016
AS173	1500	1750	**87**	<0.01	**0.144**
AS174	250	500	2	<0.01	0.008
AS174	750	1000	9	<0.01	0.017
AS174	1250	1500	7	<0.01	0.017
AS174	1750	2000	**28**	<0.01	**0.051**
AS175	250	500	4	<0.01	0.01
AS175	750	1000	6	<0.01	0.014
AS175	1250	1500	7	<0.01	0.014
AS175	1750	2000	**22**	<0.01	**0.037**
AS178	3050	3300	**23**	**0.18**	**0.221**
AS178	3550	3800	**31**	**0.05**	**0.103**
AS179	0	250	**45**	<0.01	0.074
AS179	500	750	9	<0.01	0.018
AS179	1000	1250	**64**	<0.01	0.11

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS179	1500	1750	**77**	<0.01	0.129
AS180	0	250	**19**	<0.01	**0.034**
AS180	500	750	6	<0.01	0.01
AS180	1000	1250	6	<0.01	0.01
AS180	1500	1750	**93**	<0.01	**0.154**
AS181	250	500	5	<0.01	0.011
AS181	750	1000	2	<0.01	0.006
AS181	1250	1500	**30**	<0.01	**0.054**
AS181	1750	2000	**67**	<0.01	**0.113**
AS182	0	250	**21**	<0.01	**0.04**
AS182	500	750	0	<0.01	0.006
AS182	1000	1250	13	<0.01	**0.028**
AS182	1500	1750	**35**	<0.01	**0.063**
AS183	0	250	1	<0.01	0.01
AS183	500	750	9	<0.01	0.023
AS183	1000	1250	1	<0.01	0.01
AS183	1500	1750	5	<0.01	0.016
AS183	2200	2450	**108**	<0.01	**0.181**
AS183	2700	2950	**36**	<0.01	**0.061**
AS184	1500	1750	**21**	<0.01	**0.042**
AS184	2000	2250	9	<0.01	0.018
AS185	0	250	**40**	<0.01	**0.073**
AS185	500	750	0	<0.01	0.006
AS185	1000	1250	**94**	0.01	**0.164**
AS185	1500	1750	**40**	<0.01	**0.073**
AS186	0	250	15	<0.01	**0.025**

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS186	500	750	3	<0.01	0.005
AS186	1000	1250	**62**	<0.01	**0.102**
AS186	1500	1750	**55**	<0.01	**0.092**
AS189	250	500	4	<0.01	0.015
AS189	750	1000	3	<0.01	0.012
AS189	1250	1500	**53**	<0.01	**0.094**
AS189	1750	2000	**66**	<0.01	**0.115**
AS190	750	1000	4	<0.01	0.014
AS190	1250	1500	**25**	0.01	**0.051**
AS190	1750	2000	12	<0.01	**0.028**
AS190(A)-			15	<0.01	0.024
AS190(B)-			0	<0.01	0.008
AS191	0	250	**23**	<0.01	**0.037**
AS191	500	750	2	<0.01	0.006
AS191	1000	1250	2	<0.01	0.004
AS191	1500	1750	**24**	<0.01	**0.04**
AS193	250	500	13	<0.01	**0.029**
AS193	750	1000	1	<0.01	0.01
AS193	1250	1500	3	<0.01	0.012
AS193	1750	2000	**24**	<0.01	**0.047**
AS194	250	500	5	<0.01	0.012
AS194	750	1000	5	<0.01	0.016
AS194	1250	1500	**35**	<0.01	**0.065**
AS194	1750	2000	**74**	<0.01	**0.129**
AS195	0	250	**22**	<0.01	**0.036**
AS195	500	750	5	<0.01	0.009

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS195	1000	1250	6	<0.01	0.011
AS195	1500	1750	**63**	<0.01	**0.102**
AS196	0	250	**49**	<0.01	**0.088**
AS196	500	750	3	<0.01	0.012
AS196	1000	1250	8	<0.01	0.022
AS196	1500	1750	**51**	<0.01	**0.091**
AS197	0	250	**18**	<0.01	**0.032**
AS197	500	750	2	<0.01	0.005
AS197	1000	1250	4	<0.01	0.008
AS197	1500	1750	**22**	<0.01	**0.036**
AS199	0	250	**47**	<0.01	**0.076**
AS199	500	750	0	<0.01	0.007
AS199	1000	1250	3	<0.01	0.009
AS199	1500	1750	**57**	<0.01	**0.1**
AS200	250	500	2	<0.01	0.008
AS200	750	1000	0	<0.01	0.006
AS200	1250	1500	5	<0.01	0.013
AS200	1750	2000	**30**	<0.01	**0.054**
AS201	3250	3500	**31**	**0.04**	**0.096**
AS201	3750	4000	**53**	**0.02**	**0.111**
AS202	3450	3700	**30**	0.01	**0.067**
AS202	3950	4200	**30**	0.01	**0.062**

Table 3 – Acid Sulfate Soil Analysis Summary Laboratory Test Results Precinct 8

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS203	3100	3350		**0.05**	-0.423
AS203	3600	3850		**0.71**	**0.266**
AS204	2900	3150	**21**	0.01	**0.046**
AS204	3400	3650	**31**	**0.02**	**0.072**
AS205	0	250	**41**	<0.01	**0.078**
AS205	500	750	6	<0.01	0.017
AS205	1000	1250	9	<0.01	0.02
AS205	1500	1750	**20**	<0.01	**0.035**
AS206	0	250	**48**	<0.01	**0.085**
AS206	500	750	5	<0.01	0.014
AS206	1250	1500	3	<0.01	0.013
AS206	1750	2000	4	<0.01	0.013
AS207	250	500	**38**	<0.01	**0.065**
AS207	750	1000	5	<0.01	0.011
AS207	1250	1500	**41**	<0.01	**0.073**
AS207	1750	2000	**61**	<0.01	**0.106**
AS208	250	500	17	<0.01	**0.027**
AS208	750	1000	5	<0.01	0.015
AS208	1250	1500	**42**	<0.01	**0.073**
AS208	1750	2000	**36**	<0.01	**0.065**
AS209	250	500	4	<0.01	0.012
AS209	750	1000	0	<0.01	0.005
AS209	1250	1500	9	<0.01	0.02
AS209	1750	2000	**23**	<0.01	**0.045**
AS210	250	500	7	<0.01	0.02
AS210	750	1000	3	<0.01	0.013

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS210	1250	1500	4	<0.01	0.014
AS210	1750	2000	**58**	<0.01	**0.103**
AS211	0	250	58	<0.01	0.1
AS211	500	750	0	<0.01	0.006
AS211	1000	1250	3	<0.01	0.009
AS211	1500	1750	10	<0.01	0.019
AS212	1150	1400	8	<0.01	0.019
AS212	1650	2000	1	<0.01	0.008
AS213	2300	2550	**106**	0.01	**0.183**
AS213	2800	3050	**70**	0.01	**0.125**
AS214	3250	3500	**36**	**0.02**	**0.075**
AS214	3750	4000	**37**	0.01	**0.072**
AS215	2800	3050	**26**	<0.01	**0.049**
AS215	3300	3550	**36**	**0.02**	**0.075**
AS216	0	250	14	0.01	**0.037**
AS216	500	750	2	<0.01	0.011
AS216	1000	1250	4	<0.01	0.014
AS216	1500	1750	4	<0.01	0.013
AS217	2250	2500	**24**	<0.01	**0.04**
AS217	2750	3000	**61**	0.01	**0.111**
AS218	650	900	4	<0.01	0.008
AS218	1150	1400	4	<0.01	0.011
AS218	1650	2000	6	<0.01	0.017
AS218	1650	2000	6	<0.01	0.017
AS219	2700	2950	**27**	<0.01	**0.051**
AS219	3200	3450	**59**	0.01	**0.11**

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS220	2950	3200	**32**	0.01	**0.062**
AS220	3450	3700	**53**	**0.02**	**0.106**
AS221	2650	2900	**22**	<0.01	**0.044**
AS221	3150	3400	**31**	0.01	**0.063**
AS222	2200	2450	4	<0.01	0.011
AS222	2700	2950	17	<0.01	**0.029**
AS223	2150	2400	14	<0.01	0.03
AS223	2650	2900	3	0.01	0.016
AS224	3250	3500	15	**0.02**	**0.041**
AS224	3750	4000	14	**0.05**	**0.073**
AS225	2900	3150	1	**0.05**	**0.051**
AS225	3400	3650	4	**0.03**	**0.038**
AS226	3250	3500	9	**0.02**	**0.033**
AS226	3750	4000	8	0.01	**0.029**
AS227	3250	3500	**22**	<0.01	**0.04**
AS227	3750	4000	**63**	<0.01	**0.102**
AS228	3250	3500	**26**	<0.01	**0.051**
AS228	3750	4000	13	0.01	**0.042**
AS229	3250	3500	12	**0.05**	**0.07**
AS229	3750	4000	9	**0.06**	**0.073**
AS230	3000	3250	**25**	**0.05**	**0.092**
AS230	3500	3750	**23**	**0.03**	**0.067**
AS231	3000	3250	8	**0.02**	**0.028**
AS231	3500	3750	**22**	**0.03**	**0.062**
AS232	3500	3750	7	<0.01	0.012
AS232	4000	4250	5	<0.01	0.016

Table 4 – Acid Sulfate Soil Analysis Summary Laboratory Test Results Precinct 9

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS115	0	250	**131**	**0.03**	**0.25**
AS115	500	750	<1	<0.01	0.004
AS115	1000	1250	**48**	<0.01	**0.08**
AS115	1500	1750	**53**	<0.01	**0.086**
AS116	250	500	**48**	<0.01	**0.084**
AS116	750	1000	17	<0.01	**0.031**
AS116	1250	1500	14	<0.01	**0.028**
AS116	1750	2000	9	<0.01	0.02
AS117	0	250	**71**	**0.06**	**0.17**
AS117	500	750	<1	<0.01	0.006
AS117	1000	1250	**24**	<0.01	**0.045**
AS117	1500	1750	**30**	<0.01	**0.051**
AS118	250	500	**54**	<0.01	0.09
AS118	750	1000	**54**	<0.01	0.09
AS118	1250	1500	**26**	<0.01	**0.042**
AS118	1750	2000	**21**	<0.01	**0.036**
AS119	0	250	**26**	<0.01	**0.044**
AS119	500	750	**70**	<0.01	0.115
AS119	1000	1250	**26**	<0.01	**0.042**

Table 5 – Acid Sulfate Soil Analysis Summary Laboratory Test Results Precinct 10

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS267	0	250	**49**	<0.01	**0.081**

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS268	0	250	**79**	<0.01	**0.133**
AS269	0	250	**45**	0.01	**0.1**
AS269	500	750	**115**	<0.01	**0.196**
AS270	0	250	**61**	<0.01	**0.116**
AS270	500	750	**125**	<0.01	**0.209**
AS271	0	250	**38**	<0.01	**0.08**
AS271	500	750	**134**	<0.01	**0.226**
AS272	250	500	**54**	<0.01	**0.104**
AS272	500	750	**99**	<0.01	**0.17**
AS273	250	500	**50**	<0.01	**0.086**
AS274	250	500	**38**	<0.01	**0.067**
AS274	750	1000	**107**	<0.01	**0.18**
AS275	0	250	**55**	<0.01	**0.091**
AS276	0	250	**69**	<0.01	**0.116**
AS276	500	750	**69**	<0.01	**0.112**
AS277	0	250	**41**	<0.01	**0.079**
AS277	500	750	**36**	<0.01	**0.061**
AS278	0	250	**59**	<0.01	**0.12**
AS278	500	750	**88**	<0.01	**0.154**
AS279	0	250	**75**	<0.01	0.143
AS279	500	750	**146**	<0.01	0.245
AS280	0	250	**59**	<0.01	**0.108**
AS280	500	750	**67**	<0.01	**0.12**
AS281	0	250	**62**	<0.01	**0.114**
AS281	500	750	**113**	<0.01	**0.193**
AS282	0	250	**45**	<0.01	**0.081**

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS282	500	750	**120**	<0.01	**0.197**
AS283	0	250	**87**	<0.01	**0.144**
AS283	500	750	**99**	<0.01	**0.162**
AS284	250	500	**84**	<0.01	**0.142**
AS285	1000	1250	**159**	<0.01	**0.261**
AS286	0	250	**62**	<0.01	**0.115**
AS286(a)	500	750	**99**	<0.01	**0.17**
AS286(b)	500	750	**62**	<0.01	**0.129**
AS287	0	250	**160**	<0.01	**0.271**
AS287	500	750	**154**	<0.01	**0.266**
AS288	0	250	**68**	0.01	**0.137**
AS288	500	750	**73**	0.01	**0.142**
AS289	250	500	**69**	<0.01	**0.132**
AS290	0	250	**98**	<0.01	**0.166**
AS290	500	750	**120**	<0.01	**0.198**
AS291	700	950	**130**	<0.01	**0.225**
AS293	0	250	**72**	<0.01	**0.136**
AS293	500	750	**120**	<0.01	**0.203**
AS294	250	500	**82**	<0.01	**0.149**
AS294	750	1000	**133**	<0.01	**0.231**
AS295	250	500	**111**	<0.01	**0.189**
AS296	0	250	**55**	<0.01	**0.093**
AS297	250	500	**41**	**0.02**	**0.117**
AS297	750	1000	**81**	<0.01	**0.142**
AS298	350	600	**129**	<0.01	**0.225**
AS299	0	250	**26**	0.01	**0.071**

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS299	500	750	**123**	<0.01	**0.214**
AS300	250	500	**92**	0.01	**0.176**
AS300	750	1000	**129**	<0.01	**0.221**
AS301	2500	2750	**87**	<0.01	**0.146**
AS304	2850	3100	**40**	<0.01	**0.068**
AS304	3350	3600	**45**	<0.01	**0.076**
AS305	2800	3050	**65**	**0.03**	**0.138**
AS305	3300	3550	**46**	<0.01	**0.084**
AS307	2450	2700	**57**	**0.02**	**0.11**
AS307	2950	3200	**34**	0.01	**0.07**
AS308	250	500	**94**	**0.12**	**0.269**
AS308	750	1000	**19**	0.01	**0.041**
AS308	1250	1500	13	<0.01	0.022
AS308	1750	2000	7	<0.01	0.016
AS309	1000	1250	**75**	<0.01	**0.133**
AS311	1050	1300	**63**	0.01	**0.121**
AS311	1550	1800	**100**	<0.01	**0.175**
AS312	1000	1250	**29**	<0.01	**0.062**
AS312	1500	1750	3	<0.01	0.012
AS313	0	250	**126**	<0.01	**0.213**
AS314	1300	1550	**55**	**0.03**	**0.129**
AS314	1800	2050	**75**	**0.03**	**0.162**
AS315	1100	1350	**21**	<0.01	**0.043**
AS315	1600	1850	3	<0.01	0.008
AS315	1850	2100	8	<0.01	0.013

Table 6 – Acid Sulfate Soil Analysis Summary Laboratory Test Results Precinct 11

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS120	250	500	6	<0.01	0.014
AS120	750	1000	<1	<0.01	0.005
AS120	1250	1500	**23**	<0.01	**0.044**
AS120	1750	2000	**144**	<0.01	**0.237**
AS121	0	250	**53**	<0.01	**0.092**
AS121	500	750	13	0.01	**0.033**
AS121	1000	1250	8	<0.01	0.019
AS121	1500	1750	9	<0.01	0.024
AS122	250	500	4	<0.01	0.014
AS122	750	1000	**38**	<0.01	**0.062**
AS122	1250	1500	**24**	<0.01	**0.042**
AS122	1750	2000	**53**	<0.01	**0.09**
AS123	0	250	17	<0.01	**0.035**
AS123	500	750	**69**	<0.01	**0.114**
AS123	1000	1250	**74**	<0.01	**0.127**
AS123	1500	1750	**51**	<0.01	**0.088**
AS124	250	500	**31**	**0.14**	**0.196**
AS124	750	1000	3	**0.02**	**0.025**
AS124	1250	1500	1	**0.02**	0.023
AS124	1750	2000	5	**0.03**	**0.038**
AS125	0	250	17	<0.01	**0.04**
AS125	500	750	2	<0.01	0.003
AS125	1000	1250	12	<0.01	0.025
AS125	1500	1750	<1	<0.01	0
AS126	250	500	**27**	0.01	**0.057**

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS126	750	1000	2	<0.01	0.004
AS126	1250	1500	9	<0.01	0.015
AS126	1750	2000	<1	<0.01	0
AS127	0	250	**75**	**0.05**	**0.166**
AS127	500	750	15	<0.01	0.025
AS127	1000	1250	12	<0.01	0.019
AS127	1500	1750	8	<0.01	0.013
AS128	250	500	**27**	0.01	**0.056**
AS128	750	1000	5	0.01	0.021
AS128	1250	1500	**28**	<0.01	**0.048**
AS128	1750	2000	**22**	<0.01	**0.037**
AS129	0	250	**54**	0.01	**0.103**
AS129	500	750	**36**	<0.01	**0.06**
AS129	1000	1250	**39**	<0.01	**0.065**
AS129	1500	1750	**64**	<0.01	**0.104**
AS130	250	500	**35**	<0.01	**0.056**
AS130	750	1000	**37**	<0.01	**0.06**
AS130	1250	1500	**59**	<0.01	**0.096**
AS130	1750	2000	15	<0.01	0.025
AS131	0	250	**51**	<0.01	**0.084**
AS131	500	750	**52**	<0.01	**0.083**
AS131	1000	1250	**26**	<0.01	**0.043**
AS131	1500	1750	**53**	<0.01	**0.086**
AS132	250	500	**20**	<0.01	**0.032**
AS132	750	1000	**42**	<0.01	**0.069**
AS132	1250	1500	**36**	<0.01	**0.06**

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS132	1750	2000	**37**	<0.01	**0.07**
AS133	0	250	**24**	**0.02**	**0.062**
AS133	500	750	2	<0.01	0.011
AS133	1000	1250	18	<0.01	**0.038**
AS133	1500	1750	**52**	<0.01	**0.086**
AS134	250	500	**68**	<0.01	**0.112**
AS134	750	1000	**43**	<0.01	**0.069**
AS134	1250	1500	**40**	<0.01	**0.065**
AS134	1750	2000	**31**	<0.01	**0.05**
AS135	0	250	**30**	<0.01	**0.049**

Table 7 – Acid Sulfate Soil Analysis Summary Laboratory Test Results Precinct 12

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS234(extra)	3400	3650	**21**	<0.01	**0.044**
AS234(extra)	3900	4150	**25**	<0.01	**0.048**
AS235	3100	3350	**18**	<0.01	**0.037**
AS235	3600	3850	**31**	<0.01	**0.049**
AS236	2650	2900	**24**	0.01	**0.05**
AS236	3150	3400	**41**	<0.01	**0.072**
AS237	1450	1700	101	<0.01	0.171
AS237	1950	2200	88	<0.01	0.151
AS237	1450	1700	**101**	<0.01	**0.171**
AS237	1950	2200	**88**	<0.01	**0.151**
AS238(extra)	1150	1400	**32**	<0.01	**0.058**
AS238(extra)	1650	2000	**41**	<0.01	**0.067**

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS239	2500	2750	**28**	0.01	**0.058**
AS239	3000	3250	14	<0.01	0.023
AS240	2850	3100	**34**	**0.02**	**0.073**
AS240	3350	3600	**25**	<0.01	**0.047**
AS241	2550	2800	**24**	0.01	**0.052**
AS241	3050	3300	**28**	<0.01	**0.054**
AS243	1350	1600	**19**	<0.01	**0.038**
AS243(extra)	1850	2100	**49**	<0.01	**0.085**
AS244	1600	1850	**64**	**0.06**	**0.166**
AS244	2100	2350	**29**	**0.02**	**0.065**
AS245	2450	2700	17	<0.01	**0.037**
AS245	2950	3200	**23**	<0.01	**0.046**
AS246	2900	3150	**29**	<0.01	**0.052**
AS246	3400	3650	15	<0.01	**0.032**
AS247	2500	2750	**39**	**0.02**	**0.082**
AS247	3000	3250	15	<0.01	**0.033**
AS248	2450	2700	**31**	**0.04**	**0.092**
AS248	2950	3200	**37**	**0.02**	**0.077**
AS249	2650	2900	**30**	**0.05**	**0.096**
AS249	3150	3400	10	<0.01	**0.025**
AS250	2700	2950	0	0.01	0.011
AS250	3200	3450	**24**	<0.01	**0.046**
AS251	2750	3000	**35**	<0.01	**0.065**
AS251	3250	3500	17	<0.01	**0.034**
AS252	2950	3200	**26**	<0.01	**0.049**
AS252	3450	3700	**34**	<0.01	**0.065**

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS253	2850	3100	11	<0.01	**0.026**
AS253	3350	3600	12	<0.01	**0.026**
AS254	2700	2950	**41**	**0.04**	**0.107**
AS254	3200	3450	15	<0.01	**0.035**
AS255	3150	3400	**20**	<0.01	**0.042**
AS255	3650	3900	17	<0.01	0.028
AS256	2500	2750	**29**	**0.02**	**0.068**
AS256	3000	3250	**24**	<0.01	**0.042**
AS257	2950	3200	**21**	<0.01	**0.036**
AS257	3450	3700	**32**	<0.01	**0.057**
AS258	3250	3500	1	0.01	0.015
AS258	3750	4000	5	0.01	0.02
AS259	2800	3050	**32**	<0.01	**0.058**
AS260	1950	2200	**61**	<0.01	**0.102**
AS260	2450	2700	**52**	<0.01	**0.089**
AS261	2600	2850	**58**	**0.02**	**0.118**
AS261	3100	3350	**41**	<0.01	**0.067**
AS262	2600	2850	**29**	0.01	**0.059**
AS262	3100	3350	**25**	<0.01	**0.043**
AS263	2900	3150	**21**	<0.01	**0.04**
AS263	3400	3650	**19**	<0.01	**0.033**
AS264	3550	3800	13	**0.03**	**0.055**
AS264	4050	4300	1	<0.01	0.006
AS265	3000	3250	**27**	<0.01	**0.047**
AS265	3500	3750	**24**	<0.01	**0.038**
AS266	1250	1500	**63**	<0.01	**0.104**

Borehole No.	Depth From (mm)	Depth To (mm)	Titratable Actual Acidity (Mol H+)	Chromium Reducible Sulfur (%S)	Net Acidity EQ (%S)
AS266	1750	2000	**86**	<0.01	**0.141**

Notes:

- Net Acidity sEQ(%)=Potential Sulfidic Acidity (%S) + Existing Acidity (TAA) – Acid Neutralising Capacity/Fineness factor.
- Net Acidity takes into account Calcium Carbonate present in sample that buffers potential acidity.

Bold text indicates figures in excess of trigger levels.

3.2.2. Water Testing

During this investigation, no groundwater wells were installed. Reference should be made to previous reports for discussion of sample collection techniques, results and recommendations. Specifically, plots of water level and quality with time and the handling of groundwater levels and quality have been outlined in the Groundwater Management Plan (SMEC, 2015), Section 7 Environmental Control Measures and Section 8 Groundwater Monitoring Plan.

4. POTENTIAL IMPACTS

The potential environmental impacts resulting from disturbance of ASS affected material is summarised as follows:

- Localised mobilisation of acidified leachate;
- Habitat degradation;
- Poor plant productivity and stunted growth;
- Economic losses to industries due to widespread acidification of land and waterways; and
- Increased maintenance and replacement costs to steel, aluminium and concrete structures as a result of acid weakening the concrete and steel infrastructure.

The severity of environmental impacts resulting from ASS disturbance will depend on a number of factors, including the following:

- The nature of the soil (e.g. soils will have varying acid producing potentials depending on their texture, pyritic concentration and amount of natural buffering or neutralising material present in the soil structure);
- The natural buffering capacity of the soil (i.e. presence of shell material and other readily available calcium carbonate deposits);
- The period and frequency of ASS exposure (e.g. sandy sediments may oxidise rapidly, though the ultimate acid generating potential is relatively low compared with clay soils which may take days or weeks to realise acidity following exposure, though may have a very high acid generating potential);
- The buffering capacity of the receiving waters (acidic runoff would normally be neutralised by the alkaline buffering capacity of seawater, though after heavy rainfall estuarine creeks may tend toward freshwater, which usually has little capacity to buffer acidic runoff); and
- Presence of available conduits for the transport/release of acid leachate to nearby waterways (i.e. drains, channels, groundwater flow pathways, subsurface structures and infrastructure and root matter).

New South Wales legislation requires adequate containment, treatment and management of runoff/leachate generated during the disturbance of ASS affected material in order to ensure the protection of coastal ecosystems, particularly wetlands, waterway areas and downstream of Cobaki Estate.

5. MITIGATION MEASURES

The key mitigation measure for ASS disturbance is the quantification and delineation of ASS affected material that will potentially be disturbed as a result of the construction and operation of the Project. This has been undertaken through a detailed ASS investigation completed in accordance with the New South Wales Acid Sulfate Soils Assessment Guidelines (1998) and Acid Sulfate Soils Manual (1998).

Mitigation measures for ASS disturbance have been developed and outlined in the following management plan for implementation during construction.

6. ACID SULPHATE SOILS MANAGEMENT PLAN

The following section details the Draft ASS Management Plan (ASSMP) to be implemented within Precinct 7, 8 and 9 during construction. This ASSMP will be further developed as a part of the detailed design stage of the Cobaki Estate Development.

6.1. Objectives

The objectives of ASS management on the site are to:

- Identify areas of likely ASS or PASS disturbance;
- To identify and locate ASS prior to excavation in order to minimise disturbance of these soils;
- Develop adequate management procedures and prevent impacts to the surrounding environment resulting from exposure of ASS to the atmosphere, groundwater and surface runoff; and
- To provide minimum requirements for the development of a construction ASSMP to be implemented in order to address site ASS management during construction.

6.2. Statutory Provisions

The ASSMP has been developed in accordance with the following guidelines:

- NSW Acid Sulfate Soil Management Planning Guidelines (ASSMAC, 1998); and
- NSW Acid Sulfate Soil Manual (ASSMAC, 1998).

6.3. Performance Criteria

The objective of this ASSMP is to ensure the following:

- Where ASS disturbance occurs, appropriate management measures to mitigate potential impacts are implemented;
- Validation sampling of treated ASS material to be completed to ensure sufficient neutralising capacity is available following treatment;
- Containment of ASS material stockpile and treatment areas (if required);
- No impacts to surface water or groundwater quality resulting from the disturbance storage, treatment or reuse of ASS material;
- The leachate pH of the excavated material stockpile to range between 6.5 and 8.5 prior to release off site; and
- ASS material spills to be cleaned and /or neutralised within 12 hours of occurring.

6.4. Acid Neutralisation

The most effective method that can be implemented to limit or prevent the adverse consequences of ASS or PASS excavation or disturbance is the controlled application of fine agricultural lime (Aglime/$CaCO_3$). Various neutralizing agents are available, with aglime being the most widely used product for acid sulfate soil treatment.

6.5. Lime Application

The application of lime to the soil requires thorough mixing and incorporation into the soil.

It is recommended that, because the results varied significantly, a blanket liming rate should not be adopted due to the mix of the materials. Given the clearly defined nature of the high and low acidity soil types different liming rates could be utilized for budgetary and planning purposes for the different boreholes over the separate portions of the site, but they should be subject to confirmation/validation testing on the site.

For budgetary and planning purposes the different sections of the site have been shown on the Site Plans with the predicted liming rates for each section where excavation and filling are proposed.

The construction technique implemented during the lime application is critical and as such, the following measures will be undertaken:

- Only fine grained Aglime should be used, to ensure the greatest surface area for neutralizing is present;
- The lime dosing rates will need to be reassessed following assessment of the lime sourced for the project, as the liming rates assume 100% purity of lime;
- Thorough mixing of the Aglime into the soil is paramount to ensure all treated soils have neutralizing agent evenly distributed throughout; and
- All cut batters as well as trench faces and bases excavated in the area of the site where ASS is encountered shall be coated with fine Aglime at the rate of 5kg/m^2.

Preliminary Lime dosage rate per cubic meter of soil are based on QASSIT guidelines:

LIME 2 x 1.5 (t/m^3) x 1.5 (FOS)

Where LIME 2 is presented in Appendix C within the laboratory results, based on the above equation, the average lime dosage rates (kg/m^3) to be added to the ASS materials at each investigation location are provided in Table 5, Table 6 and Table 7 below. These rates need to be further assessed during detailed design with specific reference to existing and proposed RL.

Table 8 – Preliminary Lime Dosage Rates Precinct 7

Borehole No.	Depth From (mm)	Depth To (mm)	Avg Net Acidity %S EQ	Avg Recommended Liming rates	
				kg/tonne	Kg/m3
AS136	250	2000	**0.035**	1.88	2.81
AS137	0	1750	**0.047**	2.25	3.38
AS138	250	2000	**0.041**	2.25	3.38
AS139	0	1750	0.007	0.38	0.56
AS140	1850	2600	**0.056**	2.25	3.38
AS141	250	2000	**0.046**	2.25	3.38
AS142	0	1750	**0.034**	1.13	1.69
AS143	250	2000	**0.034**	1.88	2.81
AS144	250	2000	0.022	0.75	1.13
AS145	1500	2250	**0.077**	3.75	5.63

Borehole No.	Depth From (mm)	Depth To (mm)	Avg Net Acidity %S EQ	Avg Recommended Liming rates	
				kg/tonne	Kg/m3
AS146	0	1750	**0.054**	2.63	3.94
AS147	0	1750	**0.026**	1.13	1.69
AS148	250	2000	**0.071**	3.38	5.06
AS149	250	2000	0.013	0.75	1.13
AS150	0	1750	0.016	0.75	1.13
AS151	1600	2350	0.018	0.75	1.13
AS152	250	2000	**0.053**	2.25	3.38
AS153	0	1750	0.110	4.88	7.31
AS154	0	1750	**0.037**	1.50	2.25
AS155	0	1750	**0.049**	2.25	3.38
AS156	250	2000	**0.033**	1.50	2.25
AS157	250	2000	0.022	1.13	1.69
AS158	0	1750	**0.039**	1.88	2.81
AS159	1750	2500	**0.097**	4.50	6.75
AS160	250	2000	**0.058**	2.63	3.94
AS161	250	2000	**0.032**	1.50	2.25
AS162	250	2000	**0.044**	1.88	2.81
AS163	250	2000	**0.051**	2.25	3.38
AS164	0	1750	**0.035**	1.50	2.25
AS165	250	2000	**0.033**	1.13	1.69
AS166	250	2000	**0.028**	1.13	1.69
AS167	1350	2100	**0.038**	1.50	2.25
AS168	1750	2500	**0.132**	6.75	10.13
AS169	2050	2800	**0.058**	2.25	3.38
AS170	250	2000	**0.076**	3.38	5.06

Borehole No.	Depth From (mm)	Depth To (mm)	Avg Net Acidity %S EQ	Avg Recommended Liming rates	
				kg/tonne	Kg/m3
AS171	250	2000	**0.064**	2.63	3.94
AS172	250	2000	**0.071**	3.38	5.06
AS173	0	1750	**0.063**	2.63	3.94
AS174	250	2000	0.023	1.50	2.25
AS175	250	2000	0.019	0.38	0.56
AS178	3050	3800	**0.162**	7.50	11.25
AS179	0	1750	**0.083**	3.75	5.63
AS180	0	1750	**0.052**	2.25	3.38
AS181	250	2000	**0.046**	2.25	3.38
AS182	0	1750	**0.034**	1.50	2.25
AS183	0	2000	0.014	0.50	0.75
AS183A	2200	2950	**0.121**	4.00	6.00
AS184	1500	2250	0.030	1.50	2.25
AS185	0	1750	**0.079**	3.38	5.06
AS186	0	1750	**0.056**	2.63	3.94
AS189	250	2000	**0.059**	2.63	3.94
AS190	250	2000	**0.025**	1.20	1.80
AS191	0	1750	0.022	0.75	1.13
AS193	250	2000	**0.025**	0.75	1.13
AS194	250	2000	**0.056**	2.63	3.94
AS195	0	1750	**0.040**	1.50	2.25
AS196	0	1750	**0.053**	2.63	3.94
AS197	0	1750	0.020	0.75	1.13
AS199	0	1750	**0.048**	1.88	2.81
AS200	250	2000	0.020	0.75	1.13

Borehole No.	Depth From (mm)	Depth To (mm)	Avg Net Acidity %S EQ	Avg Recommended Liming rates	
				kg/tonne	Kg/m3
AS201	3250	4000	**0.104**	4.50	6.75
AS202	3450	4200	**0.065**	3.00	4.50

Table 9 – Preliminary Lime Dosage Rates Precinct 8

Borehole No.	Depth From (mm)	Depth To (mm)	Avg Net Acidity %S EQ	Avg Recommended Liming rates	
				kg/tonne	Kg/m3
AS203	3100	3850	-0.079	3.75	5.63
AS204	2900	3650	**0.059**	2.25	3.38
AS205	0	1750	**0.038**	1.88	2.81
AS206	0	2000	**0.031**	1.13	1.69
AS207	250	2000	**0.064**	2.63	3.94
AS208	250	2000	**0.045**	1.88	2.81
AS209	250	2000	0.021	0.75	1.13
AS210	250	2000	**0.038**	1.50	2.25
AS211	0	1750	**0.034**	1.50	2.25
AS212	1150	2000	0.014	0.75	1.13
AS213	2300	3050	**0.154**	7.50	11.25
AS214	3250	4000	**0.074**	3.00	4.50
AS215	2800	3550	**0.062**	3.00	4.50
AS216	0	1750	0.019	0.38	0.56
AS217	2250	3000	**0.076**	3.00	4.50
AS218	650	2000	0.013	0.75	1.13
AS219	2700	3450	**0.081**	3.75	5.63
AS220	2950	3700	**0.084**	3.75	5.63
AS221	2650	3400	**0.054**	2.25	3.38

Borehole No.	Depth From (mm)	Depth To (mm)	Avg Net Acidity %S EQ	Avg Recommended Liming rates	
				kg/tonne	Kg/m3
AS222	2200	2950	0.020	0.75	1.13
AS223	2150	2900	0.023	0.75	1.13
AS224	3250	4000	**0.057**	2.25	3.38
AS225	2900	3650	**0.045**	2.25	3.38
AS226	3250	4000	**0.031**	1.50	2.25
AS227	3250	4000	**0.071**	3.00	4.50
AS228	3250	4000	**0.047**	2.25	3.38
AS229	3250	4000	**0.072**	3.00	4.50
AS230	3000	3750	**0.080**	3.75	5.63
AS231	3000	3750	**0.045**	2.25	3.38
AS232	3500	4250	0.014	0.00	0.00

Table 10 – Preliminary Lime Dosage Rates Precinct 9

Borehole No.	Depth From (mm)	Depth To (mm)	Avg Net Acidity %S EQ	Avg Recommended Liming rates	
				kg/tonne	Kg/m3
AS112	0	2000	**0.08**	3.75	5.6
AS113	0	1750	**0.12**	6	9
AS114	0	2000	**0.06**	2.63	3.94
AS115	0	2000	**0.11**	4.87	7.31
AS116	0	2000	**0.04**	2.25	3.38
AS117	0	1750	**0.07**	3	4.5
AS118	0	2000	**0.06**	3	4.5
AS119	1500	1750	**0.07**	3	4.5

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Table 11 – Preliminary Lime Dosage Rates Precinct 10

Borehole No.	Depth From (mm)	Depth To (mm)	Avg Net Acidity %S EQ	Avg Recommended Liming rates	
				kg/tonne	Kg/m3
AS267	0	250	**0.081**	4.50	6.75
AS268	0	250	**0.133**	6.00	9.00
AS269	0	750	**0.148**	6.75	10.13
AS270	0	750	**0.163**	8.25	12.38
AS271	0	750	**0.153**	7.50	11.25
AS272	250	750	**0.137**	6.00	9.00
AS273	250	500	0.086	4.50	6.75
AS274	250	1000	**0.124**	6.00	9.00
AS275	0	250	**0.091**	4.50	6.75
AS276	0	250	**0.116**	6.00	9.00
AS276	0	750	**0.112**	6.00	9.00
AS277	0	750	**0.070**	3.00	4.50
AS278	0	750	**0.137**	6.75	10.13
AS279	0	750	**0.194**	9.00	13.50
AS280	0	750	**0.114**	5.25	7.88
AS281	0	750	**0.154**	7.50	11.25
AS282	0	750	**0.139**	6.75	10.13
AS283	0	750	**0.153**	6.75	10.13
AS284	0	500	**0.142**	6.00	9.00
AS285	0	1250	**0.261**	12.00	18.00
AS286	0	750	**0.138**	6.50	9.75
AS287	0	750	**0.269**	12.00	18.00
AS288	0	750	**0.140**	6.00	9.00

Borehole No.	Depth From (mm)	Depth To (mm)	Avg Net Acidity %S EQ	Avg Recommended Liming rates	
				kg/tonne	Kg/m3
AS289	250	500	**0.132**	6.00	9.00
AS290	0	750	**0.182**	8.25	12.38
AS291	700	950	**0.225**	10.50	15.75
AS293	0	750	**0.170**	7.50	11.25
AS294	250	1000	**0.190**	9.00	13.50
AS295	250	500	**0.189**	9.00	13.50
AS296	0	250	**0.093**	4.50	6.75
AS297	250	1000	**0.130**	6.00	9.00
AS298	350	600	**0.225**	10.50	15.75
AS299	0	750	**0.143**	6.75	10.13
AS300	250	1000	**0.199**	9.00	13.50
AS301	2500	2750	**0.146**	7.50	11.25
AS304	2850	3600	**0.072**	3.00	4.50
AS305	2800	3050	**0.138**	6.00	9.00
AS305	3300	3550	**0.084**	4.50	6.75
AS307	2450	3200	**0.090**	3.75	5.63
AS308	250	2000	**0.087**	4.13	6.19
AS309	1000	1250	**0.133**	6.00	9.00
AS311	1050	1800	**0.148**	6.75	10.13
AS312	1000	1750	**0.037**	1.50	2.25
AS313	0	250	**0.213**	10.50	15.75
AS314	1300	2050	**0.146**	6.75	10.13
AS315	1100	2100	0.021	0.50	0.75

Table 12 – Preliminary Lime Dosage Rates Precinct 11

Borehole No.	Depth From (mm)	Depth To (mm)	Avg Net Acidity %S EQ	Avg Recommended Liming rates	
				kg/tonne	Kg/m3
AS120	0	250	**0.081**	4.50	6.75
AS121	250	2000	**0.075**	3.0	4.5
AS122	0	250	**0.042**	2.25	3.38
AS123	250	2000	**0.052**	2.25	3.38
AS124	0	1750	**0.091**	4.5	6.75
AS125	250	2000	**0.071**	3.38	5.07
AS126	0	1750	0.017	1.69	2.53
AS127	250	2000	0.019	0.75	1.13
AS128	0	1750	**0.056**	2.63	3.94
AS129	250	2000	**0.041**	2.25	3.38
AS130	0	1750	**0.083**	3.75	5.63
AS131	250	2000	**0.059**	3.0	4.5
AS132	0	1750	**0.074**	3.75	5.63
AS133	250	2000	**0.058**	2.63	3.94
AS134	0	1750	**0.049**	2.25	3.38
AS135	250	2000	**0.074**	3.38	5.06

Table 13 – Preliminary Lime Dosage Rates Precinct 12

Borehole No.	Depth From (mm)	Depth To (mm)	Avg Net Acidity %S EQ	Avg Recommended Liming rates	
				kg/tonne	Kg/m3
AS234	0	250	**0.081**	4.50	6.75
AS235	0	250	**0.133**	6.00	9.00
AS236	0	750	**0.148**	6.75	10.13

Borehole No.	Depth From (mm)	Depth To (mm)	Avg Net Acidity %S EQ	Avg Recommended Liming rates	
				kg/tonne	Kg/m3
AS237	0	750	**0.163**	8.25	12.38
AS238	3400	4150	**0.046**	2.25	3.38
AS239	3100	3850	**0.043**	2.25	3.38
AS240	2650	3400	**0.061**	3.00	4.50
AS241	1450	2200	**0.161**	7.50	11.25
AS243(extra)	1150	2000	**0.063**	3.00	4.50
AS244	2500	3250	**0.041**	2.25	3.38
AS245	2850	3600	**0.060**	2.25	3.38
AS246	2550	3300	**0.053**	3.00	4.50
AS247	1350	2100	**0.062**	3.00	4.50
AS248	1600	2350	**0.116**	5.25	7.88
AS249	2450	3200	**0.042**	1.50	2.25
AS250	2900	3650	**0.042**	2.25	3.38
AS251	2500	3250	**0.058**	3.00	4.50
AS252	2450	3200	**0.085**	3.75	5.63
AS253	2650	3400	**0.061**	3.00	4.50
AS254	2700	3450	**0.029**	0.75	1.13
AS255	2750	3500	**0.050**	2.25	3.38
AS256	2950	3700	**0.057**	3.00	4.50
AS257	2850	3600	**0.026**	1.50	2.25
AS258	2700	3450	**0.071**	3.00	4.50
AS259	3150	3900	**0.035**	1.50	2.25
AS260	2500	3250	**0.055**	2.25	3.38
AS261	2950	3700	**0.047**	2.25	3.38
AS262	3250	4000	0.018	0.75	1.13

Borehole No.	Depth From (mm)	Depth To (mm)	Avg Net Acidity %S EQ	Avg Recommended Liming rates	
				kg/tonne	Kg/m3
AS263	3250	3050	**0.058**	3.00	4.50
AS264	1950	2700	**0.096**	4.50	6.75
AS265	2600	3350	**0.093**	4.50	6.75

Notes:

- Dry density of 1.5t/m^3 adopted.
- Lime dosage rates include a factor of safety of 1.5 times theoretical lime rate to neutralize soils.
- 100% purity assumed for Aglime. Variations in the lime purity must be factored accordingly
- Net Acidity sEQ(%)=Potential Sulfidic Acidity (%S) + Existing Acidity (TAA) – Acid Neutralising Capacity/Fineness factor.
- Net Acidity takes into account Calcium Carbonate present in sample that buffers potential acidity.

Bold text indicates figures in excess of trigger levels.

6.6. Stockpiling ASS Material

All excavated ASS and/or PASS material shall be placed in a bunded area that is located to ensure minimal risk of adverse environmental impacts as a result of acid leachate.

The following recommendations are made for stockpiled material placed in a holding area:

- No ASS and/or PASS shall be stockpiled in overland flow areas.
- All stockpiles should have bunded drains surrounding them to allow collection, containment and treatment of surface runoff from the stockpile.
- The base of all areas used for stockpiling/treatment areas and all surrounding bunds and drains shall be treated with a minimum guard layer of 5kg/m^2 of fine Aglime per vertical metre of fill to be placed to neutralise the downward seepage of acidic drainage water. If the soils underlying the stockpile area are not of low permeability (clay) then the placement of a low permeability clay layer or an impermeable membrane may be undertaken to contain any leachate from the ASS/PASS if this is a significant risk to groundwater quality.
- It should be noted that by treating the ASS/PASS in discrete treatment areas prior to placing into fill areas, rather than placement directly into filled areas (therefore requiring the guard layer), a substantial reduction of lime could be achieved.

6.7. Validation Testing

On site testing and monitoring should be performed throughout the construction period:

- Testing will be carried out at a rate of at least one sample per 250m^3 to determine the net acidity and appropriate liming rate for the disturbed soil in the ASS risk area; and
- Following liming, the treated soil will be validated by collecting samples at the rate of one sample per 250m^3 and testing to ensure that treated soils have sufficient acid neutralising capacity and a pH > 5.5 and < 8.5.
- Further assessment and validation testing will be carried out at the commencement of tyning operations of final cut platforms to confirm minimum required liming rates.

6.8. Water Discharges

All water generated from dewatering activities, seepage and site runoff in the ASS risk area, defined as areas with elevation less than 5m AHD, shall be contained, tested and treated (if necessary) prior to discharge or re-use on site, in accordance with the site specific Groundwater and Surface Water Management Plans.

Water that has been ponded shall be tested for pH, turbidity and dissolved oxygen on a twice weekly basis, and no water shall be discharged to the environment unless it complies with the water quality criteria tabulated below in Table 8- Water Quality Criteria, which complies with the ANZEEC (2000) Guidelines for an estuarine environment.

Water will not be released from detention basins until samples have been tested to ensure compliance with the release criteria outlined in the Jan 2012 SMEC Urban GWMP, Section 9.2 Water Discharge, Table 6 and Section 9.2.3.

Table 14- Water Quality Criteria

Water Quality Parameters	Release Criteria
pH	7.0-8.5 (Estuarine)
Turbidity	<0.5-10 NTU or not worse than background conditions
Dissolved Oxygen	80-110% saturation or not worse than background
Al (total)	Site specific data is being recorded and compiled in SMEC environmental report.
Fe (total)	Site specific data is being recorded and compiled in SMEC environmental report.

In the event discharge waters fall outside the release criteria, discharging will cease immediately and the waters will be contained until remediation has been undertaken to meet the criteria. Remedial measures will be dependent on the type of variation from the criteria. For example if low pH is recorded lime based products would be added to the water to elevate the pH back to the required range.

It is recommended that background readings both upstream and downstream of the receiving waters be taken prior to construction.

Daily (during construction and prior to release) water quality testing is to be undertaken within the wetland in the vicinity of any discharge points to ensure that acceptable water quality parameters are maintained. Where water levels are insufficient to carry out testing as scheduled due to lack of recent rainfall, testing may occur opportunistically following the next significant rainfall event. Subsequent testing should be completed on schedule where possible.

6.9. Contingency

During construction, the contractor should have stored on site at all times, at least 200kg of Aglime to ensure potentially hazardous situations can be controlled should the need arise. Also the contractor should maintain stock of either Hydrated lime, Sodium bicarbonate or Quicklime on site to remedy any sudden drops in water pH on the site.

It should be noted that Hydrated lime and Quicklime are caustic products and will require storage and handling in accordance with their material safety data sheets.

If Hydrated lime is used on site to remedy low pH water, strict monitoring will be required to ensure overdosing beyond the acceptable range (>8.5) does not occur.

6.10. Records

All monitoring, field and laboratory sampling and testing is to be documented and recorded appropriately.

Receipts and dockets of acquisitions and delivery of neutralising agents must be kept along with records of how and where these agents were stored and used on the site.

REFERENCES

Acid Sulfate Soils Management Advisory Committee, 1998. Acid Sulfate Soil Manual. Department of Land, Water and Conservation.

Australian and New Zealand Environment Conservation Council (ANZECC) 2000, Guidelines for Fresh and Marine Water Quality, Australian Water Association, Artarmon, NSW.

Department of Land, Water and Conservation, 1997. Acid Sulfate Soils Mapping.

Queensland Government (DLGP, DNRM), 2002. Planning and Managing Development Involving Acid Sulfate Soils – State Planning Policy 2/02 Guideline.

Roads and Transport Authority (Roads and Maritime Services), 2005. Guidelines for the Management of Acid Sulfate Materials: Acid Sulfate Soils, Acid Sulfate Rock and Monosulfidic Black Ooze.

APPENDIX A BOREHOLE LOGS

APPENDIX B LABORATORY TETS RESULTS

Appendix B Groundwater Management Plans

SMEC

Local People. Global Experience.

Cobaki Estate Groundwater Management Plan

Precincts 7, 8, 9, 10, 11 and 12

October 2016

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This report is confidential and is provided solely for Leda Manorstead Pty Ltd. This report is provided pursuant to a Consultancy Agreement between SMEC Australia Pty Limited ("SMEC") and Leda Manorstead Pty Ltd under which SMEC undertook to perform a specific and limited task for Leda Manorstead Pty Ltd. This report is strictly limited to the matters stated in it and subject to the various assumptions, qualifications and limitations in it and does not apply by implication to other matters. SMEC makes no representation that the scope, assumptions, qualifications and exclusions set out in this report will be suitable or sufficient for other purposes nor that the content of the report covers all matters, which you may regard as material for your purposes.

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The report supersedes all previous draft or interim reports, whether written or presented orally, before the date of this report. This report has not and will not be updated for events or transactions occurring after the date of the report or any other matters which might have a material effect on its contents or which become known after the date of the report. SMEC is not obliged to inform you of any such event, transaction or matter nor to update the report for anything that occurs, or of which SMEC becomes aware, after the date of this report.

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ABBREVIATIONS AND ACRONYMS

Abbreviation/ Acronym	Description
AHD	Australian Height Datum
ASS	Acid Sulfate Soils
blg	Below Ground Level
DA	Development Application
DPI	Department of Primary Industries
EC	Electrical Conductivity
EPA	Environmental Protection Agency
G&S	Gilbert & Sutherland Pty Ltd
GWMP	Groundwater Management Plan
Ha	Hectares
km	Kilometres
Leda	Leda Manorstead Pty Ltd (the Proponent)
m	Metres
NSW	New South Wales
OEH	Office of Environment and Heritage, NSW
PASS	Potential Acid Sulfate Soils
SAS	Site Audit Statement
SEPP	State Environmental Planning Policy
SMEC	Snowy Mountains Engineering Corporation Pty Ltd

1. INTRODUCTION

This Groundwater Management Plan (GWMP) was prepared by SMEC Pty Ltd for LEDA Manorstead Pty Ltd (Leda), (the Proponent) as part of the proposed development of approximately 593 hectares (ha) of land to be known as the Cobaki Estate (the site).

The site comprises 17 Precincts. This GWMP supports the development application that relates to Precincts 7, 8, 9, 10, 11 and 12 for the proposed earthworks and construction phase of the development.

It is understood that bulk earthworks has already commenced on portions of Precincts 7, 8 and 9.

1.1. Location and Site Description

The site is located within the Local Government Area (LGA) of Tweed Shire Council.

The site is located approximately 6 kilometres (km) west of the Tweed Heads and Coolangatta Town Centre, 1.5 km west of the Gold Coast Airport and the Gold Coast Highway and 500 m west of the Pacific Motorway (Tugun Bypass).

The Queensland and New South Wales border the site to the north and west with Piggabean Road to the south. Adjoining the site to the east is a wetland protected by State Environment Planning Policy (SEPP) No. 14 - Coastal Wetlands, Cobaki Creek and the Cobaki Broadwater. Remnant bushland forests are located to the west and north of the site and are zoned for environmental protection. Agricultural land primarily used for cattle grazing adjoins the site to the south and to the northwest. To the southwest is a golf course, which is zoned rural.

Access is currently off Piggabean Road. Access is also proposed to Boyd Street from the north and linking Piggabean Road via the proposed Cobaki Parkway.

The site was previously cleared for agricultural purposes (cattle grazing) and has scatterings of native vegetation across the site. There are no mapped State Environmental Planning Policy (SEPP) areas on Site.

The location of the project site is shown in **Figure 1**.

Figure 1: Site Locality

COORDINATE SYSTEM GDA 1994 MGA Zone 56	0 1 2 km Scale: 1: 40,000 @ A4	**FIGURE** 1 - Site Locality	**REVISION** 0	**STATUS** FINAL
		CREATED BY AM11482	**DATE** 14/10/2013	**ISSUED FOR INFORMATION**

N

SMEC

PROJECT NO. 30031162	**PROJECT TITLE** Cobaki Estate Management Plans	**SOURCE** The State of Queensland (Department of Environment and Resource Management), Copyright 2010 Aerial Imagery from Nearmap Hypertiles, copyright 2011	**CLIENT** LEDA MANORSTEAD PTY LTD

CONSULTANT SMEC Australia

PATH:I:\Projects\30031162\007_Spatial\Workspaces\Fauna Management Maps.wor

1.2. Project Description

The proposed development as part of the Cobaki Estate Concept Plan, dated 2008 comprises:

- A new mixed, residential, commercial, community use redevelopment;
- Seventeen (17) residential precincts with a mix of housing types including detached houses, townhouses and multi-unit housing to a maximum of 3 storeys, comprising approximately 5,500 dwellings (a new population of between 10,000 and 12,000 people);
- A mixed use Town Centre and Neighbourhood Centre to a maximum of 3 storeys of retail, commercial, community and residential uses;
- Community and education precincts including 2 public primary schools;
- Active and passive open space areas covering approximately 87 ha of land;
- Environmental protection areas covering approximately 194 ha of land;
- Access network of roads, public transport routes and pedestrian/cycle path;
- Landscaping and vegetation management; and
- Utility services infrastructure.

The approved Project Application (as amended), dated 28 February 2011 authorises the following development:

- Subdivision of the entire Cobaki Estate site into seven (7) lots (including one (1) residue lot for future urban development – Lot 807);
- Staged bulk earthworks to create the central open space, structured open space, and future stormwater drainage area;
- Road forming works and culverts crossing the central open space (including Lot 802);
- Road forming works across saltmarsh areas, including culverts and trunk sewer and water services (Lot 802);
- Revegetation and rehabilitation of environmental protection areas for coastal Saltmarsh (Lots 805 and 806), and
- Establishment of freshwater wetland and fauna corridors.

This report specifically refers to Precincts 7, 8, 9, 10, 11 and 12 (the site). The proposed development of the Precincts comprises:

- Precinct 7 is located at the central eastern portion of the site and is approximately 32.83 ha in size. The proposed development comprises standard 375 m^2 to 450 m^2 residential lots.
- Precinct 8 is located at the south-eastern portion of the site and is approximately 16.96 ha in size. The proposed development comprises a mix of minimum 200 m^2 lots, standard 375 m^2 to 450 m^2 residential lots and public open space (e.g. link parks and cultural protected areas).
- Precinct 9 is located in the south-to-south-western portion of the site and is approximately 22.12 ha in size. The proposed development comprises a mix of 305 residential lots (e.g. 180 Detached and 100 Terrace and 25 Duplex Residences).
- Precinct 10 is located in the south-western portion of the site and is approximately 21.85 ha in size.
- Precinct 11 is located in the south-western portion of the site and is approximately 15.28 ha in size.
- Precinct 12 is located in the central western portion of the site and is approximately 21.95 ha in size.

1.3. Previous Studies

Numerous studies form part of the various stages of development approval for the proposed development of Cobaki Estate comprising:

- Environmental Assessment Report Part 3A Concept Plan (JBA Urban Planning Consultants Pty Ltd, 2008)
- Environmental Assessment Report Part 3A Project Application (JBA Urban Planning Consultants Pty Ltd, 2009)
- Conceptual Groundwater Assessment, Cobaki Lakes Concept Plan (Gilbert & Sutherland, 2008)
- Groundwater Management Plan, Cobaki Lakes Concept Plan (Gilbert & Sutherland, 2008)
- Groundwater Assessment and Management Plan, Cobaki Lakes Estate, Central Open Space, Cobaki, NSW (Gilbert & Sutherland, 2009)
- Groundwater Management Plan Central Open Space and Precincts 1, 2 and 6 (SMEC Pty Ltd, May 2012)

2. PURPOSE AND OBJECTIVES

2.1. Context and Purpose

This GWMP was prepared in accordance with Section 31 Groundwater Management and Monitoring Plan of the Deputy Director-Generals Project Approval dated the 28 February 2011 such that:

"Where interception or use of groundwater is likely, the proponent is to submit a detailed Groundwater Management and Monitoring Plan, prepared in consultation with NSW Office of Water, supported by baseline groundwater monitoring, for the approval of Tweed Shire Council".

This plan outlines the potential impacts of works on groundwater environments and details management strategies, actions and controls that must be used to manage these impacts.

The purpose of the GWMP is to:

- Identify the activities, hazards and environmental risks associated with the proposed development of the site;
- Identify and protect groundwater dependent ecosystems;
- Comply with environmental legislation, regulations, standards, codes of practice and any conditions of approval relevant to the development of Precincts 7, 8, 9, 10, 11 and 12, and
- Inform Tweed Shire Council, Leda staff, contractors and consultants of appropriate safeguards and controls measures to be implemented to minimise impacts to groundwater.

2.2. Objectives and Targets

The primary objective of the GWMP is to take all reasonable and practical measures to prevent or minimise environmental harm to the environment or human health.

Key targets comprise:

- No significant change to baseline groundwater quality attributed to the works e.g. no acidification, no hazardous chemical spills;
- Negligible change to the existing groundwater regimes in the project area, and
- All discharged groundwater within specified water quality criteria.

3. COBAKI BIOPHYSICAL CHARACTERISTICS

3.1. Catchment Description

The site is located within the local Cobaki Broadwater catchment, which is within the wider Tweed River Catchment. Runoff from the development flows in a south-easterly direction via a number of unnamed ephemeral gullies towards Cobaki Creek, which run along the south-eastern site boundary, and directly into Cobaki Broadwater. Cobaki Broadwater adjoins the Tweed River, which discharges into the Pacific Ocean at Tweed Heads.

The Cobaki Broadwater and Tweed River catchment has an area of approximately 1,100 km^2, the upper part of which is heavily timbered with natural vegetation, the lower floodplains cleared for cropping, plantation and urban development. The catchment encompasses Cobaki Creek and Broadwater, SEPP 14 Wetlands and Terranora Creek, and its major tributaries include the Oxley River and the Rous River.

The catchment is currently largely undeveloped, although some of the areas of the Tweed River Catchment, which are tidally connected to the Broadwater, are highly urbanised.

In accordance with the Technical Report 2009 for the waterways and catchments of Cobaki and Terranora Broadwater's:

- Cobaki Creek is in fair condition, but it suffers from elevated nutrients, and the degradation and loss of streamside vegetation, and
- The water quality in the Cobaki Broadwater deteriorates during the wetter months due to sediment and nutrient inputs from the catchment. The riparian vegetation is in good to very good condition with a 2001 rating of C.

3.2. Topography

The Cobaki Estate is situated at the foothills of the McPherson Range, with Mount Woodgee at the northern end of the Estate. The site forms a natural amphitheatre with steep rising hillsides on the northern, western and southern sides.

From the hill slopes on the northern, western and southern sides of the site, topography falls to a low-lying (< 5 m Australian Height Datum (AHD)) flat coastal plain through the central and eastern areas of the site.

Precinct 7 and 8 are both located on the low-lying, generally flat sand ridge on the central east to south-eastern portion of the site.

Precincts 9, 10, 11 and 12 are located on the hill slopes on the western side of the site, generally above the 5 m AHD contour line.

The site topography and drainage patterns have created a central valley running in a general north to south direction, which forms the proposed Central Open Space and riparian corridor. Overall, surface water drainage is in a south-easterly direction across the site.

3.3. Geology and Soils

The site is bounded to the north and west in part by a series of low hills reaching to approximately 90 m in height in some areas.

A central drainage channel running from the north to south separates the geology across the site. A general description of the geology comprises:

- Central drainage channel (Central Open Space);
- Southern floodplain (Saltmarsh Management Area);
- Sand ridge (Precincts 5, 6, 7, 8 and 9);
- Alluvial plain and low hills (Precincts 10, 11 and 12);
- Higher slopes of the low hills (Precincts 1 and 2), and
- Higher slopes (Precincts 3, 4, 13, 14, 15, 16 and 17).

Gilbert & Sutherland Pty Ltd (G&S) report titled Groundwater Assessment and Management Plan 2008 indicates that the geology of the Site comprises:

- Low Hills and Alluvial Plain
  - The low hills on the western and northern boundaries of the site were formed from Silurian aged Neranleigh-Fernvale shales, siltstones and sandstones (Precincts 1 & 2), and
  - The eroded sediments from these hills also form the alluvial plain areas of the site, characterised my silty loams and clays (Precincts 10, 11 & 12).
- Floodplain
  - The western and northern boundaries of the floodplain (where it abuts the alluvial plain), are also comprised of Neranleigh-Fernvale derived material at the basement depth (below any Holocene sediments);
  - This basement would typically have been the pre-transgressive surface, being a gently sloping continuation of the low hills;
  - As the floodplain reaches west and north, the depth of Holocene material diminishes until it is no longer present;
  - The lowest lying areas of the floodplain (Central Open Space) are predominantly of Holocene origin formed in a back swamp estuarine environment by the accretion of sediments supplied by stream, creek and tidal flow, and
  - Soils are characterised by a shallow organic layer at the surface above unconsolidated marine silty clays of a sulfidic nature.
- Relic Beach Ridge
  - Adjacent to and east of the Central Open Space is an elevated relic beach ridge of very low relief (approximately 4 m AHD), on which Precincts 5, 6, 7 and 8 are located, composed of fine to medium sand;
  - The relic beach ridge located within the low-lying area is essentially that of wave and aeolian deposited sand (beach and dune sand);
  - In this process, the beach ridge acted as a barrier behind which sediments could accumulate in a low energy environment, and
  - These deposited sediments are essentially the unconsolidated marine silty clays described above.

3.3.1. Acid Sulfate Soils

Acid Sulfate Soils (ASS) is a characteristic feature of low-lying coastal environments in eastern Australia, particularly where landform elevations are below 5 m AHD. ASS are comprised of iron sulfides generally in the form of pyritic material that is a product of the natural interaction between iron rich organic matter and sulfate rich seawater present in anaerobic low energy estuarine environments. Undisturbed, these soils are generally present in an anaerobic state within the subsurface profile (below the water table) of Holocene marine muds and sands in the form of potential acid sulfate soil (PASS). Actual acid sulfate soils (AASS) are the oxidised (disturbed) form, which may occur as the result of natural or anthropogenic disturbance from changes in groundwater levels and/or exposure to oxygen.

A review of Gilbert & Sutherland's 2008 Groundwater Assessment indicates that the soil types across the site have characteristics associated with actual and potential acidic sulphate soils. pH readings also indicate existing acidity and high concentrations of iron, aluminium, chloride, sulphate and alkalinity over the southern portion of the site, which are common characteristics of sulfidic hydrosols.

SMEC Pty Ltd conducted an Acid Sulfate Soil Investigation on 2012 in accordance with the Acid Sulfate Soils Assessment Guidelines, 1998.

Qualitative screening test results, obtained during field investigations indicated that:

- pH_f values ranged between pH 3.7 and pH 8.2
- pH_{fox} values ranged between 1.6 and 8.3, where:
  - $pH_f \leq 4.0$ indicates Actual ASS (AASS)
  - $pH_{fox} < 3.0$ indicates Potential ASS (PASS) (e.g. containing unoxidised sulphides)
- Reaction to hydrogen peroxide was rated as ranging from slight to very high
- The net acidity recorded in 82 of the 355 samples tested exceeded the action criteria guidelines, with 96 of 103 monitoring wells recording at least one (1) exceedance.

The results indicated that Potential Acid Sulfate Soils (PASS) and Acid Sulfate Soils (ASS) are present at the site.

ASS and PASS considerations of the development are addressed in SMEC's ASS Management Plan for the Site are available as a separate document.

3.3.2. Contamination

The site contains the historic Turners Creek Dip located on the northern portion of the central open space. The dip area has been remediated and at the time of writing a final Site Audit Statement (SAS) was being prepared.

In accordance Section 20. Certification of Remediation Works, the proponent must provide certification that remediation of the cattle dip site has been satisfactorily completed in accordance with the approved DA K99/1124 (approved by Tweed Shire Council on 21 July 2000). The certification must be in the form of a Site Audit Statement (SAS) completed by a NSW EPA Accredited Site Auditor in accordance with the provisions of the *Contaminated Land Management Act 1997*. The SAS must be submitted to Council prior to the dedication of land containing the approved remediation works.

A SAS will be issued for the Site made available to TSC as a separate document.

3.3.2.1. Stage 1 Preliminary Investigation 1991

NSW Department of Agriculture conducted a Stage 1 Preliminary Site Investigation of the dip during 1991. Results indicated levels of arsenic and DDT (and its derivatives) exceeded the nominated guideline criteria. As such, the NSW Department of Agriculture indicated that the site required remediation and validation of is suitability for the proposed development.

NSW Department of Agriculture's Stage 1 Preliminary Site Investigation, dated 1991 is available as a separate report.

3.3.2.2. Remedial Action Plan 2003

Aargus Pty Ltd prepared a Stage 3 Site Remedial Action Plan (RAP) during 2003. Tweed Shire Council granted approval of the RAP during 2003.

Argus Pty Ltd Stage 3 Site Remedial Action Plan (RAP) during 2003. Tweed Shire Council granted approval of the RAP during 2003.

SMEC Pty Ltd conducted a review of the RAP in 2013. SMEC Pty Ltd observed that the extent of remediation was limited to surface soils and did not extend to the lateral and vertical extent of contamination through the soil profile or the contamination status of groundwater.

As such, SMEC Pty Ltd recommended that a Stage 2 Detailed Site Investigation in accordance with NSW Guidelines for the Assessment and Management of Groundwater Contamination, 2007 was required in order to determine the extent of contamination across the site including groundwater and to assess the risk to human health and environment.

3.3.2.3. Stage 2 Assessment (Groundwater) 2013/14

SMEC Pty Ltd conducted a Stage 2 Detailed Investigation (Groundwater Contamination) of the former Tanner Dip.

Location of Monitoring Bores
During the Remediation Works, three groundwater monitoring bores were installed on 3December 2013 to target depths of approximately 3m below ground surface. The monitoring bores were installed as per "*The minimum construction requirements for water bores in Australia (2012)*". Monitoring bores GW1, GW2 and GW3 were located in order to:

- Characterise the baseline groundwater conditions;
- Check for known contaminants of concern in the groundwater; and
- Be up-gradient and down-gradient of potential contamination areas.

Survey data of the monitoring bores highest point of the PVC casing relative to Australian Height Datum (AHD) is provided in Table 1.

Gauging of Monitoring Bores
The groundwater bores were gauged on 20 December 2013 and 22 January 2014. Groundwater level gauging indicated that standing water levels ranged from 1.77 mbgl in GW3 to 2.23 mbgl in GW2. A summary of the well gauging data for 22 January 2014 is provided in Table 1.

Water Quality Parameters
During groundwater sampling, the groundwater colour was generally observed to be brown.
Groundwater quality parameters were measured to ascertain the condition of the groundwater. Table 2 shows the parameter measurements recorded post sampling on 22 January 2014.

Table 1. Groundwater Bore Gauging Data

Bore ID	Bore Depth (mbgl)	Ground level (mAHD	SWL (mbgl)	TOC Elevation from Survey (mAHD)	SWL (mAHD)	Sheen/ Odour	Observations
GW1	6.9	9.6	2.15	2.750	0.600	No	Brown Silty water
GW2	6.24	12.7	2.23	3.600	1.370	No	Brown Water
GW3	9.4	10.0	1.77	3.437	1.667	No	Brown Water

SWL = standing water level
TOC = top of casing
m = metres
bgl = below ground level
AHD = Australian Height Datum

Table 2. Groundwater Parameters

Bore ID	pH	Electrical Conductivity (us/cm)	Turbidity (NTU)	Dissolved Oxygen (%)	Temperature (°C)
GW1	6.51	374	>1000	74	22.6
GW2	6.03	253	>1000	41	22.1
GW3	5.06	196	805.8	83	22.5

Groundwater Laboratory Analysis Results

Tabulated laboratory groundwater analysis results are included in Table B3 in Appendix B of the Site Validation Report (SMEC, 2015)

Sample locations exceeding the adopted assessment criteria for groundwater are detailed below.

GW1 (monitoring bore):
- copper - 8µg/L (NEPM 2013 GIL Fresh 1.4µg/L)
- zinc - 14µg/L (NEPM 2013 GIL Fresh 8µg/L)

GW2:
- Zinc - 16µg/L (NEPM 2013 GIL Fresh 8µg/L)

GW3:
- Zinc - 100µg/L (NEPM 2013 GIL Fresh 8µg/L)

Groundwater results from samples collected by SMEC on 20 December 2012 indicate slightly elevated levels of zinc in GW1, GW2 and GW3 and elevated levels of copper in GW1. However, these concentrations in groundwater are likely to be representative of background conditions and unlikely to be associated with any site-based sources of contamination.

3.3.2.4. Site Validation Report

SMEC's Site Validation Report, dated July 2015 is available as a separate report.

Groundwater control measures were derived from SMEC Pty Ltd Site Validation Report provided in Section 7 Environmental Control Measures of this report.

3.4. Historical Hydrological Investigations

Numerous hydrological assessments were conducted at the site comprising:

- WBM Pty Ltd
- Gilbert & Sutherland Pty Ltd (G&S), 2007 - 2008
- SMEC Pty Ltd (SMEC), 2011 - 2012
- Planit Consulting Pty Ltd, 2014

Details of historical investigation are provided below.

3.4.1. Historical Monitoring Locations

The locations of historic groundwater monitoring wells installed at the site and surface water monitoring locations are shown on Figure 3, dated June 2015 comprising:

For reporting purposes, the wells are grouped according to topographical, hydrogeological and geophysical characteristics considered representative of groundwater zones at the site:

- Zone 1 – North eastern Neranleigh-Fernvale (GW8 and GW14)
- Zone 2 – North western Neranleigh-Fernvale (GW9, GW18, GW29, GW30, GW31 and GW32)
- Zone 3 – Central drainage channel (GW2A, GW4, GW19, GW20, GW24, GW25, GW26, GW27, GW28)
- Zone 4 – Sand ridge (GW3, GW5, GW6, GW7, GW10, GW10A, GW10B, GW11, GW13, GW21, GW22 and GW23)
- Zone 5 – Southern Neranleigh-Fernvale (GW1)
- Zone 6 – Southern flood plain (GW12, GW16 and GW17)

3.4.2. WBM Oceanics Australia

It is understood that prior to the investigation by Gilbert & Sutherland Pty Ltd (G&S) during 2007 to 2008, BMT WBM Oceanics Pty Ltd (WBM) installed ten (10) groundwater monitoring wells and conducted sampling of groundwaters at the site.

No report by WBM was available at the time of writing this current Groundwater Management Plan for Precincts 7, 8, 9, 10, 11 and 12.

Figure 2: Historic Groundwater and Surface Water Monitoring Locations

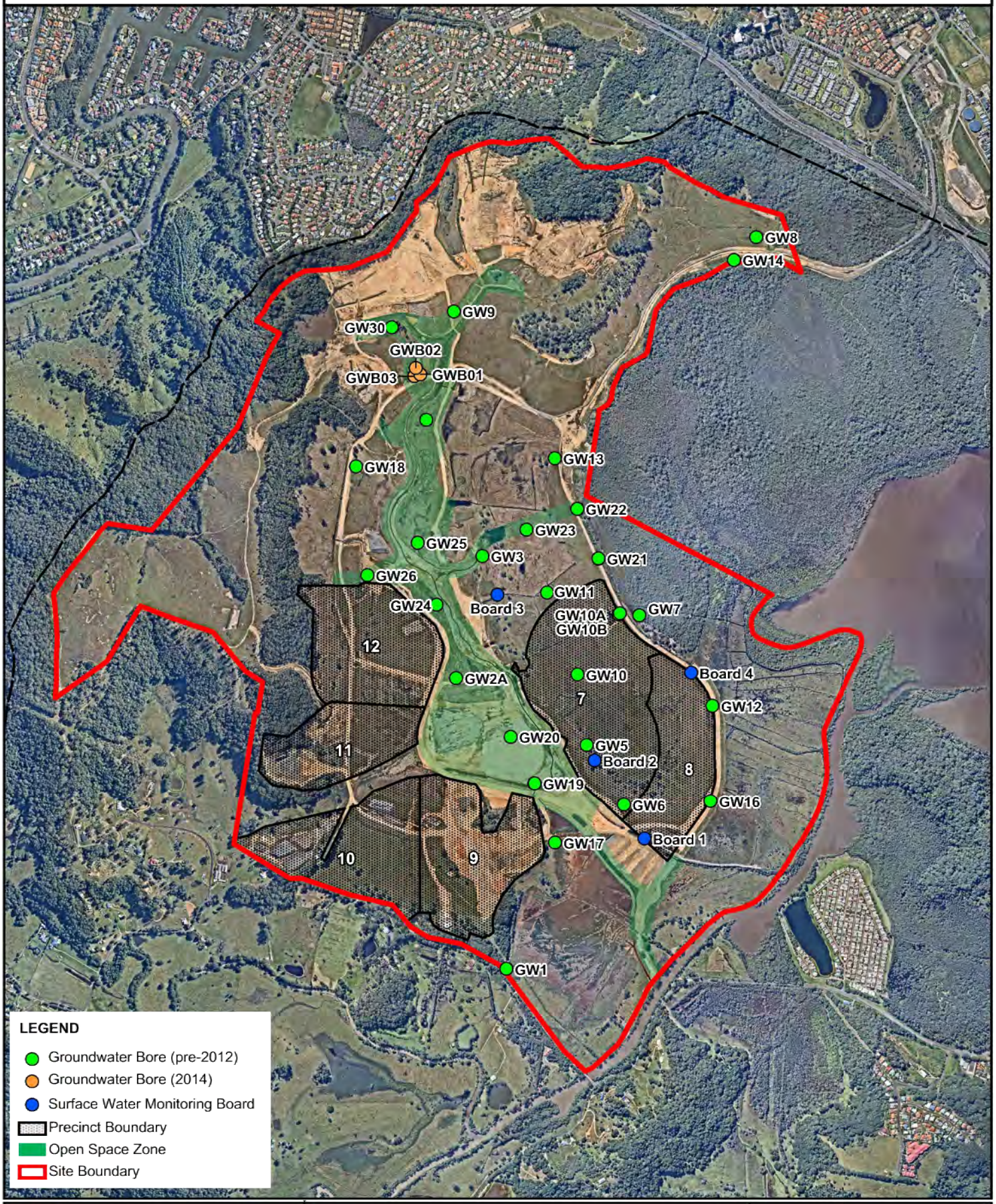

FIGURE Water Monitoring Locations	REVISION 0	STATUS FINAL
CREATED BY AM11482	DATE 25/06/2015	ISSUED FOR INFORMATION
PROJECT NO. 30031425	COORDINATE SYSTEM GDA 1994 MGA Zone 56	0 0.5 1 km Scale: 1 : 20,000 @ A4
PROJECT TITLE Cobaki Estate Environmental Management Plans	SOURCE The State of Queensland (Department of Environment and Resource Management), Copyright 2010 Aerial Imagery by Nearmap Hypertiles, Copyright 2011 Survey from Michel Group Services, 2011	CONSULTANT SMEC Australia Copyright SMEC Australia Pty Ltd. All Rights Reserved. CLIENT LEDA MANORSTEAD PTY LTD

PATH: I:\Projects\30031425\007_Spatial\Workspaces\Groundwater Maps.wor

3.4.3. Gilbert & Sutherland Pty Ltd 2007 - 2008

Gilbert & Sutherland Pty Ltd (G&S) were engaged by Leda during 2007 and 2008 to undertake a groundwater assessment that:

- considered groundwater conditions generally at the Cobaki Estate (former Cobaki Lakes) Development site;
- considered specific issues as described by the Director General of the Department of Planning;
- assessed the beneficial uses of receiving waters, and
- provided management strategies, responsibilities and procedures for the management of groundwater during the construction and operational phases of the development.

G&S's scope of work comprised:

- a desktop assessment summarising the site stratigraphy, soils, geology and landform characteristics relevant to groundwater considerations;
- Installation of eleven (11) groundwater monitoring wells to a depth of 2 m (GW1, GW3, GW4, GW11), 2.5 m (GW2A, GW10), 3.0 m (GW9) and 3.5 m (GW5, GW6, GW7 and GW8) across the low-lying portion of the site;
  - The wells were located to replicate (as closely as possible) the original WBM monitoring locations, which were demolished.
- Collection of water samples every four weeks from each monitoring well for a period of six months (e.g. seven monitoring events in total);
  - Samples were analysed for iron, aluminium, total nitrogen, total phosphorus, orthophosphorus, sulphate, chloride, nitrate, nitrite, total kjeldahl nitrogen and pH by a NATA accredited laboratory.
- Groundwater flow path assessment using a three dimension digital model e.g. Quicksurf (Groundwater levels from WBM original ten (10) wells were used in the modelling (GW2 was destroyed in 2007));
- Permeability testing of soils surrounding each of the wells using the Rising Head Test method;
- Construction phase seepage using the Darcian flow rate and groundwater drawdown using Hooghoudt's Equation;
- Groundwater level recording during the six month sampling period;
- Evaluation of groundwater users and groundwater dependent ecosystems, and
- Compilation of results and finding in report format titled "*Conceptual Groundwater Assessment, Cobaki lakes Concept Plan"* dated April 2008 (available as a separate report).

G&S's investigation findings comprised:

- Groundwater quality at the site appeared to be heavily influenced by site stratigraphy;
- Groundwater height appeared reasonably consistent over time;
- Mounding of groundwater is evident within the sand ridge in the central to eastern part of the site;
- The central drainage line draws down groundwater from the sand ridge;
- Soil permeability in the vicinity of the groundwater wells ranged from 1.9×10^{-5}m/s to 8.7×10^{-6}m/s, and
- The overall groundwater flow appeared to be in a south-easterly direction towards the Cobaki Broadwater.

Given the nature of the site soil and groundwater characteristics, G&S concluded that the most likely potential impacts on groundwater as a result of the development would be:

- impacts to the pre-development groundwater flow regimes as result of excavation, road building and hardening of the site;
- impact on groundwater quality as a result of the construction phase and subsequent urban stormwater runoff, and
- acid sulfate soils impacts as a result of disturbance of such materials.

G&S indicated that the potential impacts on groundwater quality and flow regimes did not represent an impediment to development at the site in accordance with the Cobaki Lakes Concept Plan.

3.4.4. SMEC Pty Ltd 2011 - 2012

SMEC Pty Ltd (SMEC) was engaged by Leda during 2011 and 2012 to undertake an additional groundwater assessment that:

- ensured representative samples were gathered across the site;
- further investigated groundwater conditions across the site;
- summarised the site stratigraphy, soils, geology and landform characteristics relevant to groundwater considerations, and
- provided management strategies, responsibilities and procedures for the management of groundwater during the construction and operational phases of the development of the Central Open Space and Precincts 1, 2 & 6 of the development.

SMEC's scope of work comprised:

- A site walkover of the site in 2011 observing that some of the original monitoring wells installed by G&S were no longer present due to earthwork activities;
- Installation of an additional fourteen (14)-groundwater monitoring wells across the low lying portion of the site to a depth of 2.5 m (GW19, GW20, GW21, GW22, GW23, GW26, GW28, GW29, GW30 and GW32), 3 m (GW24, GW25, GW27) and 4 m (GW31);
- In-situ recording of pH, redox, electrical conductivity (EC), turbidity, dissolved oxygen (DO) and temperature of water from each monitoring well for a period of three (3) monitoring events (i.e. November and December 2011 and February 2012);
- Collection of water samples from each monitoring well for a period of three (3) monitoring events (i.e. November and December 2011 and February 2012);
- The analytical program was conducted in accordance with G&S "*Cobaki Lakes Concept Plan, Groundwater Management Plan*" dated 2008. Samples collected from all wells were analysed by a NATA accredited laboratory for:
  - Major cations – calcium, magnesium, sodium and potassium;
  - Major anions – sulfate and chloride;
  - Alkalinity – carbonate and bicarbonate;
  - Acidity (tritratable);
  - Dissolved metals – aluminium, manganese and iron, and
  - Total metals – iron.

- Groundwater level recording for a period of three (3) monitoring events (i.e. November and December 2011 and February 2012). Relative groundwater levels were used to derive groundwater contours to assess groundwater flow as shown on Figures 4 to 6.
- Compilation of results and findings in report format titled "*Groundwater Management Plan, Central Open Space and Precincts 1, 2 & 6*" dated May 2012 (available as a separate report).

SMEC's investigation findings comprised:

- Groundwater contours and flow directions derived for November and December 2011, and February 2012 were consistent with the groundwater regimes identified by G&S, 2008
  - Following site topography, groundwater flows in a general east to south-easterly direction from the northern and western hill slopes towards the central riparian corridor.
  - Groundwater mounding in the sand ridge drives groundwater flow westward towards the:
    - central riparian corridor from the western side of the ridge, and
    - east to south easterly from the eastern side of the ridge towards the Cobaki Creek Broadwater.

Pre-construction groundwater quality results collected by SMEC during November and December 2011 and February 2012 were compared against the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000) (the ANZECC guidelines) in Table 1.

Comparisons of monitoring results against ANZECC guidelines indicate concentrations of analytes exceeding the generic guidelines in all groundwater zones at the site. In particular, pH is lower than the guidelines across the site and iron (dissolved and total) concentrations were consistently higher.

Table 3. - Result Comparison SMEC 2011 - 2012 / ANZECC Guidelines

Parameter	Units	ANZECC Guideline Value	Zone 1			Zone 2			Zone 3		
			Min	Max	Average	Min	Max	Average	Min	Max	Average
pH	pH	7.0 – 8.5[1]	**5.68**	**6.58**	**5.745**	**3.06**	**6.7**	**5.77**	**4.1**	**7.72**	**6.27**
Turbidity	NTU	0.5 – 10[1]	**455**	**max**	-	**10.3**	**max**	-	**44.4**	**max**	**-**
Dissolved oxygen	% Sat	80 – 110[1]	**33.9**	**60.7**	**46.6**	**24.1**	**137.4**	**71.2**	**44**	88	**59.4**
Sodium	mg/L	300[2]	37	189	109	31	**730**	296	220	**6000**	**2146**
Sulfate	mg/L	400[2]	12	80	36.8	<5	291	80	200	**3700**	**1298**
Chloride	mg/L	400[2]	30	261	144	46	**1600**	**521**	370	**11000**	**4157**
Carbonate Alkalinity	mg/L	>20[3]	**<1**	<10	-	**<1**	<10	-	**<1**	<10	-
Bicarbonate Alkalinity	mg/L		**14**	220	65.5	**2**	320	117	**<1**	1010	384
Dissolved Al	mg/L	0.2[2]	<0.05	**0.86**	**0.285**	<0.05	**7.16**	**2.09**	<0.05	**2.56**	**0.97**
Dissolved Mn	mg/L	0.1[2]	0.064	**0.13**	0.0855	0.05	**2.83**	**0.89**	**0.2**	**9.79**	**1.54**
Dissolved Fe	mg/L	0.3[2]	0.13	**16**	**5.03**	0.21	**21**	**7.39**	**5.7**	**316**	**87**
Total Fe	mg/L	0.3[2]	**0.64**	**22**	**9.2**	<0.05	**67.2**	**19.6**	**12**	**406**	**115**
Parameter	**Units**	**ANZECC Guideline Value**	**Zone 4**			**Zone 5**			**Zone 6**		
pH	pH	7.0 – 8.5[1]	**3.62**	**6.8**	**4.92**	**6.14**	**6.6**	**6.44**	**5.36**	**7.12**	**6.09**
Turbidity	NTU	0.5 – 10[1]	**64.3**	**max**	-	**461**	**474**	**466**	**322**	**820**	**496.2**
Dissolved oxygen	% Sat	80 – 110[1]	**11.8**	80.4	**50.1**	**36.1**	**77.4**	**63.5**	**31.6**	96.1	**62.2**
Sodium	mg/L	300[2]	4.3	**409**	78	280	297	286	66	**2600**	**1508**
Sulfate	mg/L	400[2]	2	219	39	<5	19	9.7	<5	**1920**	**717**
Chloride	mg/L	400[2]	18	**877**	135	**420**	**467**	**442**	84	**4400**	**2773**
Carbonate Alkalinity	mg/L	>20[3]	**<1**	<10	-	<1	<10	-	<1	<10	-
Bicarbonate Alkalinity	mg/L		**<1**	420	145	346	380	369	21	150	78
Dissolved Al	mg/L	0.2[2]	0.07	**4.9**	**1.29**	<0.05	<0.10	-	<0.05	**0.94**	**0.45**
Dissolved Mn	mg/L	0.1[2]	<0.005	**0.98**	**0.22**	**0.16**	**0.21**	**0.18**	0.068	**5.6**	**1.95**
Dissolved Fe	mg/L	0.3[2]	0.11	**33**	**5.57**	**12**	**53**	**27**	**3.7**	**150**	**48**
Total Fe	mg/L	0.3[2]	0.26	**181**	**12.2**	**12**	**40.8**	**30.3**	**1.9**	**226**	**65**

Exceeds generic ANZECC guideline criteria

(a). Trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems – estuaries

(b). Water quality guidelines for recreational purposes

(c). Guidelines for the protection of aquaculture species

Surface water monitoring was also undertaken at four locations previously defined by G&S, located at:

- Board 1 – southern (downstream) end of the central drainage line prior to discharge into Cobaki Creek;
- Board 2 – minor drain at southern end of sand ridge;
- Board 3 – east-west drain in the central portion of the sand ridge, which dissects Precinct 6. Drains into the central drainage line; and
- Board 4 – drain on south-eastern side of site, draining into Cobaki Broadwater.

Surface water locations were monitored for the presence of water during groundwater monitoring in November and December 2011 and February 2012. Where water was present, samples were collected and analysed for the same suite of analytes as groundwater samples. Water quality analysis had not previously been completed for the surface water monitoring locations. On all occasions, Board 2 was dry, consistent with observations by G&S, 2009. Water was only present at Board 4 in February 2012 with just 2 cm water, while water was present at Board 1 (30 to 63 cm water) and Board 3 (3 to 10 cm water) during each monitoring event. Surface water field parameters and analytical results are summarised in Table 2 below.

Table 4. – Summary 2011 - 2012 Surface Water Monitoring Results

Parameter	Units	Board 1			Board 3			Board 4
		28/11/11	20/12/11	7/2/12	29/11/11	20/12/11	8/2/12	9/2/12
pH	pH	6.34	5.78	7.1	7.71	6.87	4.66	6.29
EC	µS/cm	22830	6862	19000	307	136	104	228
Redox	mV	29	83.9		212.5	126.2	-26.1	97.7
DO	% Sat	76.8	104.5		89.2	127.3	30.7	43.5
Turbidity	NTU	37.7	316		3.3	4	108	0
Temperature	°C	28.7	28.7		37.6	31.6	32.8	30
Calcium	mg/L	310	51	140	3	2.3	2.1	20
Magnesium	mg/L	982	110	380	6	2.8	2.6	7.5
Sodium	mg/L	7930	1100	3400	27	37	9.5	20
Potassium	mg/L	320	41	130	3	0.7	0.7	1.2
Sulfate	mg/L	2150	110	280	12	< 5	<5	<5
Chloride	mg/L	13200	1900	6600	53	30	26	22
Carbonate Alkalinity	mg/L	<1	< 10	<10	<1	< 10	<10	<10
Bicarbonate Alkalinity	mg/L	80	83	96	<1	< 20	<20	100
Acidity	mg/L	14	28	19	55	66	67	15
Dissolved Al	mg/L	<0.10	0.1	<0.05	1.7	0.72	0.8	0.14
Dissolved Mn	mg/L	0.26	0.14	0.12	0.05	0.011	0.01	0.2
Dissolved Fe	mg/L	<0.05	0.54	0.92	1.59	0.59	0.63	0.64
Total Fe	mg/L	2.13	1.6	0.32	1.85	0.84	0.63	0.62

Water at Board 1 was neutral to slightly acidic, brackish to saline with high chloride and sulfate concentrations, generally consistent with surrounding and upstream groundwater (Zones 6 and 3 respectively), except iron concentrations are lower than that in groundwater. Marine waters influence this location. Conditions at Board 3 were neutral to acidic, fresh waters with low sulfate, alkalinity and chloride concentrations, consistent with surrounding groundwater conditions in Zone 4 (sand ridge). Water at Board 4 in February 2012 had slightly acidic pH, low conductivity (fresh water) and was similar to adjacent groundwater conditions in Zone 6 (southern flood plain).

Figure 3: Inferred Groundwater Contours and Flow Direction - 28 November 2011

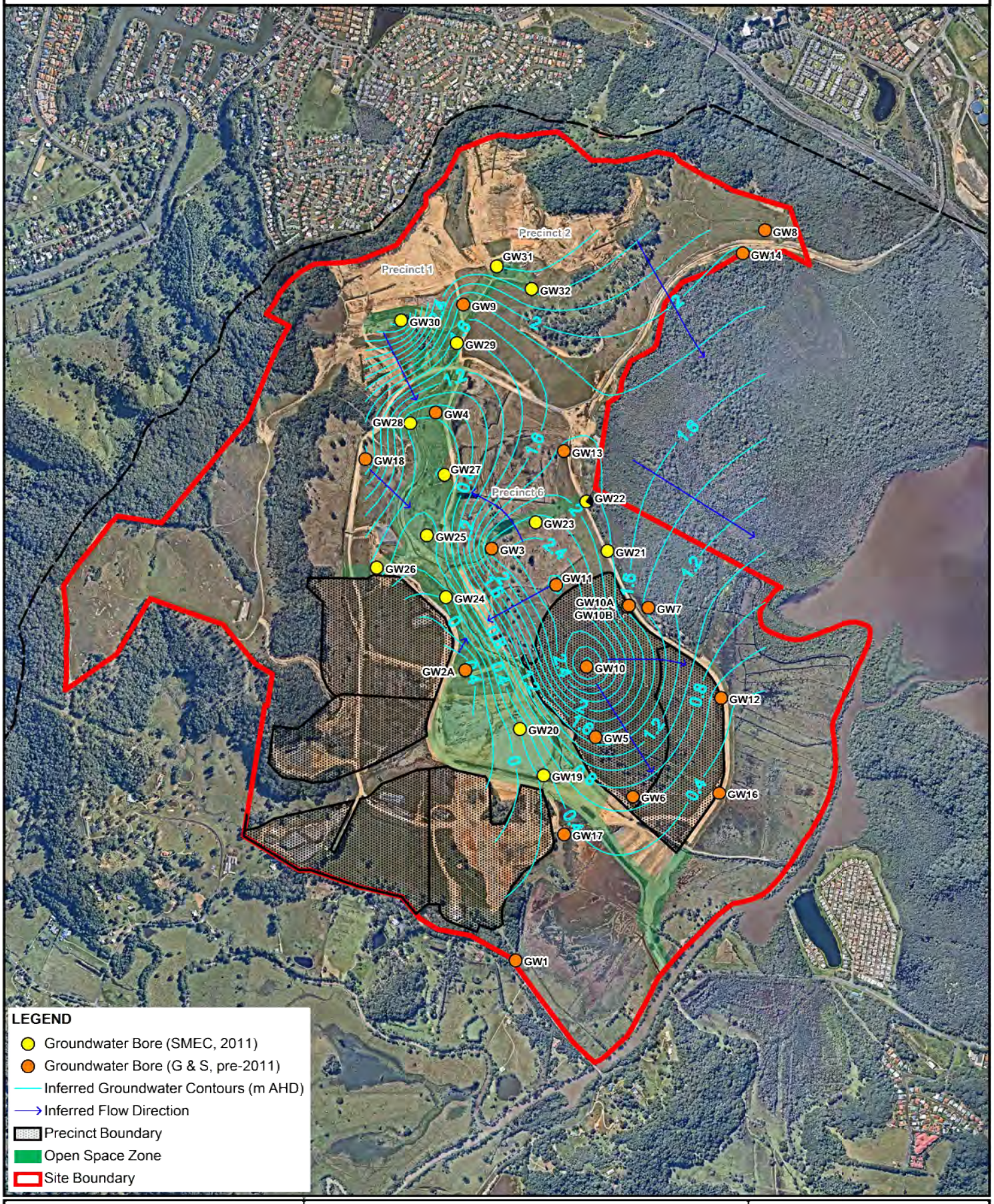

FIGURE Inferred Groundwater Contours and Flow Direction - 28 November 2011	**REVISION** 1	**STATUS** FINAL
CREATED BY AM11482	**DATE** 25/06/2015	**ISSUED FOR INFORMATION**
PROJECT NO. 30031425	**COORDINATE SYSTEM** GDA 1994 MGA Zone 56	0 0.5 1 km Scale: 1 : 20,000 @ A4
PROJECT TITLE Cobaki Estate Environmental Management Plans	**SOURCE** The State of Queensland (Department of Environment and Resource Management), Copyright 2010 Aerial Imagery by Nearmap Hypertiles, Copyright 2015 Survey from Michel Group Services, 2011	**CONSULTANT** SMEC Australia Copyright SMEC Australia Pty Ltd. All Rights Reserved. **CLIENT** LEDA MANORSTEAD PTY LTD

PATH: I:\Projects\30031425\007_Spatial\Workspace\Groundwater Maps.wor

Figure 4: Inferred Groundwater Contours and Flow Direction - 19 December 2011

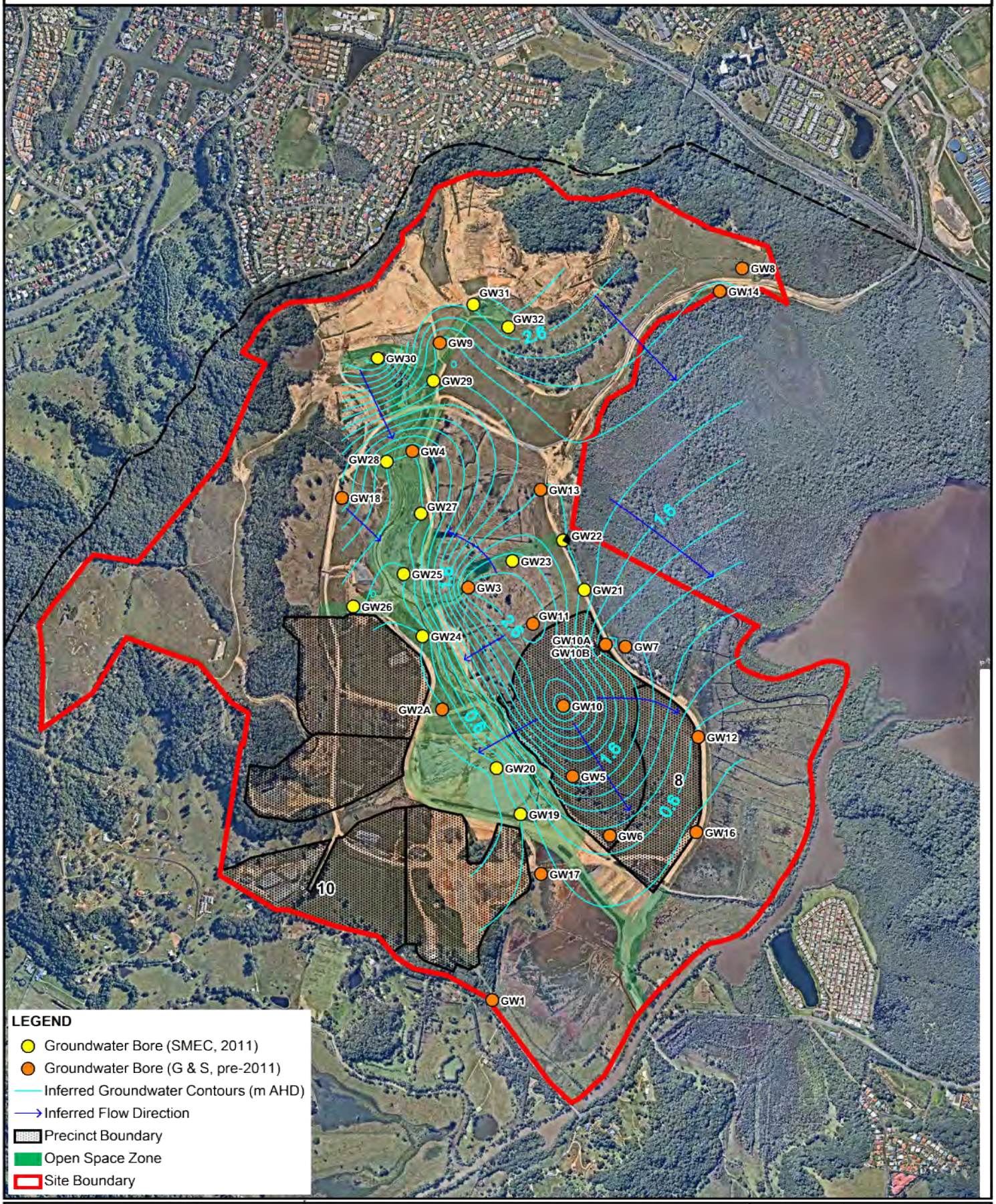

FIGURE 4: Inferred Groundwater Contours and Flow Direction - 19 December 2011

CREATED BY AM11482

REVISION 1

STATUS FINAL

DATE 25/06/2015

ISSUED FOR INFORMATION

N

PROJECT NO. 30031425

PROJECT TITLE
Cobaki Estate Environmental Management Plans

COORDINATE SYSTEM
GDA 1994 MGA Zone 56

0 0.5 1 km
Scale: 1 : 20,000 @ A4

SOURCE
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Survey from Michel Group Services, 2011

CONSULTANT SMEC Australia

CLIENT LEDA MANORSTEAD PTY LTD

PATH: I:\Projects\30031425\007_Spatial\Workspace\Groundwater Maps.wor

Figure 5: Inferred Groundwater Contours and Flow Direction - 7 February 2012

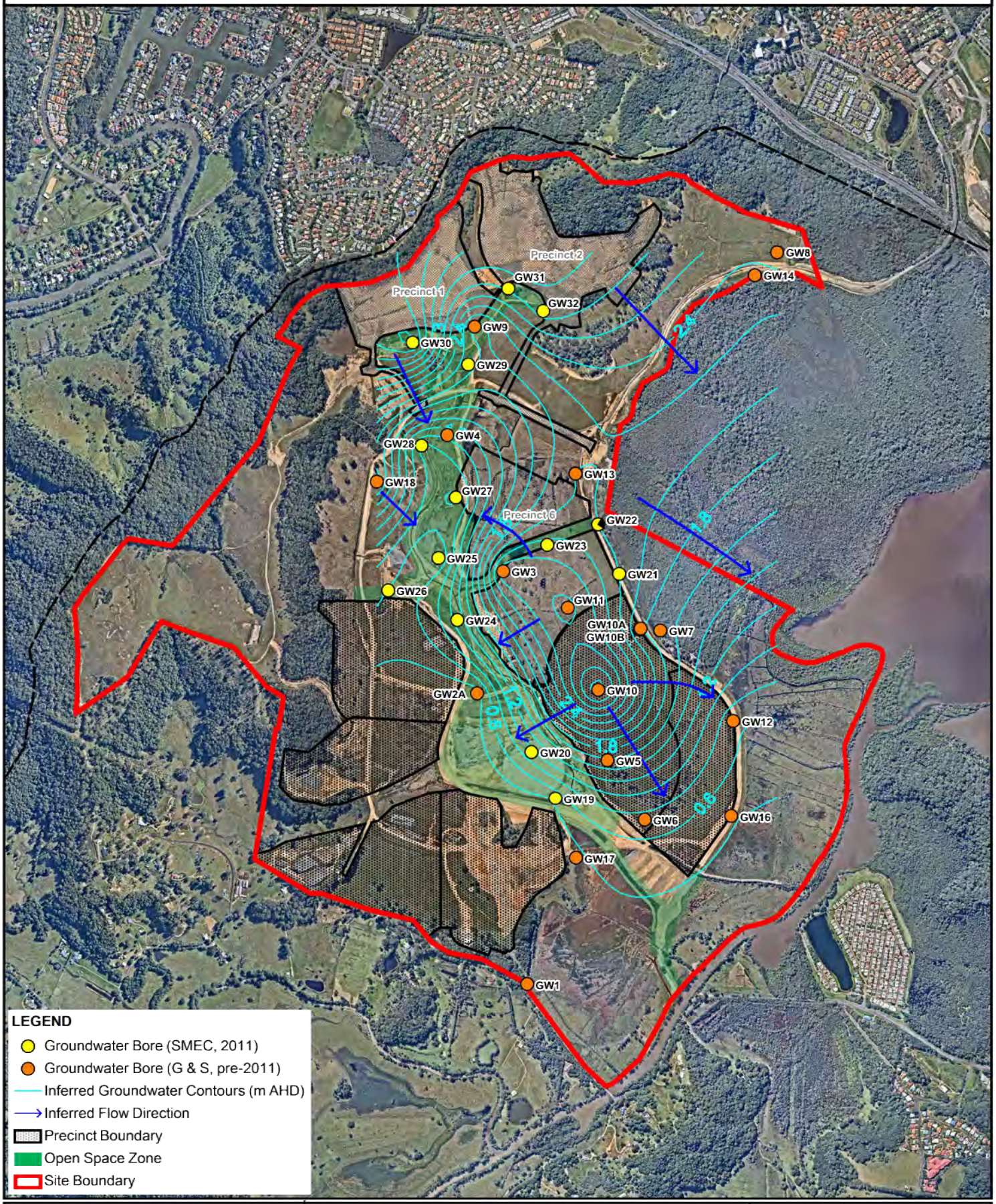

FIGURE 5: Inferred Groundwater Contours and Flow Direction - 7 February 2012	**REVISION** 1	**STATUS** FINAL
CREATED BY AM11482	**DATE** 25/06/2015	**ISSUED FOR INFORMATION**
PROJECT NO. 30031425	**COORDINATE SYSTEM** GDA 1994 MGA Zone 56	0 0.5 1 km Scale: 1 : 20,000 @ A4
PROJECT TITLE Cobaki Estate Environmental Management Plans	**SOURCE** The State of Queensland (Department of Environment and Resource Management), Copyright 2010 Aerial Imagery by Nearmap Hypertiles, Copyright 2015 Survey from Michel Group Services, 2012	**CONSULTANT** SMEC Australia

CLIENT LEDA MANORSTEAD PTY LTD

PATH: [illegible]\Cobaki Lakes\Groundwater Management Maps.wor

3.4.1. Planit Consulting Pty Ltd 2014

Planit Consulting Pty Ltd (Planit) was engaged by Leda during 2014 to undertake groundwater quality monitoring at the site during bulk earthworks at the Site e.g. Central Drainage Channel. Based on the information provided by Planit, it is understood that Planit's scope of work comprised:

- Collection of water samples from each monitoring well (GW10B, GW7, GW13, GW23, GW22, GW14, GW8) for a period of five (5) monitoring events e.g. August, September, October, November and December 2014.
- Collection of water samples from monitoring well (GW17) for a period of four (4) monitoring events e.g. August, September, October and December 2014.
- Collection of water samples from monitoring wells (GW3 and GW11) for one (1) monitoring event e.g. August 2014
- Collection of water samples from monitoring well (GW10) for three (3) monitoring events e.g. September, October and November 2014
- Samples collected were analysed for:
  - pH, dissolved oxygen, turbidity, electrical conductivity
  - Major cations – calcium, magnesium, sodium and potassium;
  - Major anions – sulfate and chloride;
  - Alkalinity – carbonate and bicarbonate;
  - Total acidity;
  - Dissolved metals – aluminium, manganese and iron, and
  - Total metals – iron.
- Groundwater level recordings were not provided.

As shown in Table 3, average laboratory results for the August to December 2014 sampling events compared against ANZECC guidelines and SMEC's Baseline Performance Criteria (refer Section 9) indicate concentrations of analytes exceeding the ANZECC guidelines in all groundwater zones at the Site.

The results from Planit's monitoring events indicate the following non-conformances with SMEC's Baseline Performance Criteria:

- pH is lower than Baseline Performance Criteria at Zones 1 and 4
- Turbidity increased in Zone 6
- Dissolved oxygen decreased in Zones 1, 4 and 6
- Major cation – sodium levels increased in Zones 1 and 6
- Major anions - sulfate and chloride levels increased in Zones 1 and 6
- Alkalinity - bicarbonate levels decreased in Zone 4
- Dissolved aluminium decreased in Zones 1 and 4 and decreased in zone 6
- Dissolved iron decreased in Zones 1 and 4
- Dissolved manganese increase in Zones 1 and 6
- Total iron increase in Zones 1, 4 and 6.

Remaining groundwater quality results were in accordance with the calculated Baseline Performance Range (i.e. adopted performance criteria).

Lower pH levels indicate an acidic influence in Zones 1 and 4. pH levels must be closely monitoring in the coming sampling events to determine if any trends are occurring.

When iron is precipitating from acidic water, very low dissolved oxygen levels may occur as results indicate that dissolved iron decreased in Zones 1 and 4 similarly as a lowering of dissolved oxygen levels in Zones 1, 4 and 6.

An increase of total iron and decrease in dissolved iron may indicate the formation of hydroxides and the oxidisation of dissolved iron. Oxidation of iron in water can lead to increases in total iron.

Total iron levels together with all other exceedances must be closely monitored in future events to ascertain if any trends are occurring.

It should be noted that fluctuating results maybe also a result of tidal influences.

As part of the environmental auditing of the development, surface water monitoring results in the areas surrounding the groundwater monitoring wells should be used to identify potential impacts on; the surrounding environment as well as visual inspection (e.g. iron staining on vegetation).

Table 5. - Result Comparison Planit 2014 Construction / SMEC Baseline Performance Range

Parameter	Units	ANZECC Guideline Value	Zone 1		Zone 4		Zone 6	
			SMEC Average	Planit Average	SMEC Average	Planit Average	SMEC Average	Planit Average
pH	pH	7.0 – 8.5[a]	**5.7**	**5.26**	**4.92**	**4.5**	**6.09**	**6.34**
Turbidity	NTU	0.5 – 10[a]	-	**1404.3**	-	**654.7**	**496.2**	**4850**
Dissolved oxygen	% Sat	80 – 110[a]	**46.6**	**10.31**	**50.1**	**8.5**	**62.2**	**7.4**
Sodium	mg/L	300[b]	109	176.5	78	66.7	**1508**	**1820**
Sulfate	mg/L	400[b]	36.8	123.8	39	33.0	**717**	**1540**
Chloride	mg/L	400[b]	144	248.1	135	107	**2773**	**3710**
Carbonate Alkalinity	mg/L	>20[c]	-	-	-	-	-	290
Bicarbonate Alkalinity	mg/L		65.5	36.16	145	**4.3**	78	154.3
Dissolved Al	mg/L	0.2[b]	**0.28**	**0.61**	**1.29**	**2.4**	**0.45**	0.01
Dissolved Mn	mg/L	0.1[b]	0.08	**1.29**	**0.22**	**0.2**	**1.95**	**2.94**
Dissolved Fe	mg/L	0.3[b]	**5.03**	2.48	**5.57**	**2.3**	**48**	**47.16**
Total Fe	mg/L	0.3[b]	**9.2**	**42.48**	**12.2**	**20.3**	**65**	**217.3**

Notes:
BOLD = ANZECC Guideline Value Exceedance
Grey = SMEC Baseline Exceedance

4. STATUTORY AND PLANNING FRAMEWORK

4.1. Current Approvals

4.1.1. NSW Department of Planning

Cobaki Estate is identified within the State Government's Far North Coast Regional Strategy and Council's own adopted "Tweed Urban and Employment Lands Release Strategy 2009" as one of the largest contributors for the provision of new housing and employment within the Tweed Shire over the next 25 year time period.

Given the scale, complexity of planning and environmental issues, and state wide planning significance, the NSW Minister for Planning took over the role as the consent authority for the assessment of the initial redevelopment proposal for the Cobaki site under Part 3A of the Environmental Planning and Assessment Act 1979. Section 75U of the EP&A Act provides that a range of NSW legislative approvals is not required for projects approved under Part 3A. The Part 3A process is quite different to the local development consent role that NSW Councils such as the Tweed Shire generally administer. The NSW Department of Planning manages the main form of planning and environmental assessment. However, the relevant regulator must be consulted and where necessary, inspections and ongoing advice must be sought during the course of the proposed development.

The Concept Plan, Ref. No. 06-0316 was approved on 6 December 2010 by the Minister of Planning in accordance with the *Environmental Planning and Assessment Act 1979*, subject to conditions of approval.

4.1.2. Tweed Shire Council

Following the initial Part 3A approvals (Concept Plan, 2010 and the first project Application) and subsequent repealing of Part 3A of the EP&A Act it is understood that Tweed Shire Council will now mostly undertake the development assessment role.

Given the scale of the likely future applications, the consent authority is likely to be the Northern Region Joint Regional Planning Panel (JRPP), not Council. Council officers will report on these applications to the JRPP for their determination at a public meeting.

To date, two development applications are approved by the JRPP for the Cobaki development. These relate to Precincts 1and 2 (DA10/0800) and Precinct 6 (DA10/0801).

Precinct 1 and 2 is comprised of 475 residential lots (including one (1) residual lot) and lots for drainage, open space and urban infrastructure. Approval was granted by the JRPP in May 2011.

This Groundwater Management Plan supports the development applications that relate to Precincts 7, 8, 9, 10, 11 and 12.

4.2. Licences and Permits

The project is expected to intercept groundwater during cutting activities, particularly in the Central Open Space. Prior to earthworks commencing, the Construction Manager and/or Environmental Officer is required to consult with the NSW Department of Primary Industries (DPI) – Office of Water (Industry and Investment), NSW Office of Environment & Heritage (OEH), and all other relevant government bodies to determine the licences necessary for the project.

It is considered that the following licences and permits may be required for the project:

- Groundwater Licence to extract groundwater under the Part 5 of the *Water Act 1912*
- Environment Protection Licence to discharge pollutants into a natural water body under the *Protection of the Environment Operations Act 1997*

There are currently ten (10) operational groundwater monitoring wells onsite as shown in Figure 8. Bore Logs for operational groundwater monitoring wells are provided in **Appendix A**. Bore License Certificates are provided in **Appendix B**.

4.3. Legislation, Policies and Guidelines

This section addresses relevant statutory provisions in relation to the proposed works. Relevant Commonwealth, State, Local Government legislation, policy and guidelines are considered and described in Table 4.

Table 6. – Applicable Groundwater Legislation, Policies and Guidelines

Applicable Groundwater Legislation, Policies and Guidelines	
Commonwealth	
Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act)	The *EPBC Act* applies 'controlled actions'. Controlled actions are actions that are proposed to take place in Commonwealth owned regions, activities that are to be carried out by the Commonwealth and activities that are likely to have a significant impact on a 'matter of national environmental significance'. Matters of national environmental significance include RAMSAR wetlands as well as migratory and threatened species and communities, all of which could potentially be dependent on groundwater. Where a proposed activity relates to a controlled action, the Environment Minister must refer the activity to the Commonwealth Government for assessment. In this way, the Commonwealth Government can oversee certain developments that will impact on groundwater. Consideration is given to the *EPBC Act*. However, the proposed works are unlikely to impact upon matters of National Environmental Significance (NES) and therefore referral under the EPBC Act is not required. Refer SMEC Pty Ltd Flora and Fauna Management Plan – Cobaki Estate, dated 2015 available as a separate document for statutory planning requirements and mitigation measures.
State	
Environment Planning and Assessment Act 1979 (EP& A Act)	Given the scale, complexity of planning and environmental issues, and state wide planning significance, the NSW Minister for Planning took over the role as the consent authority for the assessment of the initial redevelopment proposal for the Cobaki site under Part 3A of the *Environmental Planning and Assessment Act 1979* during 28 February 2011. In 2011, the NSW Government repealed Part 3A of the EP&A Act and announced that it will stop accepting any new projects in the Part 3A assessment system.

Applicable Groundwater Legislation, Policies and Guidelines	
	Refer Section 4.2 Current Approvals for detailed description.
Water Act 1912	The Water Act 1912 came into force at the turn of the last century and represented a different era in water management in NSW. This Act is being progressively phased out and replaced by the Water Management Act 2000, but some provisions are still in force. The Water Act controls the extraction of water, the use of water, the construction of works such as dams and weirs and the carrying out of activities in or near water sources in New South Wales where no water-sharing plan is in place. This Act will be fully repealed when the Water Management Act is operational in its entirety. Groundwater Licence to extract groundwater under the Part 5 of the *Water Act 1912*
Water Management Act 2000 (WM Act) *Water Management Amendment Act 2014* *Water Management (General) Regulation 2011*	The Water Management Act governs the issuance of new water licences, trading of licences and allocation of water resources in NSW where the water sources are 'regulated'; that is, where a water sharing plan is in place. Section 324 of the *Water Management Act 2000* provides for the management of local impacts in groundwater sources. The Minister may, for a specified period, prohibit or restrict the taking of water from a water source, as the case requires to: ▪ maintain or protect water levels in an aquifer; ▪ maintain, protect or improve the quality of water in an aquifer; ▪ prevent land subsidence or compaction in an aquifer; ▪ to protect groundwater dependent ecosystems; or ▪ to maintain pressure, or to ensure pressure recovery, in an aquifer. The primary tool for managing development impacts to water resources under the WMA is the requirement of Controlled Activity Approval (CAA) for activities carried out, in or under waterfront land. CAA is assessed and managed by the NSW Office of Water who is responsible for the oversight and implementation of the legislative requirements under the WMA. In accordance with Part 3, Chapter 3 of the WMA, a CAA is required for work, which causes ground disturbance or direct impact to waterways within 40 m of the high bank of a watercourse. In order to receive CAA for proposed works the applicant must demonstrate works will not impact upon a waterway or alternatively, put in place sufficient management and mitigation structures and systems to ensure minimisation of impact to the waterway.

Applicable Groundwater Legislation, Policies and Guidelines	
Protection of the Environment Operations Act 1997 (POEO Act)	The NSW Environment Protection Authority (EPA) under the *Protection of the Environment Operations Act 1997* regulates the pollution of all water, including groundwater, in New South Wales. It empowers regulatory authorities to issue pollution licences (called environment protection licences) which authorise pollution to certain capped levels and pollution notices, which notify breaches of licences. The Act also creates a range of pollution offences with associated penalties, and sets up a regime for enforcing pollution laws. Environment Protection Licence to discharge pollutants into a natural water body under the *Protection of the Environment Operations Act 1997*
Local Government Act 1993	Councils have responsibilities under this Act to manage groundwater resources by the regulation of waste management and disposal practices, protection of environmentally sensitive areas, application of standards to construction, operation and maintenance of various facilities and prevention of contamination and environmental degradation.
Threatened Species Conservation Act 1995 *National Parks and Wildlife Act 1974* *Fisheries Management Act 1995*	These Acts require that native species, particularly threatened species, communities and populations be protected unless otherwise authorised. Groundwater dependent ecosystems may be listed under these Acts.
Contaminated Land Management Act 1997	This Act regulates the management of currently contaminated sites, including groundwater that has been impacted by point source pollution. Point source pollution comes from a single particular identifiable location. The NSW Environment Protection Authority (EPA) has powers to order the investigation and remediation of land which presents a 'significant risk of harm' under the Act. The EPA is only responsible for sites where it believes that there is a 'significant risk of harm' from the contamination. Where contamination does not pose a significant risk of harm, the responsibility falls to local councils by means of land use planning processes directed by State Environmental Planning Policy (SEPP) 55 - Remediation of Land.
Tweed Shire Council	
Tweed Shire Council Coastal Zone Management Plan for Cobaki Broadwater and Terranora Broadwater, December 2010	The Tweed Shire Council's Coastal Zone Management Plan for Cobaki Broadwater and Terranora Broadwater, dated December 2010 classifies Cobaki Broadwater as one of the most sensitive of all estuaries to human interventions.

Applicable Groundwater Legislation, Policies and Guidelines	
Tweed Shire Council, Tweed Shire Urban Land Release Strategy, 2009	Section 3.9. Ground Water of the Strategy indicates: A high water table in combination with certain soil types can have implications for foundation design and road and drainage construction. Additionally, groundwater has a greater potential to become contaminated by certain land uses. Further geotechnical investigations will be required to ascertain the implications for development in locations where ground water and reactive soils are likely to be present. As further investigations are needed for future development, a ranking of two (2) for identified vulnerable ground water areas will be used or where a high water table is known to occur. That is, areas where the water table is typically within 1 metre of the soil surface.
Tweed Local Environmental Plan, 2014	The Tweed LEP 2014 was published on the NSW Legislation website and became effective on 4 April 2014. The LEP 2014 is the primary planning tool for the majority of the Tweed Shire and is based on the requirements of the Standard Instrument (Local Environmental Plans) Order 2006. The LEP 2014 includes a number of mapping layers, which need to be read in conjunction with the written instrument.
Tweed Local Environmental Plan, 2000	The Tweed Local Environment Plan (TLEP) is the primary planning tool used to control and guide the future development of land for those parts of the Shire, which have been deferred, from the LEP 2014. The LEP sets out what development is permitted on land, whether Council approval is needed and/or whether any special requirements apply, in relation to proposed development. Reference can be made to LEP 2000 where any landform alteration may result in the disturbance of acid sulfate soil. Written approvals are required in most cases before these materials are disturbed.
Tweed Shire Council Development Control Plan 2008	Tweed Development Control Plan (DCP) contains detailed guidelines that illustrate the controls that apply to a particular type of development or in a particular area. A DCP implements the Far North Coast Regional Strategy, supplements the Local Environmental Plan, and is made according to the Environmental Planning and Assessment Act 1979. Section B7 – Cobaki Lakes was repealed on 24 May 2011.

Applicable Groundwater Legislation, Policies and Guidelines	
Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources 2010	Water Sharing Rules, Cobaki Creek Water Source These rules apply to all surface waters in the water source, as well as the alluvial groundwater that is highly connected to the surface waters. ▪ Report Card for the Cobaki Creek Water Source ▪ Groundwater alluvial access licences The alluvial aquifers in this water source are highly connected to their adjoining streams and alluvial groundwater extraction can have an impact on the river. Accordingly, from year six the access rules will apply to aquifer access licences extracting from the alluvial within 40m of an unregulated river. Trading rules and rules for granting new licences will apply to aquifer access licences from year one. The groundwater "local impact" rules will also apply to all groundwater extractions. These rules can be used to limit groundwater extractions when water tables or groundwater quality is being impacted.
Relevant Policies and Guidelines in NSW	
NSW State Groundwater Policy Framework (1997)	This framework aims to achieve efficient and sustainable management of groundwater resources. The framework includes the Groundwater Quality Protection Policy, the Groundwater Quantity Management Draft, and the Groundwater Dependent Ecosystems Policy.
NSW Groundwater Quality Protection Policy (1998)	This policy is designed to protect groundwater resources against pollution. The management principles outlined in the policy include: ▪ all groundwater systems should be managed such that their most sensitive use or value is maintained; ▪ for new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to the groundwater system and the value of the groundwater resource; and ▪ groundwater ecosystems will be afforded protection.
NSW Groundwater Dependent Ecosystems Policy (2002)	This policy is designed to protect ecosystems that rely on groundwater for survival. Management principles include that groundwater systems should be managed within the sustainable yield of an aquifer system so that the ecological processes and biodiversity of dependent ecosystems are maintain and/or restored.

Applicable Groundwater Legislation, Policies and Guidelines	
Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources (2010)	Water Sharing Rules, Cobaki Creek Water Source These rules apply to all surface waters in the water source, as well as the alluvial groundwater that is highly connected to the surface waters. Report Card for the Cobaki Creek Water Source Groundwater alluvial access licences ▪ The alluvial aquifers in this water source are highly connected to their adjoining streams and alluvial groundwater extraction can have an impact on the river. Accordingly, from year six the access rules will apply to aquifer access licences extracting from the alluvial within 40 m of an unregulated river. Trading rules and rules for granting new licences will apply to aquifer access licences from year one. ▪ The groundwater "local impact" rules will also apply to all groundwater extractions. These rules can be used to limit groundwater extractions when water tables or groundwater quality is being impacted.

5. RESPONSIBILITIES AND RESOURCES

The Proponent, Leda Manorstead Pty Ltd is ultimately responsible for environmental management of the proposed development. The Proponent will ensure that adequate resources are available to carry out and maintain all works associated with groundwater in accordance with relevant legislation and the requirements of this GWMP.

The responsibilities of key staff for the project, including the Construction Manager and on-site Environmental Officer will also be detailed in the Construction Environmental Management Plan (CEMP).

The personnel that may be required during the implementation of this GWMP include:

- Hydrogeologist
- Contaminated Land Consultant
- Wastewater Collection and Disposal Contractor

Contact details for relevant personnel involved in the implementation of this GWMP are provided in Table 5.

Table 7. - Contact details relevant to this Groundwater Management Plan

Organisation	Name	Contact Details
Construction Contractors		
Project Manager	Brandon Yeats	Phone: (07)
NSW OEH		Phone: 131 555
Tweed Shire Council	Colleen Forbes	Phone: (02) 6670 2596
NSW Office of Water	Sarah Sullivan	Phone: (02) 6676 7389 Email: sarah.sullivan@water.nsw.gov.au
On-site Environmental Officer	Michelle Mills - MK Consulting	Phone: 0499 987 467 Email: Michelle@mkeh.com.au

6. OVERVIEW OF ENVIRONMENTAL ISSUES

6.1. Desktop Assessment

A preliminary desktop study was undertaken for the proposal to assess potential issues relating to:

- Surrounding Groundwater Monitoring Well Details
- Groundwater Users and Groundwater Dependent Ecosystems
- Groundwater Flow Regime and Recharge
- Groundwater Water Quality

6.1.1. Surrounding Groundwater Monitoring Wells

A search of the registered bores was made using the NSW Office of water database, NSW Government Natural Resource Atlas website (June 2015). Borehole details, approximate distance and available groundwater depths of the nearest boreholes to the site are illustrated in Figure 6.

Based on the review of the NSW Government Natural Resources Atlas website borehole information there does not appear to be any domestic or industrial groundwater users in the project area or within 1 km of the proposed development.

Figure 6: Registered Groundwater Bores

LEGEND:

- Registered Groundwater Bore
- Direction of Flow
- Site Boundary

FIGURE Registered Groundwater Bores

CREATED BY AM11482

REVISION 0

DATE 23/06/2015

STATUS FINAL

ISSUED FOR INFORMATION

PROJECT NO. 30031425

PROJECT TITLE
Cobaki Estate Management Plans

SOURCE
NSW Government (2015) NSW Natural Resource Atlas.
http://www.nratlas.nsw.gov.au

SMEC

CONSULTANT SMEC Australia Pty Ltd

LEDA

CLIENT LEDA MANORSTEAD PTY LTD

PATH: I:\Projects\30031425\007_Spatial\Workspace\Groundwater Maps.wor

6.1.2. Groundwater Users and Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs) are a diverse and important component of biological diversity. The term GDE takes into account ecosystems that use groundwater as part of their survival strategies. GDEs can potentially include wetlands, vegetation, mound springs, river base flows, cave ecosystems, playa lakes and saline discharges, springs, mangroves, river pools, billabongs and hanging swamps and near-shore marine ecosystems.

The Tweed Shire Council's Coastal Zone Management Plan for Cobaki Broadwater and Terranora Broadwater, dated December 2010 classifies Cobaki Broadwater as one of the most sensitive of all estuaries to human interventions.

The catchment of the Cobaki Broadwater includes extensive areas of both urban development and natural ecosystems. As a result, water is subject to a number of external stressors but is still of a quality which supports:

- Habitat for plants, fish, birds and mammals, including the presence of threatened species and designated coastal wetlands defined under State Environmental Planning Policy No. 14 (SEPP 14);
- Commercial requirements associated with fishing and oyster farming;
- Recreational amenity associated with boating, fishing, swimming and aesthetic enjoyment by the public.

Previous investigations by Gilbert & Sutherland 2007 – 2008 and SMEC Pty Ltd 2011 – 2012 indicate that groundwater flow is in a general south-easterly direction towards Cobaki Creek and Broadwater.

Ecological considerations of the development on and offsite with particular attention to the downstream Cobaki Creek and Broadwater are addressed in SMEC's Flora and Fauna Management Plan, dated June 2015 for the site (available as a separate document).

Similarly, surface water considerations of the development on and offsite with particular attention to the water quality migrating offsite to the downstream Cobaki Creek and Broadwater are addressed in SMEC's Stormwater Management Plan, dated June 2015 for the site (available as a separate document).

6.1.3. Groundwater Flow Regime and Recharge

Groundwater level monitoring conducted by G&S during 2007 - 2008 indicated that:

- Groundwater height appeared reasonably consistent over time, such that, during the six month monitoring period groundwater levels varied concurrently with rainfall across the site, indicating that groundwater in the area generally response to seasonal weather patterns;
- Average groundwater levels ranged from RL -0.285 m AHD to RL 3.15 m AHD between the southern and central eastern portion of the site;
- Groundwater contours and flow follow the site topography, such that, groundwater flows in a general east to south easterly direction from the northern and western hill slopes towards the central riparian corridor;
- Groundwater also mounds in the sand ridge which drives groundwater flow down and westward towards the central riparian corridor from the western side of the ridge, and east to south easterly from the eastern side of the ridge towards the Cobaki Creek Broadwater, and
- Soil permeability ranged from 1.9×10^{-5}m/s to 8.7×10^{-6}m/s across the site. Monitoring well GW10 located on Precinct 7 indicates a high soil permeability of GW10 (2.9×10^{-5}).

Groundwater level monitoring conducted by SMEC during 2011 – 2012 indicated that:

- Relative groundwater levels of -0.671 m AHD at GW2A located on the central riparian corridor east of Precinct 12 were similar to G&S levels of -0.42 m AHD recorded for GW2A during 2007 – 2008 investigation.
- Relative groundwater levels of 3.22 m AHD at GW10 located on the north-eastern boundary of Precinct 7 were within a similar range to G&S levels of 3.9 m AHD recorded for GW10 during the 2007 – 2008 investigation.

6.1.4. Groundwater Water Quality

Groundwater quality monitoring conducted by G&S during 2007 - 2008 indicated that groundwater quality at the site appeared to be heavily influenced by the soil stratum such that:

- Groundwater in the marine clay layers in the central riparian corridor was characterised by acidic, brackish water with variable aluminium and iron concentrations, high chloride and sulfate concentrations and low alkalinity;
- Groundwater in the floodplain and marine clays in the south eastern portion of the site was characterised by slightly acidic brackish waters with high concentrations of iron, aluminium, chloride, sulfate and alkalinity;
- Groundwater within the sand ridge to the east of the riparian corridor was characterised by acidic, fresh waters with low sulfate, alkalinity and chloride concentrations;
- Groundwater in the more elevated parts of the Cobaki Estate to the north and west of the riparian corridor was described as acidic, fresh water with high concentrations of chloride, sulfate, alkalinity and variable concentrations of iron and aluminium, and
- Total nitrogen and phosphorous concentrations were variable and elevated across the site; however, results indicated phosphorous is bound to sediments and unavailable.

Groundwater quality monitoring conducted by SMEC during 2011 – 2012 indicated that:

- Physical and chemical parameters measured in groundwater sampled from the existing monitoring wells in 2011 - 2012 were generally within ranges recorded by G&S in 2007 - 2008.
- Results for the newly installed monitoring wells support the findings of G&S in 2007 - 2008, such that the soil stratum influences groundwater quality.

6.2. Risk Assessment

6.2.1. High Risk Activities

SMEC Pty Ltd identified site-specific activities, which have the potential to impact on groundwater and groundwater dependent ecosystems comprising:

- alternation and compaction of the soil surface;
- cutting and filling;
- dewatering;
- disturbance of acid sulphate soils, and
- contamination.

Details of high-risk activities are outlined in Sections 6.2.3 to 6.2.7.

6.2.2. Identified Risks

A number of potential impacts to groundwater were identified comprising:

- Potential changes to pre-development groundwater flow regimes as a result of excavation, hardening of the site and road building;
- Potential exposure and oxidation of acid sulphate soils impacts on the pre-development groundwater quality at the site, and
- Potential decline of pre-construction water quality as a result of chemical/oil spills during the construction phase.
- Human health and environmental risks due to contaminated groundwater

Mitigation measures for the identified risk are outlined in Section 7. Environmental Control Measures.

6.2.3. Alteration and Compaction of Soil Surface

Alteration and compaction of the ground surface is expected as part of the proposed earthworks and construction at the site e.g. access roads, tracks, clearing of vegetation, placing of fill material and structures.

Potential impacts associated with compaction comprise:

- Compaction resulting in reduced groundwater recharge;
- Compaction resulting in a barrier to groundwater flow in shallow water table areas, and
- Compaction resulting in the migration of contaminants, particularly by driving leachate or contaminated groundwater out of fills.

6.2.4. Cut and Fill

Cutting and filling activities are expected as part of the proposed earthworks at the site.

Potential impacts associated with cutting and filling comprise:

- Cutting resulting in the reduction in the groundwater surface interface increases the risk of contaminants entering the groundwater;
- Cutting resulting in the interception of the water table increases the risk of contaminants entering the groundwater the need for dewatering and the risk of contaminated water entering receiving waters off site;
- Cutting resulting in the lowering of the existing water table resulting in the exposure and oxidation of acid sulfate soils (Refer Section 6.2.3 Disturbance of ASS);
- Cutting resulting in the increase in the height of the water table may result in an increased local gradient and increased groundwater velocities;
- Placement of fill resulting in changes to the permeability of the subsurface and the groundwater recharge regime;
- Placement of fill resulting in horizontal soil movement resulting in the oxidation of potential acid sulphate soils as these soils move from an anaerobic environment to an aerobic environment;
- Placement of fill resulting in an increase in pore pressure in the immediate areas as the fill is placed may result in an additional 'effective gradient' and subsequently the groundwater velocity would be expected to increase in the affected area, in the short term while settling, and
- Placement of imported fill containing contaminants or the placement of fill sourced from on-site containing potential acid sulphate soils can potentially contain contaminants resulting in a decline in groundwater quality.

6.2.5. Dewatering

It is understood that excavation earthworks will involve trimming of the topsoil to create a drainage system throughout the site. It is also understood that dewatering is not proposed to occur at the site, such that no groundwater extraction processes are proposed nor will any infrastructure be installed below the water table.

However, groundwater seepage and surface water runoff may enter into the newly formed drains due to changes to the hydrological regime at the site, which may then naturally flow off site to receiving waters e.g. Cobaki Creek and Broadwater.

Potential impacts associated with groundwater seepage and surface water runoff comprise:

- Generation of acidic water and mobilisation of heavy metals in surface water runoff to receiving waters (Refer Section 6.2.4 Disturbance of Acid Sulfate Soils)

Contaminated water cannot be released into the environment unless otherwise authorised by an Environmental Protection Licence.

6.2.6. Disturbance of Acid Sulfate Soils

Exposure and oxidation of acid sulfate soils (ASS) and potential acid sulphate soils (PASS) has the potential to impact on the pre-development groundwater quality at the site.

A review of Gilbert & Sutherland's 2007 – 2008 report indicates that the soil types across the low-lying sections of the site have characteristics associated with actual and potential acidic sulphate soils. pH readings also indicate existing acidity and high concentration so iron, aluminium, chloride, sulphate and alkalinity over the southern portion of the site, which are common characteristics of sulfidic hydrosols.

Potential impacts associated with disturbance of ASS and PASS comprises:

- Lowering of the water table resulting in the exposure and oxidation of acid sulphate soils (ASS) and or the accelerated oxidation of potential acid sulphate soils (PASS) resulting in:
    - Formation of sulfuric acid (acidic water) and mobilisation of heavy metals (e.g. dissolved iron, aluminium or other heavy metals) in surface water runoff resulting in disease and death to fish, aquatic organisms, riparian vegetation and macrophytes, and
    - Damage to in-ground structure and services susceptible to acidic corrosion or sulphate effects.
- Oxidation and mobilization of in situ PASS resulting in:
    - Increasing concentrations of dissolved metals within groundwater;
    - Leaching and discharge of acidic water, and
    - Creation of acidic plumes and mobilisation of heavy metals that may impact on local ecosystems in long and short-term timeframes.

Acid Sulfate Soil considerations of the development on and offsite with particular attention to the downstream Cobaki Creek and Broadwater are addressed in SMEC's Acid Sulfate soil Management Plan (available as a separate document).

6.2.7. Contamination

The historical cattle dip, Turners Creek Dip, is located on the site in the northern portion of the Central Open Space. Levels of both arsenic and DDT (and its derivatives) in soils surrounding the dip site have been identified as exceeding the nominated guideline criteria. Remediation and validation is yet to be carried out under the site specific RAP. Until remediation and validation is complete and confirms otherwise, the potential exists for contaminants associated with the dip site to have leached into groundwater.

During construction, spillage of dangerous goods and hazardous chemicals could result in contamination of groundwater.

Key issues relating to contaminated groundwater (existing and potential) include risks to human health and the environment and migration of contaminated groundwater.

7. ENVIRONMENTAL CONTROL MEASURES

This section describes mitigation measures that must be implemented during earthworks associated with Precincts 7, 8, 9, 10, 11 and 12 to protect the quality of groundwater at the site and the health of downstream receptors. This section describes management actions that aim to reduce the impact of the proposed development on groundwater beneath the site. Table 6 lists a number of proposed management strategies in relation to the identified potential impacts.

Table 8. - Proposed Management Strategies

Potential Impact	Management/ Amelioration Measures
Alterations in drainage and hydrogeological regime due to filling and compaction	▪ A Stormwater Management Plan (SMP) and an Erosion and Sediment Control (ESC) are being prepared for the proposed works and must be approved by Tweed Shire Council prior to construction commencing. The surface water management devices specified in the plans will be designed to integrate with the groundwater system to minimise any adverse impacts on the groundwater flow regime as a result of reducing infiltration through filling and compaction of the site. ▪ The Groundwater Monitoring Program outlined in Section 8. must be complied with. ▪ Negligible change to the existing groundwater regimes in the project area, and
ASS	▪ A detailed ASS investigation for the proposed development site is being prepared for the proposed works and must be approved by Tweed Shire Council prior to construction commencing. The ASS Management Plan must also be approved by TSC prior to commencement of construction. ▪ The approved ASS Management Plan must be complied with during construction.
Contamination	▪ The former dip site is not located on Precincts 7 to 12; the area has been remediated in accordance with the approved RAP. Site validation confirms that groundwater impacts have not occurred. ▪ Any contamination uncovering of contaminated soils during construction (e.g. greasy film or distinct hydrocarbon odour) must be documented, investigated by a specialist and remedial action applied before works continue in that area. ▪ Storage, use and accidental spillage of chemicals, fuel and dangerous goods must be managed in accordance with appropriate procedures detailed in the CEMP. ▪ Vehicles and machinery must be maintained in accordance with manufacturer's specifications e.g. no leaks, loose noisy parts. ▪ Imported fill material must be certified free from contaminants prior to delivery to site.

Potential Impact	Management/ Amelioration Measures
Dewatering	▪ Works and Compliance – Works timed to avoid periods of high rainfall. – Compliance with the ASS Management Plan to prevent the oxidation of PASS and creation of acidic groundwater – Liaise with NSW DPI – Office of Water and/or NSW OEH regarding all interception, extraction, use and/or treatment of groundwater. – Compliance with Section 8. Groundwater Monitoring Program to monitor any impacts of dewatering on the surrounding groundwater regimes and assess the quality of groundwater prior to re-use/discharge/disposal. – No significant change to baseline groundwater quality attributed to the works e.g. no acidification, no hazardous chemical spills. ▪ Groundwater Containment – Contain water flowing into drainage lines (that may contain groundwater) in stormwater retention basins i.e. treatment ponds as required (refer Sediment and Erosion Control Plan available as a separate document for further details). ▪ Dewatering – Although not expected, if required, mechanical dewatering of excavations must be of short duration (hours/days) to minimise any alteration to natural groundwater regimes. – Contaminated water must not be disposed to soil or receiving waters. – All discharged groundwater within specified water quality criteria. ▪ Treatment and disposal of contaminated groundwater e.g. exceeding water quality criteria – treatment of turbid water in settlement basins – application of lime to acidic water – containment of polluted water until appropriate collection and disposal to licensed disposal facilities in accordance with regulatory disposal guidelines ▪ Reuse – Possible re-use of water of suitable quality for dust suppression.

8. GROUNDWATER MONITORING PROGRAM

This section outlines the monitoring requirements for groundwater at the site, both regular and event-based monitoring throughout the term of the project. Performance criteria for assessment of monitoring results are detailed in Section 9.

8.1. Groundwater Monitoring

The primary objective at the Site is the protection of surrounding surface water and groundwater.

Groundwater monitoring is required to ensure that:

- No significant change to baseline groundwater conditions (quality) attributed to the works;
- Negligible change to pre-construction groundwater levels and flow regimes in the project area, and
- All discharged water from excavations (dewatering if required) (e.g. groundwater seepage) are within specified water quality criteria.

8.1.1. Location and Frequency

There are currently ten (10) operational groundwater monitoring wells onsite as shown in Figure 8. Bore Logs for operational groundwater monitoring wells are provided in **Appendix B**. Bore License Certificates are provided in **Appendix C**.

The locations of groundwater monitoring wells were selected up gradient and down gradient of the direction of groundwater flow where the drawdown in the groundwater is expected to exhibit changes to water quality.

Groundwater monitoring must be conducted:

- Two weeks prior to earthworks / construction (bulk earthworks);
- Monthly during the earthworks / construction (bulk earthworks) stage of the project, or
- 12 hourly during rainfall events >25 mm in 24 hours, and
- Post construction monitoring must be conducted four times over four weeks following completion of the excavation / construction (bulk earthworks) stage of the project.

In the event dewatering is required from an excavation, water level and field parameters must be monitored at the closest wells prior to commencement of dewatering and daily during dewatering.

It is noted that proposed earthworks may cover existing monitoring wells. In the event, a well is decommissioned; a new monitoring well must be installed in a location, which will be best suited to monitor changes in water quality i.e. up and down gradient of the Precinct.

Figure 7: Operational Groundwater Monitoring Locations

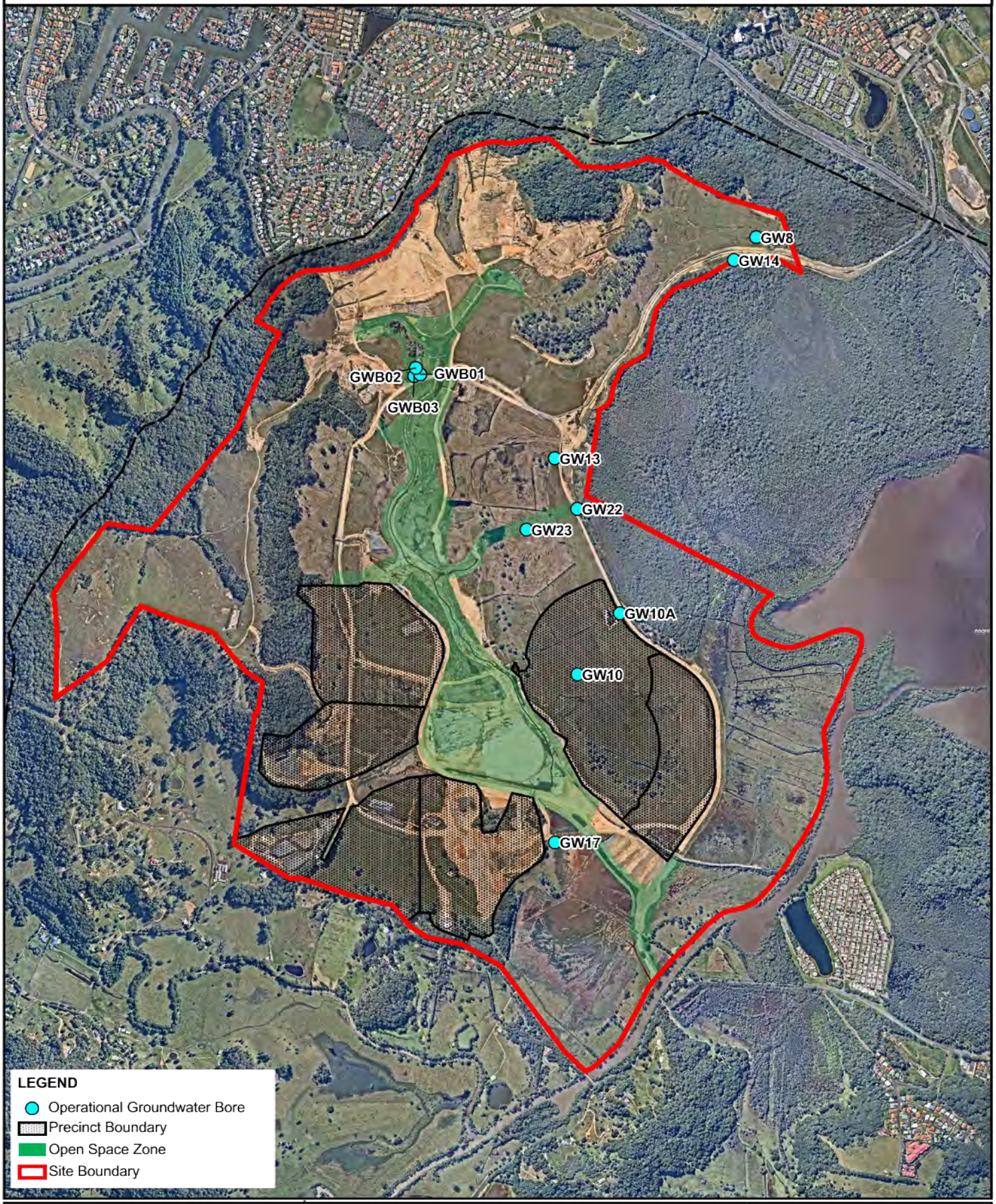

FIGURE Water Monitoring Locations

CREATED BY AM11482

REVISION 0

STATUS FINAL

DATE 25/06/2014

ISSUED FOR INFORMATION

N

PROJECT NO. 30031425

PROJECT TITLE
Cobaki Estate Environmental Management Plans

COORDINATE SYSTEM
GDA 1994 MGA Zone 56

0 0.5 1 km
Scale: 1 : 20,000 @ A4

SOURCE
Aerial Imagery by Nearmap Hypertiles, Copyright 2015
Survey from Michel Group Services, 2011

CONSULTANT SMEC Australia

CLIENT LEDA MANORSTEAD PTY LTD

PATH: I:\Projects\30031425\007_Spatial\Workspaces\Groundwater Maps.wor

8.1.2. Groundwater Monitoring Well Installation

A suitably qualified person competent in the field of hydrogeology must supervise well installation. The following recommendations apply when drilling groundwater-monitoring wells:

- Seek approval prior to the commencement of drilling and ensure bore license certificate is received for each well installed;
- The water table should be encountered and drilling should continue to ensure the slotted section of standpipe is fully saturated to allow flow, and
- All groundwater-monitoring wells must have a lockable cover.

For each new groundwater monitoring well, the following information is required:

- Date of drilling, drilling technique;
- Depth drill, drilling diameter;
- Bore log (strata log and stratigraphy details);
- Water features (water inflow, aquifer details) during drilling and water level at time of drilling;
- Bore installation information: backfill (if any), standpipe diameter, screen depth, screen opening or slots, casing details, gravel packs, bentonite seals etc., and
- Bore coordinates including elevation (GPS data as a minimum).

8.1.3. Field Suite

An experienced Environmental Scientist must undertake field sampling.

The field suite is applicable to all groundwater monitoring. It comprises a set of physical water parameters and must be performed on site (i.e. in situ) at location using a multi-probe and a water level dipper.

Field sampling will consist of measuring groundwater levels and in-situ field-testing of the following parameters:

- Water level (measured as “depth to water” from a reference point i.e. top of the casing)
- pH
- Redox (ORP)
- Electrical Conductivity (EC) (Salinity)
- Dissolved Oxygen (DO)
- Turbidity
- Temperature

Wells are required to be purged before recording field parameters. The measurement and eventual stabilisation of field parameters ensure that the water sample is representative to the aquifer.

8.1.4. Laboratory Suite

The groundwater laboratory suite applies to groundwater during routine monitoring.

Samples collected must be dispatched for analysis at a NATA accredited laboratory for the following parameters:

- Major cations – calcium, magnesium, sodium and potassium;
- Major anions – sulfate and chloride;
- Alkalinity – carbonate and bicarbonate;
- Acidity (tritratable);
- Manganese (dissolved);
- Aluminium (dissolved);
- Iron (dissolved), and
- Iron (total).

Additional monitoring must also be conducted where there is the potential for contamination (e.g. uncovering contaminated soil during excavation, fuel, soil or hydraulic fuel leaks from plant and equipment and or other hazardous chemical spill).

An experienced Environmental Scientist must conduct targeted monitoring to ensure the correct contaminants of concern are tested.

8.2. Surface Water Monitoring

The primary objective at the Site is the protection of surrounding surface water and groundwater.

Surface water monitoring is required to ensure that:

- No significant change to baseline surface water conditions (quality) in receiving waters (e.g. Cobaki Creek) attributed to the works e.g. surface water runoff and groundwater migration
- All discharged water from constructed sediment basins or excavations (dewatering if required) (e.g. groundwater seepage and rainfall accumulated onsite) are within specified water quality criteria.

8.2.1. Location and Frequency

There are currently 10 surface water monitoring locations onsite including one (1) located in Cobaki Creek as shown in Figure 8.

Surface water quality monitoring must be conducted:

- Two weeks prior to earthworks / construction (bulk earthworks);
- Monthly during the earthworks / construction (bulk earthworks) stage of the project, or
- 12 hourly during rainfall events >25 mm in 24 hour;
- Daily field parameters for all groundwater seepage into the excavations;
- Prior to discharge of all surface water from the Site e.g. stormwater retention basins or pooled water in excavations (mechanical dewatering);
    - Mechanical dewatering is not expected as part of the proposed works, however, in the event groundwater seepage enters excavations or stormwater retention basins require discharge then monitoring must be conducted, and
- Post construction monitoring must be conducted four times over four weeks following completion of the excavation / construction (bulk earthworks) stage of the project.

It is noted that proposed earthworks may require the installation of new stormwater retention basins. In the event, a new basin is constructed the Surface Water Monitoring Location on Figure 8 must be amended and water quality monitoring undertaken as outlined above.

8.2.2. Field Suite

An experienced Environmental Scientist must undertake surface water field sampling.

The field suite is applicable to all surface water monitoring and must be performed on site (i.e. in situ) at location using a multi-probe.

Field sampling of stormwater retention basins and during mechanical dewatering (as required) will consist of in-situ field-testing of the following parameters:

- pH
- Redox (ORP)
- Electrical Conductivity (EC) (Salinity)
- Dissolved Oxygen (DO)
- Turbidity (NTU)
- Temperature
- Visual evidence of contaminants (e.g. oil, grease, floating scum and litter)

In the event, results indicate a pH of <6.5 then samples must be collected and analysed by a NATA accredited laboratory for the Laboratory Suite detailed below.

8.2.3. Laboratory Suite

The surface water laboratory suite applies to groundwater during routine monitoring.

Samples collected must be analysed by a NATA accredited laboratory for the following parameters:

- Major cations – calcium, magnesium, sodium and potassium;
- Major anions – sulfate and chloride;
- Alkalinity – carbonate and bicarbonate;
- Acidity (tritratable);
- Manganese (dissolved);
- Aluminium (dissolved);
- Iron (dissolved), and
- Iron (total).

8.3. Contamination Monitoring

A suitably qualified person in accordance with NSW legislation, industry standards and guidelines must investigate any identified potential contamination immediately. Investigation may include, but not be limited to:

- *in-situ* monitoring and/or sampling from the identified location, as well as upstream, downstream and at the final receptor;
- analysis of samples at a National Association of Testing Authorities (NATA) certified laboratory;
- comparison of results against designated performance criteria;
- review of weather conditions, including rainfall;
- review of construction activities undertaken;
- determination of any incidents that have occurred; and
- determination of any external factors or activities that may have resulted in release of contaminants.

Investigations must be conducted in accordance with NEPC (1999) as amended *National Environment Protection (Assessment of Site Contamination) Measure.*

8.4. Methodology

An experienced Environmental Scientist with a background in groundwater / surface water quality monitoring and sampling must carry out monitoring.

Sampling must be conducted with reference to relevant guidelines comprising:

- ARMCANZ & ANZECC, (2000). *National Water Quality Management Strategy: Australian Guidelines for Water Quality Monitoring and Reporting*, Agriculture and Resource Management Council of Australia and New Zealand and the Australian and New Zealand Environment and Conservation Council
- AS/NZS 5667.1:1998. *Part 1 Water quality - Sampling - Guidance on the Design of Sampling Programs, sampling techniques and the preservation and handling of samples*
- AS/NZS 5667.11:1998. *Part 11 Water quality - Sampling - Guidance on sampling of Groundwaters*
- Geoscience Australia (2009). *Record 2009/27, Groundwater Sampling and Analysis – A Field Guide*
- NEPC (1999) as amended *National Environment Protection (Assessment of Site Contamination) Measure*

It is important that rigorous sampling procedures be followed to ensure good sampling practice and due diligence in tracking of samples and results. Quality assurance and quality control (QA/QC) samples and procedures must be implemented throughout the program. The primary quantitative measures or parameters used to assess data quality are accuracy, precision, completeness and the detection limit applicable to the method. Qualitative measures include representativeness and comparability.

The following minimum procedures are to ensure that quality and integrity of the samples:

- Water levels must first be measured at all locations prior to the commencement of further monitoring.
- Sampling must be completed using the analytical suites presented.
- Groundwater wells must be purged of at least three well volumes, or purged dry, prior to sampling and field parameters monitored to ensure that the collected groundwater sample is representative of groundwater in the aquifer at that location.
- Sampling for some analytes requires chemical preservation. Samples to be analysed for dissolved metals must be filtered in the field using a dedicated 0.45-micron filter for each sample and placed into laboratory supplied pre-acidified containers.
- QA/QC samples must include, as a minimum, 1 in 20 inter-laboratory and intra-laboratory field duplicate samples.
- The bottles must be labelled to allow identification of specific sampling requirements and delivered in eskies. The labels will include blank fields to be filled in by the field operator at sampling time.
- Field equipment must be calibrated and calibration records kept on file as part of the QA/QC program.
- Sampling devices must be dedicated to each monitoring well and be disposable for each sample or if not applicable rinsed between two locations samples. If rinsing is conducted, rinsate samples must be included in the QA/QC program as appropriate.
- All sampling rounds will have a QA/QC program and the QA/QC sample analysis must be checked to verify the quality of the field samples.
- Samples must be dispatched to a NATA accredited laboratory with appropriate Chain of Custody (COD) completed within specified holding times.

A monitoring record (**Appendix C**) must be completed for each monitoring site detailing all field data collected, sampling, weather (including rainfall from the Bureau of Meteorology), and tide and monitoring location information.

9. PERFORMANCE CRITERIA

The NSW Water Quality Objectives (WQO's) are the agreed environmental values and long-term goals for NSW's waterways. The NSW WQO's are consistent with the agreed national framework for assessing water quality set out in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000), from here on referred to as the "ANZECC guidelines".

The relevant ANZECC guidelines for protection of the Cobaki Broadwater's WQO's are:

- Slightly to moderately disturbed ecosystems;
  - Trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems – estuaries
  - Trigger values for toxicants – marine water, 95% level of protection (% species)
- Recreational purposes – primary contact
- Aquaculture species – saltwater production

ANZECC guideline trigger values are an early warning mechanism and are not intended to be an instrument to assess compliance. The SMEC Baseline Performance Range must be used to indicate potential water quality problems and the need for management action.

9.1. Baseline Performance Range

For reporting purposes, the groundwater monitoring wells are grouped according to topographical, hydrogeological and geophysical characteristics considered representative of groundwater zones across the site:

- Zone 1 – North eastern Neranleigh-Fernvale (GW8 and GW14)
- Zone 2 – North western Neranleigh-Fernvale – no operational wells
- Zone 3 – Central drainage channel – no operational wells
- Zone 4 – Sand ridge (GW3, GW7, GW10, GW10B, GW13, GW22 and GW23)
- Zone 5 – Southern Neranleigh-Fernvale – no operational wells
- Zone 6 – Southern flood plain (GW17)

Results from ongoing groundwater monitoring during the construction stage of the project must be compared against SMEC's Baseline Performance Range shown in Table 7. The Baseline Performance Range was calculated as per SMEC's pre-construction monitoring conducted November and December 2011 and February 2012.

Where Baseline Performance Range is not available for prescribed analytes, results must be compared to previous rounds of monitoring results to determine if trends are occurring and for the potential deleterious impacts to the environment.

The ANZECC numerical criteria can be used as a preliminary guide together with the pre-construction Baseline Performance Range. The specified ANZECC guideline values and for the prescribed Baseline Performance Range are presented in Table 8.

Table 9. - SMEC Pty Ltd Baseline Performance Range – Pre-Construction

Parameter	Units	ANZECC Guideline Value	Zone 1	Zone 4	Zone 6
			SMEC Average	SMEC Average	SMEC Average
pH	pH	7.0 – 8.5[a]	**5.74**	**4.92**	**6.09**
Turbidity	NTU	0.5 – 10[a]	-	-	**496.2**
Dissolved oxygen	% Sat	80 – 110[a]	**46.6**	**50.1**	**62.2**
Sodium	mg/L	300[b]	109	78	**1508**
Sulfate	mg/L	400[b]	36.8	39	**717**
Chloride	mg/L	400[b]	144	135	**2773**
Carbonate Alkalinity	mg/L	>20[c]	-	-	-
Bicarbonate Alkalinity	mg/L		65.5	145	78
Dissolved Al	mg/L	0.2[b]	**0.28**	**1.29**	**0.45**
Dissolved Mn	mg/L	0.1[b]	0.08	**0.22**	**1.95**
Dissolved Fe	mg/L	0.3[b]	**5.03**	**5.57**	**48**
Total Fe	mg/L	0.3[b]	**9.2**	**12.2**	**65**

Table 10. - Performance Criteria

Item	Performance Indicator	Units	Criteria
Dewatering	Groundwater Levels	cm	Groundwater levels must not drop by more than 10 cm from the pre-dewatering measurement. If groundwater drops by more than 10 cm, dewatering will cease and dewatering procedures reviewed to limit groundwater drawdown.
Groundwater Monitoring – Field Suite	pH	pH	0.3 pH units below lower bound of baseline range* or above 8.5 pH
	Turbidity	NTU	Baseline Performance Range*
	Dissolved Oxygen (DO)	% saturation	Baseline Performance Range*
	Redox (ORP)		Refer Table 9[1(d)] Baseline Performance Range*
	Electrical Conductivity (EC) (Salinity)	mS/cm	Refer Table 9[(d)] Baseline performance range*
	Temperature	°C	Baseline Performance Range*
Groundwater Monitoring – Laboratory Suite	Calcium	mg/L	Baseline Performance Range*
	Magnesium	mg/L	Baseline Performance Range*
	Sodium	mg/L	300[1(b)]
	Potassium	mg/L	Baseline Performance Range*
	Sulfate		400[1(b)]
	Chloride		400[1(b)]
	Alkalinity – carbonate and bicarbonate $CaCO_3$	Mg/L	>20[1(c)]
	Acidity (tritratable)		Baseline Performance Range*
	Manganese (dissolved)	µg/L	0.1[1(b)]
	Aluminium (dissolved)	µg/L	0.2[1(b)] Baseline Performance Range*
	Iron (dissolved)	µg/L	0.3[1(b)] Baseline Performance Range*
	Iron (total)	µg/L	Baseline Performance Range*
Surface Water Discharge Monitoring – Field Suite	pH	pH	Within the range of 7.0 – 8.5[2(a)] results indicate a pH of <6.5 then samples must be collected and analysed by a NATA accredited laboratory for the Laboratory Suite detailed below
	Turbidity	NTU	Within the range of 0.5 – 10[1(a)]
	Dissolved Oxygen (DO)	% saturation	80 – 110[1]
	Redox (ORP)		Refer Table 9[3(d)]
	Electrical Conductivity (EC) (Salinity)	mS/cm	Refer Table 9[(d)]
	Temperature	°C	-
	Oil, grease, floating scum, litter		No visual film or odour[1(b)]
Surface Water Discharge Monitoring – Laboratory Suite	Calcium	mg/L	-
	Magnesium	mg/L	-
	Sodium	mg/L	300[1(b)]
	Potassium	mg/L	-
	Sulfate		400[1(b)]
	Chloride		400[1(b)]
	Alkalinity – carbonate and bicarbonate $CaCO_3$	Mg/L	>20[1(c)]
	Acidity (tritratable)		-
	Manganese (dissolved)	µg/L	0.1[1(b)]
	Aluminium (dissolved)	µg/L	0.2[1(b)]
	Iron (dissolved)	µg/L	0.3[1(b)]
	Iron (total)	µg/L	0.3[1(b)]

* Baseline Performance Range calculated as per SMEC's preconstruction monitoring conducted November and December 2011 and February 2012 (Refer Table 7)

a) Trigger values for physical and chemical stressors for southeast Australia for slightly disturbed ecosystems – estuaries.
b) Water quality guidelines for recreational purposes.
c) Guidelines for the protection of aquaculture species.
d) The pH and redox potential characterise the type of chemical reactions likely to be occurring (Refer Table 9).

[1] Fetter, C.W., 1994, Applied Hydrogeology, 3rd ed.: Macmillan College Publishing, Inc., New York
[2] Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000)
[3] Fetter, C.W., 1994, Applied Hydrogeology, 3rd ed.: Macmillan College Publishing, Inc., New York

The electrical conductivity (EC) expressed as micro-Siemens per centimetre is a measure of the electric conductivity of the water and as such is an indicator to both total dissolved solids (TDS) and salinity. A rough estimate of TDS can be obtained by converting EC to TDS using the following relationship: TDS (mg/L) = EC (µS/cm) at 25°C) x 0.6. A summary of general water quality characteristics based on TDS and EC is provided in Table 9.

Table 11. - Salinity Classes (modified from Fetter, 1994)

Water type	TDS (mg/L)	EC (µS/cm) at 25°C	Example
Fresh	Less than 1,000	Less than 1,660	Drinking water up to 800µS/cm
Slightly brackish	1,000 to 3,000	1,660 to 5,000	
Brackish	3,000 to 10,000	5,000 to 16,600	Beef cattle tolerates a maximum of 5,000 µS/cm
Saline	10,000 to 100,000	16,600 to 166,000	Sea water around 40,000 µS/cm
Brine	More than 100,000	More than 166,000	

9.1. Management – Exceedance(s)

When groundwater quality results exceed default guideline and pre-construction values, and groundwater levels fall below those previously reported, the data must be further interpreted to assess the nature and extent of any environmental impact of the activity. The review will involve:

- re-sampling of the well after two weeks, including collection of a minimum of one (1) duplicate sample;
- review of weather conditions, including rainfall;
- review of construction activities undertaken in the region;
- determination of any incidents within the region; and
- determination of any external factors or activities that may have the potential to impact on the groundwater.

Further investigation will determine the course of action is required including notification to the Administering Authority.

9.2. Management – Release of Water

No unauthorised releases of polluted water into the environment are to occur. Performance criteria are applied for the protection of the most sensitive end users' requirements, that being the Cobaki Broadwater. In accordance with protecting the WQO's for the Cobaki Broadwater, no water must be discharged to the environment unless it complies with the ANZECC (2000) water quality criteria.

All water generated from dewatering activities, seepage and site runoff in the ASS risk areas (defined as areas with elevation less than 5m AHD) and accidental spillages must be contained, tested for all contaminants of concern and treated (if necessary) prior to discharge or re-use on site.

Where water quality does not meet the ANZECC guidelines action is required to prevent discharge to the environment. Water must be managed:

- by pumping water directly into a licensed liquid waste transport vehicle for transport off site to a licensed disposal facility;
- by pumping water directly to an approved on site hazardous liquid storage facility; or
- based on recommendation of a specialist in accordance with NSW legislation, industry standards and guidelines.

Significant penalties can apply if wastewater not managed appropriately. Disposal is to accord with the relevant laws and the NSW Waste Classification Guidelines. In NSW, the *Protection of the Environment Operations Act 1997* (and specifically the *Protection of the Environment Operations (Waste) Regulation 2005* and *Protection of the Environment Operations Amendment (Scheduled Activities and Waste) Regulation 2008*) and *Waste Avoidance and Resource Recovery Act 2001* apply. Specific requirements apply to the interstate disposal of waste. Table 10 provides contact details for licensed liquid water transport operators.

Table 12. - Liquid Waste Contractors

Contractor	Contact Details
Solo Resource Recovery	Chinderah, NSW: (02) 6674 7657
Barry Bros. Specialised Services	Gold Coast, QLD: (07) 5522 0247 NSW State Office: (02) 8723 8777
Richmond Waste	Lismore, NSW: (02) 6621 7431
Dr Pooh Environmental Solutions	Burleigh, QLD (servicing Tweed Shire): (07) 5593 4277
Veolia Environmental Services	NSW State Office: 132 955

10. REPORTING OF MONITORING RESULTS

10.1. Groundwater Monitoring Records

The following documents must be collected, maintained in the project files and made available for review by authorities if requested:

- Groundwater monitoring field sheets containing water level and field parameter data, and sampling, weather and well condition information
- Water quality meter calibration records
- Laboratory reports
- Up-to date data tables and figures (survey data, water level tables and contour figures, field parameter and laboratory analysis summary tables, etc.)
- Corrective action notices
- Approvals/licenses for works, where required
- External consultants/contractor reports
- Contaminated water transport and disposal records

10.2. Groundwater Monitoring Reports

A monthly report collating and detailing all monitoring results, comparison to performance criteria and management/treatment procedures is to be prepared for Tweed Shire Council and the Office of Environment and Heritage. A copy must be maintained in the project file.

REFERENCES

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ANZECC & ARMCANZ. 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

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Yeats. 2011. Cobaki, Tweed Heads West, Precinct 6, Bulk Earthworks Construction Certificate. Civil Engineering Drawings.

APPENDIX A OPERATIONAL GROUNDWATER BORE LOGS

ENVIRONMENTAL FIELD LOG AND MONITORING WELL "ASBUILT"

Borehole No: GW-19
Sheet No: 1 OF 1
Project No: 3003773

Client: LEDA
Project: Cobaki Estate Acid Sulfate Investigation
Feature:
Location: Refer location plan

Co-ordinates System: UTM Zone 56
Easting: 547022.9m E
Northing: 6882631.7m S

Surface RL (m):
Angle from Horz: 90
Direction: n/a

DRILLING							TESTING			SUBSTANCE			
Method	Support	Rate (Fast / Medium / Slow)			Water	Sample	Depth (m)	Depth/RL	Type	Sample or Field Test	Graphic Log	USC Symbol	Description Soil Type: density/consistency, grain size/plasticity, colour, particle shape/secondary components, minor constituents, moisture, origin, additional observations.	Well Diagram, Installation Detail
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
														Top Cap
														0.5 m Stick up
								0.0						Natural Surface
AHF					21/11/2011 ▼		0.5	0.6				CL	Sandy CLAY: Dark brown, grey fines.	Cement Seal
							1.0	1.2				SC	Clayey SAND: Fine to medium grained, grey.	Bentonite Seal PVC Casing
							1.5	1.6				CL	Brown. Silty CLAY: Low plasticity, grey.	Filter Pack Gravel/Sand (1.5 mm) PVC Screen
							2.0	2.5					Borehole discontinued at 2.50m	End Cap
							2.5							
							3.0							
							3.5							
							4.0							
							4.5							

Notes (Instrumentation etc):

Contractor: Mapstone Geotechnical
Equipment:
Commenced: 21/11/11
Completed: 21/11/11
Logged By: MM
Checked By:

Basis of description and details of abbreviations are given on explanatory notes

SMEC GOLD COAST NON CORED LOG WATER WELL \\AUGCFP02\OPERATIONS$\PROJECTS\3003773\005_OPERATIONS\ASSMP\DRAFT REPORT\APPENDIX 2 - BOREHOLE LOGS\COBAKAI LATEST.GPJ 6/1/12

ENVIRONMENTAL FIELD LOG AND MONITORING WELL "ASBUILT"

Borehole No:	**GW-20**
Sheet No:	1 OF 1
Project No:	3003773

Client: LEDA
Project: Cobaki Estate Acid Sulfate Investigation
Feature:
Location: Refer location plan

Co-ordinates System: UTM Zone 56
Easting: 546960.3m E
Northing: 6882829.4m S

Surface RL (m):
Angle from Horz: 90
Direction: n/a

DRILLING								TESTING			SUBSTANCE			
Method	Support	Rate: Fast	Rate: Medium	Rate: Slow	Water	Sample	Depth (m)	Depth/RL	Type	Sample or Field Test	Graphic Log	USC Symbol	Description: Soil Type: density/consistency, grain size/plasticity, colour, particle shape/secondary components, minor constituents, moisture, origin, additional observations.	Well Diagram, Installation Detail
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								0.0						Top Cap; 0.5 m Stick up; Natural Surface
AHF					21/11/2011▼		0.5					CL	Sandy CLAY: Low plasticity, dark brown some grey fines.	Cement Seal; Bentonite Seal
								0.7					Grey.	PVC Casing
							1.0							
								1.4					Clayey SAND: Fine to medium grained, grey.	
							1.5					SC		Filter Pack Gravel/Sand (1.5 mm); PVC Screen
							2.0							
								2.5					Borehole discontinued at 2.50m	End Cap
							2.5							
							3.0							
							3.5							
							4.0							
							4.5							

Notes (Instrumentation etc):

Contractor: Mapstone Geotechnical
Equipment:
Commenced: 21/11/11
Completed: 21/11/11
Logged By: MM
Checked By:

Basis of description and details of abbreviations are given on explanatory notes

SMEC GOLD COAST NON CORED LOG WATER WELL \\AUGCFP02\OPERATIONS$\PROJECTS\3003773\005_OPERATIONS\ASSMP\DRAFT REPORT\APPENDIX 2 - BOREHOLE LOGS\COBAKAI LATEST.GPJ 6/1/12

ENVIRONMENTAL FIELD LOG AND MONITORING WELL "ASBUILT"

Borehole No:	**GW-21**
Sheet No:	1 OF 1
Project No:	3003773

Client: LEDA
Project: Cobaki Estate Acid Sulfate Investigation
Feature:
Location: Refer location plan

Co-ordinates System: UTM Zone 56
Easting: 547333.7m E
Northing: 6883529.2m S

Surface RL (m):
Angle from Horz: 90
Direction: n/a

DRILLING								TESTING			SUBSTANCE			
Method	Support	Rate: Fast	Rate: Medium	Rate: Slow	Water	Sample	Depth (m)	Depth/RL	Type	Sample or Field Test	Graphic Log	USC Symbol	Description: Soil Type: density/consistency, grain size/plasticity, colour, particle shape/secondary components, minor constituents, moisture, origin, additional observations.	Well Diagram, Installation Detail
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
AHF					21/11/2011 ▼		0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5	0.0 1.5 1.7 2.3 2.5				GW CL SP	GRAVELS/COBBLES: Road base. Sandy CLAY: Low plasticity, dark brown, grey fines. SAND: Dark brown, fine to medium grained. Fine grained. Borehole discontinued at 2.50m	Top Cap 0.5m Stick up Natural Surface Cement Seal Bentonite Seal PVC Casing Filter Pack Gravel/Sand (1.5 mm) PVC Screen End Cap

Notes (Instrumentation etc):

Contractor: Mapstone Geotechnical
Equipment:
Commenced: 21/11/11
Completed: 21/11/11
Logged By: MM
Checked By:

Basis of description and details of abbreviations are given on explanatory notes

SMEC GOLD COAST NON CORED LOG WATER WELL \\AUGCFP02\OPERATIONS$\PROJECTS\3003773\005_OPERATIONS\ASSMP\DRAFT REPORT\APPENDIX 2 - BOREHOLE LOGS\COBAKAI LATEST.GPJ 6/1/12

ENVIRONMENTAL FIELD LOG AND MONITORING WELL "ASBUILT"

Borehole No:	**GW-22**
Sheet No:	1 OF 1
Project No:	3003773

Client: LEDA
Project: Cobaki Estate Acid Sulfate Investigation
Feature:
Location: Refer location plan

Co-ordinates System: UTM Zone 56
Easting: 547265.2m E
Northing: 6883705.7m S

Surface RL (m):
Angle from Horz: 90
Direction: n/a

DRILLING								TESTING			SUBSTANCE			
Method	Support	Rate: Fast	Rate: Medium	Rate: Slow	Water	Sample	Depth (m)	Depth/RL	Type	Sample or Field Test	Graphic Log	USC Symbol	Description: Soil Type: density/consistency, grain size/plasticity, colour, particle shape/secondary components, minor constituents, moisture, origin, additional observations.	Well Diagram, Installation Detail
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
AHF					21/11/2011 ▼		0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0	0.0 0.8 1.3 1.8 2.3				GW Cl SP	GRAVELS/BOULDERS: Road base. Silty CLAY: Mottled grey, cream, white, red. SAND: Medium grained, dark grey. Fine to medium grained, dark brown. Borehole discontinued at 2.30m	Top Cap 0.7m Stick up Natural Surface Cement Seal PVC Casing Bentonite Seal Filter Pack Gravel/Sand (1.5 mm) PVC Screen End Cap

Notes (Instrumentation etc):

Contractor: Mapstone Geotechnical
Equipment:
Commenced: 21/11/11
Completed: 21/11/11
Logged By: MM
Checked By:

Basis of description and details of abbreviations are given on explanatory notes

ENVIRONMENTAL FIELD LOG AND MONITORING WELL "ASBUILT"

Borehole No:	**GW-23**
Sheet No:	1 OF 1
Project No:	3003773

Client: LEDA
Project: Cobaki Estate Acid Sulfate Investigation
Feature:
Location: Refer location plan

Co-ordinates System: UTM Zone 56
Easting: 547025.0m E
Northing: 6883647.5m S

Surface RL (m):
Angle from Horz: 90
Direction: n/a

DRILLING								TESTING			SUBSTANCE			
Method	Support	Rate: Fast	Rate: Medium	Rate: Slow	Water	Sample	Depth (m)	Depth/RL	Type	Sample or Field Test	Graphic Log	USC Symbol	Description: Soil Type: density/consistency, grain size/plasticity, colour, particle shape/secondary components, minor constituents, moisture, origin, additional observations.	Well Diagram, Installation Detail
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
AHF					22/11/2011 ▼		0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5	0.0 0.5 2.5				CI SP	Silty CLAY: Medium plasticity, dark brown. SAND: Fine to medium grained, dark brown. Borehole discontinued at 2.50m	Top Cap 0.5m Stick up Natural Surface Cement Seal PVC Casing Bentonite Seal Filter Pack Gravel/Sand (1.5 mm) PVC Screen End Cap

Notes (Instrumentation etc):

Contractor: Mapstone Geotechnical
Equipment:
Commenced: 22/11/11
Completed: 22/11/11
Logged By: MM
Checked By:

Basis of description and details of abbreviations are given on explanatory notes

SMEC GOLD COAST NON CORED LOG WATER WELL \\AUGCFP02\OPERATIONS$\PROJECTS\3003773\005_OPERATIONS\ASSMP\DRAFT REPORT\APPENDIX 2 - BOREHOLE LOGS\COBAKAI LATEST.GPJ 6/1/12

ENVIRONMENTAL FIELD LOG AND MONITORING WELL "ASBUILT"

Borehole No:	**GW-24**
Sheet No:	1 OF 1
Project No:	3003773

Client: LEDA
Project: Cobaki Estate Acid Sulfate Investigation
Feature:
Location: Refer location plan

Co-ordinates System: UTM Zone 56
Easting: 546669.5m E
Northing: 6883349.9m S

Surface RL (m):
Angle from Horz: 90
Direction: n/a

DRILLING							TESTING			SUBSTANCE			
Method	Support	Rate: Fast	Rate: Medium	Rate: Slow	Water	Sample	Depth (m)	Depth/RL	Type	Sample or Field Test	Graphic Log	USC Symbol	Description: Soil Type: density/consistency, grain size/plasticity, colour, particle shape/secondary components, minor constituents, moisture, origin, additional observations.	Well Diagram, Installation Detail
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
AHF					22/11/2011 ▼		0.5 1.0 1.5 2.0 2.5 3.0 3.5	0.0 0.3 3.0				CI CL	Silty CLAY: Medium plasticity, dark grey. Silty CLAY: Low plasticity, grey. Borehole discontinued at 3.00m	Top Cap 1.5 m stick-up due to scheduled future earthworks Natural Surface Cement Seal PVC Casing Bentonite Seal Filter Pack Gravel/Sand (1.5 mm) PVC Screen End Cap

Notes (Instrumentation etc):

Contractor: Mapstone Geotechnical
Equipment:
Commenced: 22/11/11
Completed: 22/11/11
Logged By: MM
Checked By:

Basis of description and details of abbreviations are given on explanatory notes

SMEC GOLD COAST LOG WATER WELL 1.5M STI \\AUGCFP02\OPERATIONS$\PROJECTS\3003773\005 OPERATIONS\ASSMP\DRAFT REPORT\APPENDIX 2 - BOREHOLE LOGS\COBAKAI LATEST.GPJ 6/1/12

ENVIRONMENTAL FIELD LOG AND MONITORING WELL "ASBUILT"

Borehole No:	**GW-25**
Sheet No:	1 OF 1
Project No:	3003773

Client: LEDA
Project: Cobaki Estate Acid Sulfate Investigation
Feature:
Location: Refer location plan

Co-ordinates System: UTM Zone 56
Easting: 546595.5m E
Northing: 6883593.9m S

Surface RL (m):
Angle from Horz: 90
Direction: n/a

DRILLING								TESTING			SUBSTANCE			
Method	Support	Rate: Fast	Rate: Medium	Rate: Slow	Water	Sample	Depth (m)	Depth/RL	Type	Sample or Field Test	Graphic Log	USC Symbol	Description: Soil Type: density/consistency, grain size/plasticity, colour, particle shape/secondary components, minor constituents, moisture, origin, additional observations.	Well Diagram, Installation Detail
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
AHF					22/11/2011 ▼		0.5 1.0 1.5 2.0 2.5 3.0 3.5	0.0 0.6 3.0				CI	Silty CLAY: Medium plasticity, dark brown. Silty CLAY: Low plasticity, grey. Borehole discontinued at 3.00m	Top Cap 1.5 m stick-up due to scheduled future earthworks Natural Surface Cement Seal PVC Casing Bentonite Seal Filter Pack Gravel/Sand (1.5 mm) PVC Screen End Cap

Notes (Instrumentation etc):

Contractor: Mapstone Geotechnical
Equipment:
Commenced: 22/11/11
Completed: 22/11/11
Logged By: MM
Checked By:

Basis of description and details of abbreviations are given on explanatory notes

ENVIRONMENTAL FIELD LOG AND MONITORING WELL "ASBUILT"

Borehole No: GW-26
Sheet No: 1 OF 1
Project No: 3003773

Client: LEDA
Project: Cobaki Estate Acid Sulfate Investigation
Feature:
Location: Refer location plan

Co-ordinates System: UTM Zone 56
Easting: 546397.9m E
Northing: 6883466.8m S

Surface RL (m):
Angle from Horz: 90
Direction: n/a

DRILLING							TESTING			SUBSTANCE			
Method	Support	Rate (Fast / Medium / Slow)			Water	Sample	Depth (m)	Depth/RL	Type	Sample or Field Test	Graphic Log	USC Symbol	Description Soil Type: density/consistency, grain size/plasticity, colour, particle shape/secondary components, minor constituents, moisture, origin, additional observations.	Well Diagram, Installation Detail
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								0.0						Top Cap 0.5 m stick-up Natural Surface
AHF					18/11/2011▼		0.5	0.8				GW	Silty GRAVEL/BOULDERS: Road base.	Cement Seal Bentonite Seal PVC Casing
							1.0					CL	Sandy CLAY: Low plasticity, dark grey.	
							1.5	1.7						Filter Pack Gravel/Sand (1.5 mm)
							2.0					SC	Clayey SAND: Fine to medium grained, grey.	PVC Screen
							2.5	2.5					Borehole discontinued at 2.50m	End Cap
							3.0							
							3.5							
							4.0							
							4.5							

Notes (Instrumentation etc):

Contractor: Mapstone Geotechnical
Commenced: 18/11/11
Logged By: MM
Equipment:
Completed: 18/11/11
Checked By:

Basis of description and details of abbreviations are given on explanatory notes

SMEC GOLD COAST NON CORED LOG WATER WELL \\AUGCFP02\OPERATIONS$\PROJECTS\3003773\005_OPERATIONS\ASSMP\DRAFT REPORT\APPENDIX 2 - BOREHOLE LOGS\COBAKAI LATEST.GPJ 6/1/12

ENVIRONMENTAL FIELD LOG AND MONITORING WELL "ASBUILT"

Borehole No:	**GW-27**
Sheet No:	1 OF 1
Project No:	3003773

Client: LEDA
Project: Cobaki Estate Acid Sulfate Investigation
Feature:
Location: Refer location plan

Co-ordinates System: UTM Zone 56
Easting: 546663.5m E
Northing: 6883829.7m S

Surface RL (m):
Angle from Horz: 90
Direction: n/a

DRILLING								TESTING			SUBSTANCE			
Method	Support	Rate: Fast	Rate: Medium	Rate: Slow	Water	Sample	Depth (m)	Depth/RL	Type	Sample or Field Test	Graphic Log	USC Symbol	Description: Soil Type: density/consistency, grain size/plasticity, colour, particle shape/secondary components, minor constituents, moisture, origin, additional observations.	Well Diagram, Installation Detail
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
AHF					22/11/2011 ▼		0.5 1.0 1.5 2.0 2.5 3.0 3.5	0.0 1.0 2.7 3.0				CI SC	Silty CLAY: Medium plasticity, dark brown. Low to medium plasticity, grey. Clayey SAND: Fine to medium grained, grey with yellow fines. Borehole discontinued at 3.00m	Top Cap 1.5 m stick-up due to scheduled future earthworks Natural Surface Cement Seal PVC Casing Bentonite Seal Filter Pack Gravel/Sand (1.5 mm) PVC Screen End Cap

Notes (Instrumentation etc):

Contractor: Mapstone Geotechnical
Equipment:
Commenced: 22/11/11
Completed: 22/11/11
Logged By: MM
Checked By:

Basis of description and details of abbreviations are given on explanatory notes

ENVIRONMENTAL FIELD LOG AND MONITORING WELL "ASBUILT"

Borehole No: GW-28
Sheet No: 1 OF 1
Project No: 3003773

Client: LEDA
Project: Cobaki Estate Acid Sulfate Investigation
Feature:
Location: Refer location plan

Co-ordinates System: UTM Zone 56
Easting: 546528.1m E
Northing: 6884034.1m S

Surface RL (m):
Angle from Horz: 90
Direction: n/a

DRILLING							TESTING			SUBSTANCE			
Method	Support	Rate (Fast / Medium / Slow)			Water	Sample	Depth (m)	Depth/RL	Type	Sample or Field Test	Graphic Log	USC Symbol	Description: Soil Type: density/consistency, grain size/plasticity, colour, particle shape/secondary components, minor constituents, moisture, origin, additional observations.	Well Diagram, Installation Detail
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								0.0						Top Cap; 0.5 m stick-up; Natural Surface
AHF					18/11/2011 ▼		0.5	0.6				OL	Clayey SILT: Low plasticity, dark brown, organic.	Cement Seal; PVC Casing
							1.0	1.3				SC	Clayey SAND: Fine to medium grained, dark grey.	Bentonite Seal
							1.5	1.8					Grey with orange fines.	Filter Pack Gravel/Sand (1.5 mm); PVC Screen
							2.0	2.5					Grey.	End Cap
							2.5						Borehole discontinued at 2.50m	
							3.0							
							3.5							
							4.0							
							4.5							

Notes (Instrumentation etc):

Contractor: Mapstone Geotechnical
Commenced: 18/11/11
Logged By: MM
Equipment:
Completed: 18/11/11
Checked By:

Basis of description and details of abbreviations are given on explanatory notes

SMEC GOLD COAST NON CORED LOG WATER WELL \\AUGCFP02\OPERATIONS$\PROJECTS\3003773\005_OPERATIONS\ASSMP\DRAFT REPORT\APPENDIX 2 - BOREHOLE LOGS\COBAKAI LATEST.GPJ 6/1/12

ENVIRONMENTAL FIELD LOG AND MONITORING WELL "ASBUILT"

Borehole No:	**GW-29**
Sheet No:	1 OF 1
Project No:	3003773

Client: LEDA
Project: Cobaki Estate Acid Sulfate Investigation
Feature:
Location: Refer location plan

Co-ordinates System: UTM Zone 56
Easting: 546717.7m E
Northing: 6884356.3m S

Surface RL (m):
Angle from Horz: 90
Direction: n/a

DRILLING								TESTING			SUBSTANCE			
Method	Support	Rate: Fast	Rate: Medium	Rate: Slow	Water	Sample	Depth (m)	Depth/RL	Type	Sample or Field Test	Graphic Log	USC Symbol	Description: Soil Type: density/consistency, grain size/plasticity, colour, particle shape/secondary components, minor constituents, moisture, origin, additional observations.	Well Diagram, Installation Detail
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
AHF					18/11/2011▼		0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5	0.0 0.8 1.3 2.0 2.3 2.5				OL Cl CL SP CL	SILT: Brown, organic. Silty CLAY: Medium plasticity, brown. Sandy CLAY: Low plasticity, grey with orange-yellow mottling. SAND: Fine to medium grained, grey. Sandy CLAY: Low plasticity, grey with orange fines, fine grained sands. Borehole discontinued at 2.50m	Top Cap 0.5 m stick-up Natural Surface Cement Seal PVC Casing Bentonite Seal Filter Pack Gravel/Sand (1.5 mm) PVC Screen End Cap

Notes (Instrumentation etc):

Contractor: Mapstone Geotechnical
Equipment:
Commenced: 18/11/11
Completed: 18/11/11
Logged By: MM
Checked By:

Basis of description and details of abbreviations are given on explanatory notes

SMEC GOLD COAST NON CORED LOG WATER WELL \\AUGCFP02\OPERATIONS$\PROJECTS\3003773\005_OPERATIONS\ASSMP\DRAFT REPORT\APPENDIX 2 - BOREHOLE LOGS\COBAKAI LATEST.GPJ 6/1/12

ENVIRONMENTAL FIELD LOG AND MONITORING WELL "ASBUILT"

Borehole No:	**GW-30**
Sheet No:	1 OF 1
Project No:	3003773

Client: LEDA
Project: Cobaki Estate Acid Sulfate Investigation
Feature:
Location: Refer location plan

Co-ordinates System: UTM Zone 56
Easting: 546491.5m E
Northing: 6884485.4m S

Surface RL (m):
Angle from Horz: 90
Direction: n/a

DRILLING							TESTING			SUBSTANCE			
Method	Support	Rate: Fast	Rate: Medium	Rate: Slow	Water	Sample	Depth (m)	Depth/RL	Type	Sample or Field Test	Graphic Log	USC Symbol	Description: Soil Type: density/consistency, grain size/plasticity, colour, particle shape/secondary components, minor constituents, moisture, origin, additional observations.	Well Diagram, Installation Detail
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
AHF					18/11/2011▼		0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5	0.0 0.2 0.9 1.9 2.5				OL CI	SILT: Low plasticity, grey, organic. Brown. Silty CLAY: Medium plasticity, brown. SILTSTONE: Extremely weathered, brown. Borehole discontinued at 2.50m	Top Cap 0.5 m stick-up Natural Surface Cement Seal PVC Casing Bentonite Seal Filter Pack Gravel/Sand (1.5 mm) PVC Screen End Cap

Notes (Instrumentation etc):

Contractor: Mapstone Geotechnical
Equipment:
Commenced: 18/11/11
Completed: 18/11/11
Logged By: MM
Checked By:

Basis of description and details of abbreviations are given on explanatory notes

SMEC GOLD COAST NON CORED LOG WATER WELL \\AUGCFP02\OPERATIONS$\PROJECTS\3003773\005_OPERATIONS\ASSMP\DRAFT REPORT\APPENDIX 2 - BOREHOLE LOGS\COBAKAI LATEST.GPJ 6/1/12

ENVIRONMENTAL FIELD LOG AND MONITORING WELL "ASBUILT"

Borehole No:	**GW-31**
Sheet No:	1 OF 1
Project No:	3003773

Client: LEDA
Project: Cobaki Estate Acid Sulfate Investigation
Feature:
Location: Refer location plan

Co-ordinates System: UTM Zone 56
Easting: 546897.0m E
Northing: 6884678.7m S

Surface RL (m):
Angle from Horz: 90
Direction: n/a

DRILLING								TESTING			SUBSTANCE			
Method	Support	Rate: Fast	Rate: Medium	Rate: Slow	Water	Sample	Depth (m)	Depth/RL	Type	Sample or Field Test	Graphic Log	USC Symbol	Description: Soil Type: density/consistency, grain size/plasticity, colour, particle shape/secondary components, minor constituents, moisture, origin, additional observations.	Well Diagram, Installation Detail
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
AHF					18/11/2011		0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5	0.0 0.2 0.6 1.2 1.5 2.5 4.0				ML CI CH	SILT: Low plasticity, cream. Sandy SILT: Low plasticity, brown, some fine-grained soils. Silty CLAY: Medium plasticity, brown. Silty CLAY: High plasticity, brown mottled grey. Cream and white. Wet. Borehole discontinued at 4.00m	Top Cap 0.5 m stick-up Natural Surface Cement Seal PVC Casing Bentonite Seal Filter Pack Gravel/Sand (1.5 mm) PVC Screen End Cap

Notes (Instrumentation etc):

Contractor: Mapstone Geotechnical
Equipment:
Commenced: 18/11/11
Completed: 18/11/11
Logged By: MM
Checked By:

Basis of description and details of abbreviations are given on explanatory notes

SMEC GOLD COAST NON CORED LOG WATER WELL \\AUGCFP02\OPERATIONS$\PROJECTS\3003773\005_OPERATIONS\ASSMP\DRAFT REPORT\APPENDIX 2 - BOREHOLE LOGS\COBAKAI LATEST.GPJ 6/1/12

ENVIRONMENTAL FIELD LOG AND MONITORING WELL "ASBUILT"

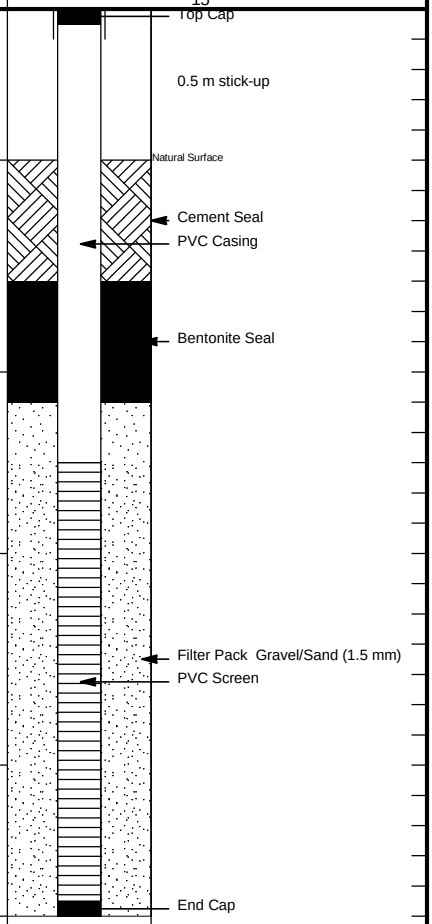
Borehole No:	**GW-32**
Sheet No:	1 OF 1
Project No:	3003773

Client: LEDA
Project: Cobaki Estate Acid Sulfate Investigation
Feature:
Location: Refer location plan

Co-ordinates System: UTM Zone 56
Easting: 547012.2m E
Northing: 6884570.6m S

Surface RL (m):
Angle from Horz: 90
Direction: n/a

DRILLING							TESTING			SUBSTANCE			
Method	Support	Rate: Fast	Rate: Medium	Rate: Slow	Water	Sample	Depth (m)	Depth/RL	Type	Sample or Field Test	Graphic Log	USC Symbol	Description: Soil Type: density/consistency, grain size/plasticity, colour, particle shape/secondary components, minor constituents, moisture, origin, additional observations.	Well Diagram, Installation Detail
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								0.0						
AHF					21/11/2011▼		0.5	0.7				OL	Clayey SILT: Low plasticity, brown, organic.	
							1.0	1.3				CL	Silty CLAY: Low plasticity, brown.	
							1.5	2.0				SP	SAND: Fine to medium grained, grey.	
							2.0	2.5				CH	Silty CLAY: High plasticity, grey brown mottling.	
							2.5						Borehole discontinued at 2.50m	
							3.0							
							3.5							
							4.0							
							4.5							



Notes (Instrumentation etc):

Contractor: Mapstone Geotechnical
Equipment:
Commenced: 21/11/11
Completed: 21/11/11
Logged By: MM
Checked By:

Basis of description and details of abbreviations are given on explanatory notes

SMEC GOLD COAST NON CORED LOG WATER WELL \\AUGCFP02\OPERATIONS$\PROJECTS\3003773\005_OPERATIONS\ASSMP\DRAFT REPORT\APPENDIX 2 - BOREHOLE LOGS\COBAKAI LATEST.GPJ 6/1/12

APPENDIX B GROUNDWATER BORE LICENCES

NSW GOVERNMENT | Office of Water

RECEIVED
2 NOV 2011
BY:

Ref.No: 30BL185853
Contact: K Dighton
Ph.No: (02) 66 416561

Leda Manorstead Pty Limited
Level 1, Cavill Park
46 Cavill Ave
SURFERS PARADISE QLD 4217

28 October, 2011

Dear Sir or Madam,

Reference. Your application for a Bore license under the Water Act.

Please find enclosed license **30BL185853** for construction of fourteen (14) monitoring bores near Piggabeen Road, Tweed Heads, NSW, to monitor ground water quality. Your attention is drawn to the nature and description of the work, terms, limitations and conditions under which the license is issued.

You are reminded that upon completion of the works it is necessary for you to forward to this office:

(a) a copy of Form 'A' (Particulars of Completed Bore – issued to you by the driller) for each work constructed;

(b) a copy of a plan of the property confirming the bore sites;

IF YOU DECIDE NOT TO PROCEED WITH THE DRILLING PLEASE ADVISE THIS OFFICE SO THAT THE LICENSE CAN BE CANCELLED.

You are advised that parts of Lots 54,199, 206 and 228, all DP 755740 may be in areas at risk of Acid Sulphate Soils and that a dip site was located in Lot 199 DP755740 referred to on the 'Currumbin' Topographic Map as Turners Dip.

Yours sincerely

K Dighton
Licensing Officer
Grafton

(76 Victoria Street), Locked Bag 10, Grafton NSW 2460
Telephone: (02) 6641 6500

NSW GOVERNMENT

NSW Office of Water

Department of Environment Climate Change and Water

GROUND WATER LICENSING PROCEDURES

1. After receiving this bore licence from the Department the licence holder then makes arrangements with a **licensed driller** to sink and construct the bore. A work plan and contractual agreement by both parties, prior to commencement of construction work is highly recommended.

2. The driller must sight the bore licence before constructing the bore.

3. The driller is required to complete the Form A. The completed form requires signatures from both the driller and licence holder.

4. As a licence holder you are advised to make and keep copies of the completed Form A and the plan showing the location of the bore.

5. The signed and completed Form A together with the plan provided is to be returned to:

NSW Office of Water
Department of Environment Climate Change and Water
Locked Bag 10
GRAFTON NSW 2460

NSW Office of Water

North Coast Region
Locked Bag 10
76 Victoria Street
Grafton NSW 2460
Phone: (02) 66416500

BORE LICENSE CERTIFICATE
UNDER SECTION 115 OF THE WATER ACT, 1912

30BL185853

Office of Water

Leda Manorstead Pty Limited
Level 1, Cavill Park
46 Cavill Ave
Surfers Paradise QLD 4217

LICENSE NUMBER
30BL185853
DATE LICENSE VALID FROM
27-Oct-2011
DATE LICENSE VALID TO
PERPETUITY
FEE
$0.00

ABN 47661556763 GST NIL

LOCATION OF WORKS

Portion(s) or Lot/Section/DP	PARISH	COUNTY
54//755740	Terranora	Rous
199//755740	Terranora	Rous
200//755740	Terranora	Rous
206//755740	Terranora	Rous
228//755740	Terranora	Rous

TYPE OF WORKS	PURPOSE(S) FOR WHICH WATER MAY BE USED
Bore	Monitoring Bore

CONDITIONS APPLYING TO THIS LICENSE ARE

As shown on the attached Condition Statement

ORIGINAL

NSW Office of Water

CONDITIONS STATEMENT REFERRED TO ON 30BL185853 ISSUED UNDER PART V OF THE WATER ACT, 1912 ON 27-Oct-2011

(1) THE LICENCE SHALL LAPSE IF THE WORK IS NOT COMMENCED AND COMPLETED WITHIN ONE YEAR OF THE DATE OF ISSUE OF THE LICENCE.

(2) THE LICENSEE SHALL WITHIN TWO (2) MONTHS OF COMPLETION OR AFTER THE ISSUE OF THE LICENCE IF THE WORK IS EXISTING, FURNISH TO NSW OFFICE OF WATER:-

(A) DETAILS OF THE WORK AS SET OUT IN THE FORM "A" (MUST BE COMPLETED BY A DRILLER, DULY LICENSED IN NEW SOUTH WALES).

(B) A PLAN SHOWING ACCURATELY THE LOCATION OF THE WORK IN RELATION TO PORTION AND PROPERTY BOUNDARIES,

(C) DETAILS OF ANY PUMPING TESTS CARRIED OUT,

(D) DETAILS OF ANY WATER ANALYSIS.

(3) THE LICENSEE SHALL ALLOW NSW OFFICE OF WATER OR ANY PERSON AUTHORISED BY IT, FULL AND FREE ACCESS TO THE WORKS, EITHER DURING OR AFTER CONSTRUCTION, FOR THE PURPOSE OF CARRYING OUT INSPECTION OR TEST OF THE WORKS AND ITS FITTINGS AND SHALL CARRY OUT ANY WORK OR ALTERATIONS DEEMED NECESSARY BY THE DEPARTMENT FOR THE PROTECTION AND PROPER MAINTENANCE OF THE WORKS, OR THE CONTROL OF THE WATER EXTRACTED AND FOR THE PROTECTION OF THE QUALITY AND THE PREVENTION FROM POLLUTION OR CONTAMINATION OF SUB-SURFACE WATER.

(4) IF DURING THE CONSTRUCTION OF THE WORK, SALINE OR POLLUTED WATER IS ENCOUNTERED ABOVE THE PRODUCING AQUIFER, SUCH WATER SHALL BE SEALED OFF BY:-

(A) INSERTING THE APPROPRIATE LENGTH(S) OF CASING TO A DEPTH SUFFICIENT TO EXCLUDE THE SALINE OR POLLUTED WATER FROM THE WORK.

(B) CEMENTING BETWEEN THE CASING(S) AND THE WALLS OF THE BORE HOLE FROM THE BOTTOM OF THE CASING TO GROUND LEVEL.

ANY DEPARTURE FROM THESE PROCEDURES MUST BE APPROVED BY THE DEPARTMENT BEFORE UNDERTAKING THE WORK.

(5) IF A WORK IS ABANDONED AT ANY TIME THE LICENSEE SHALL NOTIFY NSW OFFICE OF WATER THAT THE WORK HAS BEEN ABANDONED AND SEAL OFF THE AQUIFER BY:-

(A) BACKFILLING THE WORK TO GROUND LEVEL WITH CLAY OR CEMENT AFTER WITHDRAWING THE CASING (LINING); OR

(B) SUCH METHODS AS AGREED TO OR DIRECTED BY NSW OFFICE OF WATER.

(6) THE LICENSEE SHALL NOT ALLOW ANY TAILWATER/DRAINAGE TO DISCHARGE INTO OR ONTO:-

- ANY ADJOINING PUBLIC OR CROWN ROAD;
- ANY OTHER PERSONS LAND;
- ANY CROWN LAND;
- ANY RIVER, CREEK OR WATERCOURSE;
- ANY NATIVE VEGETATION AS DESCRIBED UNDER THE NATIVE VEGETATION CONSERVATION ACT 1997;

- ANY WETLANDS OF ENVIRONMENTAL SIGNIFICANCE.

(7) IF THE BORE AUTHORISED BY THIS LICENSE IS LINED WITH STEEL OR PLASTIC CASING THE INSIDE DIAMETER OF THAT CASING SHALL NOT EXCEED 220 MM.

(8) WATER SHALL NOT BE PUMPED FROM THE BORE AUTHORISED BY THIS LICENSE FOR ANY PURPOSE OTHER THAN GROUNDWATER INVESTIGATION.

End Of Conditions

APPENDIX C GROUNDWATER MONITORING FIELD SHEETS

Groundwater Sampling Field Sheet

Job no:		**Well no:**	
Client:		**Purging date:**	
Site location:		**Sampling date:**	

Casing diameter (mm):		**Depth to floating product (mBTOC):**	
Casing height above-ground level (mAGL):		**Depth to groundwater (mBTOC):**	
Bore locked/covered?:		**Product thickness (mm):**	
Cap type:		**Well depth from TOC (m):**	
Well condition:		**Depth to be purged (m):**	

Purging information

Purge 3-5 casing volumes, or until 'dry', and until field parameters have stabilised:

1 casing volume = 5.9 L/m for 50 mm ID wells. *1 casing volume = 10.3 L/m for 100 mm ID wells.*

Method/Pump Type: Bailer ☐ Waterra ☐ Whaler ☐ Micro-Purge ☐	Planned Purge Volume: Litres (3 well vols)
Material: Teflon ☐ S/Steel ☐ HDPE ☐ PVC ☐ Other: _____	Actual Purge Volume: Litres
Start time (2400 hour):	Did well purge 'dry'? No ☐ Yes ☐ At?: Litres

Field results while purging

	Time	**pH**	**EC (___S/cm)**	**Redox (mV)**	**DO units** % ☐ ppm ☐	**Turbidity (NTU)**	**Temp. (^{o}C)**
After **1** purge volume:							
After **2** purge volume:							
After **3** purge volume:							
After **4** purge volume:							
After **5** purge volume:							
Additional volume:							
Acceptable variation:	N/A	+/- 0.05	+/- 3%	+/- 10%	+/- 10%	N/A	+/- 10%

Are the field results acceptable?:

Sampling details

Method/Pump Type: Bailer ☐ Waterra ☐ Whaler ☐ Micro-Purge ☐

Material: Teflon ☐ S/Steel ☐ HDPE ☐ PVC ☐ Other: _____

Equipment: Dedicated ☐ Decontaminated ☐ Other: _____

Is there a hydrocarbon sheen?: Yes ☐ No ☐

Analysis details

Major cations (Ca, Mg, K, Na) ☐	Alkalinity (bicarbonate, carbonate) ☐
Major anions (Cl, SO_4) ☐	Total acidity (titratable) ☐
Total iron ☐	☐
Dissolved metals (Fe, Mn, Al) ☐	(field filtered) ☐

Colour:	Odour:	Sample ID:	Duplicate ID:
Turbidity: Low ☐ Medium ☐ High ☐		Rinse Blank After: Yes ☐ No ☐	Triplicate ID:

Weather conditions

☐ Cold ☐ Cool ☐ Mild ☐ Warm ☐ Hot	☐ Clear ☐ Medium ☐ Cloudy	☐ Dry ☐ Medium ☐ Humid ☐ Rain	☐ Still ☐ Breeze ☐ Windy	☐ Dusty

Other comments and observations:

Sampler's Initials:	Purger's Initials:

Prepared:	***Approved:***

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