Appendix 4

Acid Sulfate Soil Management Plan

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Acid Sulfate Soil Management Plan

"Riveroaks Estate", Pacific Highway, North Ballina

(Proposed 236 Lot Residential Subdivision at Lots 1, 2, 3 & 5 DP1074242 and part Lot 269 DP755684 on behalf of RAYSHIELD Pty. Ltd.)

24 January 2008

Nick Davison
Environmental Scientist, LandPartners Limited

benchmark IN QUALITY AS/NZS ISO 9001

Ref No. **LM070113.000**

DISCLAIMER

This report has been prepared for the use of the stated client and for the specific purpose described in the Introduction and is not to be used for any other purpose or by any other person or corporation. LandPartners Limited accepts no responsibility for any loss or damage suffered howsoever arising to any person or corporation who may use or rely on this report in contravention of the terms of this disclaimer.

Due consideration has been given to site conditions and to appropriate legislation and documentation available at the time of preparation of the report. As these elements are liable to change over time, the report should be considered current at the time of preparation only.

The report relies on information supplied by the client and on findings obtained using accepted survey and assessment methodology. Specific survey methodology is described in the relevant section of the report.

While due care was taken during field survey and report preparation, LandPartners accepts no responsibility for any omissions that may have occurred due to the nature of the survey methodology.

Conclusions to the report are professional opinions and LandPartners cannot guarantee acceptance or consent of the relevant determining/ consent authorities.

This Acid Sulfate Soil Management Plan was written by Nick Davison (Environmental Scientist) and peer reviewed by Bruce Hammond (Project Manager, LandPartners Ltd).

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1. Introduction

LandPartners Limited ("LandPartners") has been commissioned by Rayshield Pty. Ltd. to prepare an Acid Sulfate Soil (ASS) Management Plan in accordance with the findings of the Acid Sulfate Soil Assessment undertaken in order to satisfy Section 6.2 of the director-general's requirements (DGR) regarding the proposed 236 Lot "*Riveroaks Estate*" residential subdivision. Therefore, in accordance with the requirements set forth in Section 6.2 (DGR) and the Ballina LEP 1987 - Clause 36 (BSC 1987), this ASS Management Plan provides appropriate mitigation strategies and best management practices applicable to the subject site and the proposed works.

1.1 Background

The proposed development entails the subdivision of Lots 1, 3 and 5 DP 1074242 and part Lot 269 DP755684 to form 236 residential allotments, with provisions for the establishment of a childcare centre, playing fields and retained open spaces. The proposed works associated with the subdivision development will include:

- Filling of Lots 1, 3 and 5 with regard to the minimum specified 1 in 100 year flood height, however this may vary depending upon the ultimate land use for specific areas within the subdivision (i.e. dwelling, road, park etc.);

- Construction of internal roads and a temporary access road originating from the Pacific Highway;

- Installation of critical infrastructure including mains water, reticulated sewer, mains power, telecommunications etc; and

- Construction and alteration of stormwater collection, diversion and detention infrastructure within Lots 1, 2, 3 and 5.

Earthworks will be required to divert and redirect stormwater flows entering the site through a series of engineered flow paths within the existing drainage easements of Lot 2 DP1074242 and the construction of a floodway to cater for periods of excessive precipitation and high rainfall runoff events, also to be located within Lot 2. The adaptation and enhancement of the existing altered flow paths is proposed, incorporating enlargement of the western and central drains within the existing easements and the implementation of detention basins and Floodway paths.

1.2 Summary of Investigation Findings

The ASS Assessment identified the following subsurface characteristics regarding the acid generating capabilities of the subject site:

- The subsurface conditions within the subject site were predominantly clayey sand – sandy clay alluvial sequences, consistently overlying waterlogged sandy – clayey sand subsoils;
- Field sampling and subsequent laboratory analyses identified **Actual Acid Sulfate Soils** within samples collected from BH 2 (refer Fig. 8; ASS Assessment) at a depth of approximately 1.4 m below EGS. **Potential Acid Sulfate Soils** were identified within samples collected from all excavated boreholes with the exception of BH 6 (refer Fig. 8; ASS Assessment). The typical depth to PASS ranged between **0.75 – 1.5 m** below Existing Ground Surface (EGS).
- The Reduced Inorganic sulphur (%S) levels were observed to exceed the ASSMAC action criteria (0.03 %Scr; 18 mol H^+/tonne) in the analysed samples from **five (5) of the six (6)** excavated boreholes. Recorded (%Scr) levels ranged between 0.005 to 0.684 %Scr (average; 0.316 %Scr) (refer Table 6; ASS Assessment); and
- Given the sandy nature of the subsoils observed within the excavated boreholes and the lack of shell materials (containing $CaCO_3$ available for buffering of generated acid), the **Acid Neutralising Capability (ANC) has been assessed as negligible whilst the Acid Generating Capability (AGC) has been assessed as significant**;

Therefore, as a result of these findings, it has been assessed that the proposed works associated with the residential subdivision of Lots 1, 3 and 5 DP1074242 and the associated drainage works on adjoining Lot 2 DP1074242 will disturb ASS layers occurring at a minimum depth of 0.75 m below EGS. In an effort to reduce the risk of exposure and subsequent oxidation of these materials, this Acid Sulfate Soil Management Plan has been prepared to provide effective management guidelines and mitigation practices that are to be incorporated as a part of the proposed works. These guidelines and practices have been prepared in accordance with the recommendations specified in Stone et al (1998).

2. Scope of Treatment

2.1 Estimated Treatment Area

As described in Section 1.1 the proposed development will disturb ASS materials during three (3) key activities. These activities are identified below and an outline of the processes involved in their undertaking is provided. It must be noted that Acid Sulfate Soil levels have been assessed as occurring at approximately 0.75 m below EGS. This equates to varying AHD levels of – 0.3 m to 0.8 m AHD across the site.

2.1.1 Excavation of Stormwater Drainage Swales and Constructed Floodway

The widening and deepening of existing drainage pathways running north-south and north-west to south-east within adjoining Lot 2 DP1074242 is proposed as part of the stormwater management concept for the subdivision development.

These stormwater measures will entail:

1) Approximately 30 m wide x (maximum) 0.70 m deep excavation running approximately 600 m from north-west to south east across Lot 2 DP 1074242. A total expected excavation volume of 3,150 m^3. With an identified depth to ASS materials of 0.75 m below EGS the potential to encounter ASS materials is assessed as minimal; and

2) 10 m wide x 1.2 m deep excavation running approximately 360 m from north to south across the central area of Lot 2 DP1074242. The central constructed drain line will require extensive excavations as the existing drainage structure is considerably smaller than that of the western drainage line. A total excavation volume of 2,020 m^3 is expected for the central excavated drainage path. With an identified depth of 0.75 m below EGS to PASS materials and the absence of ASS materials from the south-eastern portion of Lot 2, this equates to approximately 65 m^3 of ASS materials included in the excavation activities for the central drainage path.

3) With the existing artificial drainage structure (located on western boundary of Lot 2) accepting flows from the subject site and adjoining lands to the west already appropriately sized, excavation is expected to only entail widening of the current structure with no increase in the current depth. As no deepening of the structure is expected to occur the potential for intersection and disturbance of ASS layers is assessed as minimal.

2.1.2 Excavation of Sewer Pump Stations

Excavations to install two (2) sewer pump stations at locations shown in Fig. 1. A total depth of 4.5 m is expected with an excavation diameter of approximately 5.0 m at surface and approximately 2.5 m at base of excavation. With the required level of filling (2.1 m AHD) a maximum of 1.6 m of fill material will be placed in the location of each sewer pump station. A total excavated soil volume of approximately 52 m^3 is expected at each sewer pump station. With an estimated depth to ASS materials of 0.75 m below EGS, a total disturbed ASS volume of 18.35 m^3 is expected within each pump station excavation.

2.1.3 Excavations for Stormwater Pipes and Sewer Reticulation

Excavations to install three (3) main stormwater pipes (max 1200 mm Ø) running north south within the estate. . A maximum EGS level of 1.4 m AHD occurs within the nominated stormwater pipe routes. With an estimated depth to ASS materials of 0.75 m below EGS, the maximum depth of excavation (1.5 m) will not intersect identified ASS layers within these road reserves.

Sewer reticulation invert levels are anticipated to range between 1.1m and – 1.4 m AHD. Assuming an average ASS level of 0.5 m AHD and a sewer pipe invert at the pumping station of – 1.4 m AHD, approximately 190 m of sewer reticulation upstream of the pump station will be acid sulfate affected. It is estimated that the total disturbed ASS volume will be 285 m^3.

2.2 Total Expected Excavation of ASS Materials

Utilising an average bulk density figure of 1.4 tonne/m^3, and given the total disturbance volumes as calculated in the above section 2.1, the total mass of excavated ASS materials is expected to be **554 tonnes**.

2.3 Treatment Category

Based on the overall expected volume of excavations (550 tonnes) and the highest net acidity potential recorded (0.684%S or 432 moles H^+/m^3) the project may be considered within the **Very High Treatment Category** (in accordance with Table 4.5; Stone et al 1998).

2.4 Liming Rate

Given that the proposed works will entail the use of excavated materials as both backfill and site-won fill, the potential for acidification is limited by the total period of PASS exposure to an oxidising environment. The construction activities have been separated into three (3) individual components as described above.

The maximum Total Oxidisable Sulfur (TOS) content (%Scr) for each component (as indicated by the laboratory results) will be utilised to calculate a suitable liming rate for each component of works.

2.4.1 Floodway and Drainage Path Construction and Alterations

Using the maximum TOS value of 0.394 %Scr and including a safety and neutralising factor of 1.5, the liming calculation for materials excavated as part of these activities is as follows (in accordance with Section 6.1; Stone et al 1998):

Lime required (kg $CaCO_3$/tonne material at 1.0 t/m^3)

= kg H_2SO_4/tonne of material x 1.5

= (%S x 30.59) x 1.5

Therefore:

= (0.394 x 30.59) x 1.5

= 18.08 kg $CaCO_3$ / tonne of material

As the bulk density of the identified ASS layers is not 1.0 t/m^3, a correction factor to increase the liming rate per m^3 of disturbed ASS material must be used. For the purpose of this management plan, the average bulk density figure (i.e. 1.4 t/m^3) has been used as the correction factor. Therefore the total estimated liming rate for treatment of ASS materials disturbed during the construction of the floodway and drainage paths is expected to be 25.31 kg $CaCO_3$ / m^3 of excavated ASS materials.

2.4.2 Construction of Sewer Pump Stations

Sewer Pump Station 1

Using the maximum TOS value for Pump Station 1 (i.e. BH 1) of 0.684 %Scr and including a safety and neutralising factor of 1.5, the liming calculation Sewer Pump Station 1 is as follows (in accordance with Section 6.1; Stone et al 1998):

Lime required (kg $CaCO_3$/tonne material at 1.0 t/m^3)

= kg H_2SO_4/tonne of material x 1.5

= (%S x 30.59) x 1.5

Therefore:

= (0.684 x 30.59) x 1.5

= 31.38 kg $CaCO_3$ / tonne of material

As the bulk density of the identified ASS layers is not 1.0 t/m^3, a correction factor to increase the liming rate per m^3 of disturbed ASS material must be used. For the purpose of this management plan, the average bulk density figure (i.e. 1.4 t/m^3) has been used as the correction factor. Therefore the total estimated liming rate for treatment of ASS materials disturbed during the construction of sewer pump station 1 is expected to be 43.94 kg $CaCO_3$ / m^3 of excavated ASS materials.

Sewer Pump Station 2

Using the maximum TOS value for Pump Station 2 (i.e. BH 2) of 0.361 %Scr and including a safety and neutralising factor of 1.5, the liming calculation for Sewer Station 2 is as follows (in accordance with Section 6.1; Stone et al 1998):

Lime required (kg $CaCO_3$/tonne material at 1.0 t/m^3)
= kg H_2SO_4/tonne of material x 1.5
= (%S x 30.59) x 1.5
Therefore:
= (0.361 x 30.59) x 1.5
= 16.56 kg $CaCO_3$ / tonne of material

As the bulk density of the identified ASS layers is not 1.0 t/m^3, a correction factor to increase the liming rate per m^3 of disturbed ASS material must be used. For the purpose of this management plan, the average bulk density figure (i.e. 1.4 t/m^3) has been used as the correction factor. Therefore the total estimated liming rate for treatment of ASS materials disturbed during the construction of sewer pump station 2 is expected to be 23.19 kg $CaCO_3$ / m^3 of excavated ASS materials.

2.4.3 Stormwater and Sewer Piping

Excavation for stormwater piping is not expected to intersect ASS layers however the excavation works involved in the installation of sewer reticulation is expected to disturb potential acid sulfate soil layers.

Using the average TOS value of 0.364 %Scr and including a safety and neutralising factor of 1.5, the liming calculation for these activities is as follows (in accordance with Section 6.1; Stone et al 1998):

Lime required (kg $CaCO_3$/tonne material at 1.0t/m^3)
= kg H_2SO_4/tonne of material x 1.5
= (%S x 30.59) x 1.5
Therefore:
= (0.364 x 30.59) x 1.5
= 16.70 kg $CaCO_3$ / tonne of material

As the bulk density of the identified ASS layers is not 1.0 t/m^3, a correction factor to increase the liming rate per m^3 of disturbed ASS material must be used. For the purpose of this management plan, the average bulk density figure (i.e. 1.4 t/m^3) has been used as the correction factor. Therefore the total estimated liming rate for treatment of ASS materials disturbed during the installation of stormwater piping and sewer reticulation is expected to be 23.38 kg $CaCO_3$ / m^3 of excavated ASS materials.

2.4.4 Estimated Neutralising Agent Requirements

The total amount of disturbed ASS materials in each component activity is estimated to be approximately:

- Floodway and Drainage Path Construction and Alterations – 65 m^3;
- Sewer Pump Stations Construction – 23 m^3 each; and
- Stormwater and Sewer Piping – 285 m^3.

Total – 396 m^3 or 554 tonne

Therefore the total quantity of lime required for treatment of excavated acid generating soils in each component activity will be as follows:

- Floodway and Drainage Path Construction and Alterations – 1.65 tonnes at 25.31 kg/m^3 of ASS material;
- Sewer Pump Station 1 Construction – 1.01 tonnes at 43.94 kg/m^3 of ASS material;
- Sewer Pump Station 2 Construction – 0.53 tonne at 23.19 kg/m^3 of ASS material; and
- Stormwater and Sewer Piping – 6.66 tonnes at 23.38 kg/m^3 of ASS material.

Subtotal – 9.85 tonne

Additional treatment procedures will include the liming of the base of all excavations within the open trenching (road reserve) with a rate of 10kg/m^2, as well as placing guard layers around concrete structures (pump station excavations) and bund pad preparations at a similar application rate.

- Open trenching – 376 m x 1.2 m → 451 m^2 → 4.51 tonne;
- Pump Stations – Л x 0.6 ^{2} m → 1.1 m^2 x 2 pump stations → 0.02 tonne.

Subtotal – 4.53 tonne

Therefore the total neutralising agent requirements for the proposed works will be approximately **14.38 tonnes of fine agricultural lime ($CaCO_3$)**.

3. Neutralising Material Information

Medium to fine agricultural lime ("aglime") is the preferred neutralisation additive for the management of ASS materials, as this material is slightly alkaline and of low solubility in water. The aglime should be fine ground (at least < 1 mm; preferably < 0.3 mm) calcium carbonate or calcite (limestone or marble). Course-grained calcite is not recommended, as one of the products of neutralisation reaction is gypsum ($CASO_4.2H_2O$) which has a relatively low solubility and tends to coat the reacting calcite grain, forming a partial barrier to further reaction. Gypsum may also give off hydrogen sulfide if in reaction with acidic conditions and can itself result in the generation of sulfuric acid.

Dolomitic aglime, or magnesium-blend aglime, should not be used as these materials impose environmental risks from overdosing with the potential to damage estuarine ecosystems.

The effectiveness of the lime is referred to as the Effective Neutralising Value (ENV), which is determined by the (theoretical) Neutralising Value (NV) and particle size.

The aglime purity should preferably be 95% or better (i.e. NV > 90). Alternatively a material with a higher NV/ENV can be used (e.g. magnesia (MgO) however additional safety measures/risk management may be required. The aglime should also be fine and dry, as the texture and moisture can also decrease the effective neutralising value.

The use of a correction factor for the ENV is required to ensure sufficient quantities of aglime are applied in the respective management areas. The correction factor can be calculated by the following formula (as recommended in Table 5.2; Stone et al 1998):

ENV [dry] = NV x [(Proportion of size fraction > 0.85 mm) x 0.1
+ (Proportion of size fraction 0.3 mm - 0.85 mm) x 0.6
+ (Proportion of size fraction < 0.3 mm) x 1.0]
/100

To correct for moisture content (MC) the following formula should be applied:

ENV (moisture adjusted) = ENV [dry] x (1 – MC/100)

To determine the amount of product needed to be equivalent to pure, fine $CACO_3$:

Liming Rate = 100/ENV (moisture adjusted) x calculated liming rate

It must be noted that alkaline substances (pH > 7) recommended in the treatment of ASS-affected soils can be just as damaging to the environment as acidic substances (pH < 7). If measurements of pH values greater than 8.5 occur in leachates, surface waters and groundwaters, adjustment prior to release will be required.

The caustic nature of the recommended neutralising agents will require the implementation of OHS procedures in accordance with product advice. Personal Protective Equipement (PPE) is likely to be required during handling and mixing. Secure on site storage for aglime ($CaCO_3$) and hydrated/slaked lime ($Ca(OH)_2$) will also be required

4. Management of Potential Impacts

4.1 Responsible Personnel

The Project Coordinator will be responsible for ensuring the appropriate management of acidic soil and associated leachate as outlined in this document.

4.2 Operational Policy

To effectively treat excavated soils and generated leachate within the identified ASS affected areas and avoid and/or mitigate any adverse environmental impacts during the construction and operational phases of the development.

4.3 Performance Criteria

All soils excavated within the identified ASS affected area are to be appropriately treated for potential acid generation in accordance with the recommendations outlined in this document.

All leachate discharged from site excavations is to comply with the criteria outlined in Table 1.

Table 1. Water Quality Criteria

Parameter	Release Criteria
pH	7.0 – 8.4 [A]
Dissolved Oxygen (% Saturation)	90 – 110 [A]
Turbidity (ntu)	0.5 – 10 [B]
Suspended Solids (mg/L)	20 [C]
Iron (soluble) (mg/L)	1.0 [D]
Aluminium (soluble) (mg/L)	< 0.005 (if ph < 6.5) [D] < 0.10 (if ph > 6.5) [D]

Table Notes:

[A] Freshwater Lakes and Reservoirs criterion from Australia New Zealand Environment and Conservation Council (ANZECC) / Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality – Section 3 Aquatic Ecosystems: Table 3.3.2;

[B] Department of Environment and Conservation (NSW) Marine Water Quality Objectives for NSW Oceans – North Coast (October 2005);

[C] Adopted from Table 2.5.1.1 of the Queensland Water Quality Guidelines, March 2006 (Mid-estuarine and tidal canals, constructed estuaries, marinas and boat harbours); and

[D] Freshwater criteria from Table 5-B National Environment Protection (Assessment of Site Contamination) Measure 1999 Schedule B (1): Guideline on the Investigation Levels for Soil and Groundwater. No criteria are specified for marine waters.

4.4 Treatment of Identified Acid Sulfate Soil

4.4.1 Implementation Strategy

The proposed treatment procedure will entail the excavation of soil materials to the required depth for each specific activity (i.e. open trenching, drain construction and sewer pump station installation). The removal of non-ASS topsoil materials is to include the collection and field testing of topsoil samples to ensure overstripping has not occurred. Topsoils materials may be stockpiled on site to be used as top dressing of treated ASS materials.

Once excavations reach the identified ASS layers (i.e. 0.75 m below EGS), the works are to proceed in a staged manner. Excavated ASS materials are to be placed in a prepared treatment area for treatment and stockpiling purposes. Total expected time of exposure for each excavation period is to be limited (where possible) with ASS affected materials stockpiled, treated accordingly and returned to the excavation and then subsequently capped by the replacement of the non-ASS affected topsoils. Table 2 provides indicative maximum periods for short-term stockpiling of untreated ASS materials.

Table 2. Indicative maximum periods for short-term stockpiling of ASS materials

Type of Material		Duration of Stockpiling	
Texture Range	**Approx. Clay Content (%)**	**Days**	**Hours**
Coarse Sands to Sandy Loams	≤ 5	Overnight	18
Medium Sandy Loams to Light Clays	5 - 40	2.5 Days	70
Fine Medium to Heavy Clays	≥ 40	2.5 Days	70

For ASS affected materials that are surplus to backfill requirements and are intended to be used as site-won fill, treatment and transportation to the designated fill area is to occur as soon as practically possible following excavation and disturbance.

The following outlines the treatment and management procedures recommended for adoption during the proposed works:

- Pads constructed for treatment of excavated potential acid generating soils are to be bunded and located in areas that will minimise their potential for surface run-off interaction. Treatment pads, bund areas and bund walls are to be prepared with a guard layer consisting of lime mixed at a minimum rate of 10 kg/m^2;
- Excavated potential acid generating soils are to be stockpiled on treatment pads and surface limed at the rate as specified for that section of works (refer Section 2.4). Mixing via mechanical means is to be used to evenly distribute the neutralising agent throughout the ASS materials. Lime is to be in the form of fine agricultural lime (refer Section 3);
- n all areas of open excavation that are at or below 0.75 m (below EGS), neutralising agent is to be applied to the base of excavated area at a rate of 10kg/m^2;
- Prior to backfilling or disposal of treated ASS materials sampling is to be undertaken to ensure the effectiveness of the treatment method. Testing of samples is to entail pH_F and pH_{FOX} analysis to ensure treated soils meet the screening criteria set forth in Table 3 (below);
- Extraction of groundwaters during dewatering exercises is to be conducted in line with a suitably designed sampling and analysis protocol to determine the safest method of disposal; and
- A minimum of 1,000 kg of fine agricultural lime is to be maintained on-site at all times during the construction phase to ensure any potentially hazardous situations can be suitably controlled.

4.5 Treatment of Acidic Waters

A calcium hydroxide solution may be used for rapid neutralisation of leachate waters. This solution could be produced using either hydrated/slaked lime or quicklime, by stirring approximately 0.3 kg of either material into water, in a container of sufficient volume (e.g. a plastic 200 L drum). The slurry should be allowed to settle, and the clear solution (which will be highly caustic with a pH of 12) can be pumped or sprayed into standing water in small amounts. This procedure should be continued until the pH is raised to acceptable levels, taking great care to not overdose the treatment waters.

Hydrated/slaked lime and quicklime is very reactive, and relatively corrosive (due to its caustic nature). Therefore special handling requirements and safety procedures should be adhered to.

4.6 Monitoring

Regular visual monitoring is to be undertaken to detect:

- Unexplained scalding or degradation of vegetation;
- Evidence of leachate originating from stockpiles;
- Loss of neutralising agent from stockpile materials following rainfall events; and/or
- Green-blue or extremely clear waters indicating high concentrations of aluminium.

Special precautions should be taken over extended non-work periods (such as weekends) and periods following significant rainfalls. All identified leachate should be inspected and tested accordingly (pH). A written log of events and results should be maintained and reported weekly to the site supervisor.

The implementation of a groundwater and surface water monitoring strategy is recommended to ensure that deterioration of background water quality does not occur as a result of acidification and metal mobilisation. The utilisation of current accessible monitoring positions is recommended although if these are not available the installation of site specific monitoring stations will be required. Groundwater monitoring is to be conducted in accordance with the National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ & ANZECC 1995) and surface water monitoring is to be conducted in accordance with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality(ARMCANZ & ANZECC 2000).Table 3 below provides the suggested monitoring frequencies for on site monitoring protocols.

Table 3. Suggested monitoring frequency and target levels

Material	Test	Frequency
Leachate Water		
Ponded Leachate water (including from dewatering and ASS treatment	pH	Field Measurement: • Daily; and • Immediately following rainfall events
Leachate for off site disposal	pH	Field measurement: • Immediately prior to disposal; and • Daily checks during discharge period
	Total Suspended Solids (TSS)	Visual assessment: • Daily during discharge period Field laboratory measurement: • As required based on visual observations; and • Immediately prior to disposal
	Iron (Total and Soluble)	Laboratory analysis: • Immediately prior to disposal; • Weekly checks during discharge period; and • As required as based on visual observations
Treated Acid Sulfate Soils		
Soil during treatment	Field pH	Field measurement: • Daily during treatment
	Oxidised pH	Field measurement: • Weekly during treatment
Soil for off site disposal	Various as required for waste classification	Visual Assessment: • Prior to disposal Field Measurement: • pH/oxidised pH Laboratory analysis: • Prior to disposal

4.7 Auditing

A suitably qualified appointee is to undertake fortnightly audits of the collected groundwater and surface water quality data to ensure that the potential for acid generations has been controlled and suitably mitigated and no significant impacts upon the surrounding environment have occurred.

4.8 Reporting

The project co-ordinator will keep records of all test results and quantities of lime used during treatment. All records are to be available for inspection during the construction phase.

Water quality reports are to be prepared monthly. All reports are to be kept on-site and are to be made available for inspection by relevant authorities.

4.9 Corrective Actions

If visual and/or water quality monitoring indicates the production and migration of acidic leachate has or is occurring, additional treatment measures are to be implemented as necessary. Measures may include:

- The cessation of all works within the affected area;
- The application of additional neutralising agent to temporary and permanent stockpiles; and
- The application of additional neutralising agent to overland flow paths and surface waters containing mobilised leachate.

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"Riveroaks Estate", Pacific Highway, North Ballina

(Development Application 2002/566)

October 2007

Nick Davison
Environmental Scientist, LandPartners Limited

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AS/NZS ISO 9001

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1. Introduction

LandPartners Limited ("LandPartners") has been commissioned by Rayshield Pty. Ltd. to prepare an Acid Sulfate Soil (ASS) Management Plan in order to satisfy clause 1.27 of the development approval.

1.1 Background

The proposed development will be undertaken in 7 stages. Stages 1 -5 will include the construction of the Link Road. Bulk earthworks will be undertaken initially on stages 1 – 5 and the Link Road.

This Acid Sulphate Management Plan is for the works associated with the bulk earthworks for the construction of the earthworks formation for Lots 1 – 5 and the Link Road.

Earthworks will be required to divert and redirect stormwater flows entering the site through a series of engineered flow paths within existing drainage easements and the construction of a floodway to cater for periods of excessive precipitation and high rainfall runoff events, also to be located within Lot 2. The adaptation and enhancement of the existing altered flow paths is proposed, incorporating enlargement of the western and central drains within the existing easements and the implementation of detention basins and Floodway paths.

1.2 Summary of Investigation Findings

The ASS Assessment (August 2007) identified the following subsurface characteristics regarding the acid generating capabilities of the subject site:

- The subsurface conditions within the subject site were predominantly clayey sand – sandy clay alluvial sequences, consistently overlying waterlogged sandy – clayey sand subsoils;
- Field sampling and subsequent laboratory analyses identified **Actual Acid Sulfate Soils** within samples collected at a depth of approximately 1.5 m below EGS. **Potential Acid Sulfate Soils** were identified within samples collected from excavated boreholes. The typical depth to PASS ranged between **0.75 – 1.5 m** below Existing Ground Surface (EGS).
- The Reduced Inorganic sulphur (%S) levels were observed to exceed the ASSMAC action criteria (0.03 %Scr; 18 mol H^+/tonne) in the analysed samples from **five (5) of the six (6)** excavated boreholes. Recorded (%Scr) levels ranged between 0.005 to 0.684 %Scr (average; 0.316 %Scr)
- Given the sandy nature of the subsoils observed within the excavated boreholes and the lack of shell materials (containing $CaCO_3$ available for buffering of generated acid), the **Acid Neutralising Capability (ANC) has been assessed as negligible whilst the Acid Generating Capability (AGC) has been assessed as significant**;

Therefore, as a result of these findings, it has been assessed that the proposed works associated with the residential subdivision will disturb ASS layers occurring at an approximate depth of 0.75 m below EGS. In an effort to reduce the risk of exposure and subsequent oxidation of these materials, this Acid Sulfate Soil Management Plan has been prepared to provide effective management guidelines and mitigation practices that are to be incorporated as a part of the proposed works. These guidelines and practices have been prepared in accordance with the recommendations specified in Stone et al (1998).

2. Scope of Treatment

2.1 Estimated Treatment Area

As described in Section 1.1 the proposed development will disturb ASS materials during three (3) key activities. These activities are identified below and an outline of the processes involved in their undertaking is provided. It must be noted that Acid Sulfate Soil levels have been assessed as occurring at approximately 0.75 m below EGS. This equates to varying AHD levels of – 0.3 m to 0.8 m AHD across the site.

2.1.1 Excavation of Stormwater Drainage Swales and Constructed Floodway

The widening and deepening of existing drainage pathways is proposed as part of the stormwater management concept for the subdivision development.

These stormwater measures will entail:

1) Approximately 30 m wide x 0.70 m deep excavation running approximately 600 m from north-west to south east across Lot 2 DP 1074242. A total expected excavation volume of 3,150 m^3. With an identified depth to ASS materials of 0.75 m below EGS the potential to encounter ASS materials is assessed as minimal; and

2) 10 m wide x 1.2 m deep excavation running approximately 360 m from north to south across the central area of Lot 2 DP1074242. A total excavation volume of 2,020 m^3 is expected for the central excavated drainage path. With an identified depth of 0.75 m below EGS to PASS materials and the absence of ASS materials from the south-eastern portion of Lot 2, this equates to approximately 65 m^3 of ASS materials included in the excavation activities for the central drainage path.

3) With the existing artificial drainage structure (located on the western boundary of Lot 2) accepting flows from the subject site and adjoining lands to the west already appropriately sized, excavation is expected to only entail widening of the current structure with no increase in the current depth. As no deepening of the structure is expected to occur the potential for intersection and disturbance of ASS layers is assessed as minimal.

2.2 Total Expected Excavation of ASS Materials

Utilising an average bulk density figure of 1.4 tonne/m^3, and given the total disturbance volumes as calculated in the above section 2.1, the total mass of excavated ASS materials is estimated at approximately **90 tonnes**.

2.3 Treatment Category

Based on the overall expected volume of excavations and the highest net acidity potential recorded (0.684%S or 432 moles H^+/m^3) the project may be considered within the **High Treatment Category** (in accordance with Table 4.5; Stone et al 1998).

2.4 Liming Rate

Given that the proposed works will entail the use of excavated materials as both backfill and site-won fill, the potential for acidification is limited by the total period of PASS exposure to an oxidising environment. The construction activities have been separated into three (3) individual components as described above. The maximum Total Oxidisable Sulfur (TOS) content (%Scr) for each component (as indicated by the laboratory results) will be utilised to calculate a suitable liming rate for each component of works.

2.4.1 Floodway and Drainage Path Construction and Alterations

Using the maximum TOS value of 0.394 %Scr and including a safety and neutralising factor of 1.5, the liming calculation for materials excavated as part of these activities is as follows (in accordance with Section 6.1; Stone et al 1998):

Lime required (kg $CaCO_3$/tonne material at 1.0 t/m^3)

= kg H_2SO_4/tonne of material x 1.5
= (%S x 30.59) x 1.5

Therefore:

= (0.394 x 30.59) x 1.5
= 18.08 kg $CaCO_3$ / tonne of material

Therefore the total estimated liming rate for treatment of ASS materials disturbed during the construction of the floodway and drainage paths is expected to be **1,627 kg of $CaCO_3$.**

2.4.2 Stormwater and Sewer Piping

There is no stormwater piping associated with the bulk earthworks that is expected to intersect ASS layers.

3. Neutralising Material Information

Medium to fine agricultural lime ("aglime") is the preferred neutralisation additive for the management of ASS materials, as this material is slightly alkaline and of low solubility in water. The aglime should be fine ground (at least < 1 mm; preferably < 0.3 mm) calcium carbonate or calcite (limestone or marble). Course-grained calcite is not recommended, as one of the products of neutralisation reaction is gypsum ($CASO_4.2H_2O$) which has a relatively low solubility and tends to coat the reacting calcite grain, forming a partial barrier to further reaction. Gypsum may also give off hydrogen sulfide if in reaction with acidic conditions and can itself result in the generation of sulfuric acid.

Dolomitic aglime, or magnesium-blend aglime, should not be used as these materials impose environmental risks from overdosing with the potential to damage estuarine ecosystems.

The effectiveness of the lime is referred to as the Effective Neutralising Value (ENV), which is determined by the (theoretical) Neutralising Value (NV) and particle size.

The aglime purity should preferably be 95% or better (i.e. NV > 90). Alternatively a material with a higher NV/ENV can be used (e.g. magnesia (MgO) however additional safety measures/risk management may be required. The aglime should also be fine and dry, as the texture and moisture can also decrease the effective neutralising value.

The use of a correction factor for the ENV is required to ensure sufficient quantities of aglime are applied in the respective management areas. The correction factor can be calculated by the following formula (as recommended in Table 5.2; Stone et al 1998):

ENV [dry] = NV x [(Proportion of size fraction > 0.85 mm) x 0.1
+ (Proportion of size fraction 0.3 mm - 0.85 mm) x 0.6
+ (Proportion of size fraction < 0.3 mm) x 1.0]
/100

To correct for moisture content (MC) the following formula should be applied:

ENV (moisture adjusted) = ENV [dry] x (1 – MC/100)

To determine the amount of product needed to be equivalent to pure, fine $CACO_3$:

Liming Rate = 100/ENV (moisture adjusted) x calculated liming rate

It must be noted that alkaline substances (pH > 7) recommended in the treatment of ASS-affected soils can be just as damaging to the environment as acidic substances (pH < 7). If measurements of pH values greater than 8.5 occur in leachates, surface waters and groundwaters, adjustment prior to release will be required.

The caustic nature of the recommended neutralising agents will require the implementation of OHS procedures in accordance with product advice. Personal Protective Equipement (PPE) is likely to be required during handling and mixing. Secure on site storage for aglime ($CaCO_3$) and hydrated/slaked lime ($Ca(OH)_2$) will also be required

4. Management of Potential Impacts

4.1 Responsible Personnel

The Project Coordinator will be responsible for ensuring the appropriate management of acidic soil and associated leachate as outlined in this document.

4.2 Operational Policy

To effectively treat excavated soils and generated leachate within the identified ASS affected areas and avoid and/or mitigate any adverse environmental impacts during the construction and operational phases of the development.

4.3 Performance Criteria

All soils excavated within the identified ASS affected area are to be appropriately treated for potential acid generation in accordance with the recommendations outlined in this document.

All leachate discharged from site excavations is to comply with the criteria outlined in Table 1.

Table 1. Water Quality Criteria

Parameter	Release Criteria
pH	7.0 – 8.4 [A]
Dissolved Oxygen (% Saturation)	90 – 110 [A]
Turbidity (ntu)	0.5 – 10 [B]
Suspended Solids (mg/L)	20 [C]
Iron (soluble) (mg/L)	1.0 [D]
Aluminium (soluble) (mg/L)	< 0.005 (if ph < 6.5) [D] < 0.10 (if ph > 6.5) [D]

Table Notes:

[A] Freshwater Lakes and Reservoirs criterion from Australia New Zealand Environment and Conservation Council (ANZECC) / Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality – Section 3 Aquatic Ecosystems: Table 3.3.2;

[B] Department of Environment and Conservation (NSW) Marine Water Quality Objectives for NSW Oceans – North Coast (October 2005);

[C] Adopted from Table 2.5.1.1 of the Queensland Water Quality Guidelines, March 2006 (Mid-estuarine and tidal canals, constructed estuaries, marinas and boat harbours); and

[D] Freshwater criteria from Table 5-B National Environment Protection (Assessment of Site Contamination) Measure 1999 Schedule B (1): Guideline on the Investigation Levels for Soil and Groundwater. No criteria are specified for marine waters.

4.4 Treatment of Identified Acid Sulfate Soil

4.4.1 Implementation Strategy

The proposed treatment procedure will entail the excavation of soil materials to the required depth for each specific activity (i.e. open trenching, drain construction etc). Topsoil materials may be stockpiled on site to be used as top dressing of treated general fill areas and ASS materials.

Once excavations reach the identified potential ASS layers (i.e. 0.75 m below EGS), then the works are to proceed in a staged manner. At this depth, excavated ASS materials are to be checked for ASS and if recording positive will be placed in a prepared treatment area for treatment and stockpiling purposes. Total expected time of exposure for each excavation period is to be limited (where possible) with ASS affected materials stockpiled, treated accordingly and utilised as filling material on site either in the general formation if acceptable, or in landscaping mounds or bunding. They should be capped by non-ASS affected topsoils or imported fill materials. Table 2 provides indicative maximum periods for short-term stockpiling of untreated ASS materials.

Table 2. Indicative maximum periods for short-term stockpiling of ASS materials

Type of Material		Duration of Stockpiling	
Texture Range	**Approx. Clay Content (%)**	**Days**	**Hours**
Coarse Sands to Sandy Loams	≤ 5	Overnight	18
Medium Sandy Loams to Light Clays	5 - 40	2.5 Days	70
Fine Medium to Heavy Clays	≥ 40	2.5 Days	70

For ASS affected materials that are surplus to backfill or fill requirements and are intended to be used as site-won fill, treatment and transportation to the designated fill area is to occur as soon as practically possible following excavation and disturbance.

The following outlines the treatment and management procedures recommended for adoption during the proposed works:

- Pads constructed for treatment of excavated potential acid generating soils are to be bunded and located in areas that will minimise their potential for surface run-off interaction. Treatment pads, bund areas and bund walls are to be prepared with a guard layer consisting of lime mixed at a minimum rate of 10 kg/m^2;
- Excavated potential acid generating soils are to be stockpiled on treatment pads and surface limed at the rate as specified for that section of works (refer Section 2.4). Mixing via mechanical means is to be used to evenly distribute the neutralising agent throughout the ASS materials. Lime is to be in the form of fine agricultural lime (refer Section 3);
- all areas of open excavation that are at or below 0.75 m (below EGS) and which test positive for ASS are to have neutralising agent applied to the base of excavated area at a rate of $10kg/m^2$;
- Prior to backfilling or disposal of treated ASS materials sampling is to be undertaken to ensure the effectiveness of the treatment method. Testing of samples is to entail pH_F and pH_{FOX} analysis to ensure treated soils meet the screening criteria set forth in Table 3 (below);
- A minimum of 1,000 kg of fine agricultural lime is to be maintained on-site at all times during the construction phase to ensure any potentially hazardous situations can be suitably controlled.

4.5 Treatment of Acidic Waters

A calcium hydroxide solution may be used for rapid neutralisation of leachate waters. This solution could be produced using either hydrated/slaked lime or quicklime, by stirring approximately 0.3 kg of either material into water, in a container of sufficient volume (e.g. a plastic 200 L drum). The slurry should be allowed to settle, and the clear solution (which will be highly caustic with a pH of 12) can be pumped or sprayed into standing water in small amounts. This procedure should be continued until the pH is raised to acceptable levels, taking great care to not overdose the treatment waters.

Hydrated/slaked lime and quicklime is very reactive, and relatively corrosive (due to its caustic nature). Therefore special handling requirements and safety procedures should be adhered to.

4.6 Monitoring

Regular visual monitoring is to be undertaken to detect:

- Unexplained scalding or degradation of vegetation;
- Evidence of leachate originating from stockpiles;
- Loss of neutralising agent from stockpile materials following rainfall events; and/or
- Green-blue or extremely clear waters indicating high concentrations of aluminium.

Special precautions should be taken over extended non-work periods and periods following significant rainfalls. All identified leachate should be inspected and tested accordingly (pH). A written log of events and results should be maintained and reported weekly to the site supervisor.

The implementation of a surface water monitoring strategy is recommended to ensure that deterioration of background water quality does not occur as a result of acidification and metal mobilisation. Monitoring locations and protocols for surface water run off are as designated in the stormwater "Works Process Strategy".

Table 3 below provides the suggested monitoring frequencies and protocols for leachate and treated acid sulphate soils.

Table 3. Suggested monitoring frequency and target levels

Material	Test	Frequency
Leachate Water		
Ponded Leachate water (including from dewatering and ASS treatment	pH	Field Measurement: • Daily; and • Immediately following rainfall events
Leachate for off site disposal	pH	Field measurement: • Immediately prior to disposal; and • Daily checks during discharge period
	Total Suspended Solids (TSS)	Visual assessment: • Daily during discharge period Field laboratory measurement: • As required based on visual observations; and • Immediately prior to disposal
	Iron (Total and Soluble)	Laboratory analysis: • Immediately prior to disposal; • Weekly checks during discharge period; and • As required as based on visual observations
Treated Acid Sulfate Soils		
Soil during treatment	Field pH	Field measurement: • Daily during treatment
	Oxidised pH	Field measurement: • Weekly during treatment
Soil for off site disposal	Various as required for waste classification	Visual Assessment: • Prior to disposal Field Measurement: • pH/oxidised pH Laboratory analysis: • Prior to disposal

4.7 Auditing

The groundwater and surface water quality data is to be reported to the engineer on a fortnightly basis to ensure that the potential for acid generations has been controlled and suitably mitigated and no significant impacts upon the surrounding environment have occurred.

4.8 Reporting

The contractors project co-ordinator will keep records of all test results and quantities of lime used during treatment. All records are to be available for inspection during the construction phase.

Water quality reports are to be prepared monthly. All reports are to be kept on-site and are to be made available for inspection by relevant authorities.

4.9 Corrective Actions

If visual and/or water quality monitoring indicates the production and migration of acidic leachate has or is occurring, additional treatment measures are to be implemented as necessary. Measures may include:

- The cessation of all works within the affected area;
- The application of additional neutralising agent to temporary and permanent stockpiles; and
- The application of additional neutralising agent to overland flow paths and surface waters containing mobilised leachate.

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