THUNDERBIRD MINERAL SANDS PROJECT
DERBY EXPORT FACILITY BASELINE CONTAMINATION AND ACID SULFATE SOIL ASSESSMENT

PREPARED FOR:

SHEFFIELD RESOURCES LIMITED

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EXECUTIVE SUMMARY

Sheffield Resources Limited is preparing approval documentation for the proposed development of the Thunderbird Mineral Sands Project including construction and operation of an associated export facility for export of products (ilmenite, zircon and high titanium leucoxene) to overseas markets from Derby Port. MBS Environmental (MBS) was commissioned to undertake a review and baseline assessment of the Derby Port project area to assist with environmental impact assessment and to provide a summary of existing conditions. A baseline contamination assessment (BCA) was undertaken during June 2016. This included a review of previous site history and contamination assessment reports, as well as a site visit to collect representative samples of soils, basement clays and marine sediment. These samples were analysed for potential contaminants of concern and potential presence of acid sulfate soils (ASS).

The findings of this report are as follows:

- Derby Port is situated on a section of reclaimed mudflats located approximately 2 km northwest of the Derby townsite. Much of the port area is situated on imported fill material comprising Pindan soils overlying the natural marine sediment/mud.
- Derby Port has a history of contamination issues due to the historic export of lead and zinc metal concentrates.
- The port area was remediated in 2010 to 2011 by Rey Resources Limited.
- Residual low level zinc concentrations remain in some of the imported Pindan soils across the port, however these levels are significantly below industrial health investigation levels (HIL). The maximum concentration of zinc (360 mg/kg) was equal to the site specific calculated National Environmental Protection Measure (NEPM) 2013 added contaminant level (ACL) for this sandy soil type and would be at or below a calculated environmental investigation level (EIL) for the site depending on background concentrations. This is consistent with the previous site history and validation report (MBS 2012).
- Concentrations of lead were correlated with zinc from previous site use of exporting lead/zinc sulfide mineral concentrates, but no samples were found to exceed industrial EIL or HIL values for lead.
- Examination of subsoil basement clays in accessible areas of the port area indicated a slight presence of sulfidic material in an otherwise alkaline clay matrix which was insufficient for classification as ASS materials. Further samples for assessment were taken from the eastern mudflats and considered to represent the same underlying heavy clay/silt – these were also not classified as being ASS. This indicates that site works/trenching of this material to depths of less than 2 m for construction of a new export facility poses very limited potential for acid generation.
- Samples of the mudflats east of the lease area indicate some elevation of zinc and lead above background levels in the areas adjacent to the culverts and particularly at location DS4 (360 mg/kg zinc, 95 mg/kg lead). These elevated results were attributed to previous site history and road run off. The zinc concentration is above the lower interim sediment quality guideline (ISQG-Low) of 200 mg/kg, but below the calculated NEPM 2013 ACL of 1,200 mg/kg based on an assigned land use of recreational/public open space.
- All samples of clay/silt sediment including in-shore marine, mudflats and basement clays were found to be in a range of 22 to 31 mg/kg for nickel, which marginally exceeds the ISQG-Low of 21 mg/kg. This strongly suggests a natural enrichment of nickel at this concentration in the estuarine silt/clay from the area.
- Copper concentrations in marine sediment samples DMS1 (90 mg/kg) and DMS2 (66 mg/kg) were above the ISQG-Low of 65 mg/kg and significantly higher than other clay/silt based samples (range 23 to 35 mg/kg). Both these locations are used for boat launching and marginally elevated copper levels may be the result of copper anti-fouling paint from boats hulls.
- No ISQG exceedances for arsenic, cadmium, chromium, silver or mercury were recorded. Selenium concentrations were all below the level of reporting. Uranium concentrations in silt/clay dominant sediment

samples were consistently in a range of 2.4 to 5.2 mg/kg, which are similar to the average crustal abundance (2.7 mg/kg). Sandier samples DS1 and DMS7 had lower concentrations (0.81 and 0.75 mg/kg respectively).

- Estuarine tidal water sampled at the boat ramp indicated no results above ANZECC 2000 EIL trigger values with dissolved metals and metalloids very low and mostly below laboratory limits of reporting (including lead, zinc, copper and nickel). Dissolved uranium was observed at a concentration of 0.0035 mg/L which is very consistent with a previously reported value (0.0033 mg/L) for uranium in seawater.

Overall the assessment of all samples taken in and adjacent to the proposed Derby facility for analysis of metals and metalloids indicated concentrations considered either representative of the region or reflective of a Port facility with prior history of (in particular) lead and zinc exports. Further assessment of the soils and sediments within the lease area which may be disturbed in minor volumes by construction of a product storage shed indicated no significant risk of ASS. No significant disturbance of marine sediment and hence opportunity for oxidation and metals/metalloids release is expected in the proposed development as the wharf is already constructed.

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1. INTRODUCTION

1.1 PROJECT BACKGROUND

Sheffield Resources Limited (Sheffield Resources) is proposing to develop the Thunderbird Mineral Sands Project (the project), located on the Dampier Peninsula within the West Kimberley region of Western Australia (Figure 1). The project will involve the mining of heavy mineral sands and subsequent export of products (ilmenite, zircon, and HiTi88 leucoxene) by shipping to overseas markets from Derby Port.

Sheffield Resources is preparing for submission of approval documents for the proposed development of the project including construction of a product storage shed at Derby Port, referred to as the Derby Port Development Envelope (the facility). The proposed facility will comprise a large storage shed (approximately 160 m long by 85 m wide), conveyor and barge loading infrastructure. The product storage facility will receive heavy mineral sand product via quad road trains.

MBS Environmental (MBS) was commissioned by Sheffield Resources to undertake a review and baseline assessment of the Derby Port area prior to commencement of any operations.

1.2 OBJECTIVES AND SCOPE OF WORKS

The objective of the study was to undertake a baseline contamination assessment of the area proposed for construction and operation of the facility. This included the following scope of work:

- Review previous site contamination assessment, clean-up and validation reports.
- Visit the Derby Port facilities and collect representative samples of soils, underlying basement clays and in-shore marine sediment for laboratory analysis.
- Assess baseline concentrations of contaminants of potential concern (CoPC) including pre-existing levels of uranium as an indicator of natural radiological levels.
- Assess the presence of and potential for acid sulfate soil (ASS) disturbance by proposed export facility construction, which may involve disturbance of material up to a depth of 2 m below ground level.

Figure 1: Location Plan

2. SITE HISTORY

The Derby Port area has a long history of site contamination and remediation due to the former storage and export of lead and zinc sulfide concentrates (galena and sphalerite respectively) from the Lennard Shelf Lead and Zinc Operations.

The Contaminated Sites Branch of DER carried out inspections at the port in June and August 2007 at which time the port was being used for export of lead and zinc mineral concentrates. A Notice of Classification of a Known or Suspected Contaminated Site was subsequently issued by DER on 12 September 2008 to the former sublessees, Lennard Shelf Pty Ltd. The category of site classification was 'Possibly Contaminated - Investigation Required' on the basis of the identification of lead and zinc concentrations above the Ecological Investigation Levels (EIL) for soil.

A Detailed Site Investigation (DSI) was undertaken and a site closure plan prepared in March 2009 by MBS (MBS 2009). This included a site management plan for the remediation of contaminated areas. The closure plan was assessed as satisfactory by DER in a letter dated 7 April 2009 and the site was subsequently closed and remediated from 2010 to 2011. Adopted clean up criteria for the site were to DER 2010 Health Investigation Levels (HIL) for industrial/commercial use of 1,500 mg/kg for lead and 35,000 mg/kg for zinc.

Validation sampling and reporting was undertaken at the site in 2012. Adopted DER 2010 EIL values for the site were 600 mg/kg for lead and 200 mg/kg for zinc. While some residual lead (3 of 40 locations) and zinc (11 of 40 locations) concentrations remained at discrete locations across the site, exceeding the respective EILs, the risk to the surrounding environment and site workers and visitors was assessed as low. The site was deemed to be remediated to a level that is appropriate for its intended land use (industrial/commercial), with minimal risk to the surrounding environment as a result of residual soil contamination (MBS 2012). Due to the absence of any groundwater data from beneath the site, the site remains classified as 'Possibly Contaminated – Investigation Required'.

3. EXISTING ENVIRONMENT

3.1 SITE IDENTIFICATION

The site location and legal description of the site is given in Table 1.

Table 1: Site Identification Summary

Identification	Details
Name of Site	Derby Product Storage Facility
Coordinates (Centre point, MGA 94 Zone 51)	564768 mE, 8087940 mS
Street Address	Part of Lot 325, Jetty Road, Derby, WA 6733
Lot number and plan/folio number	Lot 325 on Plan 64512
Property Size (m^2)	Approximately 24,000 (2.4 ha)
Local Government Authority	Shire of Derby/West Kimberley
Site Ownership	WA Department for Planning and Infrastructure
Lease Holder	Shire of Derby/West Kimberley
Current Land Use	Vacant land
Current Land Use Zoning	Industrial
Proposed Land Use	Storage and export of mineral sands concentrates/products for export.
Proposed Development/Disturbance	Construction of the facility will involve only minor soil disturbance as required for groundworks and electrical/services to an expected maximum depth of 2 m below ground level. No dewatering of the site is anticipated.
Proposed Land Use Zoning	Industrial

3.2 LAND USE

The Derby townsite includes a number of areas zoned for a variety of different land uses including commercial, industrial, residential and various other public and recreational land uses. The port area has been zoned for ‘Port industry’.

There are no other industrial or agricultural land uses in the immediate vicinity of the port. The closest operating commercial enterprise is a privately run cafe located approximately 150 m north of the site and an industrial laydown area located approximately 100 m to the northeast, which is used for the former Cockatoo and Koolan Island iron ore operations. A portion of the wharf is used for the storage and export of fish produce (barramundi). A non-operating mud crab enterprise is located approximately 100 m northeast of the site.

The wharf area is a popular recreational area for local residents and tourists and a public boat ramp is located to the immediate west of the proposed storage facility. The most popular activities include fishing (including mud crabs) and passive recreation. Several professional fishermen are licensed to catch barramundi (MBS 2009).

The western shores of King Sound and the islands and bays of the Buccaneer Archipelago to the northeast of King Sound support a large cultured pearling industry (MBS 2009).

3.3 CLIMATE

The climate at Derby comprises a tropical monsoon climate with a winter dry season and a summer wet season. The mean annual rainfall for Derby is 691 mm. Mean monthly rainfall is highest in February (199.6 mm) and lowest in August (0.8 mm). Rainfall intensity may be high (e.g. the highest 24 hour rainfall recorded at Derby was 418 mm in January 1917) and is mostly associated with cyclonic activity. Average monthly minimum temperatures are lowest in July at 14.7° and average monthly maximum temperatures are highest in November at 38.1° (BOM 2016a). Prevailing morning winds are mainly strong easterly to southeasterly, while the predominant prevailing afternoon winds are mainly southeasterly to northwesterly.

Climatic data collected by the Bureau of Meteorology (2016) at Derby Aero (Site No. 003032) is presented in Chart 1.

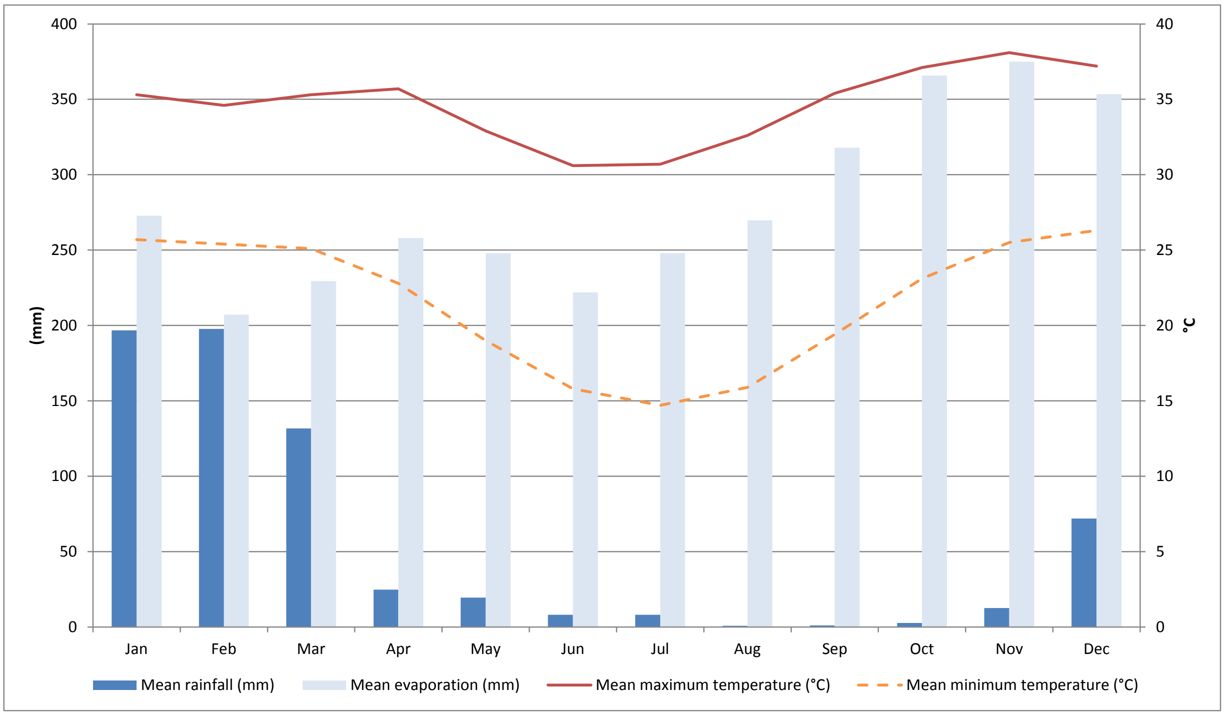

Chart 1: Climate Data at Derby Aero (Site No: 003032)

Derby has the highest tidal range in Australia. Tides are macrotidal, and diurnal, with a spring range of 11.8 m. The large tidal variations and low probability of a significant cyclone over King Sound results in a low chance of a significant storm tide (BOM 2016b). Accordingly, there are no historical records of a significant storm surge at Derby. However, the worst possible scenario of a severe cyclone arriving at high tide and coinciding with floodwaters from the Fitzroy and other rivers into King Sound, would almost certainly inundate all of Derby. Fortunately, this extreme scenario has a very low probability of occurring (BOM 2016b).

3.4 TERRESTRIAL GEOLOGY AND SOILS

3.4.1 Geology

The geology of the catchment area draining into King Sound is extremely diverse. The southern areas overlay the Canning Basin, a sedimentary sequence of rocks and carboniferous deposits (extending from the early Ordovician to the early Cretaceous and overlain by recent alluvial and aeolian sediments (MBS 2009).

To the north of the Canning basin, the geology of the Kimberley region consists of diverse igneous and metamorphosed sedimentary rocks of Proterozoic to Archaean age (Halls Creek Orogen). Between these two geological provinces is the Lennard Shelf, a Devonian system of reef carbonates, limestones and sandstones. The karst limestone geology is commonly associated with zones of lead and zinc sulfides, several of which have been mined. These include former mines operated by Western Metals and Lennard Shelf, viz. Cadjebut, Pillara, Goongewa and Kapok (MBS 2009).

3.4.2 Soils of the Derby Region

The soils of the Derby region belong to the Dampier Sandplain zone, comprising sandplains, dunes and coastal mudflats overlying the sedimentary rocks of the Canning Basin. Locally, the sandplain grasslands, Pindan dunes/woodlands and mudflats belong to the Camelgooda, Wanganut and Carpentaria systems respectively.

3.4.3 Acid Sulfate Soils

The export facility is located in Australian Soil Resources Information System (ASRIS) ASS mapping as "High Probability of Occurrence" as ASS in tidal zones (Landgate 2016).

3.5 INTERTIDAL GEOLOGY AND SOILS

3.5.1 Intertidal Mudflats

The geomorphology of the tidal mudflats of King Sound has been described by Semeniuk (1982). Erosion over the past 5,000 years has been the dominant shore-forming process, resulting in the erosion of coastal sediments deposited from the major river systems during the Holocene (up to 10,000 years before present) (Semeniuk 1982).

The sub-tidal areas between the Derby wharf and townsite comprise the following landforms:

- Tidal mudflats, which are partially or fully exposed at low tide.
- Mangal flats, which are stabilised by mangroves and incised by numerous tidal creeks.
- Saline mudflats, which are bare of vegetation and only inundated following high rainfall or by the sea at spring high tide.
- Samphire flats, which are vegetated with salt tolerant (halophytic) plants.
- Red sand dunes, as described in Section 3.4.2.

The stratigraphy of the natural soil sequence near the Derby wharf is summarised below (from the surface downwards):

- A surface horizon of bio-turbated brown mud found within the root zone of the mangroves.
- Christine Point Clay, a slate grey coloured clay horizon containing fossil mangrove stumps.
- Mowanjum Sand, similar to the red Pindan soil of the West Kimberley region.
- Airport Creek Formation, a semi-lithified and nodular cemented deposit of interlayed sand and mud.

The physical presence of the existing Derby wharf structure has resulted in a substantial deposition of coarse sand sediments immediately below and to the north and south of the wharf. These sand banks are exposed at low tide (MBS 2009).

3.5.2 Reclaimed Land

The causeway across the mudflats between the port and Derby townsite was constructed from local rock and soil sourced from the Derby hinterland. Much of the soil at Derby Port and the proposed facility consists of fill material, typically Pindan soil sourced from the mainland over its 120 year history. A large proportion of this material was imported and placed in 1997 as part of construction works for the former lead and zinc concentrate storage facility.

3.6 HYDROLOGY, TIDES AND HYDROGEOLOGY

3.6.1 Hydrology

The proposed export facility area is situated on a raised section of reclaimed land. King Sound is located to the immediate north-west and its associated saline mudflats are situated to the immediate east. Stormwater runoff from the reclaimed section of land drains directly into either King Sound or its associated mudflats. The mudflats are rarely inundated. Inundation typically occurs following a high rainfall event or by the sea during a spring high tide or storm surge (MBS 2009).

3.6.2 Subsurface Water Quality and Levels

Subsurface water underlying the proposed storage area is controlled by tidal movements, consisting predominantly of brackish water becoming more saline with depth as levels approach the seawater interface. The position of the site on the western edge of the tidal mudflats and the very low elevation results in saturated subsurface conditions at depths greater than 2.0 m below the reclaimed facility ground surface with the water table expected to occur slightly above mean sea level. Outflow of superficial tidal groundwater at the top of the compacted clays underlying the site can be seen at low tides entering King Sound.

3.6.3 Tidal Movement

King Sound is a highly dynamic environment and has one of the world's largest tidal ranges, with the highest astronomical tide recorded as 11.8 m. Tides within King Sound are semi-diurnal with a full tidal cycle of approximately 12.5 hours. The astronomical tides and heights for Derby are listed below:

• Highest astronomical tide	11.8 m
• Mean spring high tide	9.7 m
• Mean neap high tide	5.4 m
• Mean neap low tide	3.5 m
• Mean spring low tide	0.5 m
• Lowest astronomical tide	0.0 m

Extreme high tide events can leave parts of the port area inundated, while extreme low tide events can expose the sea bed below the port wharf. The tides are a significant constraint on historical shipping operations from Derby, limiting berthing time at the wharf to between six and seven hours, depending upon the vessel draft. The extreme tidal variation and strong flow rates between tides results in significant dispersion of fine sediment entering King Sound (MBS 2009).

3.6.4 Hydrogeology

Derby is located on the northern part of the Canning Basin that comprises Phanerozoic sediments of approximately 8,000 m thickness at the Derby Peninsula (DoW 2008).

The stratigraphic sequence at Derby in order of increasing age is as follows:

- Quaternary Sediments.
- Meda Formation.
- Wallal Sandstone.
- Munkayarra Shale.
- Erskine Sandstone.
- Blina Shale.
- Liveringa Group.
- Nookanbah Formation.
- Poole Sandstone.
- Grant Group.

The principal regional aquifers with potential for potable water supply are the Wallal Sandstone and the Erskine Sandstone. The Liveringa Group, Poole Sandstone and the Grant Group also contain groundwater at depth. With the exception of the Liveringa Group in the deep Derby Town Bore (600 to 700 m), these aquifers have only been exploited in areas where they occur at shallow depths (DoW 2008).

The Wallal Sandstone aquifer is unconfined and receives recharge via direct rainfall infiltration. Groundwater flow in the aquifer is westerly toward King Sound. An unconfined aquifer with a maximum saturated thickness of 60 m is located in the Derby area, comprising of the Quaternary Sediments, the Meda Formation, and the Wallal Sandstone (DoW 2008).

The Erskine Sandstone is a multilayered aquifer with shale interbeds, and is generally confined by the overlying Munkayarra Shale. Groundwater flow in the aquifer is generally northerly toward the May River, however near Derby; the Erskine Sandstone is in direct hydraulic connection with the Wallal Sandstone as the confining Munkayarra Shale is absent (DoW 2008).

Groundwater in the vicinity of the proposed export facility has no beneficial water use.

4. SITE INSPECTION

A detailed site inspection was undertaken by MBS staff (James Cumming – Senior Environmental Geoscientist and Dr Michael North – Senior Environmental Geochemist) on 24 June 2016 to assess site conditions and collect samples for laboratory analysis. The inspection was completed on foot and covered the site and its surrounds. Any relevant features were photographed and their location recorded using GPS. The following site conditions were noted at the time of the inspection:

- The main site area for the proposed storage and handling sheds was fenced and largely flat in terrain with a slightly lower lying area (shallower depth fill material) in the northwest corner. Fill material covering the site was fine red/brown Pindan sand overlying either coarse gravel/rocks (refusal - majority of site) or coarse sand and a marine clay basement (northwest corner). The depth of fill material over the natural clay base was variable but estimated to be approximately 1 m for the majority of the site and 600 mm in the northwest corner (sites D2TS and D4TS). An example of the main site area is given in Plate 1.
- Test auger digging at location D2 showed some visual indication of AAS (as black sulfides) in the basement clay material (sample D2Base).
- No visible evidence of petroleum hydrocarbons or asbestos material contamination was noted on site or in areas adjacent to the site.
- Nearshore sediment (within 30 m of the shore), consisted of fine silt/clay (with indications of sulfides) overlying coarser sand material. Sediment underneath and around the wharf was mixed with some areas of silt/clay but also some of exposed coarser sand material.

Example photographs from the site and surrounding areas are shown in Plate 1 to Plate 6 below.

Plate 1: Main Facility Area Showing Remaining Infrastructure

Plate 2: Wharf and Conveyor for Loading

Plate 3: Looking East from the Wharf Along the Conveyor

Plate 4: **Exposed Fine Sediment Over Coarse Sand at Base Low Tide**

Plate 5: **Near Shore Sediment and Mangroves Immediately West of Site**

Plate 6: Mudflats to the East of the Site

5. SAMPLING AND ANALYSIS QUALITY PROGRAM

5.1 DATA QUALITY OBJECTIVES

The Data Quality Objectives (DQO) process is a seven-step iterative planning approach that is used to define the type, quantity and quality of data needed to inform decisions relating to the environmental condition of a site (NEPC 2013a). The seven steps of the DQO process are:

- Step 1: State the problem.
- Step 2: Identify the decision/goal of the study.
- Step 3: Identify the information inputs.
- Step 4: Define the boundaries of the study.
- Step 5: Develop the analytical approach.
- Step 6: Specify performance or acceptance criteria.
- Step 7: Develop the plan for obtaining data.

The DQO process applied to the project is summarised in Table 2.

Table 2: Data Quality Objectives

Step		Project Detail
Step 1	State the problem.	Sheffield Resources wishes to ensure that long-term, ongoing export of heavy mineral sands products from the Thunderbird Mineral Sands Project will not increase concentrations of metals and metalloids at Derby Port and surrounds. The port has been used in the past to export various mineral products. Therefore the baseline concentrations of metals and metalloids must be determined. As this is not a contaminated sites assessment no involvement with regulatory authorities or local government is required.
Step 2	Identify the decision/goal of the study.	Determine the baseline concentrations of metals and metalloids that pose a potential environmental risk. As this is not a contaminated sites assessment, no decision statements are required.
Step 3	Identify the information inputs.	Analytical results from representative surface and subsurface soil and marine sediment samples taken from within the proposed facility area and surrounds. Samples will be analysed for the following metals and metalloids: arsenic, cadmium, chromium, copper, mercury, nickel, lead, zinc and uranium. In addition sediment samples will also be analysed for vanadium, silver and selenium.
Step 4	Define the boundaries of the study.	Within the lease area, lease surrounds (maximum distance from lease boundary 120 m), along wharf and road into Port (maximum distance from lease 650 m).
Step 5	Develop the analytical approach.	Standard laboratory analysis for metals and metalloids by a NATA accredited laboratory using test methods included in Schedule B3 of NEPC 2013b. As this is not a contaminated sites assessment no decision rules are required.

Step		Project Detail
Step 6	Specify performance or acceptance criteria.	Laboratory results with field and laboratory Quality Assurance/Quality Control (QA/QC) measures meeting the following criteria: • Reporting limits for each analyte at least an order of magnitude below the relevant guideline value or Ecological Investigation Level (EIL). • RPDs for laboratory duplicates ideally below 30% (NEPC 2013b) and not to exceed 50% (*AS 4482.1-2005*) unless results are within five times the limit of reporting (USEPA 540/R-94/013). • Recovery of spiked analyte in laboratory QC samples to be within the range 70 to 130% (MPL 2013).
Step 7	Develop the plan for obtaining data.	Refer to Section 5.2.

5.2 SAMPLING AND ANALYSIS QUALITY PROGRAM

5.2.1 Sampling Program

A total of 21 soil samples from 12 locations were collected of which one was a duplicate (D7SSA/B). A total of 12 sediment samples from 11 locations were collected of which one was a duplicate (DMS5A/B). Sample locations are shown in Figure 2 (where the suffix TS indicates topsoil – subsoil (SS) and basement clay (base) samples were taken where relevant from the same locations. The suffix MS indicates marine sediments). Descriptions of all samples are provided in Table 3. Soil samples were collected at depths of 0 to 100 mm, between 200 to 800 mm and at greater than 1 m based on soil horizons/changes in texture. Sediment samples were collected from the surface (0 to 100 mm). Following the initial site visit, a sample of tidal water was also collected on 1 September 2016 from the main boat ramp (sample ID DER BR1, Figure 2) for assessment of existing baseline levels of metals and metalloids in marine water.

5.2.2 Sampling Methodology

All soil and sediment sampling was undertaken with a stainless steel trowel with the exception of DMS7 which was sampled with a specialised sediment sampler (Wildco Ekman grab sampler). Sampling equipment was cleaned between each location and sampling points recorded with reference to global positioning system (GPS). Samples were stored in zip lock bags. All sampling was undertaken according to the following Australian Standards:

- AS 4482.1-2005 Guide to the Sampling and Investigation of Potentially Contaminated Soil – Non-volatile and Semi-volatile Compounds (Standards Australia 2005).
- Assessment and Management of Contaminated Sites – Contaminated Sites Guidelines. (DER 2014).
- AS 1726-1993 Australian Standard – Geotechnical Site Investigations. International Standards Organisation (ISO). ISO5667-3:2012. *Water Quality – Sampling Part 3: Preservation and Handling of Water Samples.* ISO 2012.

5.2.3 Quality Assurance Plan and Quality Control

The following steps were taken during sampling to ensure the quality of the samples:

- Soils and sediment samples were collected and homogenised via removal of large rocks using a stainless steel trowel and bucket that was rinsed and cleaned prior to the collection of each sample.
- Collection of field duplicates every 20 samples for laboratory submission and analysis.

- Samples of basement clays for ASS analysis were squeezed in ziplock bags to exclude air, chilled and frozen prior to laboratory submission.
- Water samples for analysis of dissolved metals were collected and field filtered (0.45 µm) using disposable syringes into laboratory supplied and previously acid rinsed polyethylene bottes with an appropriate preservative (nitric acid).
- Water samples for analysis of general parameters (e.g. pH, EC, TDS) were collected directly using bottles provided by the laboratory.
- All field details were recorded on field sheets and Chain of Custody (CoC) forms for submission to the laboratory.

Table 3: Sample Summary

Sample ID	Depth	Easting	Northing	Colour	Texture	Comments
Soils						
D1TS	0-100 mm	564715	8087888	Red/brown	Fine sand/Pindan	-
D1SS	1000 mm	564715	8087888	Red/brown	Fine sand/Pindan	Refusal at 1 m - gravel/rocks from imported basement fill.
D2TS	0-100 mm	564745	8087968	Red brown	Fine sand/Pindan	0-55 cm Pindan sand, 55 cm onwards coarse sand.
D2SS	1.0-1.1 m	564745	8087968	Light brown	River gravel	Coarse river sand/gravel.
D2Base	1.1-1.3 m	564745	8087968	Grey	Clay	Some sulfidic black ooze present, heavy clay.
D3TS	0-100 mm	564759	8088066	Red/brown	Loamy sand	Shallow refusal – hardset.
D4TS	0-100 mm	564771	8088000	Red/brown	Loamy sand	Red/brown to 20 mm only then river sand.
D4SS	200-600 mm	564771	8088000	Light brown	Coarse sand	River sand/gravel.
D4Base	>600 mm	564771	8088000	Grey	Sediment	Marine sediment, wet.
D5TS	0-100 mm	564813	8087957	Red brown	Fine sand/Pindan	0-100 mm Pindan sand, 100-110 mm gravelly sand.
D5SS	400-410 mm	564813	8087957	Dark brown	Clayey sand	110-500 mm dark brown silty sand.
D6TS	0-100 mm	564867	8087970	Red brown	Fine sand	Shallow refusal - hard packed clay/loam roots to soil only.
D7TS	0-100 mm	564778	8087917	Red brown	Fine sand	Fine sand over hard set clayey sand (50 mm).
D7SSA	600-800 mm	564778	8087917	Orange/red	Fine sand	Extends to >1 m.
D7SSB	600-800 mm	564778	8087917	Orange/red	Fine sand	Extends to >1 m, field duplicate of D7SSB.
D8TS	0-100 mm	564766	8087875	Red/brown	Fine sand/Pindan	Extends to 200 mm.
D8SS	400-800 mm	564766	8087875	Red/brown	Fine sand/Pindan	Extends to 800 mm.
D9TS	0-100 mm	564760	8087798	Light red brown	Fine sand/Pindan	Topsoil only, outside sublease.
DSY1	0-100 mm	564872	8088010	Red/brown	Fine sand/Pindan	Topsoil, opportunistic sample.
D10TS	0-100 mm	565065	8087934	Grey	Sandy clay loam	Surface of salt flat, adjacent wharf access road.
D11TS	0-100 mm	565454	8087714	Grey	Sandy clay loam	Surface of salt flat, adjacent wharf access road.
Mudflats and Marine Sediment						

Sample ID	Depth	Easting	Northing	Colour	Texture	Comments
DS1	0-100 mm	564909	8087963	Red brown	Sandy silt	Grey crust, mudflats. Possibly Pindan sands washed to this location.
DS2	0-100 mm	564865	8087937	Brown	Sandy silt	Grey crust, mudflats. Possibly Pindan sands washed to this location.
DS3	0-100 mm	564823	8087877	Brown	Silt/clay	Grey crust, mudflats.
DS4	0-100 mm	564795	8087831	Brown	Silt/clay	Grey crust, mudflats. Road culvert drains to this location.
DMS1	0-100 mm	564696	8087746	Grey and black	Silt/clay sediment	Boat ramp (old).
DMS2	0-100 mm	564601	8087883	Grey and black	Silt/clay sediment	New boat ramp south.
DMS3	0-100 mm	564630	8087964	Grey	Sediment/sand	Silt/sand layer over silt/clay marine sediment.
DMS4	0-100 mm	564722	8088040	Grey	Sediment/gravel	Silt over coarse material. Sample from <50 mm.
DMS5A	0-100 mm	564726	8088127	Grey	Silt/clay sediment	Next to cafe.
DMS5B	0-100 mm	564726	8088127	Grey	Silt/clay sediment	Duplicate of DMS5B.
DMS6	0-100 mm	564780	8088170	Grey	Silt/clay sediment	-
DMS7	0-100 mm	564447	8088002	Medium brown	Sand	Medium sand, shell fragments, from wharf.
Marine Water						
DER BR1	Surface	564696	8087746	Grey-Brown	Highly turbid	Collected 9.30 am approximately 20 minutes after low tide

Figure 2: Sample Locations

5.3 LABORATORY PROGRAM

5.3.1 Analyses

5.3.1.1 Soils

Surface soil samples were submitted to MPL Laboratories in Myaree, WA, which is accredited by the National Association of Testing Authorities (NATA) for all analyses performed. Samples were analysed for the following suite of metals and metalloids:

- Arsenic.
- Cadmium.
- Chromium.
- Copper.
- Mercury.
- Nickel.
- Lead.
- Zinc.
- Uranium.

Additional analysis of soils was also conducted for pH, electrical conductivity (EC) and cation exchange capacity (CEC) on selected samples.

5.3.1.2 Sediments

Sediment samples were submitted to MPL Laboratories in Myaree, WA, which is accredited by the National Association of Testing Authorities (NATA) for all analyses performed. Samples were analysed for the following suite of metals and metalloids:

- Arsenic.
- Cadmium.
- Chromium.
- Copper.
- Mercury.
- Nickel.
- Lead.
- Zinc.
- Vanadium.
- Silver.
- Uranium.
- Selenium.

Analysis for ASS suite parameters (chromium reducible sulfur (CRS), titratable actual acidity (TAA), acid neutralisation capacity (ANC), net acidity and pHKCl) was conducted on selected samples. A brief introduction to laboratory methods and terminology for ASS assessment is provided in Appendix 1. Further information on ASS assessment is provided in the glossary of technical terms (Section 8), as well as Australian Standard AS4969-2008 and ISO Standard 14388-1:2014.

5.3.1.3 Water

The sample of tidal marine water collected on September 1 2016 was submitted to ChemCentre in Bentley, WA, which is accredited by the National Association of Testing Authorities (NATA) for all analyses performed with the exception of zirconium. Samples were analysed for the following suite of parameters: silver, aluminium, alkalinity, arsenic, carbonate, calcium, cadmium, chloride, cobalt, chromium, copper, EC, iron, bicarbonate, potassium, magnesium, manganese, molybdenum, sodium, nickel, lead, sulfate, selenium, total suspended solids (TSS), thorium, titanium, turbidity, uranium, vanadium, zinc, zirconium and pH.

5.3.2 Quality Control Measures

Results of internal laboratory and field duplicates are summarised in the following subsections – quality assurance results are presented and discussed in Appendix 2. Collated analysis results are presented in Section 6. A copy of the CoC form is provided in Appendix 3 and the laboratory certificate of analysis in Appendix 4.

5.3.2.1 Internal Laboratory QA/QC

The laboratory internal blanks analysed as part of analysis batches all returned values below the limits of reporting for all metals and parameters analysed. No issues with laboratory cross contamination of samples within the laboratory is therefore suggested.

The percentage recovery values for the internal laboratory control standards (LCS) are included in the laboratory reports presented in Appendix 2. An acceptable range for the analytes measured in this study is defined as 70 to 130% (MPL 2013). All reported LCS analyte recoveries fell within this range for all parameters tested, indicating no observable issues with accuracy of determination based on LCS analyte recovery.

Matrix spikes were performed on soil samples by MPL with an overall range of reported percentage recovery from 82 to 119% which is within the accepted range of 70 to 130% (MPL 2016). Sample spike recovery for zinc on one sample was not reported due to matrix effects.

Relative percent difference (RPD) values for all internal laboratory duplicate samples are included in the laboratory reports (Appendix 4) and collated in Appendix 2. Acceptable RPDs of within 50% (*AS 4482.1-2005 and* MPL 2016 criteria) and within 30% (NEPC 2013b Schedule B3) for values more than five times the limit of reporting were reported for all samples except:

- Lead in soil D1SS (52 and 30 mg/kg, 54% RPD).
- Zinc in soil D1SS (84 and 44 mg/kg, 62% RPD).

Sample D1SS was a coarser grained subsoil considered to have some residual grains of high concentration lead/zinc sulfide concentrate from previous operations giving rise to sample heterogeneity on a 2 mm sieved sample. As only this sample recorded greater than 30% RPD (less than 5% of the duplicate analyses performed for this report as per NEPC 2013b), results indicate an acceptable level of reproducibility in subsampling and analytical techniques.

5.3.2.2 Field Duplicate Results

Field duplicate sampling was undertaken at a rate of 1 in 20 samples to verify the reproducibility of sampling techniques in the field and analytical techniques in the laboratory.

Soil and sediment field duplicate sampling comprised the collection of two duplicate samples; one soil and one sediment:

- Soil - D7SSA/D7SSB.
- Sediment - DMS5A/DMS5B.

RPD values for field duplicate samples are summarised and provided in Table A2-2 of Appendix 2. All RPD values for all metals and metalloids tested were within 30% (NEPC 2013b Schedule B3) for values greater than five times the laboratory limit of reporting (USEPA 1994), indicting low variation in field duplicates taken for the SAQP.

5.3.2.3 Quality Assurance Summary

Based on the quality assurance controls assessment detailed above, it is considered that the reported results are of an acceptable quality upon which to draw reliable conclusions regarding baseline contaminant concentrations at Derby Port.

5.4 ECOLOGICAL INVESTIGATION LEVELS

5.4.1 Soil Screening Levels

For assessment purposes, a comparison of the analytical results was made with EILs contained in both NEPC 2013 and the earlier DEC 2010 guidelines.

NEPM 1999, as amended in 2013 (NEPC 2013), does not assume fixed criteria for each contaminant as per the earlier DEC 2010 guidelines, but rather for metals with available toxicology and bioavailability data, calculates a site-specific EIL based on an added contaminant level (ACL) plus the ambient background concentration (ABC) where:

- ABC determination requires measurement of appropriate reference samples and data. The work undertaken for this investigation will provide this detail.
- ACL is calculated for each contaminant on the basis of specific soil properties including cation exchange capacity (CEC), clay content and soil pH. ACL values for particular metals and metalloids will therefore vary with soil type.
- The final site specific EIL for each element equals the ABC plus the ACL (EIL = ABC + ACL), this calculation is outlined in Schedule B1 (NEPC 2013a).

EILs thus vary with contaminant, soil properties and assigned land use category (ecological significance, recreational/urban or commercial/industrial). Where a contaminant EIL is not outlined in this fashion for NEPC 2013, guideline values have been assumed to revert to those indicated by DEC 2010.

As this study was a baseline contamination assessment, the primary aim was to provide data relating to ambient background concentrations values along the transport route, prior to heavy mineral product transport, as a reference for future work.

Chromium(III) ACL calculation in NEPC 2013a (Schedule B1) is based on clay content, which was not measured in the laboratory. An approximation of percentage clay content for chromium(III) guideline setting has been based on field texture descriptions and previous experience.

Soil pH was measured in the laboratory for calculation of appropriate copper and zinc added contaminant levels. Copper ACL calculation in NEPC 2013 uses either CEC-based or pH-based formulae, with the lowest (most conservative) value from either used as the ACL for each site. Given the alkaline nature of almost all soils in the present study, the CEC-based formula provided the lowest, most conservative ACL values for all samples. Further refinement of the site specific CEC or clay content for a particular soil may be conducted at a future date should a question of contamination arise at a particular location, the NEPC has a spreadsheet tool for calculation of ACL based on the exact rather than approximate CEC and this was used for samples with measured CEC values.

Table 4 presents a summary of the EILs used for comparison for most samples in this report which had CEC values of close to 5 cmol/kg (Pindan sands over lease area) or 40 cmol/kg (clay sediment base under lease and surrounding mudflats). The EILs are derived from both DEC 2010 and NEPC 2013 (EIL or added contaminant level) for the metals analysed based on land use category and CEC category. Note that NEPC 2013 values for Cu, Cr, Ni, Pb and Zn are actually ACL values and should be added to the site specific ABC to derive an appropriate EIL. Uranium has no currently established environmental guidelines in soil in Australia but can be compared for screening purposes to an average crustal abundance concentration of 2.7 mg/kg (AIMM 2001).

Table 4: Ecological Investigation Levels (mg/kg)

Contaminant	DEC 2010 (EIL)	NEPC 2013 Land Use (Maximum CEC – cmol(+)/kg)					
		Ecological (5)	Ecological (40)	Urban (5)	Urban (40)	Industrial (5)	Industrial (40)
As (EIL)	20	40	40	100	100	160	160
Cd (EIL)	3	N/G	N/G	N/G	N/G	N/G	N/G
Cr[1] (ACL)	400	60	130	190	400	310	660
Co (EIL)	50	N/G	N/G	N/G	N/G	N/G	N/G
Cu[2] (ACL)	100	30	75	95	220	140	330
Hg (EIL)	1	N/G	N/G	N/G	N/G	N/G	N/G
Ni (ACL)	60	5	70	30	420	55	730
Pb (ACL)	600	470	470	1,100	1,100	1,800	1,800
Zn[3] (ACL)	200	50	260	230	1,200	360	1,900

N/G indicates no guideline value set.

[1] *Assumes chromium is present as chromium(III).*

[2] *Assumes CEC criteria for NEPC 2013, copper guidelines also depend on soil pH and the lowest value is applied.*

[3] *Varies with soil pH in accordance with NEPC 2013, based on measured pH values a pH of 7.5 was used for the above.*

5.4.2 Sediment Screening Levels

Metal and metalloid contaminant concentrations in marine sediment samples were compared to the Interim Sediment Quality Guidelines (ISQGs)-Low and -High (ANZECC 2000/DER 2014). Comparison to these sediment quality guidelines is first done by comparison of total metals concentrations. If exceedances of the ISQG values (especially of ISQG high) are found for total concentrations, then the bioavailable fraction concentrations (1 molar hydrochloric acid extraction) are then assessed. Exceedance of the ISQG values by the bioavailable fraction would normally warrant further work such as remediation or development of site specific criteria.

Mudflats to the east of the site were compared to both soil and sediment ecological screening levels.

5.4.3 Marine Water Screening Levels

EIL screening values for the estuarine/marine water sample were taken from trigger values for the 99 to 95% level of protection of marine water ecosystems, National Water Quality Management Strategy, Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000). These values correspond to those applied in slightly to moderately disturbed systems as per ANZECC 2000.

5.5 HEALTH INVESTIGATION LEVELS

For human health risk assessment purposes, a comparison of the analytical soil results in the lease (industrial) and mudflats (public open space/recreational) areas was also made with generic Health Investigation Levels (HILs) contained in the NEPM 2013 and DER 2014 guidelines (NEPC 2013a). A summary of these health investigation levels is provided in Table 5.

Table 5: Health Investigation Levels (mg/kg)

Analyte	NEPC 2013 Default HIL by Land Category		
	Residential A (Garden Soil)	**Recreational C (Public Open Space)**	**Commercial/Industrial D**
As	100	300	3,000
Cd	20	90	900
Cr[1]	100	300	3,600
Cu	6,000	17,000	240,000
Hg	40	80	730
Ni	400	1,200	6,000
Pb	300	600	1,500
Zn	7,400	30,000	400,000
U	-	-	-

[1] *Assumes chromium is present as chromium(VI) which is the most toxic form.*

6. RESULTS AND DISCUSSION

A copy of the laboratory report is provided in Appendix 4.

6.1 SOILS FROM THE LEASE AREA

A comparison of analytical results with the reference industrial land use screening values is provided in Table 6. NEPM EIL ACL comparison values (Cr, Cu, Pb, Ni, Zn) in mg/kg are given for CEC values of 5 (sand) and 40 (clay) cmol(+)/kg, respectively e.g. Zn (360/1,900 mg/kg) for the differing soil and subsoil types on the lease area. Analytical results for these elements are also compared to previous generic DEC 2010 EIL values given at the top of the table which are considered conservative for this location. The land use category assigned for the lease was industrial. A plot of EIL exceedances is given in Figure 3.

A summary and interpretation of soil results from the lease area is as follows:

- All results were significantly below Industrial HIL values and only zinc (see below) at two locations exceeded the DEC 2010 EIL screening values.
- Values for soil pH ranged from 6.6 to 9 with the majority (all but D7SS) being in the range 7.5 to 9. As the soil pH values were alkaline, soil CEC values were the basis for calculating NEPM ACL values.
- EC values ranged between 41 to 3,500 µS/cm with most samples in the range of 41 to 420 µS/cm, which classifies the soils as low to moderately saline – the coastal location likely influences the soil salinity. Higher results were found for topsoil at D2TS (2,400 µS/cm) which was in a low lying area of the lease where runoff from surrounding soil runs to and evaporates. Basement heavy clay samples (D2Base and D4 Base) also had higher salinity of 3,500 and 2,000 µS/cm respectively and may be influenced by tidal estuary water flow at high tide.
- Concentrations of arsenic, cadmium, mercury and uranium were all very low and close to limits of reporting.
- All uranium concentrations (which can be present in naturally occurring heavy mineral sand particles as monazite were at or below 1 mg/kg).
- Copper (<1 to 34 mg/kg), nickel (1 to 26 mg/kg) and chromium (9 to 59 mg/kg) concentrations were well below EIL/ACL values. Nickel and copper concentrations were highest in the heavy clay basement samples and similar to concentrations found in the mudflats and marine sediments (Table 7 and Table 8) – indicating these are natural levels in the estuarine clays of the area.
- Zinc concentrations ranged from 1 to 360 mg/kg with two exceedances of the DEC 2010 EIL value of 200 mg/kg at D4TS (300 mg/kg) and D7TS (360 mg/kg). As lead was also significantly higher in concentration (110 mg/kg and 300 mg/kg respectively) at these locations and based on site history, some residual lead/zinc sulfide material is likely present at these locations. Sample D7TS (360 mg/kg) based on the expected CEC would be equal to the NEPM Industrial ACL of 360 mg/kg for a sandy (Pindan) soil type.
- As expected based on site history, lead concentrations were generally correlated with zinc across the locations. Lead concentrations ranged from 2 to 300 mg/kg but were generally below 53 mg/kg, with the exception of D4TS (110 mg/kg), D7TS (300 mg/kg) and D8TS (150 mg/kg).

6.2 SOILS/SEDIMENTS FROM EASTERN MUDFLATS

A comparison of analytical results with the reference Recreational/Public Open Space screening values is provided in Table 7. NEPM EIL ACL comparison values (Cr, Cu, Pb, Ni, Zn) in mg/kg are given for CEC values of 5 and 40, cmol(+)/kg, respectively e.g. Zn (230/1,200) for the differing soil and subsoil types on the lease area. Sample DS2 in particular was sandier in nature than other mudflat (clay) samples with a lower CEC and probably represents Pindan sand having washed to this location. Analytical results for these elements are also compared to previous fixed DEC 2010 EIL values given at the top of the table. The land use category assigned for the mudflats areas was recreational/public open space as the area immediately surrounding the facility and road are not considered of particular ecological significance. A plot of EIL exceedances is given in Figure 3.

A summary of soil/sediment results and key points from these mudflat areas is as follows:

- Values for 1:5 soil pH were alkaline (pH 8.1 to 8.3), which is consistent with other samples in the area and hence CEC values were the basis of NEPM ACL values.
- EC values (not measured on all samples) were extremely saline (28,000 to 37,000 µS/cm), consistent with a high clay content mudflat area exposed to occasional estuarine flooding and subsequent evaporation.
- Concentrations of arsenic, cadmium, mercury and uranium were all very low and close to limits of reporting. Uranium concentrations (which can be present in heavy mineral concentrate), were marginally higher in the eastern mudflat sediment samples (maximum 2.7 mg/kg) than in soil within the lease area (at or below 1 mg/kg).
- Copper (15 to 31 mg/kg), nickel (5 to 30 mg/kg) lead (16 to 95 mg/kg) and chromium (25 to 75 mg/kg) concentrations were variable but significantly below respective EIL/ACL values.
- Zinc concentrations ranged from 34 to 360 mg/kg with exceedance of the DEC 2010 EIL value of 200 mg/kg at DS4 (360 mg/kg). This location also had the highest lead concentration (95 mg/kg) and is located at the outfall of the road stormwater culvert. It is considered some road run-off from historical use has elevated the zinc (and lead) concentration at this location. Concentrations of zinc in mudflat soil/sediment were much lower adjacent to the road at locations D10TS (52 mg/kg) and D11TS (66 mg/kg) further away from the lease area.

6.3 MARINE SEDIMENT METALS AND METALLOIDS

A comparison of analytical results with the ANZECC 2000 Interim Sediment Guidelines (ISQG)-Low and -High is provided in Table 8 and a plot of all exceedances (only ISQG-Lows were exceeded) is given in Figure 3. Samples from the mudflats immediately east of the lease area are also included in Table 8 as this area could also be considered more tidal (sediment) rather than terrestrial (soil) in nature.

There were no ISQG exceedances for arsenic, cadmium, chromium, silver or mercury and selenium concentrations were all below the level of reporting. ISQG-Low exceedances of other metals were recorded for:

- Nickel (ISQG-Low of 21 mg/kg) at most locations except DS1 (5 mg/kg) and DMS7 (3 mg/kg). These locations represented much sandier material than other locations which were a very fine silt/clay. The nickel concentrations in the silt/clay sediment samples were consistent (range 22 to 31 mg/kg) and suggests a natural presence of nickel in the estuarine silt/clay from the area.
- Copper at locations DMS1 (90 mg/kg) and DMS2 (66 mg/kg) was above the ISQG-Low of 65 mg/kg and significantly higher than other clay/silt based samples (range 23 to 35 mg/kg). Both these locations are used for boat launching and elevated copper may be the result of copper anti-fouling paint from boats hulls.
- Lead at locations DS2 (52 mg/kg) and DS4 (95 mg/kg) versus an ISQG-Low of 50 mg/kg for lead. As noted previously, zinc was also elevated at DS4 (360 mg/kg). Both these locations are close to where road culverts discharge stormwater onto the eastern mudflat area and may be influenced by historical contamination as a result. DS1 and DS3 locations on the eastern mudflats were away from road culverts and recorded lower concentrations than DS2 and DS4.

Uranium concentrations in silt/clay dominant sediment samples were consistent with a range of 2.4 to 5.2 mg/kg. Sandier samples DS1 and DMS7 had lower concentrations (0.81 and 0.75 mg/kg respectively). These concentrations are equal to or marginally above the average earth crustal concentration of 2.7 mg/kg (AIMM 2001). Alkaline marine sediment is expected to be a 'sink' for naturally sourced uranium leached over geological timeframes from the surrounding land.

6.4 MARINE WATER ANALYSIS

A comparison of analytical results for the water sample collected at the boat ramp (Figure 2, DER BR1) with ANZECC 2000 EIL trigger values is provided in Table 9. There were no results above the corresponding trigger values for any parameters analysed and the concentrations of dissolved metals and metalloids was very low with most below laboratory limits of reporting. Notable aspects were:

- Lead, copper, zinc and nickel despite varying degrees of enrichment in sediment or soils were all below laboratory limits of reporting.
- As expected for the silt laden waters of this estuary area, the turbidity (62 NTU) and suspended solids (89 mg/L) was very high. Other general parameters of salt content and salt composition are consistent with typical seawater.
- The reported uranium concentration of 0.0035 mg/L is consistent with a previously reported value of 0.0033 mg/L for seawaters of the western north Pacific (Miyake *et. al.* 1966).

Table 6: Summary of Soil Results – Industrial Land Use (Lease Area)

Sample ID	**CEC***	**pH (1:5)**	**EC (1:5)**	**Arsenic (EIL)**	**Cadmium (EIL)**	**Chromium (ACL)**	**Copper (ACL)**	**Mercury (EIL)**	**Nickel (ACL)**	**Lead (ACL)**	**Zinc (ACL)**	**Uranium**
Units	cmol (+)/kg	pH Units	µS/cm	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
DEC 2010 EIL Value	-	-	-	20	3	400	50	1	60	600	200	-
NEPM 2013 EIL or ACL Value				160	-	310/660	140/330	-	55/730	1,800	360/1,900	-
NEPM 2013 HIL Value	-	-	-	3,000	900	3,600	240,000	730	6,000	1,500	400,000	-
D1TS	5	Not Analysed		<2	0.5	10	1	<0.1	1	22	100	<1
D1SS	**6**	8.5	360	<2	<0.4	10	1	<0.1	2	52	84	<1
D2TS	5	7.8	2400	2	<0.4	17	3	<0.1	3	13	50	<1
D2Base	40	9.0	3500	8	<0.4	53	34	<0.1	26	20	55	1
D3TS	5	8.6	620	<2	<0.4	15	4	<0.1	2	38	100	<1
D4TS	5	8.5	140	4	0.6	30	9	<0.1	7	110	300	<1
D4Base	**45**	9.0	2000	8	<0.4	53	34	<0.1	26	18	54	1
D5TS	5	7.7	420	<2	<0.4	9	<1	<0.1	1	8	15	<1
D5SS	5	7.8	400	<2	<0.4	17	3	<0.1	3	6	3	<1
D6TS	**<5**	7.5	54	2	<0.4	20	5	<0.1	4	30	53	<1
D7TS	5	8.8	83	2	0.9	17	5	<0.1	3	300	360	<1
D7SSA	5	6.6	41	<2	<0.4	9	<1	<0.1	1	2	1	<1
D7SSB	5	Not Analysed		<2	<0.4	9	<1	<0.1	1	3	2	<1
D8TS	5	9.0	46	<2	0.5	10	1	<0.1	1	150	180	<1
D8SS	5	Not Analysed		<2	<0.4	11	2	<0.1	2	46	75	<1
D9TS	5	8.3	60	<2	<0.4	11	2	<0.1	2	36	140	<1
DSY1	5	Not Analysed		12	<0.4	59	19	<0.1	8	53	170	<1

Key

🟦	DER 2010 EIL Value Exceedance	🟨	NEPM 2013 EIL/ACL Exceedance	🟧	HIL (Industrial) Value Exceedance

**CEC values in bold were laboratory measured, others are approximated to tabulated NEPM 2013 values based on observed soil types.*

Table 7: Summary of Soil/Sediment Results – Recreational Land Use (Mudflats)

Sample ID	**CEC***	**pH (1:5)**	**EC (1:5)**	**Arsenic (EIL)**	**Cadmium (EIL)**	**Chromium (ACL)**	**Copper (ACL)**	**Mercury (EIL)**	**Nickel (ACL)**	**Lead (ACL)**	**Zinc (ACL)**	**Uranium**
Units	cmol (+)/kg	pH Units	µS/cm	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
DEC 2010 EIL Value	-	-	-	20	3	400	50	1	60	600	200	-
NEPM 2013 EIL or ACL Value				100	-	190/400	95/220	-	30/420	1,100	230/1,200	-
NEPM 2013 HIL Value	-	-	-	300	90	300	17,000	80	1,200	600	30,000	-
D10TS	**39**	8.3	37,000	8	<0.4	48	28	<0.1	22	16	52	1
D11TS	40	8.1	28,000	9	<0.4	51	29	<0.1	23	21	66	<2
DS1	40	Not Analysed		4	0.03	25	15	<0.05	5	16	34	0.81
DS2	**6**	Not Analysed		10	0.22	64	23	<0.05	23	52	190	2.4
DS3	40	Not Analysed		10	0.07	73	31	<0.05	30	45	140	2.6
DS4	40	Not Analysed		12	0.39	75	27	<0.05	30	95	360	2.7

Key

🟦	= DER 2010 EIL Value Exceedance	🟨	NEPM 2013 EIL/ACL Exceedance	🟧	HIL (Recreational) Value Exceedance

**CEC values in bold were laboratory measured, others are approximated to tabulated NEPM 2013 values based on observed soil types.*

Table 8: Summary of Marine Sediments and Mudflat Samples Results (mg/kg)

Sample ID	Sample Type	Arsenic	Cadmium	Chromium	Copper	Mercury	Nickel	Lead	Zinc	Vanadium	Silver	Uranium	Selenium
	ISQG Low	20	1.5	80	65	0.15	21	50	200	-	1	-	-
	ISQG High	70	10	370	270	1	52	220	410	-	3.7	-	-
DS1	Soil/Sediment	4	0.03	25	15	<0.05	5	16	34	35	<0.05	0.81	<0.5
DS2	Soil/Sediment	10	0.22	64	23	<0.05	23	52	190	89	<0.05	2.4	<0.5
DS3	Soil/Sediment	10	0.07	73	31	<0.05	30	45	140	99	<0.05	2.6	<0.5
DS4	Soil/Sediment	12	0.39	75	27	<0.05	30	95	360	110	0.07	2.7	<0.5
DMS1	Marine Sediment	11	0.07	74	90	<0.05	31	21	160	98	0.05	2.5	<0.5
DMS2	Marine Sediment	10	0.04	60	66	<0.05	22	19	50	76	<0.05	2.5	<0.5
DMS3	Marine Sediment	15	0.08	68	35	<0.05	27	21	78	99	<0.05	5.2	<0.5
DMS4	Marine Sediment	12	0.06	62	28	<0.05	22	18	49	78	<0.05	2.5	<0.5
DMS5A	Marine Sediment	10	0.05	68	27	<0.05	25	19	58	85	<0.05	2.5	<0.5
DMS5B	Marine Sediment	11	0.04	66	27	<0.05	24	19	52	87	<0.05	2.6	<0.5
DMS6	Marine Sediment	13	0.02	81	28	<0.05	29	21	57	120	<0.05	2.6	<0.5
DMS7	Marine Sediment	10	0.03	10	5	<0.05	3	11	9	21	<0.05	0.75	<0.5

Key

🟦	ISQG Low Exceedance
🟨	ISQG High Exceedance

Figure 3: Soil EIL and Sediment ISQG-Low Exceedances

Table 9: Marine Water Analysis Results

Analyte	Units	DER BR1	ANZECC 2000 Marine Trigger Value
Ag	mg/L	<0.0010	0.0014
Al	mg/L	<0.005	N/G
Alkalinity	mg/L	129	N/G
As	mg/L	<0.010	N/G
Carbonate	mg/L	<1	N/G
Calcium	mg/L	423	N/G
Cadmium	mg/L	<0.0010	0.0007
Chloride	mg/L	19500	N/G
Cobalt	mg/L	<0.0010	0.001
Chromium	mg/L	<0.001	0.027
Copper	mg/L	<0.0010	0.0013
EC	mS/m	5350	N/G
Fe	mg/L	<0.005	N/G
Bicarbonate	mg/L	157	N/G
Potassium	mg/L	447	N/G
Magnesium	mg/L	1240	N/G
Manganese	mg/L	0.017	N/G
Molybdenum	mg/L	0.014	N/G
Sodium	mg/L	11800	N/G
Nickel	mg/L	<0.010	0.007
Lead	mg/L	<0.0010	0.0044
Sulfate	mg/L	2800	N/G
Selenium	mg/L	<0.010	N/G
TSS	mg/L	89	N/G
Thorium	mg/L	<0.0010	N/G
Titanium	mg/L	<0.002	N/G
Turbidity	NTU	62	N/G
Uranium	mg/L	0.0035	N/G
Vanadium	mg/L	0.0036	N/G
Zinc	mg/L	<0.005	0.015
Zirconium	mg/L	<0.002	N/G
pH	pH Units	8	N/G

N/G indicates no guideline value is applicable

6.5 ACID SULFATE SOILS ASSESSMENT

6.5.1 Field Observations

Results of field observations and sample depths are presented in Table 3. In reference to field observations of potentially ASS material the following is noted:

- Sample D2Base from the lease at a depth of 1.2 m was noted to have presence of sulfidic material (mottling with black patches) in the heavy clay. Sample D4Base from a depth of 0.6 below ground level had no observable sulfidic material.
- Other locations around the lease area could not be dug to the basement clay due to shallow refusal – samples from the surrounding mudflats are considered to be of the same material for ASS assessment.
- Samples of clay from surrounding mudflats had evidence to varying degrees of sulfidic material at depth.
- All samples of fresh marine silt/clay had evidence of sulfidic material below the surface.
- All samples submitted for analysis for heavy clay/silt samples - no evidence of oxidised material (jarosite) was noted in the field.

6.5.2 Analysis for ASS Parameters

A summary of all analysis parameters is provided in Table 10, refer to Section 8 and Appendix 1 for an explanation of terms and methods. The following key points are noted from the current assessment:

- The measured pH and pH_{KCl} values of all samples were alkaline (8.2 to 8.4). TAA values were less than the reporting limit. This indicates that none of the soils sampled are acidic as a consequence of previous oxidation (actual acid sulfate soils - AASS).
- Measured ANC was significant at 1.3 to 3.7% S equivalents (Table 10). Shell fragments were not observed and this ANC is expected to be in the form of readily available carbonates.
- One sample of fresh marine sediment collected at low tide (DMS3) had a pH_{FOX} of less than 3 (1.8 with a pH drop of 6.8), all other samples tested had alkaline pH values following oxidation with hydrogen peroxide.
- CRS values were above the reporting limit of 0.005% for all samples and significantly higher in fresh marine sediment samples (0.053 to 1.3 %S for DMS1, DMS3, DMS5A and DMS6) than for the exposed mudflats or underlying basement clay of the lease area (0.007 to 0.025 %S).
- As all samples tested comprised heavy clay/silt, the assessment criteria for ASS potential based on net acidity is 0.1% S - heavy clays will limit oxygen ingress and oxidation.

6.5.3 ASS Classification

On the basis of measured parameters, all mudflat and basement clay samples around the lease area are classified as non acid sulfate soils (NASS) with no detectable net acidity- Table 10. One sample of fresh marine sediment with higher sulfide content and lower ANC (DMS3) is classified as potentially acid sulfate soil (PASS).

No significant disturbance of marine sediment is expected in the proposed development as the wharf is already constructed. Construction of a new shed on the lease area for storage and loading the conveyor is expected to involve only minimal and short term disturbance into the subsurface basement clays as may be required for service trenching or foundations to a depth of less than 2 m bgl.

Table 10: Summary of Acid Sulfate Soil Assessment Results

Sample ID	**Depth**	**Depth to Water***	**pH$_F$**	**pH$_{FOX}$**	**pH Drop**	**Reaction Rate**	**pH KCl**	**TAA**	**CRS**	**ANC**	**Net Acidity**	**Classification**
Units	mBGL	m	pH Units	pH Units	pH Units	LMHXV**	pH Units	%S	%S	%S	%S	
Criteria			4.5	3	1	N/G	4.5	0.1	0.1	N/G	0.1	
D2Base	1.2	0.5	N/A	N/A	N/A	N/A	8.9	<0.01	0.020	2.2	<0.005	NASS
D4Base	0.6	0.5	N/A	N/A	N/A	N/A	8.9	<0.01	0.007	1.8	<0.005	NASS
D10TS	0.1	0.8	N/A	N/A	N/A	N/A	9.1	<0.01	0.025	2.9	<0.005	NASS
DS2	0.2	0.8	8.3	7.8	0.5	X	9	<0.01	0.024	2.0	<0.005	NASS
DMS1	0.1	0	8.4	7.8	0.6	H	8.8	<0.01	0.053	3.5	<0.005	NASS
DMS3	0.1	0	8.2	1.8	6.4	V	8.2	<0.01	1.3	1.3	0.46	PASS
DMS5A	0.1	0	8.3	8.4	-0.1	X	8.8	<0.01	0.1	3.7	<0.005	NASS
DMS6	0.1	0	8.3	8.2	0.1	X	8.7	<0.01	0.065	3.0	<0.005	NASS

** Depths to water from lease area and mudflats are approximate*

*** L = Low, M = Medium, H = High, X = Extreme, V = Volcanic*

N/A indicates not analysed

N/G indicates no guideline criteria

7. CONCLUSIONS

Overall the assessment of all samples taken in and adjacent to the proposed Derby facility for analysis of metals and metalloids of potential concern were considered either representative of the region or reflective of a Port facility with prior history of (in particular) lead and zinc exports. Further assessment of the soils and sediments within the lease area which may be disturbed in minor volumes by construction of a product storage shed indicated no significant risk of acid sulfate soils. No significant disturbance of marine sediment and hence opportunity for oxidation and metals/metalloids release is expected in the proposed development as the wharf is already constructed.

7.1 LEASE AREA SOILS AND SUBSOILS

Assessment of soils and subsoils across the lease area by hand augering, field observations and laboratory assessment indicated the following key aspects:

- Although some residual low level zinc remains in several Pindan soils across the lease, levels are significantly below industrial health investigation levels. The maximum concentration of zinc (360 mg/kg) was equal to the site specific calculated NEPM 2013 ACL for this sandy soil type and would be at or below a calculated EIL for the site depending on background concentration. This is consistent with the previous site history and validation report (MBS 2012).
- Concentrations of lead were correlated with zinc from previous site history with lead/zinc sulfides, but no samples were found to exceed industrial EIL or HIL values for lead.
- Concentrations of all other metals and metalloids at the site were low to very low including uranium, which was generally less than 1 mg/kg.
- Examination of subsoil basement clays in accessible areas of the lease indicated slight presence of sulfidic material in an otherwise alkaline clay matrix. Concentrations of ASS parameters were insufficient for classification as ASS materials. Further samples for assessment were taken from the eastern mudflats and considered to represent the same underlying heavy clay/silt. This indicates that limited siteworks/trenching of this material to depths of less than 2m for construction of a new shed has very limited potential for acid generation.

7.2 EASTERN MUDFLATS SOILS/SEDIMENTS

Assessment of the soil/sediments from the eastern mudflats indicated the following key aspects:

- Samples were highly saline and alkaline, which is consistent with exposed mudflat/salt lake areas of an estuarine area.
- Zinc concentrations ranged from 34 (DS1) to 360 mg/kg (DS4) – location DS4 also had the highest lead concentration (95 mg/kg) and is located (along with DS2) at the outfall of the road culvert. It is considered some road run-off from historical use has elevated the zinc (and lead) concentration at this location. The concentration of 360 mg/kg zinc exceeds the previous DEC 2010 EIL/ISQG-Low value of 200 mg/kg, but is below the site specific NEPM 2013 calculated ACL of 1,200 mg/kg based on the CEC and assigned land use of recreational/public open space.
- DS1 and DS3 locations on the mudflats east of the lease were away from road culverts and recorded lower concentrations of lead and zinc than DS2 and DS4. Lead at DS2 (52 mg/kg) and DS4 (95 mg/kg) exceeded the ISQG-Low for lead of 50 mg/kg. Concentrations of zinc and lead in mudflat soil/sediment at locations D10TS and D11TS further away from the lease area and road runoff from it were significantly lower
- Uranium concentrations (which can be present in heavy mineral concentrate), were marginally higher in the eastern mudflat samples (maximum 2.7 mg/kg) than in the lease area (at or below 1 mg/kg).

7.3 MARINE SEDIMENTS

Sampling and laboratory assessment of marine sediments adjacent to the lease area and wharf indicated the following key aspects:

- No ISQG exceedances for arsenic, cadmium, chromium, silver or mercury.
- Selenium concentrations were all below the level of reporting (0.5 mg/kg).
- Nickel (ISQG-Low of 21 mg/kg) at most locations except DS1 (5 mg/kg) and DMS7 (3 mg/kg), which were much sandier in texture, exceeded ISQG-Low. The nickel concentrations in the silt/clay sediment samples were consistent (range 22 to 31 mg/kg for marine sediment) and nickel also found in basement clays beneath the lease and in the mudflats areas. This strongly suggests a natural enrichment of nickel at this concentration in the estuarine silt/clay from the area.
- Copper at locations DMS1 (90 mg/kg) and DMS2 (66 mg/kg) was above the ISQG-Low of 65 mg/kg and significantly higher than other clay/silt based samples (range 23 to 35 mg/kg). Both these locations are used for boat launching and elevated copper may be the result of copper anti-fouling paint from boats hulls.
- Uranium concentrations in silt/clay dominant sediment samples were consistent with a range of 2.4 to 5.2 mg/kg. Sandier samples DS1 and DMS7 had lower concentrations (0.81 and 0.75 mg/kg respectively).
- Fine grained (silt/clay) fresh marine sediments were variable in sulfide content and potential for acid generation. Only one of the four samples analysed had sufficiently high sulfide content and low ANC (DMS3) to be classified as PASS. No significant disturbance of marine sediment and hence opportunity for oxidation is expected in the proposed development as the wharf is already constructed.

7.4 MARINE WATER

Sampling and laboratory assessment of the estuarine tidal water at the boat ramp indicated no results above ANZECC 2000 EIL trigger values with dissolved metals and metalloids very low and mostly below laboratory limits of reporting (including lead, zinc, copper and nickel). Dissolved uranium was observed at a concentration of 0.0035 mg/L which is very consistent with a previously reported value (0.0033 mg/L) for uranium in seawater (Miyake *et. al.* 1966). Apart from elevated turbidity/suspended solids due to the nature of the estuarine clay/silt, all other parameters (namely salt content and composition) were consistent with typical seawater.

8. GLOSSARY OF TECHNICAL TERMS

Term	Explanation
Acid fizz test	A field test used to test for the presence of carbonate minerals in soil and sediment. Dilute hydrochloric acid is added to the sample and an effervescent reaction indicates the presence of carbonate minerals.
Action criteria	The critical net acidity values (expressed as % pyrite sulfur or the equivalent moles H^+/t) for different soil texture groups and sizes of soil disturbance that trigger the need for ASS management.
alunite	A hydrated aluminium potassium sulfate mineral, formula $KAl_3(SO_4)_2(OH)_6$. It is an analogue of jarosite where aluminium has replaced iron and can hydrate to aluminium hydroxide and release soluble free acidity. It is thus a source of stored or 'retained' acidity.
Actual acidity	The soluble and exchangeable acidity already present in the soil, often as a result of previous oxidation of sulfides. It is measured in the laboratory using the TAA method, but does not include the less soluble acidity (i.e. residual acidity) held in minerals such as alunite and jarosite.
ANC	Acid Neutralising Capacity. A measure of a soil's inherent ability to buffer acidity and resist the lowering of the soil pH.
ANC_E	Acid Neutralising Capacity (Excess). Found in soils with acid neutralising capacity in excess of that needed to neutralise acid generation from sulfides. Measured by titration down to pH 6.5 after oxidation of the sample with peroxide. If ANC_E of a soil is positive, then TPA is zero and vice versa.
ASS	Acid Sulfate Soils.
Ca_A	Reacted calcium. The calcium solubilised after reaction with peroxide that was not soluble in 1M KCl (i.e. Ca_P minus Ca_{KCl}). It is a measure of the calcium present and available for acid neutralisation in the form of carbonates (e.g. calcite, dolomite).
Ca_{KCl}	Calcium soluble in 1 M KCl. It is a measure of the soluble and exchangeable calcium as well as calcium from gypsum.
Ca_P	Peroxide soluble calcium. Calcium measured after peroxide oxidation, it includes soluble and exchangeable calcium as well as calcium dissolved by acid produced from oxidation of sulfides.
Chromium suite	The approach of calculating net acidity using the chromium reducible sulfur method to determine potential sulfidic acidity. It is combined with a decision process based on pH_{KCl} to determine the other components of acid-base accounting (TAA, ANC).
CRS	Chromium Reducible Sulfur. A measurement of reactive sulfide sulfur normally applied to acid sulfate soils using reaction with metallic chromium and hydrochloric acid to liberate hydrogen sulfide gas, which is trapped and then measured by iodometric titration.
dolomite	Calcium magnesium carbonate $CaMg(CO_3)_2$
calcite	Calcium carbonate $CaCO_3$
Carb NP	Carbonate Neutralisation Potential. The amount of ANC provided by carbonate minerals.
CEC	Cation Exchange Capacity of a soil is defined as the total sum of exchangeable cations that it can retain at a specific pH. Cation exchange of exchangeable cations in reversible chemical reactions is a quality important in terms of soil fertility, erosion and plant nutritional studies.
circum-neutral pH	pH value near 7.
EC	Electrical conductivity. A measurement of solution salinity.

	Conversion: 1,000 µS/cm = 1 dS/m = 1 mS/cm
ENV	Effective neutralising value of a liming product (normally calcite) which takes into account the chemical purity of the lime, particle size and solubility in its ability to neutralise acid.
Existing acidity	The acidity already present in soils, usually as a result of oxidation of sulfides, but which can also be from organic material or ions which release acid upon hydrolysis (Fe and Al). Existing acidity is the sum of actual acidity and retained acidity.
Fineness factor	A factor applied to the amount of acid neutralising material required to neutralise the acid potential due to the poor reactivity of coarser carbonate or other acid neutralising material. The minimum factor is 1.5 for finely divided pure agricultural lime (calcium carbonate), but may be as high as 3.0 for coarser shell material.
Fulvic acid	A complex mixture of small organic molecules derived from biological breakdown of plant matter (humus). They are organic acids (carboxyl and phenolate groups) which remain soluble in water below pH 2 (compare with Humic acid).
Humic acid	A complex mixture of large (high molecular weight) organic molecules derived from biological breakdown of plant matter (humus). They are organic acids (carboxyl and phenolate groups) which are insoluble in water below pH 2.
Jarosite	A hydrated iron potassium sulfate mineral, formula $KFe_3(SO_4)_2(OH)_6$. It can hydrate to iron (III) hydroxide and release soluble free acidity. It is thus a source of stored or 'retained' acidity. Jarosite is often distinguished by its yellow colouration among dark sediments exposed to oxygen. A sodium analogue is known as natrojarosite.
laterite	Highly weathered soils/subsoils developed by extensive leaching of iron and aluminium rich parent rocks in tropical climates to leave soils rich in hydrous iron and aluminium oxides.
Mg_A	Reacted magnesium. The magnesium solubilised after reaction with peroxide that was not soluble in 1M KCl (i.e. Mg_P minus Mg_{KCl}). It is a measure of the magnesium present and available for acid neutralisation in the form of carbonates (e.g. dolomite, magnesite).
Mg_{KCl}	Magnesium soluble in 1 M KCl. It is a measure of the soluble and exchangeable magnesium.
Mg_P	Peroxide soluble magnesium. Magnesium measured after peroxide oxidation, it includes soluble and exchangeable magnesium as well as magnesium dissolved by acid produced from oxidation of sulfides.
Monosulfides	The term given to highly reactive iron sulfide minerals found in ASS of approximate formula 'FeS' and are soluble in hydrochloric acid which distinguishes them from disulfides such as pyrite, which are insoluble in dilute hydrochloric acid.
MBO	Monsulfidic Black Ooze. Black, oily in appearance gel-like substances highly enriched (up to 27%) in monosulfides and organic matter which can form thick deposits in waterways in acid sulfate soil landscapes.
Net acidity	Result obtained after accounting for all forms of soil acidity and neutralising capacity. Net acidity = Potential acidity + Existing acidity – (ANC/Fineness Factor)
pH_F	pH field of a 1:2 soil:water paste
pH_{FOX}	pH field after addition of a few drops of strong oxidant (hydrogen peroxide).
pH_{KCl}	pH in a 1M potassium chloride solution (laboratory measured).
pH_{OX}	pH in a peroxide oxidised suspension as per the SPOCAS method (laboratory measured).
Potential acidity	The latent acidity in ASS that can be generated if the sulfide minerals present are fully oxidised to generate sulfuric acid. It is estimated by measurement of SPOS (SPOCAS Suite) or SCR (Chromium Suite).
Pyrite	Iron (II) sulfide, FeS_2. Pyrite is the most common sulfide minerals and the major acid forming mineral oxidising to produce sulfuric acid
Retained acidity	The less available fraction of existing acidity which is not measured as part of TAA and is

	due to hydrolysis of relatively insoluble minerals such alunite and jarosite.
S_{CR}	The symbol often given to the result for sulfur measured by the chromium reducible sulfur method i.e. CRS.
S_{KCl}	Potassium chloride extractable sulfur measured following the TAA analysis, it includes soluble and adsorbed sulfate as well as sulfate from gypsum.
S_P	Peroxide soluble sulfur. Sulfur measured following the TPA analysis, which includes soluble and exchangeable sulfate, sulfate from gypsum, as well as sulfides and organic sulfur converted to sulfate as a result of peroxide oxidation.
S_{POS}	Peroxide oxidisable sulfur from the SPOCAS method. SPOS = SP - SKCl It is the estimate used for soil sulfide content but is affected by presence of organic sulfur.
S_{NAS}	Net acid soluble sulfur. Sulfur measured by 4M HCl extraction on the soil after determination of TPA and S_{POS} in the SPOCAS method if pH_{KCl} is <4.5. It is used to estimate residual acidity from insoluble minerals such as alunite and jarosite.
S_{TOS}	Total oxidisable sulfur ($S_{POS} = S_T – S_{HCl}$). An estimate of oxidisable sulfur often used as part of a chromium reducible sulfur suite of analysis by subtracting acid soluble sulfate sulfur (S_{HCl}) from Total sulfur (S_T) measured by combustion analysis. It tends to provide an overestimate of soil sulfide content (e.g. it includes organic sulfur).
Self-neutralising soil	A term given to ASS where there is sufficient acid-neutralising capacity (with relevant safety factors applied) to neutralise potential sulfidic acidity within the soil. i.e. net acidity is zero or negative.
SPOCAS	An acronym for suspension peroxide combined acidity and sulfur method; a combination of decision tree approach and analytical methods to allow estimation of net acidity.
TAA	Titratable actual acidity. Used in both the S_{CR} and SPOCAS suites; it determines the present soil acidity by titration with sodium hydroxide after extraction in potassium chloride up to pH 6.5.
TPA	Titratable peroxide acidity. The acidity measured by titration following peroxide digestion in the SPOCAS method.
TSA	Titratable sulfidic acidity. The difference in acidity between TPA and TAA i.e. the increase in acidity caused by peroxide oxidation.

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APPENDICES

APPENDIX 1: ACID SULFATE SOIL ASSESSMENT METHODS

APPENDIX 2: QUALITY ASSURANCE RESULTS

APPENDIX 3: CHAIN OF CUSTODY FORMS

APPENDIX 4: LABORATORY CERTIFICATES OF ANALYSIS