6

Geology, Landforms and Soils

6.1 Existing Environment

6.1.1 Surface Elevations and Bathymetry

The general landform of the EAW area is shown in Figure 6-1. The figure shows plains areas (0 m to 9 m relative to Australian Height Datum, rises (9 to 30 m), swamp areas, drainage systems and marine areas.

The proposed development of the barge ramp and hardstand, and MSB, located to the south of the existing wharf, will involve dredging of the channel and reclamation. Currently, the existing level along the wharf structure is of the order of 2.5 m AHD to 3.5 m AHD and the bed level shown on the bathymetric survey is between 3 m Chart Datum (CD) in the north with areas as low as -2 m CD in the south, were for Darwin Harbour 0 m Australian Height Datum (mAHD) is based on Mean Sea Level (MSL) which corresponds to a tide height of 4.1m Chart Datum (CD). Chart Datum is based on Lowest Astronomical Tide[1].

The levels along the existing rail line are of the order of 5-7 m AHD; the proposed development will involve construction of a loop running west of the existing line and will extend beyond the shoreline to approximately the same levels.

The extension of the quay line to the west will be protected by a sea wall and significant dredging and reclamation will be required to cover the area of approximately 9 ha. The bathymetry in this area of the development ranges from around 3 m AHD to as low -9 m CD in the south west.

The general landform in the coastal area of EAW area is described as marine and comprises a combination of the following:

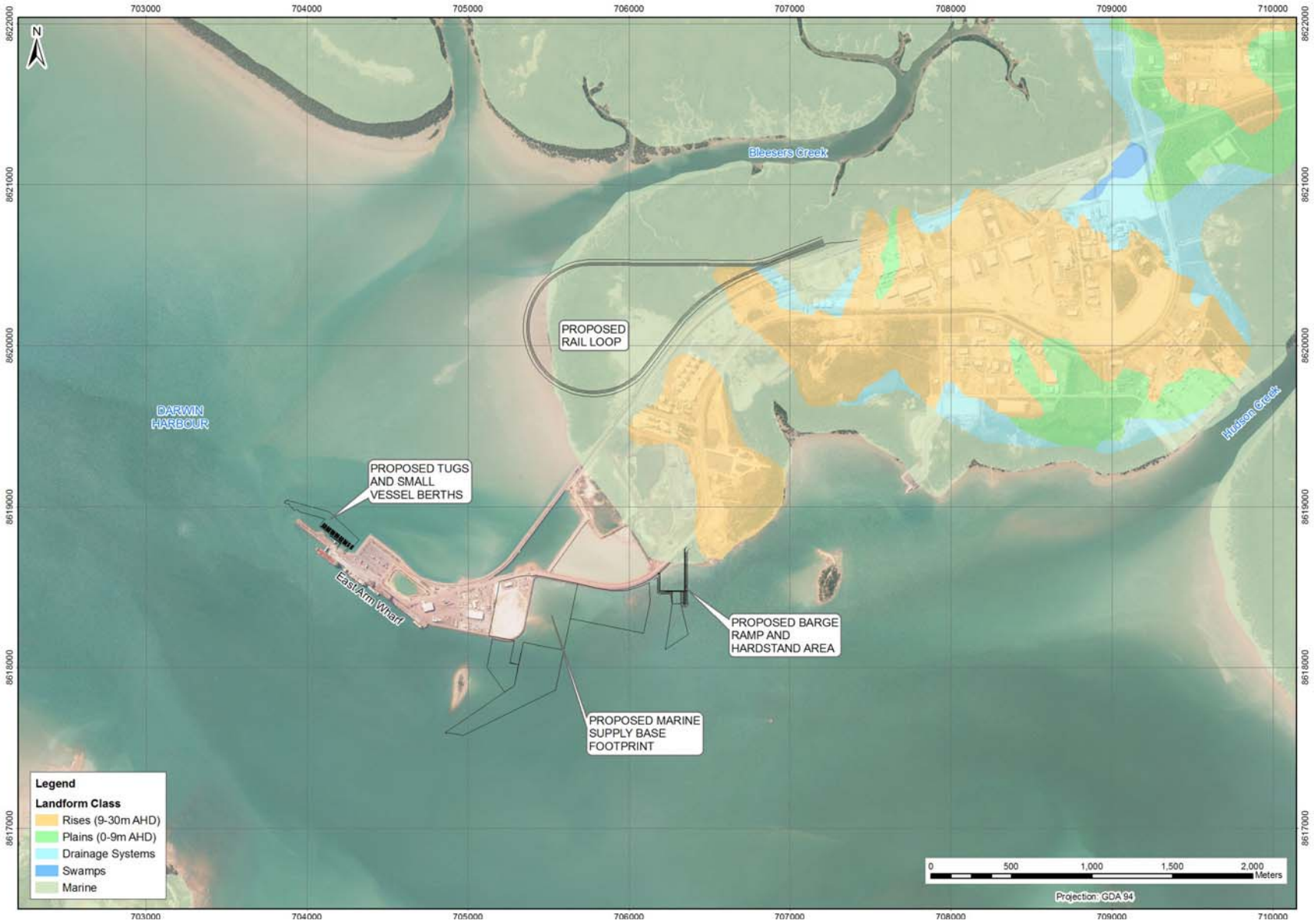
- Lower intertidal areas of marine alluvium consisting of wet clays and silts with variable sand content.
- Upper intertidal areas of mixed marine colluvium and alluvium consisting mainly of silty sand and gravelly sand.

Generalised soil and soil drainage classification for EAW (Figure 6-2) indicates that the northern part of the area (the area comprising the current rail line and the coastal fringe to the north of the rail line) comprises seasonally or permanently wet soils, which in terms of soil drainage classification are poorly or very poorly drained. The area of EAW to the south of the rail line includes similar soils and drainage characteristics, but also includes a significant area of soils without structure (earths); these are described as rapidly, well or moderately well drained soils.

A number of smaller areas with minimal soil development are also indicated to be present within the area to the south of the rail line.

The soils in the area are known to have various levels of ASS and potential acid sulphate soils (PASS), shown in Figure 6-3.

[1] The Australian Height Datum (AHD) is used as a reference for terrestrial elevations / depths. Chart Datum (CD) references lowest astronomical tide (LAT) and is used for marine elevation / depth measurements.

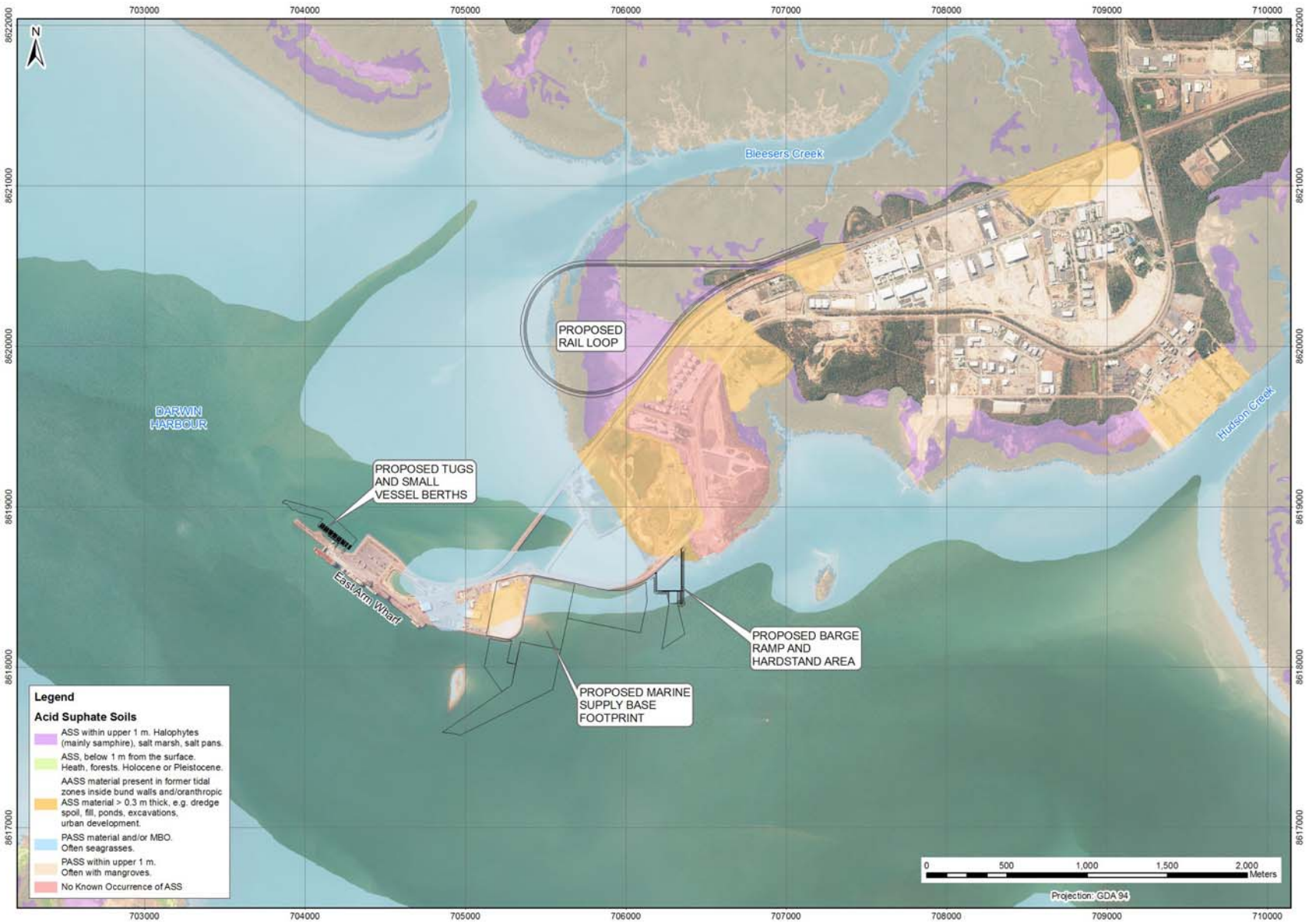


Source: Fogarty, Lynch and Wood, 1984

Figure 6-1 EAW Landform

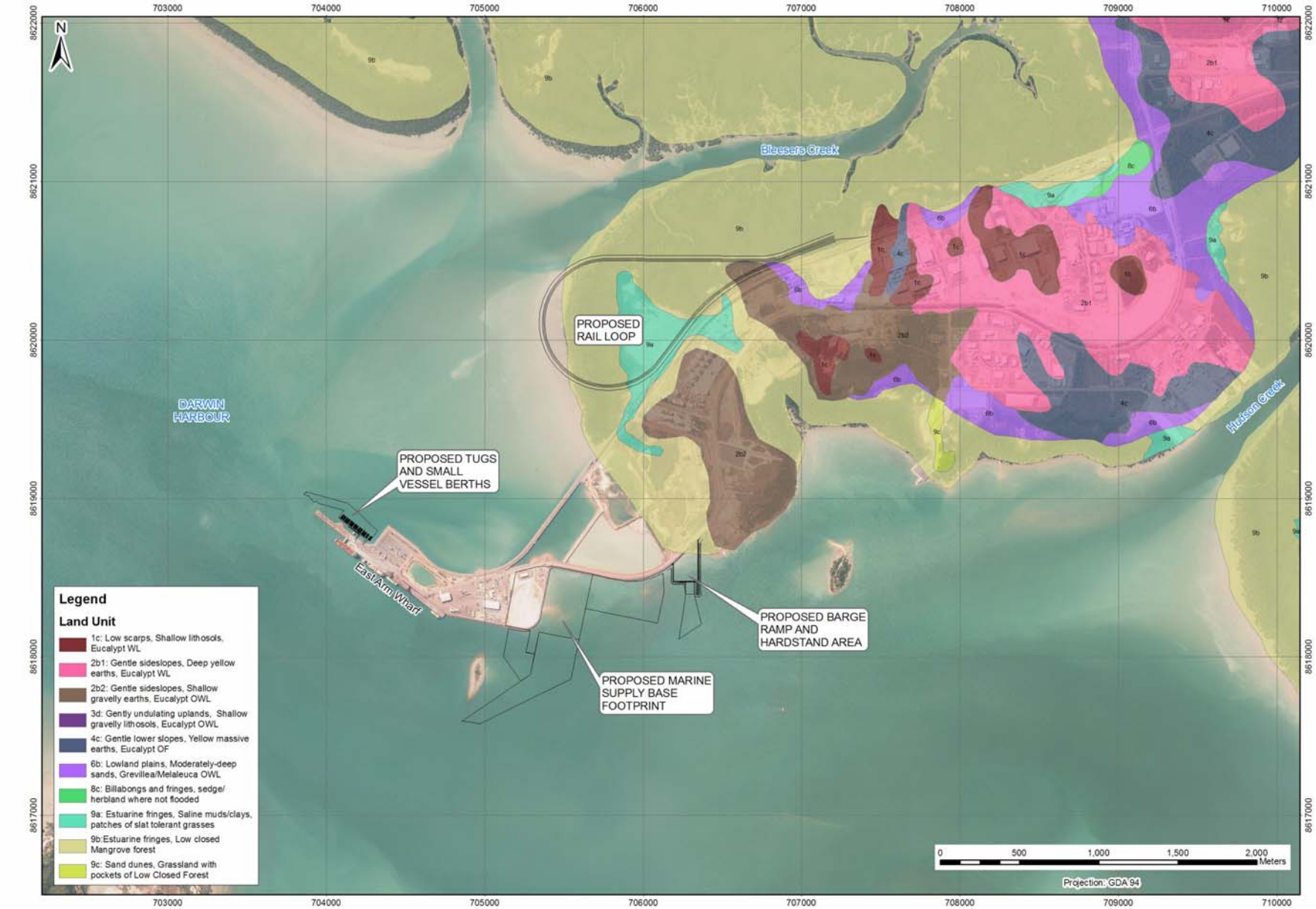
Source: Fogarty, Lynch and Wood, 1984

Figure 6-2 EAW Soil Classifications



Source: Fogarty, Lynch and Wood, 1984

Figure 6-3 East Arm Wharf – Acid Sulphate Soils



Source: Fogarty, Lynch and Wood, 1984

Figure 6-4 EAW Geology

6.1.2 Geology

Reference to the 1:100,000 scale geological maps (Darwin 5073) for the area indicates the presence of metasediments belonging to the Burrell Creek formation (BCF), which is typically described as siltstone, shale, sandstone and quartz pebble conglomerate metamorphosed to lower greenschist facies. The coastal fringes of the area are underlain by Quaternary intertidal marine deposits of mud, clay and silt.

6.1.3 Seismicity

Darwin is in an area of generally low seismic activity, despite the relative proximity to the tectonic plates of South East Asia. Design procedures for earthquake loadings are outlined in the Australian Standard (AS1170.4, Ref 1). Reference to Table 3.2 and Figure 3.2(E) of this standard indicates that the hazard factor (Z) for Darwin is 0.09. Proposed buildings should be designed for earthquake loading in accordance with the standard using an earthquake design category selected from Table 2.1, and an assumed site sub-soil class of Ce/De.

Darwin Harbour is well sheltered from long period tsunami and ocean swell waves by the Tiwi (Melville and Bathurst) Islands. Due to the harbour orientation, bathymetry and coastline configuration, energy of long period waves entering the Harbour quickly dissipates.

6.2 Previous Investigations

A number of previous geotechnical or soils investigations have been undertaken. A brief summary of the key findings from each of the principal reports reviewed is provided below, in reverse chronological order 2010 to 1968. Full references are provided in the reference list.

A preliminary site-specific investigation is still underway; the report on this is not yet available, and the outcomes of this investigation will be provided in the EIS Supplement.

The four main proposed developments discussed are:

1. Barge ramp and hardstand area
2. MSB
3. Additional rail loop
4. Tug and small vessel berth.

The numbers above are used to refer the appropriate area during the summaries below.

Darwin Harbour, Vibrocore Sample Acquisition Analysis and Report (Seas Offshore, 2010)

As part of a bathymetric validation program in 2010, a total of 147 seabed vibrocore samples were undertaken in East Arm, Elizabeth River and Middle Arm. At East Arm, 43 samples were taken. In summary, the depth of core obtained from the EAW sites ranged from 0.53 m to 2.80 m (providing an indication of the depth of refusal). However, the depth of core barrel used was 2.80 m; therefore this investigation may not give a true reflection of the depth of marine sediments at the site for depths greater than 2.80 m.

Three Proposed Dredge Areas, Report on Previous Geotechnical Information and Suggested Further Work (Douglas Partners, 2010)

This report (prepared in October 2010) presents the findings of a desk study covering development area sites (1), (2) and (3). In particular this report outlines the likely depth of dredging required at each site and provides recommendations for further investigation. A summary of the findings relevant to each of the development areas is provided below.

- For the MSB, the development plans indicate that up to 10 m of dredging will be required at the northern end of the site, varying to zero at the southern end. The previous investigations in this site suggest that the dredging will generally be in overburden soils (depths in the range 3 m to 5 m) and varying depths in the underlying rock. The depth of rock to be removed varies from 0.5 m of low strength phyllite to 3 m of very low to low strength meta-siltstone (phyllite). There is no information on the rock level in the north-east corner of the site. The report recommends drilling six additional boreholes in this area.
- For the barge ramp and hardstand area, the report indicates that the dredge depths will range form zero at the southern end to 3 m at the northern end. Previous investigations in this area indicate that up to 3.2 m of overburden overlies rock in this area. No information is available on the strength of the overburden soils, or of the underlying rock. The report recommends drilling three additional boreholes at this site.
- There is no information available for the tug berth area. Five boreholes are recommended for this site.

Sediment Sampling for Rock Hardstand and MSB (TR21/09) (Douglas Partners, 2009)

This report presents the results of an investigation conducted in 2009 to provide information on the depth of marine sediments at the site of the proposed MSB and RLO hardstand. This investigation took place on the site of development areas (1) and (2).

The investigation comprised land based fieldwork (utilising dynamic cone penetrometer [DCP] testing and sediment sampling) and overwater work (DCP testing). The results of the investigation indicate that in the hardstand area, up to 1 m of very soft marine mud, or sand and mud, was encountered until refusal was met. In the southern part of the area a mixture of marine mud, sand and gravel-sized coral fragments was encountered.

The results of the probing at the proposed MSB site indicate that, in the north of the site, less than 0.2 m of sand and mud was encountered, with the mud and sand increasing in depth to 2 m in the south of the site. The maximum thickness recorded was 2.6 m in the south-west corner of the site.

Based on the results of the investigation and state of knowledge of the proposed development, the report suggested a construction strategy, summarised below:

- Excavate or dredge the marine sediments from the north-west corner of the site, and from the footprint of the bund walls.
- Construct a perimeter bund wall by end-tipping rock fill and then shaping the side slopes to the final design profile.
- Place geotextile and rock armour on the side slopes.
- Fill the area inside the bund wall by end-tipping rock fill.

6 Geology, Landforms and Soils

Geotechnical Investigations for Intermodal Container Terminal and Access Embankments (TR17-01) (Gutteridge, Haskins & Davey, 2001)

This report presents the findings of an investigation for Stage 2A of the EAW – an area immediately to the north west of the MSB (2). Broadly speaking, the sub-surface profile is described as marine sediments over weathered rock, and the report further classifies the sub-surface profile into nine material types, summarised below:

- A – clay - soft mud, marine sediment.
- Ao – organic clay – soft organic mud, marine sediment.
- A(s) – sandy clay – soft sandy mud, marine sediment.
- As – sand to clayey sand – predominantly sand, marine sediment.
- B – stiff clay.
- C – stiff clay, residual.
- 1 – gravel and clay, extremely weathered phyllite.
- 2 – phyllite, more weathered.
- 3 – phyllite, less weathered.

Testing of Potential Acid Soil Samples from Railway and Marshalling Yards (TR23/99) (Melville, Macdonald and Keene, 1999)

Assessment and testing of the geochemical properties of 40 samples taken from ten cores of marine and estuarine sediments from the above site was undertaken in 1999. No ASS were identified; however PASS were identified in 12 of the samples. The report highlights that there are high environmental risks associated with the excavation of sampled soils and preparation of an ASS management plan was recommended.

Preliminary Geotechnical Investigation on Spoil Areas A and B (TR29/98) (Ullman & Nolan Geotechnic, 1998)

This investigation was undertaken in 1998 to assess the trafficability of spoil areas (mainly dredged spoil) and to advise on methods of access to the areas for testing.

Old Man Rock Sandbar, Search for Reclamation Material (TR35-97) (Acer Forester, 1998)

An investigation was undertaken in 1997 at the site of a sand bar, to search for a suitable source of sand for use in reclamation as part of the EAW development. The report concluded that the sand bar was a viable source of sand fill (shell or quartz sand with little or no fines and of low to medium density).

Report and Calculations Darwin East Arm Wharf (TR49-97) (Pells Sullivan Meynink, 1997)

Analysis and computations for sheet pile embedment design at EAW, undertaken for the Barclay Mowlem Thiess Joint Venture in 1997, are presented in this letter report.

Earthworks Characterisation and Trunk Drainage Study (TR19-98) (Gutteridge, Haskins & Davey, 1997)

This report presents the results of a desktop study carried out to set site development levels, identify fill requirements and sources of fill, and to prepare a drainage masterplan. The study appears to cover most of the area proposed as part of the existing EAW development. Based on a minimum site development level of 5.5 m AHD, it was established that significant filling would be required and that terrestrial fill was in short supply.

Report on Preliminary Site Investigation for Joint User Fuel Storage Terminal (Dames and Moore, 1997)

This investigation was undertaken in 1997 to provide an estimate of the nature and extent of soft marine sediments across the site, evaluate their geotechnical properties and advise on fill placement. The fieldwork consisted of mud probing and vane shear testing. The results of the mud probing indicated that refusal was met on either gravel or rock at depths in the range of approximately 1 m to 5 m. Field vane shear testing results showed that the clay was very soft (residual shear strengths less than 5 kPa).

Different options for filling to create the bund are also presented in the report – these include volume and cost comparisons for filling different lengths of the wall and at different rates (i.e. with or without surcharging). The recommendation made in the report was to construct the bund as a floating embankment type, with rock fill placed on a geotextile.

Geotechnical Investigation - Water Main Cochrane Road to East Arm Port (TR40/96) (Ullman & Nolan Geotechnic, 1996)

The above investigation was undertaken in 1996 to provide information for the design and construction of a water main (approximately 4 km long). The investigation consisted of test pits, DCP tests and mud probing. Six different soil/rock types were identified along the route, and shear strength parameters and excavation characteristics were assigned to each type.

Wharf Alignment Geotechnical Investigation (TR28/96) (Acer Vaughan, 1996f)

A geotechnical investigation was undertaken in 1996 to evaluate foundation conditions along the EAW alignment. Overwater diamond core drilling was undertaken and the report concluded that there was an irregular distribution of strength and weathering in the underlying phyllite rock and that it was difficult to assess sheet pile driveability.

Walker Shoal Drilling Investigation (TR29/96) (Acer Vaughan, 1996e)

This 1996 investigation consisted of drilling of ten boreholes at Walker Shoal, described as a submarine high (or ridge), within EAW. The investigation concluded that Walker Shoal is composed of quartz conglomerate of high to very high strength.

Supplementary Investigation for Wharf Embankment Bund N (TR21-96) (Gutteridge Haskins & Davey, 1996)

This report presents the results of a geotechnical investigation carried out in 1996, to provide input to the construction of a 450 m long embankment. This is a factual report, including borehole logs and laboratory test results only, with no interpretation of the results.

6 Geology, Landforms and Soils

Description of Dredged Materials (TR24/96) (B. Webber, 1996)

This brief report summarises the results of the visual description and classification testing of eight samples obtained from dredging points for the first phase of the EAW project. The samples are described as either the basal layer of seabed sediments (5 samples) or extremely weathered phyllite (3 samples).

Probe Sampling beneath Bund Wharf 'N' (TR01/96) (Acer Vaughan, 1996d)

An investigation was undertaken in late 1995, whilst the bund wharf was under construction, to confirm the bund foundation level. At the time of construction, CSDs were experiencing difficulties in removal of stiff high plasticity clays. The investigation confirmed the presence of very soft to soft marine clay overlying a stiff to very stiff high plasticity clay. The probes were terminated on dense to very dense gravel or phyllite bedrock.

Bund Wall K Slip Investigation (TR29-95) (Acer Vaughan, 1995b)

A geotechnical investigation was undertaken at the partially constructed bund wall in 1995 after a slip failure had occurred, resulting in the displacement of fill and formation of a mud wave at the toe of the failure. Slope stability analysis was undertaken to provide the geometry of a stabilising berm for the failed area of the bund wall.

Geotechnical Investigation of East Arm Port Alternative Development Stage 1A (TR02-95) (Acer Vaughan, 1995c)

This report presents the results of an investigation carried out between January and April 1995 for Stage 1A of the East Arm Port Development. The investigation consisted of geophysics, in situ (piezo cone) testing and offshore drilling. The report concluded that the soft / loose sediments were unsuitable as a founding layer, and parameters were provided for deep and shallow foundation design in the underlying rock. Recommendations for batter angles for excavation in the rock material at different heights were also provided.

Assessment of Acid Leachate in Marine Sediments (TR23/95) (Acer Vaughan, 1995a)

In 1995, an assessment of geochemical properties of 21 samples taken from 4 cores of marine sediments from the EAW development area was undertaken to confirm, or otherwise, the presence of ASS. The testing indicates that no ASS, highly reactive ASS or moderately reactive PASS was encountered. However, weakly reactive PASS was encountered in three of the core samples, indicating low acidification potential. Note that this report refers to core samples taken from an area about 1 km to 2 km east of the proposed expansion of the quay line, to the south of the rail line.

Geotechnical Investigation Stage 2 (Volume 3 Dredging and Reclamation) (Acer Vaughan, 1994d)

This report summarises a geotechnical investigation undertaken in 1994 to assess the suitability of dredged material for reuse in reclamation. A number of issues are highlighted in the document and these are outlined below.

- Difficulties in identification of areas of sandstone and quartzite (typically these rock types are higher strength than phyllite and are not able to be ripped and could cause problems in dredging).

- Cohesive marine mud sediments are not considered suitable for reuse due to their low strength and high compressibility.
- The granular sediments are likely to be suitable for reuse, but there are difficulties in sourcing this material owing to issues with the thickness and continuity of the layers.
- Phylllite is described as being a poor quality fill due to its tendency to deteriorate under compactive effort.

Geotechnical Investigation Stage 2 – Volume 2 Wharf Foundations (TR01-94) (Acer Vaughan, 1994c)

This report summarises the results of the 1994 investigation into the foundations for the wharf structure. The key finding from the investigation was that the sediments overlying rock would be unsuitable as a founding strata for gravity structures, and that either the sediments be removed and structures founded on rock, or large diameter bored piles be used (with a socket into the rock).

Geotechnical Investigation Stage 2 - Volume 1 Bund Wall and Access Road Construction (Addendum Report, TR01-94)) (Acer Vaughan, 1994b)

This is an Addendum report which presents the findings of additional mud probes carried out along the wharf alignment, to provide additional information to the designers as the original investigation showed variations in sediment thickness over short distances. Long sections along the bund wall are presented in the report.

Geotechnical Investigation Stage 2 (Volume 1 Bund Wall and Access Road Construction) (Acer Vaughan, 1994a)

This investigation was undertaken in 1994 and consists of two main components – an investigation into the potential for supply of construction material for the initial stages of the development, and an assessment of foundation conditions along the alignment of the proposed embankments.

The resource investigation classified the rock lithology into two broad types – sandstone and phyllite – and mechanical properties of each type were defined. The report concluded that the sandstone was likely to be suitable as a rock fill or armour stone, and that the phyllite would not be suitable for use as a rock armour or rock fill, but could potentially be used as a bulk fill if placed in dry weather.

Three potential quarry sites were identified and the report indicated that blasting would likely be required at each site to win the material required.

The foundation investigation found that sediment thicknesses (soft organic silty clay or soft silty clay) ranged from 0.5 m to 5.0 m, and varied considerably over short distances.

Geotechnical Studies – Desiccation of Marine Sediments from Darwin Harbour (TR02/94) (Clark / Foscaro, 1994)

This study was carried out in 1994 to determine the optimum methods for drying high-plasticity marine clays for use in fills. A laboratory testing program was carried out on a number of samples of clay obtained from Darwin Harbour. The results of the tests are summarised in the report; however, no interpretation or conclusions are provided.

Stage 1 Geotechnical Investigation (TR34/93) (Dames & Moore, 1993a)

This report presents the findings of a preliminary (Stage 1) geotechnical investigation carried out for the East Arm Project between November 1992 and April 1993. Onshore and offshore investigations were performed at Quarantine Island.

The onshore investigation was undertaken to assess the suitability of materials on Quarantine Island for use in construction of a seawall and reclamation area; this was based on review of previous data. The review found that phyllite was suitable for use in reclamation areas, but not below water, and that quartzite and sandstone are suitable for use in the upper layers of the reclamation areas. Regarding rippability of rock material, the review found that phyllite should be rippable by a D8 dozer or similar, and that the quartzite and sandstone would be unlikely to be able to be ripped.

The offshore investigation consisted of drilling five boreholes and the results of the investigation indicate the presence of around 1 m to 3.6 m of seabed sediments overlying phyllites, with interbedded sandstones and quartzites. Limited testing indicated that the sediments have low potential for acid sulphate generation when exposed to air.

The report indicates that the phyllite should be capable of excavation by CSD, but that dredgeability could be restricted by the presence of the higher strength quartzite and sandstone.

East Arm Stages 1B and 2A Industrial Subdivision (TR50/92) (Dames & Moore, 1993b)

This report presents the findings of a geotechnical investigation carried out for industrial land located in the area to the north of the eastern end of the proposed rail loop.

East Arm Trawler Facility Investigation Report (TR32-88) (Gutteridge Haskins & Davey, 1988)

This report summarises the findings of a feasibility study into the construction of a fishing facility at EAW, and geotechnical considerations were included as part of the wider study brief. The report references a geotechnical investigation carried out in 1981, which found that the area was underlain by soft estuarine sediments overlying siltstone rock. Probing found that the top of the siltstone was generally at a level of -3.0 m to -3.5 m CD.

Subgrade Investigation – East Arm Industrial Area (TR59/97) (Dames & Moore, 1987)

This report presents the results of a pavement subgrade investigation undertaken in 1987 at Cochrane and Muramats Roads. These sites are around 1.2 km south of the eastern end of the proposed rail loop. A soaked California Bearing Ratio test was undertaken on a single sample from each road and values of 40 and 35 were reported.

Geotechnical Investigation for Proposed East Arm Trawler Facility (TR06-81) (Dames & Moore, 1981)

This report summarises the results of a preliminary investigation into a trawler facility at East Arm. Foundation and borrow source investigations were undertaken in 1981 and the generalised profiles of the onshore and offshore subsurface conditions are provided in the report. These are summarised below.

- The offshore geological sequence is described as estuarine mud (up to 2.5 m thickness of silty sand and 4.7 m thickness of very soft silty clay) over residual soil (1.0 m to 7.0 m of gravelly sand and sandy clay), over micaceous siltstone.
- The onshore geological sequence is described as colluvium (up to 2.5 m thickness of silty gravels) over residual soil (up to 0.8 m), over siliceous siltstone (porcellanite) overlying interbedded siltstone, greywacke and conglomerate.

Site Investigation and Testing for Bulk Cargo Facility at Darwin East Arm (TR01-71) (Soilmech, 1971)

This report summarises the results of an investigation conducted for a proposed embankment running from Quarantine Island into Darwin Harbour. The investigation was undertaken in 1971 and provides information on the properties of the clay sediments along the embankment alignment and an investigation into the quarry potential of rock on Quarantine Island.

The clay is described as very soft to soft in consistency and was found to reach a maximum thickness of around 5 m. The rock on Quarantine Island in the area investigated was found to be a laminated phyllite and deemed to be unsuitable as rock armour.

Geotechnical Investigation (Volume VII Reclamation Area) (Coffey and Hollingsworth, 1970c)

This report presents the findings of a geotechnical investigation undertaken in 1970 in the Outer Harbour area of Darwin to locate a borrow source for sand fill suitable for use in reclamation work in the proposed port facilities. The investigation was predominantly carried out in an area to the north and west of Middle Point. The results of the investigation concluded that suitable sandy material, estimated to be in the order of several million cubic yards, was located in one area (designated Area A). No suitable material was found in six other areas investigated.

Geotechnical Investigation, Volume V, Frances Bay (TR04-70) (Coffey and Hollingsworth, 1970b)

An offshore site investigation was carried out in 1970 in an area to the north of Stokes Hill (the site of a proposed small ships facility in Frances Bay). The results of the investigation indicated that soft, high plasticity clay (mud) of around 1 m to 2 m thickness was encountered over phyllite rock.

Geotechnical Investigation (Volume III) (Coffey and Hollingsworth, 1970a)

This report presents the findings of a 1970 geotechnical investigation carried out at Quarantine Hill. The purpose of the investigation was to make an assessment of the area as a possible borrow source for rock fill for the construction of the East Arm causeway. The investigation identified the presence of fresh to moderately weathered medium strong or stronger greywacke, conglomerate and quartzite and medium strong phyllite as being suitable for use as select rock fill.

Proposed Port Development at Darwin, Report on Site Investigation (TR01-68) (George Wimpey & Co)

The results of a site investigation undertaken in 1968 at two sites (East Arm and Middle Arm) are presented in this report. The results of the investigation at East Arm found that phyllite rock was overlain by either sands and gravels (north of the site) or silts, clays and shells (south of the site).

6.3 Potential Impacts and Management

The review of the published information and previous investigations in the area, summarised in Section 6.2, identified the key soils, landform and geotechnical issues to be addressed as part of the EAW development. These are summarised below.

6.3.1 Soil Erosion and Disturbance

The proposed rail loop will be the main land-based activity where soil erosion is a potential issue. Cut and fill earthworks will be required and, if embankments are required to form the new rail loop, erosion could be an issue during heavy rainfall events. Consequently, soil erosion and sedimentation control and management measures will be implemented during construction.

The dredging and reclamation activities associated with the other components of the development will also require soil erosion and sedimentation management measures in place during construction.

A Soil Erosion and Drainage Management Plan would be prepared for the construction activities at the site. This Plan will address items as such as stabilisation and rehabilitation of exposed soils, and provision of silt fences and other such controls during construction.

6.3.2 Acid Sulphate Soils

ASS generates sulphuric acid when exposed to oxygen and can also mobilise metals. Earthworks, dredging and reclamation activities are likely to result in material being exposed to oxygen and this is considered to be a potential risk.

Previous investigations indicate the presence of PASS and possible ASS in the area. Thus, given that significant amounts of dredging and earthworks will be required there is the risk that ASS could be encountered.

An ASS Management Plan would be prepared for the construction activities at the site. The primary aims of the Plan will be to:

- Outline measures for minimisation of disturbance of areas where ASS may occur.
- Implement appropriate management techniques to reduce the potential for production of acid and / or release of acidity as run off caused by exposing ASS to oxygen.
- Ensure that adequate Occupational Health and Safety (OH&S) measures are adopted when dealing with ASS soils, and incorporation of this information into the OH&S Plan.

6.3.3 Sourcing of Fill

Fill material will be required mainly for construction of bunds and infilling of reclaimed areas, although fill material may be required in other areas. It is noted that the final design for the site is not available, and thus quantities of volumes of cut and fill are not finalised. Thus at this time it is possible only to provide general comment on the types of material that could be encountered, and their potential use; also potential specific borrow sources for fill are unknown at present.

It is likely that a select rock fill will be required for construction of the bunds, and larger rock will be required for use as rock armour. Previous investigations indicate that in general a layer of marine sediments of variable thickness overlies weathered rock at the site. The marine sediments are described as either very soft to soft clay or mud or clayey sand or sand. In some locations thin layers

of residual soils, consisting of either stiff clay or sand and gravels, were also encountered underlying the soft marine mud.

The underlying weathered rock is typically described as very low to low strength phyllite (or meta-siltstone) with interbedded sandstones and quartzites. The phyliite is described as being rippable, however, it is unlikely to be suitable for use as rock armour or rip rap due to its relatively low strength and susceptibility to slaking and deterioration. However, it is possible that the phyllite could be used in reclamation as a general fill.

The presence of sandstone and particularly high strength quartzite bands may result in ripping of the rock not being possible. However, if this type of material can be recovered on site, it may be suitable for use as select rock fill.

The key areas that need to be addressed as part of the design development process and that prevent further, more detailed, comment on earthworks being made are outlined below.

- An Earthworks Plan (or separate Plans for each of the individual development areas) that details cut and fill volumes, finished site levels, excavation or formation levels and specifications for fill materials will be prepared.
- The Earthworks Plan will be used to determine the net quantities required from external sources, following which potential borrow sources can be identified and investigated. This will likely involve field investigations to assess the nature and suitability of materials to meet the specifications, and also to evaluate the likely available quantities of suitable fill in specific locations.
- Further geotechnical investigation will be undertaken in the three areas to be dredged, as well as along the alignment of the proposed rail loop. This investigation has been commissioned; however the results are not available for inclusion in this DEIS.

6.3.4 Foundations and Geotechnical Matters

Based on the currently available information, the following items are considered to be the main issues associated with foundations for the proposed development.

Bund Wall Foundations

A significant length of bund wall is to be constructed by end-tipping rock fill. Based on the anticipated sub-surface soil profiles at the sites, establishment of a suitable foundation layer will be a key issue. Weak marine sediments, present from bed level to underlying rock, are unlikely to be suitable as a foundation and if feasible the weak material would be removed to ensure that the foundation has adequate bearing capacity to prevent failure of the bund and to minimise settlement.

Alternatively, if the weak material is left in place and the bund wall is constructed by end tipping, it is likely that select rock fill would be placed directly onto the seabed sediments, followed by mud waving. Mud waving refers to refers to the lateral squeezing of soft foundation soil that occurs due to the surcharging effect of dumped embankment fill. The impacts of adopting this as an alternative construction method will be:

- A net increase in required fill volumes
- The presence of mud waves at and beyond the toe of the bund walls may have to be addressed
- The potential for slip failures in the bund wall during construction will also need to be addressed – most likely by provision of flat side slopes or stabilising berms

- Increase in dredge plumes.

These construction issues would be addressed during the detail design stage of the project.

Sheet Pile Installation

The extension of the quay line and construction of the MSB will involve sheet pile installation. Design details are not known at this stage; however, it is anticipated that the following will need to be addressed in design and installation of the sheet piles:

- The presence of weak marine sediments will likely mean that the piles will need to be embedded into the underlying weathered rock to give an adequate factor of safety for stability of the sheet pile wall. Refusal could be met before the target toe level, when driving sheet piles into underlying weathered rock and it is possible that pre boring may be necessary. Pile installation will be addressed as part of the design process. Cathodic protection will be designed and included to expand life of piles.
- Long-term corrosion of the sheet piles will be addressed as part of the design process to ensure that the bending stresses in the pile can be catered for by the potential loss of section thickness.

It is noted that it is possible that other foundation and geotechnical matters will encountered and addressed during the detail design process, and other marine investigations may be required. The EIS Supplement will provide an update on any investigations undertaken.

6.4 Commitments

- *A Soil Erosion and Drainage Management Plan would be prepared.*
- *An ASS Management Plan would be prepared.*
- *Adequate OH&S measures for dealing with ASS soils will be incorporated into the Construction OH&S Plan.*
- *An Earthworks Plan (or separate Plans for the individual development areas) would be prepared that details cut and fill volumes, finished site levels, excavation or formation levels and specifications for fill materials.*
- *Specific site geotechnical land and marine investigations will be undertaken as required; the EIS Supplement will provide an update on any investigations undertaken.*

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