12. SEDIMENT CHARACTERISATION

Arrow Energy is undertaking a geotechnical investigation program to provide geotechnical information to support the design of the proposed LNG facility and ancillary infrastructure. The program is also providing sediment sampling data to inform the development of dredge management plans and acid sulfate soil management plans which will be prepared and submitted prior to construction commencing.

Final results of the geotechnical investigation and sediment sampling program were not available at the time of writing this report. Analysis of samples collected to date has enabled preliminary results of the sampling program to be presented in this chapter. They have been augmented with sampling analysis data from the Western Basin Dredging and Disposal Project for the LNG jetty, as that site had not been investigated at the time of writing this report. The preliminary results were used to highlight any departures from the conclusions reached in studies undertaken for the Arrow LNG Plant Environmental Impact Statement (EIS) (Coffey Environments, 2012).

The findings of studies undertaken for the EIS to ascertain sediment particle size and contamination, and acid sulfate soils are summarised in this chapter along with changes to the project description. The preliminary results of the sampling program and recommendations for further management measures are also presented.

The preliminary results of sediment characterisation described in this chapter relate to dredging areas only and have been used to inform the coastal processes study completed by BMT WBM Pty Ltd (Appendix 7) and the marine ecology study completed by Coffey Environments Pty Ltd (Appendix 9). Impacts on coastal processes are summarised in Chapter 14, Coastal Processes and impacts on marine ecology in Chapter 15, Marine Ecology.

Several submissions on the EIS raised issues in relation to marine sediment quality. Details of the submissions are set out in the submissions issues register in Part B of the SREIS, together with responses to specific issues raised.

12.1 Studies and Assessments Completed for the EIS

This section describes the sediment characterisation studies completed for the EIS and the key findings of those studies. Chapter 12, Land Contamination and Acid Sulfate Soils and Chapter 16, Marine Water Quality and Sediment of the EIS describe in detail the assessments completed, potential impacts and key findings of the studies.

12.1.1 Contaminants and Particle Size Distribution

Existing sediment quality in the study area was described and based on a desktop review of previous studies, supported by a two-part sediment sampling campaign conducted by Central Queensland University (CQU) in May 2010 and February 2011 (Appendix 8 of the EIS). Sediment samples were collected from 13 sites in Port Curtis and along the Calliope River. Samples were analysed for particle size distribution, metals, carbon content and polycyclic aromatic hydrocarbons (PAH).

Results from the sampling campaign were assessed against the criteria set out in the National Assessment Guidelines for Dredging (NAGD) (DEWHA, 2009a) which set out the regulatory framework for assessing impacts from dredging and offshore disposal, and ANZECC/ARMCANZ (2000) guidelines, which provide interim sediment quality guidelines. These guidelines were used to determine project sediment quality assessment criteria which are provided in Table 12.1.

Table 12.1 Project sediment quality criteria

Parameter	Project criteria[a]	
	Unit	Value
Metals and metalloids		
Arsenic	mg/kg dry weight	20
Cadmium	mg/kg dry weight	1.5
Chromium	mg/kg dry weight	80
Copper	mg/kg dry weight	65
Nickel	mg/kg dry weight	21
Lead	mg/kg dry weight	50
Zinc	mg/kg dry weight	200
Organometallics		
Tributyltin (TBT)	µg Sn/kg dry weight	5
Organics		
Total polycyclic aromatic hydrocarbon (PAH)	µg/kg dry weight	4,000
Total polychlorinated biphenyl (PCB)	µg/kg dry weight	23
Herbicides and organochloride (OC) and organophosphate (OP) pesticides		
Total dichlorodiphenyltrichloroethane (DDT)	µg/kg dry weight	1.6
Chlordane	µg/kg dry weight	0.5
Dieldrin	µg/kg dry weight	0.02
Endrin	µg/kg dry weight	0.02
Lindane	µg/kg dry weight	0.32

[a] Project targets are for interim sediment quality guideline low trigger values (ANZECC/ARMCANZ, 2000).

The results of the sediment analysis found that metals and metalloids at the project dredge sites did not exceed project sediment quality criteria.

Sediment particle size distributions were found to be consistent in the intertidal and subtidal areas of Boatshed Point, Hamilton Point and Calliope River. Sediments at those sites comprised 60% to 80% muds and silts, and 20% to 40% sands and gravels. Some intertidal sediments in the Calliope River were found to have lower mud and silt fractions (20% to 40%) and higher sand and gravel fractions (60% to 80%).

The study concluded that further investigation of marine sediment using geotechnical drill cores was required to characterise material that will be disturbed during dredging and construction of marine facilities. The investigation would also inform the development of a dredge management plan.

The EIS commitments to further investigate the characteristics of sediments in the project area are listed in Table 12.2.

Table 12.2 EIS commitments: sediment quality

No.	Commitment
C12.01	Prior to construction, the extent of contamination will be further defined where required, and mitigation measures will be refined as appropriate.
C12.17	Develop an ASS management plan prior to construction work. In the plan, specify how onsite ASS disturbances should be managed in accordance with SPP2/02 and the methods set out in Queensland acid sulfate soils technical manual soil management guidelines (Dear et al., 2002). Common with Chapter 14, Groundwater.
C15.02	Develop a dredge management plan that considers the appropriate water and sediment monitoring data (e.g., current WBDD Project data) and will include:
C15.03	• Requirements for monitoring of water quality.
C15.04	• Actions to be taken to minimise the impacts of dredging on sensitive areas should water quality monitoring data show performance criteria are exceeded. Finalise specific actions in the dredge management plan.
C16.02	Obtain sediment samples from geotechnical drill cores to further characterise marine sediments disturbed during construction. Use the results to inform the development of the dredge management plan.

12.1.2 Acid Sulfate Soils

Coffey Geotechnics investigated the presence of acid sulfate soils (ASS) and potential acid sulfate soils (PASS) in marine and estuarine environments in the study area (Appendix 4 of the EIS, Acid Sulfate Soil Impact Assessment). A desktop study, soil investigation and risk assessment were conducted as part of a preliminary investigation to identify the presence of acid sulfate soil horizons in the study area and inform the design of a site-specific acid sulfate soil sampling program.

The acid sulfate soils investigation method for the EIS followed procedures set out in the State Planning Policy 2/02 (SPP 2/02) and associated Queensland Acid Sulfate Soils Investigation Team (QASSIT) Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland (Ahern et al., 1998).

The desktop study determined that ASS usually occur in Holocene marine and estuarine environments below 2.5 m AHD. The desktop study identified deficiencies in the existing data sets, with no or inadequate acid sulfate soils records for launch site 1, Boatshed Point, Hamilton Point and the LNG jetty sites.

The presence of acid sulfate soils at the project sites was confirmed using existing quantitative data sets from boreholes sampled within 200 m of the proposed areas of disturbance. The extent and severity of acid sulfate soils horizons in the project area varies greatly, ranging from no acid generating potential (self-neutralising) to extremely high acid generating potential (up to 4.67% oxidisable sulfur).

The study concluded that additional site-specific acid sulfate soils investigation for all project sites below 5 m AHD was required to characterise sediment and facilitate the development of an acid sulfate soils management plan.

The EIS commitments to further investigate and manage acid sulfate soils in the project area are included in Table 12.2 above.

12.2 Project Description Update

This section presents a summary of the changes to the project description resulting from front-end engineering design (FEED) and investigations carried out since the EIS was published, specifically in relation to dredging and dredge spoil disposal.

12.2.1 Marine Infrastructure

The layout of launch site 1 (mainland launch site)and the materials offloading facility (MOF) and integrated personnel jetty at Boatshed Point have been revised. Boatshed Point remains the preferred site for the MOF and integrated personnel jetty. The alternate site at Hamilton Point South has been discontinued. Launch site 1 remains Arrow Energy's preferred option for mainland launch facilities, with launch site 4N retained as an option. Changes to the Boatshed Point MOF and integrated personnel jetty and mainland launch site are illustrated in figures 4.4 and 4.5 respectively.

12.2.2 Dredging Footprint and Volumes

With the exception of dredging required for launch site 4N, all dredge footprints and/or volumes have been revised due to design changes and improved bathymetry. Table 6.1 (Chapter 6, Project Description: Dredging) lists the revised dredge volumes and Figure 6.1 shows the extent of capital dredging. The volumes and extents will be further refined during detailed design to reflect amongst other things, construction schedule requirements and equipment selection.

Despite improved bathymetry which shows dredging may not be required in the vicinity of the personnel jetty to be constructed as part of the mainland launch site in the Calliope River, the estimated volume of material to be dredged to create the Calliope River access channel has been retained at 900,000 m^3.

Changes to the design of the Boatshed Point MOF and integrated personnel jetty have resulted in an increased capital dredging volume of 148,000 m^3. The inclusion of an access channel and swing basin (165,000 m^3) has increased the estimated dredging volume at this site to 313,000 m^3.

Reconfiguration of the dredge footprint at the LNG jetty to account for revised marine-based construction methods has resulted in the capital dredging volume increasing from 120,000 m^3 to 131,000 m^3.

12.2.3 Disposal of Dredge Spoil

The EIS identified several options for disposal of dredged material. These options have been revised, with the preferred option to place dredge material in a combination of existing, approved disposal areas and facilities as follows:

- All PASS dredge spoil removed from Boatshed Point, the LNG jetty and Calliope River to be placed in the East Banks Disposal Site.
- Non-acid sulfate soils dredge spoil:
  - Boatshed Point dredge spoil to be placed in the East Banks Sea Disposal Site.
  - LNG jetty dredge spoil to be placed in the East Banks Sea Disposal Site or the Western Basin Reclamation Area.
  - Calliope River access channel dredge spoil to be disposed in the Wiggins Island Coal Terminal dredge placement facility or in the East Banks Disposal Site.

Other approved dredge spoil disposal sites will also be considered should they become available in time to receive material dredged to facilitate construction and operation of the project.

12.3 Applicable Guidelines

Guidelines presented in the EIS that are relevant to the analysis of sediment and acid sulfate soils are set out below.

The NAGD (DEWHA, 2009a) sets out the framework for the assessment and permitting of the ocean disposal of dredged material. The framework provides a case-by-case assessment decision tree for designing an applicable sediment sampling program.

State Planning Policy 2/02 Planning and Managing Development Involving Acid Sulfate Soils (SPP 2/02) (LGP/NRM, 2002) sets out the requirements for assessment and management of acid sulfate soils occurring in sediments at or below 5 m AHD. It applies to activities involving the excavation or filling of land. The associated guideline SPP 2/02 Guideline: Acid Sulfate Soils (LGP/NRM, 2002) provides advice on interpreting and implementing the policy including the need to consult the Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils in Queensland 1998 (QASSIT guidelines) (Ahern et al., 1998).

The QASSIT guidelines provide a state-wide approach for the sampling and analysis of acid sulfate soils. The guidelines follow a risk-based approach whereby the design of the sampling program is dependent on the nature, depth and size of the proposed disturbance.

Table 12.3 sets out the QASSIT guidelines action criteria against which oxidisable sulphur values are measured. For activities disturbing more than 1,000 tonnes of soil with greater than 0.03% oxidisable sulfur, a detailed management plan and development consent are required.

Table 12.3 Action criteria based on ASS analysis for three broad texture categories

		<1,000 Tonnes Disturbed		>1,000 Tonnes Disturbed	
Soil Texture	**Clay Content %**	**Sulfur trail (%S oxidisable)**	**Acid trail (H+ mol/tonne)**	**Sulfur trail (%S oxidisable)**	**Acid trail (H+ mol/tonne)**
Coarse texture (sandy – gravels)	<5	0.03	18	0.03	18
Medium texture (sandy loam – light clay)	5 – 40	0.06	36	0.03	18
Fine texture (medium to heavy clays, silty clays)	> 40	0.10	62	0.03	18

12.4 Sampling Program and Method

This section describes the sampling program and method used to characterise marine sediments in the project area.

12.4.1 Sampling Program Design

The geotechnical investigation included a sediment sampling campaign consistent with the requirements of the NAGD and QASSIT guidelines to inform water quality, coastal processes and marine and estuarine ecology investigations undertaken as part of the SREIS.

Contaminants

The NAGD specify the requirements for sediment sampling programs. Figure 5 of the guidelines sets out a sampling design decision tree. The number of sampling sites is determined by the volume of potentially contaminated material. Potentially contaminated sediment is defined in NAGD as:

> Sediment that is contiguous with an area of known sediment contamination, or sediment exposed to known contamination sources.

Further clarification of the strata that might be contaminated is provided in the following extract from page 60 of the NAGD.

> … the layer of recent sediments which could be contaminated, but does not include the volume of underlying natural geological materials which are, except for a thin boundary layer, expected to be uncontaminated.

Apte et al. (2005) estimated the top 28 cm of sediments at intertidal and subtidal sites in Port Curtis have been deposited since 1958. This date coincides approximately with the start of industrialisation in Gladstone and defines the sediment layer that may contain anthropogenic contaminants. Consequently, for this project, it has been assumed that the top 1 m of sediment to be dredged could potentially be contaminated. This assumption allows for potential mixing of underlying sediments and the deposition of additional sediments since 2005.

Previous investigations of sediments in Port Curtis have found sediment quality to be compliant with the NAGD sediment quality guidelines. Therefore, the material at the proposed dredge sites is defined as being ‘probably clean’ as opposed to ‘probably contaminated’ or ‘suspect’, as defined under the NAGD.

The NAGD specifies the number of sampling locations required per dredge area, based on the volume of potentially contaminated material to be dredged. For potentially contaminated material classified as ‘probably contaminated’ or ‘probably clean’, the number of sampling locations is halved.

Acid Sulfate Soils

The QASSIT guidelines set out the requirements for the sampling and analysis of acid sulfate soils. The guidelines use a risk-based approach for the design of sampling programs dependent on the nature, depth and size of the proposed disturbance.

Where the area of disturbance exceeds 4 ha, the QASSIT guidelines recommend two holes per hectare for environmental impact assessment purposes. If ASS/PASS is identified, the density of holes may need to be increased to 50 m intervals to inform the development of acid sulfate soil and dredge management plans.

12.4.2 Sampling Locations and Sample Site Selection

The sampling program for sediment characterisation for dredge spoil classification and determination of disposal options focussed on the three key dredging sites:

- Boatshed Point (geotechnical investigation area 8).
- LNG jetty (geotechnical investigation area 10).
- Calliope River (geotechnical investigation area 13).

Historic evidence indicates that sediments in Port Curtis are 'probably clean' and unlikely to be contaminated. Consequently, the number of sampling sites required by NAGD for particle size and contamination testing could be halved.

Completion of the geotechnical investigation will satisfy the requirements of NAGD and QASSIT guidelines. However, at the time of writing this report, not all sampling sites had been completed and a subset of the required sites was adopted for the purposes of the supplementary report to the EIS.

The subset was based on the requirements of NAGD which require the random selection of sampling sites based on an evenly spaced grid on the dredge footprint. The sites identified by this method were augmented with additional sites to ensure adequate coverage of the areas of interest and to enable screening for the presence of ASS/PASS.

As noted, the LNG jetty site had not been sampled at the time of writing this report and consequently, data from a limited number of sampling sites from the Western Basin Dredging and Disposal Project was used to screen for contamination and ASS/PASS, and to confirm particle size and composition assumptions used in the EIS for that site.

Table 12.4 lists the number of sampling sites required under NAGD assuming 'probably clean' sediment and QASSIT guidelines, along with the number of sampling sites available for analysis at the time of writing this report.

Table 12.4 Number of sampling sites available for analysis

Area No	Dredge Site	Dredge Volume (m^3)	Dredge Area (ha)	No. of Sampling Sites (NAGD)[1]	No. of Sampling Sites (QASSIT)[2]	No. of Sampling Sites (SREIS)[3]
8	Boatshed Point[4]	313,000	6.2	12	14	30
10	LNG Jetty	131,000	4.9	10	10	11[5]
13	Calliope River	900,000	30.2	19	62	35
Total		**1,344,000**	**41.3**	**41**	**86**	**76**

1. Assumes 'probably clean' sediment i.e., NAGD sampling requirements have been halved.
2. Based on the environmental impact assessment requirement of 2 samples per hectare.
3. The number of samples available at the time of writing this report.
4. This volume of dredge material at Boatshed Point does not include small volumes from dredging required to remove two high points near the mouth of the proposed access channel.
5. Sampling data from boreholes drilled and sampled for the Western Basin Dredging and Disposal Project outside the proposed dredge site.

12.4.3 Depth of Sampling and Collection Method

The NAGD require the full depth of material that is to be dredged to be sampled to enable sediment to be accurately characterised. Full depth is taken to mean at least 1 m below the maximum depth of dredging and includes the 'probably clean' upper 1 m of sediment and the underlying geological material. The full depth profile is required to inform turbidity during dredging and material behaviour during and post disposal. Sampling at prescribed intervals is required for the entire investigation profile.

Samples were collected using a combination of vibracore and marine borehole techniques to ensure recovery of sufficient material for laboratory analysis. On occasions, if refusal was met in vibracoring, additional marine boreholes were drilled to ensure sampling requirements were satisfied.

12.4.4 Core Sub-sampling Method

Sample cores were split in half on recovery and sub-sampled for laboratory analysis at the following depth intervals:

- Contaminants and particle size:
  - 0.0 to 0.5 m.
  - 0.5 to 1.0 m.
  - 1.0 to 2.0 m.
  - 2.0 to 3.0 m (or to end of core).
- Acid sulfate soils were sampled at 0.25 m intervals from 0.0 m to end of core.

The second half of each core was sub-sampled at 0.5 m intervals for the entire length of the core and the samples stored in appropriate conditions at the laboratory for further analysis if required. Vibracoring and split sampling tubes are common techniques adopted for obtaining samples for dredge characterisation testing. However, it must be noted that these sampling techniques typically have a maximum sampling tube diameter between 25 mm and 50 mm. As such, in coarse-grained material, it is likely that the coarse fraction of the insitu material will be under represented in the sample.

12.4.5 Data Collected in Field

The following data were recorded for each sub-sample:

- Core depth and colour.
- Odour and plasticity.
- Sand grain size.
- Physical appearance (e.g., silty sand).
- Time and date of sampling of each core and sub-sample.
- Person conducting the sampling, client, project, unique sample location reference and coordinates.
- Digital photographs of cores and sampling equipment and method.
- Water depth at time of sampling, and relevant tide chart for each day of sampling.
- Weather conditions including wind speed, sea state, currents and rainfall for each day of sampling.
- pH field (pH_F) and field peroxide oxidised pH (pH_{FOX})
- Presence of organic matter, marine organisms, coal and shell particles.

Field pH_F and pH_{FOX} testing was performed to determine existing sediment acidity and its potential to produce acid once oxidised.

12.4.6 Laboratory Analysis

The following laboratory analyses were conducted.

Particle Size and Contaminants

Available samples were analysed for the following physical and chemical characteristics in accordance with the particle size and contaminant testing requirements set out in the NAGD:

- Particle size distribution.
- Settling rate.
- Total organic carbon.
- Total metals (Ag, Cd, Se, Sb, Cu, Pb, Zn, Cr, Ni, As, Co, V, Mn, Se and Hg).

- Total petroleum hydrocarbons (TPHs).
- BTEX (benzene, tolune, ethylenebene and xylenes).
- Tributyltin (and dibutyltin and monobutyltin at select locations).
- Organics (polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs)).
- Organophosphate pesticides (OP).
- Organochlorine pesticides (OC).

The preliminary results were augmented with the results of analyses of 11 samples collected as part of the Western Basin Dredging and Disposal Project in the vicinity of the LNG jetty site.

Results of the contaminant testing were assessed against the project sediment quality criteria.

Acid Sulfate Soils

Quantitative laboratory analyses were undertaken on 53 available samples to determine the presence of acid sulphate soils in the project area. The analyses included the measurement of:

- Titratable actual acidity (TAA) to evaluate the existing acidity of the soils.
- Chromium reducible sulfur (Scr) to assess the sulfuric acid generating capacity of the soils.
- Acid neutralising capacity (ANC) to assess the natural capacity of the soils to neutralise any acids generated.
- Net acidity which is calculated from Scr, TAA and ANC. The net acidity is the existing acidity plus the acid generating capacity minus the acid neutralising capacity of the soils. Where net acidity is positive, there is potential for generation of sulfuric acid when the soils are exposed to the atmosphere and commence oxidising.

Analytical results for a further 11 samples collected as part of the Western Basin Dredging and Disposal Project were reviewed to provide an understanding of possible ASS/PASS conditions at the adjacent LNG jetty site.

The results of analysis were assessed against the QASSIT guidelines action criteria.

12.5 Preliminary Results of Sampling Program

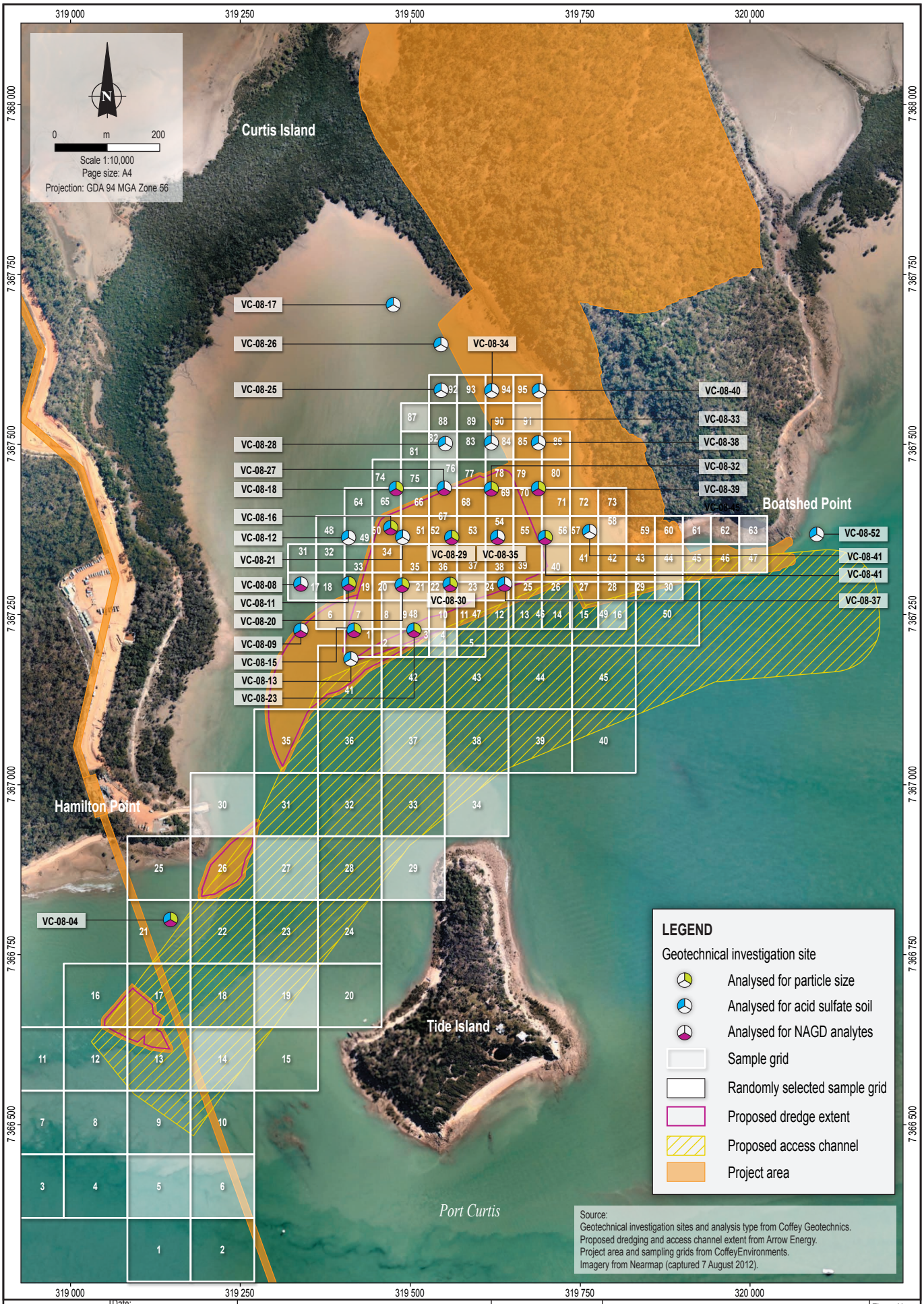
This section summarises the preliminary results of the sampling program being undertaken for the project. Completion of the geotechnical program and reporting will include the results of the sediment sampling program.

12.5.1 Boatshed Point (geotechnical investigation area 8)

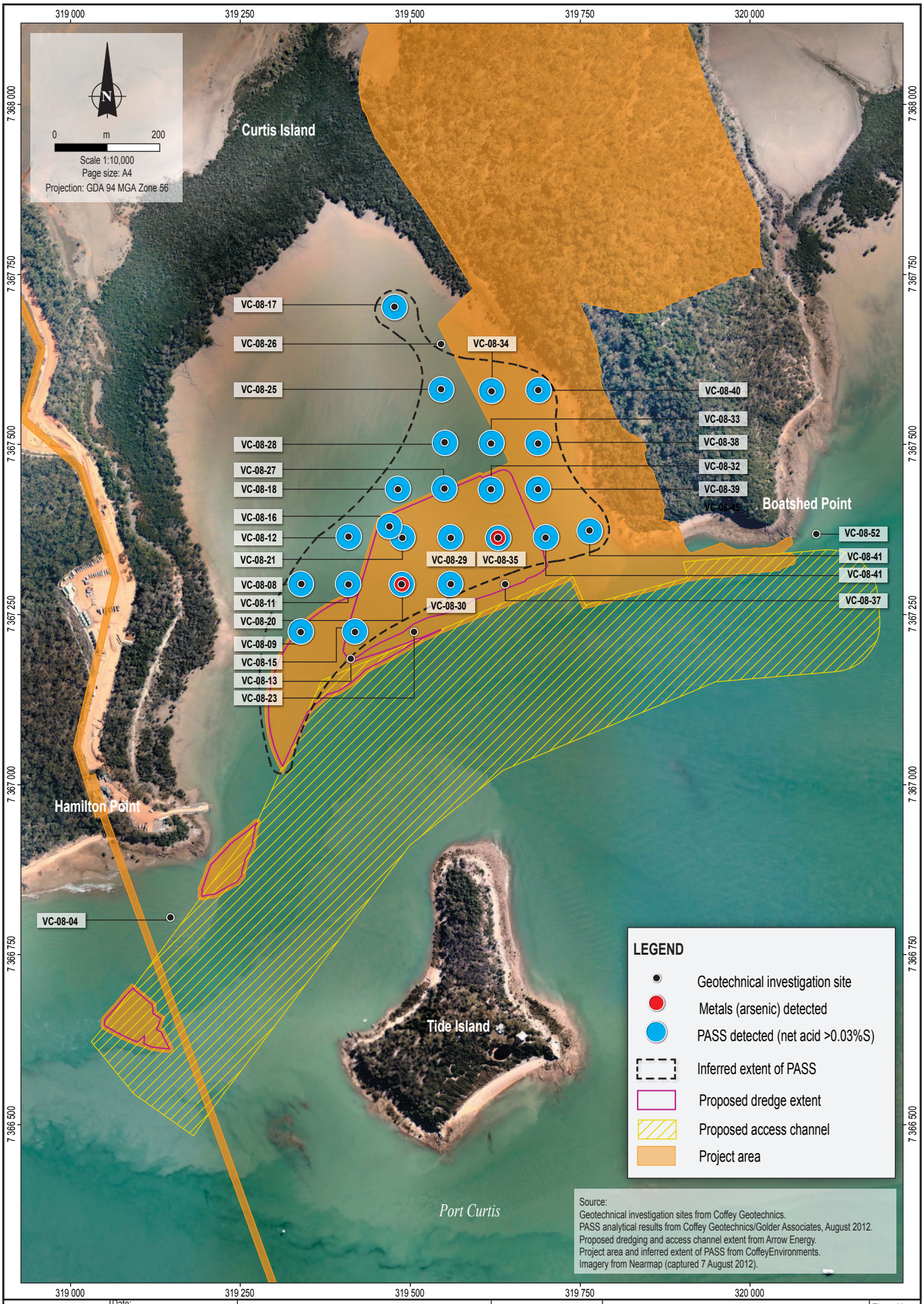
The preliminary results of analyses of samples from sediment cores (Figure 12.1) taken in and adjacent to the area to be dredged at Boatshed Point are discussed below. Figure 12.2 shows the sample sites where elevated metals and PASS were detected.

Particle Size Distribution

A total of 12 sediment samples from 30 sample sites were analysed for particle size distribution at Boatshed Point. The predominant grain sizes were consistent with silt and clay with average proportions being 35% and 42% respectively. Grain sizes in the swing basin and access channel were found to be largely sand with the maximum proportion of sand being 98% at sampling site VC-08-04.



coffey environments	Date: 10.12.2012 MXT: 7033CC_16_GIS020_v0_8v File Name: 7033_16_F12.01_GIS_GL	Arrow Energy Arrow LNG Plant	arrow energy go further	Sample site selection and type at Boatshed Point (Area 8)	Figure No: 12.1



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Date: 11.12.2012
MXT: 7033CC_16_GIS099_v1_1
File Name: 7033_16_F12.02_GIS_GL

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Metals detected and inferred extent of PASS at Boatshed Point (Area 8)

Figure No: **12.2**

Contaminants

The only exceedences of project sediment quality criteria were arsenic at sampling sites VC-08-20 and VC-08-35, where concentrations of 20.3 mg/kg and 23.5 mg/kg respectively, exceeded the criteria of 20 mg/kg. The arsenic concentration exceedences were found in the surface horizons (0 to 0.5 m) of these sites. Samples in the lower horizons (from 1.0 m) had concentrations below NAGD screening levels. When compared against the 95% upper confidence limit of the mean for arsenic, samples were not found to be in excess of the project sediment quality criteria.

Concentrations of organic contaminants (BTEX, butyltins, pesticides, PCB and PAHs) in all samples were found to be below project sediment quality criteria.

There is no evidence of concentrations of contaminants increasing (or decreasing) in deeper sediment horizons as metal and TPH concentrations were generally similar throughout the core profile.

Acid Sulfate Soils

For all but one sample, the TAA was below the level of registration of the test method. One sample has a TAA of 0.06%S, marginally above the QASSIT indicator level of 0.03%S. The soils therefore do not have significant existing acidity.

Acid generating capacity was detected (greater than 0.03%S) in all 100 samples analysed, with a maximum of 4.27% S_{CR}, a mean of 1.5%S_{CR} and a median of 1.33%S_{CR}.

All samples showed some ANC. The ANC is likely to be associated with coral fragments, shell or discarded exoskeletons in the soil profile. The highest ANC value was 18.3% $CaCO_3$ in the profile and the average was 2.4% $CaCO_3$. In most cases, the acidity generating capacity is greater than the ANC.

The net acidity was found to be greater than the indicator level of 0.03%S for 78 of the 100 samples tested. The highest value was 3.97%S and the average over all samples was 1.2%S. The results indicate the soils have extremely high acid generating capacity and that there is very limited opportunity for neutralisation through natural processes.

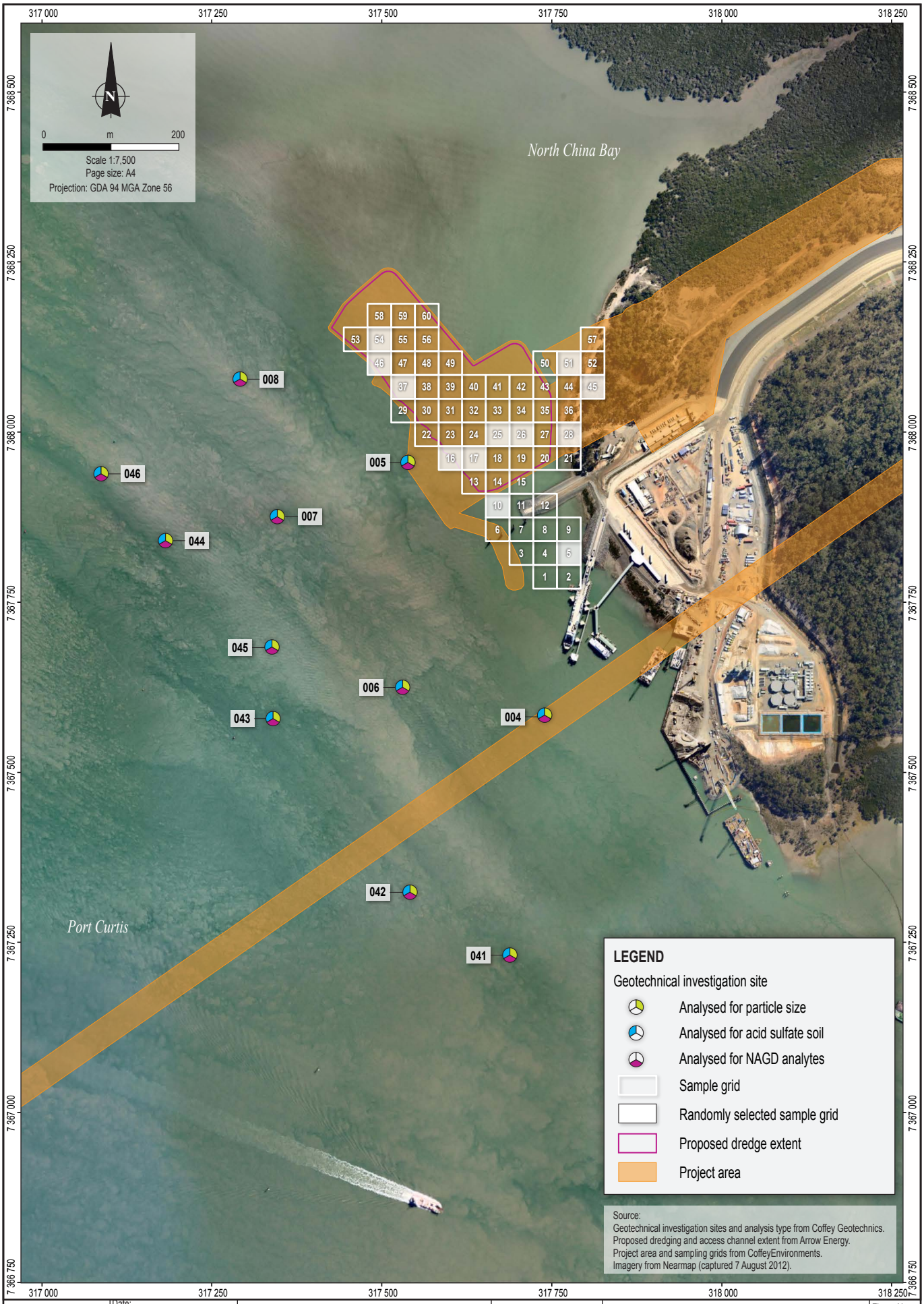
The inferred extent of PASS (net acid greater than 0.03%S) is shown in Figure 12.2. Based on the inferred extent of PASS and the preliminary results of sampling that indicate the depth of the affected soil horizon, the estimated volume of PASS is in the order of 50,000 m^3.

12.5.2 LNG Jetty (geotechnical investigation area 10)

Particle size, contamination and ASS/PASS at the LNG jetty dredge site have been inferred from the results of sediment sampling and analysis (Figure 12.3) undertaken as part of the Western Basin Dredging and Disposal Project. The results are detailed in reports prepared by GHD as part of the Western Basin Dredging and Disposal Project EIS prepared for the Gladstone Ports Corporation. Site specific data will be available on completion of the geotechnical program and reporting. Figure 12.4 shows the sample sites where elevated metals and PASS were detected.

Particle Size Distribution

Particle size distribution at the 11 sample sites adjacent to the LNG jetty was found to vary with depth. Within the shallower depth profile (0.0 to 0.5 m) the dominant grain size was sand with an average portion of 51%, followed by clay. Within the deeper sediments, gravel was the dominant portion with an average of 29%. These results indicate that, overall, sediments are finer in the surface profile in the area adjacent to the LNG jetty.



coffey environments	Date: 10.12.2012 MXT: 7033CC_16_GIS021_v1_2 File Name: 7033_16_F12.03_GIS_VS	Arrow Energy Arrow LNG Plant	arrow energy go further	Sample sites and type at the LNG jetty site (Area 10)	Figure No: 12.3

coffey environments	Date: 11.12.2012 MXT: 7033CC_16_GIS100_v1_2 File Name: 7033_16_F12.04_GIS_VS	Arrow Energy Arrow LNG Plant	arrow energy go further	Metals detected and inferred extent of PASS at LNG jetty site (Area 10)	Figure No: 12.4

Contaminants

Arsenic detected in shallow depth samples taken at sampling sites 006, 008, 043 and 044 exceeded the NAGD screening level of 20 mg/kg. The sampling sites are located in deep water in the natural channel indicating the arsenic is naturally occurring in the geological strata. The results show that the 95% upper confidence limit of all metals and metalloids analysed in all samples from the locations adjacent to the LNG jetty were below the project sediment quality criteria.

Concentrations of organic contaminants (BTEX, butyltins, pesticides, PCB and PAHs) in all samples were found to be below project sediment quality criteria.

There is no evidence of concentrations of contaminants increasing or decreasing with depth.

Acid Sulfate Soils

The TAA was below the level of registration of the test method for all samples, indicating soils adjacent to the LNG jetty site have no existing acidity.

The acid generating capacity was detected above the action criteria of 0.03%S in 33 out of 42 samples analysed, with a maximum of 0.95%S_{CR}, a mean of 0.34%S_{CR} and a median of 0.43%S_{CR}.

All samples showed some ANC. The ANC is likely to be associated with coral fragments, shell or discarded exoskeletons in the soil profile. The highest ANC value was 10.48%S equivalent in the profile while the average was some 3%S equivalent. In most cases, the ANC is greater than the acidity generating capacity.

The net acidity was greater than the indicator level of 0.03%S for 3 of the 42 samples tested. The highest value was 0.3%S and the average over the three samples was 0.15%. The soils have moderate to high acid generating capacity but with a high natural neutralisation potential, which reduces the level of risk associated with management of these soils.

The inferred extent of PASS (net acid greater than 0.03%S) is shown in Figure 12.4. Based on the inferred extent of PASS and the results of sampling in the adjacent area that indicate the depth of the affected soil horizon, the estimated volume of PASS is in the order of 59,000 m^3.

12.5.3 Calliope River (geotechnical investigation area 13)

The preliminary results of analyses of samples from available sediment cores (Figure 12.5) taken from the Calliope River are discussed below. Sampling sites in which elevated metals and/or PASS were detected are shown in Figure 12.6.

Particle Size Distribution

Sediment samples from 15 sample sites were analysed for particle size distribution in the Calliope River. The particle size of the materials was predominantly sand (average proportion 55%) although this was found to vary with depth. Results show that generally the top 2 m of sediment in the Calliope River consists of finer sediments (clay, silt and sand) with grain sizes below 2 m largely comprising gravels (average 29%). This pattern suggests that sediments are finer in the surface horizons of the Calliope River bed.

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Date: 10.12.2012
MXT: 7033CC_16_GIS019_v1_6
File Name: 7033_16_F12.05_GIS_GL

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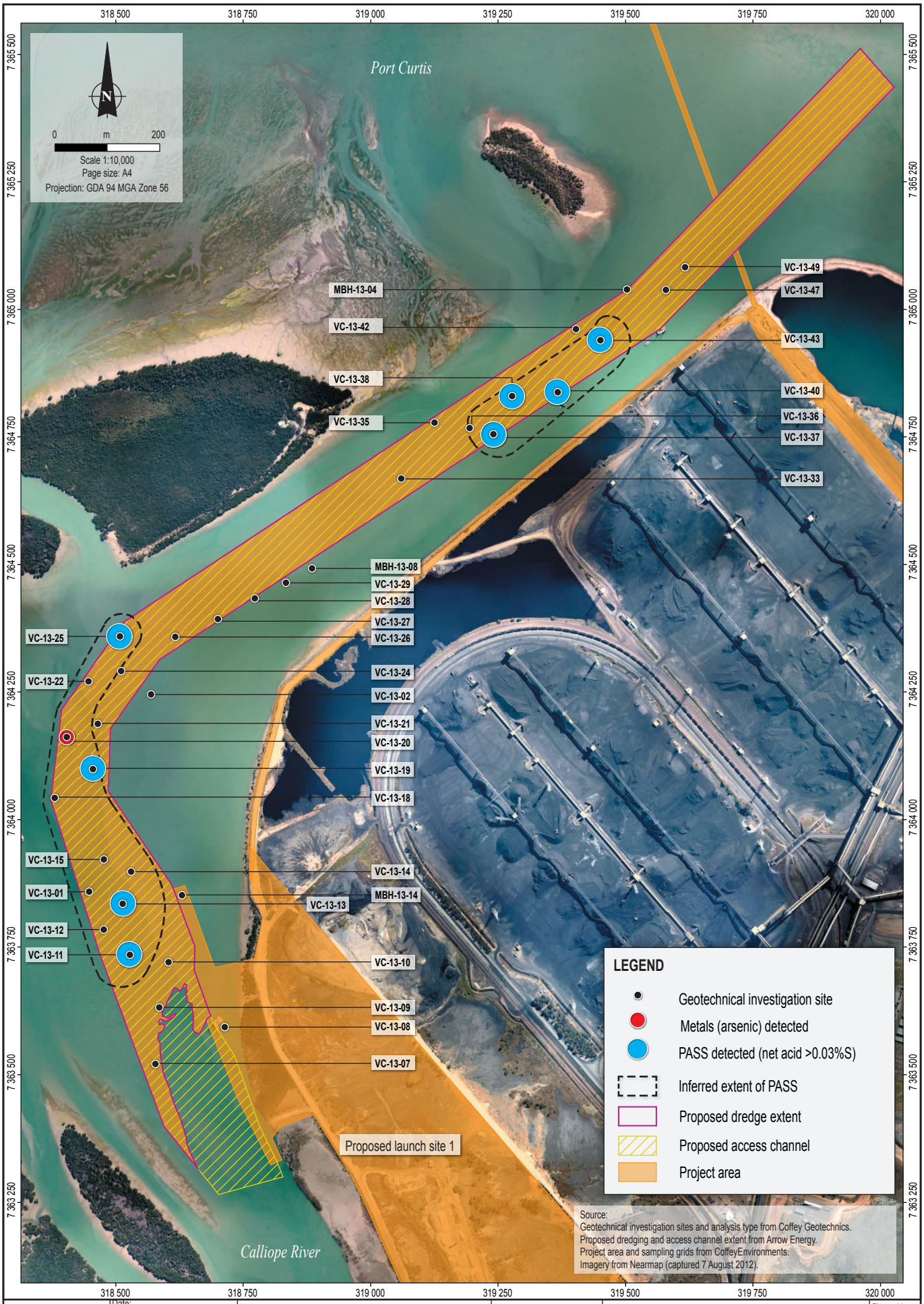
Sample site selection and type at Calliope River (Area 13)

Figure No: **12.5**



coffey environments	Date: 11.12.2012 MXT: 7033CC_16_GIS101_v1_1 File Name: 7033_16_F12.06_GIS_VS	Arrow Energy Arrow LNG Plant	arrow energy go further	Metals detected and inferred extent of PASS at Calliope River (Area 13)	Figure No: 12.6

Contaminants

The only project sediment quality criteria exceedence was arsenic at a depth of between 2.0 m and 3.0 m at site VC-13-20, where the concentration of 30.9 mg/kg exceeds the NAGD screening level of 20 mg/kg. Arsenic concentrations in the upper horizons at this location (0 to 0.5 m, 0.5 to 1.0 m and 1.0 to 2.0 m) were less than the screening level. When compared to the 95% upper confidence limit of the mean for arsenic, samples were found not to be in excess of the project sediment quality criteria.

Concentrations of organic contaminants (BTEX, butyltins, pesticides, PCB and PAHs) in all samples were found to comply with project sediment quality criteria.

There is no evidence of concentrations of contaminants increasing or decreasing in deeper sediment horizons. Metal concentrations are generally similar throughout the core profile, except for manganese, which is higher in the surface horizon (0 to 0.5 m). This is likely due to the process of diagenesis which results in particulate manganese oxides being enriched in the oxic layer of marine sediments, compared to deeper anoxic zones.

No other contaminant concentrations in core samples were found to exceed the project sediment quality criteria, indicating that sediments are uncontaminated.

Acid Sulfate Soils

Acid generating capacity (S_{CR}) was detected above the action criteria of 0.03% in 26 out of 60 samples analysed, with a maximum of 1.21% S_{CR}, a mean of 0.13%S_{CR} and a median of 0.023%S_{CR}. The results indicate the soils have a high acid generating capacity.

All samples showed some ANC. The ANC is likely to be associated with coral fragments, shell or discarded exoskeletons in the soil profile. The highest ANC value was 8.21% $CaCO_3$ in the profile while the average was 2.2% $CaCO_3$. In most cases, the ANC is greater than the acidity generating capacity indicating some of the soils have natural neutralising capacity.

The net acidity was greater than the indicator level of 0.03%S for 11 samples from 8 different sampling sites. The highest value was 0.62%S and the average over the 11 samples was 0.27%S.

The inferred extent of PASS (net acid greater than 0.03%S) is shown in Figure 12.6. Based on the inferred extent of PASS and the preliminary results of sampling that indicate the depth of the affected soil horizon, the estimated volume of PASS is in the order of 40,000 m^3.

12.6 Conclusions

At the time of preparing the supplementary report to the EIS, sediment sampling was being carried out as part of the geotechnical investigation for the project. Samples from 65 sampling sites were available for analysis. Sample analysis results from a further 11 sites – adjacent to the LNG jetty dredge site – collected for the Western Basin Dredging and Disposal Project were used to compile preliminary results for the proposed dredge sites at Hamilton Point (LNG jetty), Boatshed Point and Calliope River.

Analysis and/or review of the available samples from each of the dredge and marine construction sites has demonstrated that the sediments meet project sediment quality criteria, with no exceedences of the 95% upper confidence limits for contaminants. Small concentrations of arsenic compounds were observed in three samples across the three sampling areas. The NAGD recognise that sediments in Australia commonly have high levels of naturally occurring arsenic compounds. Samples containing arsenic that exceeded the project sediment quality criteria were

collected from depths exceeding 2 m below seabed level. At these depths, the sediment is likely to represent geological material with naturally-elevated occurrences of arsenic.

The NAGD provides that where no analytes exceed the 95% upper confidence limit of the project sediment quality criteria, sediments are categorised as uncontaminated and are considered suitable for ocean disposal, and by inference to approved onshore and offshore disposal sites. These results are consistent with the findings of the EIS, which found that no samples exceeded the project sediment quality criteria at the proposed dredge sites. These results, together with results from ongoing geotechnical investigations, will be used to inform the development of the dredge management plan for the project.

Particle size distributions were found to vary within and between each of the three sampling areas. Calliope River and the area adjacent to the LNG jetty site were characterised as predominantly sand in the surface horizons, with grain size increasing with depth to gravels and cobbles. Boatshed Point was found to have a generally uniform particle size throughout the sediment profiles, consisting largely of finer sediments (clay and silt).

These results are consistent with the assumptions for particle size used in studies completed for the EIS at Boatshed Point and the LNG jetty. The studies carried out for the EIS assumed higher proportions of silts and clays than reported in the current results for Calliope River. The results of sampling and testing at the LNG jetty site were not available at the time of preparing this chapter.

Most of the soils in and adjacent to Boatshed Point and adjacent to the LNG jetty site are PASS with moderate to extremely high acid generating capacity. A small proportion of this acid generating potential is nullified by the natural ANC of the soils. However, the net acid generating capacity is more than 100 times the QASSIT indicator levels in some soils and is 40 times this limit based on average values. The results of testing on samples taken from the Calliope River suggest that PASS is restricted to two localised areas. The results for Boatshed Point are consistent with the findings of the desktop study completed for the EIS.

Arrow Energy has committed to developing an acid sulfate soil management plan in accordance with State Planning Policy SPP 2/02 (Planning and Managing the Development of Acid Sulfate Soils 2002) and SPP 2/02 Guideline: Acid Sulfate Soils which references the QASSIT guidelines. The plan will detail strategies for the management and disposal of ASS/PASS including options for offshore management, as is currently being undertaken for materials dredged as part of the other LNG projects. Offshore disposal is likely to minimise PASS oxidation and potential acid generation.

The commitments set out in the EIS remain applicable to the management of marine sediments and PASS as well as ASS in undertaking dredging and marine construction activities in the project area.

12.7 Commitments Update

Measures to manage marine sediments and ASS/PASS presented in the EIS are unchanged and are included in Attachment 7, Commitments Update. An update on the implementation of two of these commitments is set out in Table 12.5.

Table 12.5 Commitments update: sediment characterisation

No.	Commitment	Comment
C12.01	Prior to construction, the extent of contamination will be further defined where required, and mitigation measures will be refined as appropriate.	This commitment has been partly fulfilled as a sampling program in accordance with NAGD is in progress. Preliminary results indicate there is no contamination in areas where dredging and marine construction activities will be carried out for the project.
C16.02	Obtain sediment samples from geotechnical drill cores to further characterise marine sediments disturbed during construction. Use the results to inform the development of the dredge management plan.	This commitment has been partly fulfilled in accordance with NAGD, QASSIT and SPP 2/02 Guideline. A dredge management plan will be prepared prior to construction commencing.