Benthic habitat surveys of potential LNG hub locations in the Kimberley region

A joint CSIRO and AIMS Preliminary Report for the Western Australian Marine Science Institute

18th July 2008

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Department of Environment and Conservation
Our environment, our future

Western Australian marine science institution
Benthic habitat surveys of potential LNG hub locations in the Kimberley region

A study commissioned by the Western Australian Marine Science Institution on behalf of the Northern Development Taskforce

CSIRO and AIMS Joint Preliminary Report for The Western Australian Marine Science Institution

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CONTENTS

CONTENTS .................................................................................................................................................. I

LIST OF FIGURES ................................................................................................................................. IV

LIST OF TABLES ........................................................................................................................................ V

LIST OF ASSOCIATED MAPS ................................................................................................................. VI

ACKNOWLEDGEMENTS ........................................................................................................................ IX

1. EXECUTIVE SUMMARY ................................................................................................................... 10

2. INTRODUCTION ............................................................................................................................... 13

3. OBJECTIVES ..................................................................................................................................... 15

  3.1 Primary .......................................................................................................................................... 15

  3.2 Secondary ...................................................................................................................................... 15

  3.3 Project outputs ................................................................................................................................. 15

4. METHODS .......................................................................................................................................... 17

  4.1 Description of Study Area ............................................................................................................. 17

  4.2 Basemaps ....................................................................................................................................... 17

  4.3 Sampling Design ............................................................................................................................ 17

  4.4 Field Sampling ............................................................................................................................... 22

  4.5 Habitat Classification System ....................................................................................................... 22

  4.6 Benthic sample collection .............................................................................................................. 25

  4.7 Depth Data Analysis ....................................................................................................................... 25

    4.7.1 Conversion of measured water level to survey datum ......................................................... 31

    4.7.2 Approximation of predicted tide ............................................................................................ 31

    4.7.3 Bathymetry processing ........................................................................................................... 33

        CSIRO C-Plot soundings ........................................................................................................... 33

        WALCOTT C-Plot soundings .................................................................................................. 33

        DEC tow cam soundings .......................................................................................................... 33

    4.7.4 Cross calibration of bathymetric data sets ............................................................................. 33

    4.7.5 Interpolation & contouring of corrected bathymetry ............................................................. 34

    4.7.6 Inverse distance-weighted interpolation – ARC GIS help files 35

        Power ........................................................................................................................................... 35
LIST OF FIGURES

Figure 4-1: Map showing the stratified sample design with grid cells chosen for video tow transects at Location 1; Gourdon Bay. Colours within sampling location represent stratification clustering based on available biophysical parameters. ................................................................. 19
Figure 4-2: Map showing the stratified sample design with grid cells chosen for video tow transects at Location 2; Quondong Point to Coulomb Point. Colours within sampling location represent stratification clustering based on available biophysical parameters. ................................................................. 19
Figure 4-3: Map showing the stratified sample design with grid cells chosen for video tow transects at Location 3; Perpendicular Head. Colours within sampling location represent stratification clustering based on available biophysical parameters. ................................................................. 20
Figure 4-4: Map showing the stratified sample design with grid cells chosen for video tow transects at Location 4; Packer Island. Colours within sampling location represent stratification clustering based on available biophysical parameters. ................................................................. 20
Figure 4-5: Map showing the position of the supplementary transect lines 1 and 2 between Gourdon Bay and Quondong Point. ................................................................. 21
Figure 4-6: Map showing the position of the supplementary transect lines 3, 4 and 5 between Coulomb Point and Perpendicular Head. ................................................................. 21
Figure 4-7: Comparison of tidal data from the four locations surveyed. ................................................................. 32
Figure 4-8: Kimberley bathymetry survey overview. Detailed maps of each bounded location are provided separately in pdf format. ................................................................. 36
Figure 5-1: Silt (Sandy-Mud) rippled with a fine layer of filamentous algae on the sand shown in the top left corner. ................................................................. 37
Figure 5-2: Sand Waves (~0.5 m amplitude) with small ripples less than 100 mm in amplitude. Coarse sand in the troughs between the crests of the waves. ................................................................. 38
Figure 5-3: Rubble and stones (<250 mm) overlying sand. ................................................................. 38
Figure 5-4: Coarse Sand substratum with shell, coral, echinoderm and rubble fragments. ................................................................. 39
Figure 5-5: Low relief reef (< 0.5m) comprising sponges, whips, gorgonians, hard corals and algae. There is a thin layer of sand over a firmer substrate of rock. ................................................................. 39
Figure 5-6: High relief reef (> 0.5m) comprising sponges, whips, gorgonians and hard corals on a rock ridge. ................................................................. 40
Figure 5-7: Rock substratum with a hard coral (Turbinaria sp) attached at the middle left hand side. The foreground is sand. Classified as rocks. ................................................................. 40
Figure 5-8: Sand with protruding rock substratum. Gorgonian garden medium and sparse sponges attached to the rock. This is classified as low relief reef (< 0.5m). ................................................................. 41
Figure 5-9: Bioturbated sand with many burrows evident, the dark patches are algae turf / microphyte mats. ................................................................. 41
Figure 5-10: Bioturbated sand with many heart urchins turning over the sand. ................................................................. 42
Figure 5-11: Sponge garden sparse showing individual scattered sponges. May be represented by a single sponge. ................................................................. 42
Figure 5-12: Sponge garden medium showing a denser community of sponges. ................................................................. 43
Figure 5-13: Sponge garden dense has many sponges of various species adjacent to each other. ................................................................. 43
Figure 5-14: Alcyonarian garden sparse with smaller sparse sponges. The Alcyonarian is the multi-branched organism in the fore-ground. ................................................................. 44
Figure 5-15: Alcyonarian garden medium with smaller sparse barrel sponge in the middle. ................................................................. 44
Figure 5-16: Alcyonarian garden dense on sand. ................................................................. 45
Figure 5-17: Pennatulacea garden dense consisting of possibly two species of sea pen. Very common at Packer Island deep transects. ................................................................. 45
Figure 5-18: Gorgonian garden sparse on a rock substratum, several species of sponge can be seen in background. ................................................................. 46
Figure 5-19: Gorgonians garden medium, species of Solenocaulon on a sand substratum. ................................................................. 46
Figure 5-20: Whip garden sparse mixed with sponge garden sparse. ................................................................. 47
Figure 5-21: Whip garden medium on sand. ................................................................. 47
Figure 5-22: Whip garden dense on a sand and rock substratum. ................................................................. 48
Figure 5-23: Hard coral garden sparse – a solitary flowerpot coral with white rim (Turbinaria sp) interspersed with gorgonians and sponges ................................................................. 48
Figure 5-24: Hard coral garden medium with numerous flowerpot corals (Turbinaria sp) interspersed with sponges ........................................................................................................ 49
Figure 5-25: Algae turf / microphyte showing tufts of algae on the crests of rippled sand .............. 49
Figure 5-26: Seagrass sparse (Halophila sp) centre of picture on sand with algae turf / microphyte . 50
Figure 5-27: Algae Sargassum sp on sand .................................................................................... 50
Figure 5-28: Algae mix. Sargassum sp and runners of Caulerpa sp on sand ........................................ 51
Figure 5-29: Algae red/green mix on a rocky substratum ............................................................... 51
Figure 5-30: Live reef coral on a rocky outcrop with encrusting algae and bryozoans ...................... 52

LIST OF TABLES
Table 4-1: Summary of the number of transects assigned to within each of the priority boundaries at each location. (Location 1: Gourdon Bay, Location 2: Quondong – Coulomb Point, Location 3: Perpendicular Head, Location 4: Packer Island, Line 1: north of Gourdon Bay, Line 2: south of Quondong Point, Line 3: north of Coulomb Point, Line 4: mid Coulomb Point and Perpendicular Head, Line 5: south of Perpendicular Head) ........................................................................ 18
Table 4-2: Data output example of the habitat classification from the tappity software ................. 23
Table 4-3: Look up list of substratum, biohabitat and animal events used in the tappity habitat classification system. These events were standardised between the CSIRO and AIMS classification systems ........................................................................ 24
Table 4-4: Summary of depth data for the Gourdon Bay and Quondong Point – Coulomb Point locations ................................................................................................................................. 27
Table 4-5: Summary of the depth data for the Perpendicular Head and Packer Island locations .... 28
Table 4-6: Summary of the depth data for the five supplementary transect lines ......................... 29
Table 4-7: Summary of the observed tide data at each location .................................................... 31
Table 4-8: Summary of approximated tide data for the four sampling locations .......................... 32
Table 4-9: Summary of the compiled bathymetry and grid data for the four locations .................. 34
LIST OF ASSOCIATED MAPS

Kimberley Benthic Habitat Survey 2008: Bathymetry Contours (A1)
Satellite image overlaid with 5, 10, 15, 17 and 20 metre bathymetric contours lines.

Gourdon Bay: Bathymetry Grid (A3)
Satellite image overlaid with 5, 10, 15, 17 and 20 metre bathymetric contours lines.

Quondong Point – Coulomb Point: Bathymetry Grid (A3)
Satellite image overlaid with 5, 10, 15, 17 and 20 metre bathymetric contours lines.

Perpendicular Head: Bathymetry Grid (A3)
Satellite image overlaid with 5, 10, 15, 17 and 20 metre bathymetric contours lines.

Packer Island: Bathymetry Grid (A3)
Satellite image overlaid with 5, 10, 15, 17 and 20 metre bathymetric contours lines.

Gourdon Bay: Ungridded Bathymetry Data (A3)
Satellite image of ungridded bathymetric data collected for bathymetry contours.

Quondong Point – Coulomb Point: Ungridded Bathymetry Data (A3)
Satellite image of ungridded bathymetric data collected for bathymetry contours.

Perpendicular Head: Ungridded Bathymetry Data (A3)
Satellite image of ungridded bathymetric data collected for bathymetry contours.

Packer Island: Ungridded Bathymetry Data (A3)
Satellite image of ungridded bathymetric data collected for bathymetry contours.

Lines 1 and 2: Ungridded Bathymetry Data (A3)
Satellite image of ungridded bathymetric data collected for bathymetry contours.

Lines 3, 4 and 5: Ungridded Bathymetry Data (A3)
Satellite image of ungridded bathymetric data collected for bathymetry contours.

Kimberley Benthic Habitat Survey 2008: Survey Locations (A1)
Satellite image of the study area in the Kimberley region of Western Australia, including transect sites in the four bounded sampling locations and five supplementary transect lines, overlaid with the 5, 10, 15 and 20 metre bathymetric contours.

Kimberley Benthic Habitat Survey 2008: Substratum Percent Coverage Pie Charts (A1)
Satellite images (a-e) overlaid with pie charts showing the percent coverage of substratum types in each transect at the four locations; Gourdon Bay (a), Quondong – Coulomb Point (b), Perpendicular Head (c) and Packer Island (d) and the five supplementary transect lines (e). Pie charts based on visual interpretation of video data. Image overlaid with 5, 10, 15 and 20 metre bathymetric contours.

Kimberley Benthic Habitat Survey 2008: Biohabitat Percent Coverage Pie Charts (A1)
Satellite images (a-f) overlaid with pie charts showing the percent coverage of biohabitat types in each transect at the four locations; Gourdon Bay (a), Quondong – Coulomb Point (b), Perpendicular Head (c), Packer Island (d) and the five supplementary transect lines (e, f). Pie charts based on visual interpretation of video data. Image overlaid with 5, 10, 15 and 20 metre bathymetric contours.

**Kimberley Benthic Habitat Survey 2008: Substratum Percent Coverage Bubble Plot (A1)**

Satellite images (a-i) overlaid with bubble plots of a size proportional to the percent coverage of substratum types in each transect at the four locations; Gourdon Bay, Quondong – Coulomb Point, Perpendicular Head and Packer Island and the five supplementary transect lines. Bubble plots based on visual interpretation of video data. Image overlaid with 5, 10, 15 and 20 metre bathymetric contours. (a: soft mud, b: silt, c: sand, d: coarse sand, e: sand waves/dunes, f: rubble/stones, g: rocks, h: low relief reef, i: high relief reef).

**Kimberley Benthic Habitat Survey 2008: Biohabitat Percent Coverage Bubble Plot (A1)**


**Kimberley Benthic Habitat Survey 2008: Animal Count per Transect Kilometre Bubble Plot (A1)**

Satellite images (a-l) overlaid with bubble plots of a size proportional to the number of animals per km in each transect at the four locations; Gourdon Bay, Quondong – Coulomb Point, Perpendicular Head and Packer Island and the five supplementary transect lines. Bubble plots based on visual interpretation of video data. Image overlaid with 5, 10, 15 and 20 metre bathymetric contours. (a: anemone, b: ascidian, c: seapen, d: solitary coral, e: hydroid, f: bryozoan, g: gastropod, h: tridacnid clam, i: starfish, j: urchin, k: crinoid, l: holothurian).

**Kimberley Benthic Habitat Survey 2008: Substratum Transition Bar Charts (A1)**

Satellite images (a-f) overlaid with bars representing the video transect showing the transition of substratum type along each transect within the four locations; Gourdon Bay (a), Quondong – Coulomb Point (b), Perpendicular Head (c), Packer Island (d) and the five supplementary transect lines (e, f). Bars based on visual interpretation of video data. Image overlaid with 5, 10, 15 and 20 metre bathymetric contours.

**Kimberley Benthic Habitat Survey 2008: Biohabitat Transition Bar Charts (A1)**

Satellite images (a-f) overlaid with bars representing the video transect showing the transition of biohabitat type along each transect within the four locations; Gourdon
Bay (a), Quondong – Coulomb Point (b), Perpendicular Head (c), Packer Island (d) and the five supplementary transect lines (e, f). Bars based on visual interpretation of video data. Image overlaid with 5, 10, 15 and 20 metre bathymetric contours.

Kimberley Benthic Habitat Survey 2008: Biohabitat Percent Coverage Graduated Colour Plot “EXAMPLE” (A1)
Satellite image overlaid with graduated colour plot of the percent coverage of biohabitat type in each transect at the four locations; Gourdon Bay, Quondong – Coulomb Point, Perpendicular Head and Packer Island and the five supplementary transect lines. Graduated colour plot based on visual interpretation of video data. Image overlaid with 5, 10, 15 and 20 metre bathymetric contours. *Example map for sponge density where high percent coverage on bubble plots cause difficulty in map interpretation.*
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The Department of Environment and Conservation Western Australia staff provided a key role in scoping and facilitating the surveys. Their participation in the field program provided project leadership and significantly extended the number of sites and depth zones that could be surveyed. We greatly appreciate the efforts of Dr Ray Masini, Project Leader on behalf of the Northern Development Taskforce Marine Experts Working Group, Dr Cameron Sim, Kevin McAlpine, Tim Daly and Kevin Bancroft.

We would like to thank the Raptis and Sons fleet manager Phil Robson for his time and effort in arranging and setting up the vessel on such short notice and the skipper, Paul Williamson and the crew, Wade Riethmuller, Widoyo, Angie Christensen and Nikki Pallot from the FV Eylandt Pearl for their participation and tireless help throughout the survey trip.

Members of the Pearl Producers Association are gratefully thanked for providing us access to a number of areas within their existing pearl leases to carry out the survey.

The AIMS field program was undertaken in the WA Fisheries vessel PV Walcott, in collaboration with a team of DECWA scientists. We gratefully acknowledge the support of WA Fisheries CEO Peter Millington in making the vessel available, Rod O’Halloran for vessel management and participation along with the other Masters and crew, Laurence Bellottie, Garry Johannesen, Tony Lemmon, Michael Lock and Matthew Wilson.

For technical support with instrumentation, video systems and wide ranging troubleshooting during the cruise, we are sincerely grateful to David Whillas, from Seatools Pty Ltd.
1. EXECUTIVE SUMMARY

Four locations along the Kimberley coast were surveyed to describe the substratum type, biohabitat type and the bathymetry of the seabed. The four survey locations were in the vicinity of Gourdon Bay, Quondong – Coulomb Points, Perpendicular Head and Packer Island. The data, providing improved knowledge on biodiversity, habitat complexity and bathymetry, will be used by the Northern Development Taskforce as part of a selection process to rank the suitability of a range of locations for a proposed common-user liquefied natural gas hub precinct.

Three vessels worked simultaneously in each of the four locations to complete sites from the intertidal zone out to approximately 20 m depth. A gridded sample design with stratification based on a range of available biophysical parameters was used to select transect sites within each of the four locations. The relative abundance of the main functional groups of benthic organisms and substratum types were recorded along 500 m transects at 606 sites using underwater towed video and analysed in real time according to a standardised habitat classification system. A further 169 sites were surveyed, with video footage recorded but habitat classification was not completed in the field. Sounding data was also collected by each vessel during the survey to validate the existing bathymetry contour data.

Most of the seabed surveyed in the four locations was fine sand, ranging between 50 and 70% coverage within each location. The other major seabed types were sand dunes and waves and coarse sand, each with about 15% coverage. These substratum types generally occurred in small patches between low and high relief reef areas, except for the Quondong Point – Coulomb Point location where extensive areas of sand dunes and waves were found in the northern offshore region and along the shallow nearshore stretch at the southern extent. There was very little mud or silt substratum throughout any of the four locations surveyed.

All four locations showed some presence of low to high relief reef structure, predominantly around the shallow waters off the headlands at the two most northern locations surveyed. At the Quondong Point – Coulomb Point location, low relief reef habitat was found extending along most of the length of the survey area in the shallows (around 5 m) and patches offshore at the northern end. Within the Gourdon Bay survey location, low relief reef was in a more patchy distribution around the shallows of the headland and around the many isolated shoals in the offshore waters.

The distribution of hard substratum type influenced the abundance and distribution of biohabitats and benthic animals within these locations. Where there was low relief solid structure present, there were generally diverse patches of filter feeding communities, such as sponges, whips and gorgonians. These filter feeding communities also occurred in patches on the flat fine sand substrates within each location. Soft corals and hard corals were encountered at each location, however they were generally low and variable in abundance. There were some isolated medium to dense patches of alcyonarians at Coulomb Point and medium patches of *Turbinaria* sp (flowerpot coral) at Perpendicular Head and Packer Island.

The green, red and brown algae and seagrass (predominantly *Halophila* sp) were restricted to the shallow areas at Gourdon Bay, Perpendicular Head and Packer Island locations. In contrast, these groups were found in patches throughout the shallow to deep waters of the survey area at Quondong Point – Coulomb Point location. In areas characterised by sandy substrate with a significant coverage of microphytobenthos, heart urchins and crinoids were found to be the most dominant animal groups, often in dense patches numbering in the thousands.

Depth soundings were recorded with four standard singlebeam echosounders from three vessels. These data were adjusted to local tide using a tide gauge deployed at each location. Bathymetric
contours at depths of 5, 10, 15 and 20 m were calculated from the interpolated grid using the ARC GIS spatial toolbox.
2. INTRODUCTION

A number of sites in the Kimberley region are being considered for their suitability as a location for a proposed common-user liquefied natural gas hub precinct. The marine benthic communities at these prospective sites are largely undescribed. The Northern Development Taskforce (NDT) has approached the Western Australian Marine Science Institute (WAMSI) to co-ordinate a rapid assessment that could contribute new information to the selection process. WAMSI, with facilitation and development of project scope by the Western Australian Department of Environment and Conservation (DECWA), contracted CSIRO Marine and Atmospheric Research (CMAR) and the Australian Institute of Marine Science (AIMS) to undertake a joint benthic community survey of four locations in this region. This survey data will compliment the limited existing data and will used by NDT to rank and select suitable locations to be included in a Strategic Environmental Assessment (SEA).

The SEA also requires adequate characterisation of the hub infrastructure and its construction and operational pressures on the environment to the extent that its environmental effects can be reasonably predicted and quantified. Prediction and interpretation of many of the biological and ecological impacts arising from the LNG Hub will be strongly dependent upon a detailed understanding of the oceanography, biology and sedimentology of the seabed within and adjacent to these sites.

A Principal Investigator (PI) from each of AIMS and CSIRO lead the projects for each of those organisations. The PIs from AIMS and CSIRO were given primary responsibility for decisions regarding the scientific components of the survey program. DECWA provided overarching project leadership involving facilitation and coordination of the survey program. Where decisions were taken to modify the proposed scheduling, then these were made by the DECWA Project Leader in consultation with each of the PIs or Cruise Leaders from AIMS and CSIRO.

This project used towed video transect surveys to provide a quantitative habitat assessment of the key marine bio-physical attributes of four potential locations selected for consideration of the LNG hub; (i) the bathymetry, (ii) the seabed substrates and (iii) the main functional groups of the benthic communities. The marine benthic characteristics of the four locations will be compared on the basis of the broad habitat analysis.
3. **OBJECTIVES**

3.1 **Primary**

1) To classify and spatially define the distribution and extent of the major benthic habitat types in four selected localities within the Kimberleys. Spatially, the major focus of surveys to meet this objective are waters where no aerial photography is available or where water clarity or sun glare does not allow the phototonal variation of seabed features to be discerned, and seaward to approximately the 20 m bathymetric contour. A goal is to achieve as broad and even coverage of the selected localities as possible in the time allocated. The preference is for the major outputs of this work to be presented in the form of benthic substratum, biohabitat and bathymetry maps for each locality. This is the highest priority objective.

2) Further to the objective above, lesser survey effort is to be placed on acquiring data to ground truth and classify phototones on the aerial photography of the nearshore portions of the selected localities. Surveys to address this objective should be highly targeted to a number of specific areas of significant phototonal variation/different tones and target sites seaward of mean low water neap out to the extent of the photo run to ensure some overlap with surveys of the upper intertidal zone.

3) To survey the benthos along five supplementary transect lines between localities.

4) To validate the location of the tide height-corrected 10, 15 and 20 m bathymetric contours for the four selected localities. While undertaking work to address objectives 1, 2 and 3 above, complementary work should be done on an opportunistic basis to validate available bathymetric data and generate a coarse-resolution tidal height-corrected bathymetric map by acquiring bathymetric data with as even and broad coverage of the selected localities as possible in the time allocated to each area.

3.2 **Secondary**

5) As time permits, to collect biological samples from each habitat type identified at each location and along each supplementary transect line between localities to allow identification of benthic flora and fauna, and fish.

3.3 **Project outputs**

The main aim is to capture benthic substratum, habitat and bathymetric data and produce spatial products (e.g. substratum and habitat maps) that enable technical experts convened as part of the Northern Development Taskforce process to compare and contrast benthic habitats at the different localities. The information collected as part of this project will also inform planning for future marine environmental research in Kimberley. Future research may for example assist in progressing national heritage nomination for the Kimberley. A final report is to follow this report to provide a more comprehensive description and comparison of each of the survey locations.
4. METHODS

4.1 Description of Study Area

Within the Kimberley region in Western Australia, four localities were chosen for video surveying; Gourdon Bay (Location 1), Quondong Point to Coulomb Point (Location 2), Perpendicular Head (Location 3) and Packer Island (Location 4) (see Figure 4-1 to Figure 4-4). Three of these locations; one south and two north of Broome were located around prominent headlands, while the remaining location (Location 2) was situated along a sandy coastal stretch north of Broome. The ocean area of each of the four locations are approximately 228, 302, 266 and 205 km² respectively and bounded from the shoreline (intertidal) to approximately the 20 m depth contour based on available bathymetric data. The Kimberley region is well-known for its wide tidal ranges, reaching 8 m within the study area, with two cycles per 24 hours. It was anticipated that the video surveying of the nearshore areas were tide and weather dependant as currents and turbidity might be unfavourable for much of each day. The weather was generally good during the survey period and the sampling schedule was not greatly disrupted. However, some time was lost in the nearshore of Location 2 due to unfavourable currents and swell. Water clarity was also good in both shallow and deep water, to enable substratum and biohabitat classification in real time and throughout the day and tide ranges.

4.2 Basemaps

Satellite imagery data was obtained from the Australian Centre for Remote Sensing (ACRES). These images were overlaid with the proposed survey area boundary supplied by DECWA to show the areas of priority for the video work (refer to associated maps). The substratum and biohabitat charts were superimposed on these basemaps with bathymetric contours also overlaid.

4.3 Sampling Design

The survey design was stratified based on a range of biophysical parameters (see Appendix A). Each location was stratified independently with the main drivers of the strata listed in order of influence; bathymetry, seabed stress, seabed slope, percent of mud, Sea Wifs Chlorophyll, aspect, other sediment attributes and available physico-chemical parameters (from the CSIRO Atlas of Regional Seas [CARS2000]; refer to Ridgway et al 2002).

Each of the four locations was partitioned into 500 x 500 m grid cells. It was estimated that each vessel could complete about 17 video transects (grids) per day. Therefore, a total of 815 possible survey grid cells were identified within the four locations. It was recognised that it may not be possible to video all of the transects selected so the project leaders assigned each transect a primary, secondary or tertiary level of priority. The main aim of the survey was to complete the transects at each location in the priority order. If time was limited at a location, sampling grids were removed, maintaining as even coverage as possible across the stratifications until a manageable number were remaining.
There were also five supplementary transect lines, perpendicular to the shoreline, identified between the four locations that could be surveyed when the vessels were in transit between locations. Along each of these lines, a number of transect points were selected for video towing (Table 4-1). These were chosen to provide some additional substratum and biohabitat data to serve as a basis for placing the survey locations into some regional context.

Table 4-1: Summary of the number of transects assigned to within each of the priority boundaries at each location. (Location 1: Gourdon Bay, Location 2: Quondong – Coulomb Point, Location 3: Perpendicular Head, Location 4: Packer Island, Line 1: north of Gourdon Bay, Line 2: south of Quondong Point, Line 3: north of Coulomb Point, Line 4: mid Coulomb Point and Perpendicular Head, Line 5: south of Perpendicular Head).

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</tbody>
</table>

Figure 4-1 to Figure 4-6 below provide a representation of the stratification in the sample design and the positions of each transect in the four locations and five supplementary transect lines. The transect allocation did not take into account that some locations have navigation hazards and access restrictions such as Pearling leases which may not be surveyed. In these instances, adjacent grid cells in the same stratification cluster were selected as alternate transects to video. In the very nearshore shallow waters where notable features were identified by aerial photography or identified during the survey, there was the capacity to survey these additional sites to ensure these features were adequately covered.
METHODS

Figure 4-1: Map showing the stratified sample design with grid cells chosen for video tow transects at Location 1; Gourdon Bay. Colours within sampling location represent stratification clustering based on available biophysical parameters.

Figure 4-2: Map showing the stratified sample design with grid cells chosen for video tow transects at Location 2; Quondong Point to Coulomb Point. Colours within sampling location represent stratification clustering based on available biophysical parameters.
Figure 4-3: Map showing the stratified sample design with grid cells chosen for video tow transects at Location 3: Perpendicular Head. Colours within sampling location represent stratification clustering based on available biophysical parameters.

Figure 4-4: Map showing the stratified sample design with grid cells chosen for video tow transects at Location 4: Packer Island. Colours within sampling location represent stratification clustering based on available biophysical parameters.
Figure 4-5: Map showing the position of the supplementary transect lines 1 and 2 between Gourdon Bay and Quondong Point.

Figure 4-6: Map showing the position of the supplementary transect lines 3, 4 and 5 between Coulomb Point and Perpendicular Head.
4.4 Field Sampling

Due to the tight timelines on the field survey, sampling design and depth range coverage proposed, a three vessel approach was adopted for the surveying work. CSIRO chartered a 25.95 m Raptis Northern Prawn Trawler, the *FV Eylandt Pearl* for the deeper waters. This vessel has a range of winch capabilities, the stern try-winch suited to deploy and tow the heavy video equipment (200kg +) in deep water and the port and starboard boom winches to tow benthic dredges to collect biological material. The WA Department of Fisheries under arrangements with WAMSI, provided the 23 m Patrol Vessel, *PV Walcott* for the shallower waters. This vessel supported AIMS operations and additional very shallow water investigations from a tender by DECWA staff. The *PV Walcott* was setup with an aluminium A-frame on the stern to tow the AIMS lightweight (30kg) digital video equipment. DECWA staff used a 5.8 m centre console vessel, the *Diadema*, to cover the nearshore and intertidal transects not able to be covered by the other two larger vessels. AIMS staff integrated position and depth logging equipment with a small drop video camera on the *Diadema*, which enabled collection of video footage, position and depth data to complement the video and depth data collected in the deeper waters by the *FV Eylandt Pearl* and *PV Walcott*. Limitations of space and shelter on the *Diadema* meant that video and depth data was acquired, but benthic substratum and biohabitat could not always be classified in the field.

Video surveying was carried out over a 20 day period from 9 – 10th June to 28 – 29th June, 2008. The three vessels spent around four days at each of the four locations, starting at the southern location (Location 1: Gourdon Bay) and working north, finishing at Packer Island (Location 4). Weather conditions during sampling were relatively favourable, with only a couple of days lost from the *Diadema* and *PV Walcott* sampling schedule due to a large swell and 25 – 30 knot winds at Location 2 during the middle of the survey period.

All sampling work was carried out during daylight hours between approximately 0745h to 1615h (Western Australian Local Time). The video tow technique was similar on each vessel with the camera deployed over the stern of the vessel and towed at 1 – 1.5 knots for about 500 m with the transect centred on the midpoint of the grid cell. At the completion of each transect, the video camera was retrieved onboard and the vessel steamed to the next transect site. Although sampling grids were assigned to each vessel prior to the survey, regular communication between the CSIRO, AIMS and DECWA staff during the course of the sampling was critical in order to efficiently cover all stations as there may be differences in station sampling rates and keep track of stations completed.

On the two larger vessels, the video tows were analysed onboard in real time using the computer-based habitat classification system with a GPS interface (see below for details). This video classification system generates a continuous record of the substratum and biohabitat type for each transect in csv formats as the camera moves along the transect. The *Diadema* transect recordings will be analysed post-collection by AIMS and CSIRO staff.

4.5 Habitat Classification System

On each of the three vessels, a computer was set up with a keyboard controlled habitat classification system installed. The systems used on each of the vessels were essentially the same, except for some minor software differences. The Tappity system used by the CSIRO staff was designed and developed at CSIRO Marine and Atmospheric Research Laboratories, Cleveland, while AIMS and DECWA used a system (Towvid) built by AIMS staff at their Townsville laboratories. These two base systems were configured prior to the beginning of the survey for standardisation between vessels. However,
the outputs for the habitat classification data were slightly different and required a degree of data manipulation to convert to comparable formats. The differences were in that the video transects were GPS coded at one second for the CSIRO system and every two seconds for the AIMS systems and the AIMS system has an event update function set at two seconds.

When the video transect tow is underway, the classification system is manually operated by a scientific staff member using a modified keyboard to enter a real-time summary of the seabed substratum type, biological habitats and conspicuous individual animals (Table 4-2). A lookup table is used with the transcribed keyboard and scans codes into the seabed types listed below which were logged and prefixed with date and time (in WA local time), position (in WGS84 datum) and depth data for each seabed event recorded on the tappity system.

There were three key types set up in the tappity system; Event 1 – Substratum, Event 2 – Biohabitat and Event 3 – Animal Event (Table 4-3). When the video camera commenced recording along a transect, the appropriate Event 1 and 2 keys are pressed, creating a record of position, date and time, substratum type and biohabitat cover (or no biohabitat). Following a subsequent keystroke in Event 1 or 2, a new data record is generated with the new substratum or biohabitat classification recorded (either substratum or biohabitat), but retaining the common key event. Event 3 keys are single event keys whereby pressing the appropriate key will generate a new record with the same substratum and biohabitat type as the previous record but with a record of the animal encountered. An example of the data output format of the tappity software is given below.

Table 4-2: Data output example of the habitat classification from the tappity software.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Site</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Event 1</th>
<th>Event 2</th>
<th>Event 3</th>
<th>Event 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>17/06/2008</td>
<td>09:46</td>
<td>1695</td>
<td>-17.3395</td>
<td>122.0522</td>
<td>Sand</td>
<td>Sponge Garden Sparse,</td>
<td>122.052283,Sand</td>
<td></td>
</tr>
<tr>
<td>17/06/2008</td>
<td>09:46</td>
<td>12,1695</td>
<td>-17.3395</td>
<td>122.0523</td>
<td>Sand</td>
<td>Whip Garden Sparse,</td>
<td>122.052233,Sand</td>
<td></td>
</tr>
<tr>
<td>17/06/2008</td>
<td>09:46</td>
<td>12,1695</td>
<td>-17.3395</td>
<td>122.0523</td>
<td>Sand</td>
<td>Whip Garden Medium,</td>
<td>122.052233,Sand</td>
<td></td>
</tr>
<tr>
<td>17/06/2008</td>
<td>09:46</td>
<td>13,1695</td>
<td>-17.3395</td>
<td>122.0523</td>
<td>Sand</td>
<td>Sponge Garden Sparse,</td>
<td>122.052233,Sand</td>
<td></td>
</tr>
<tr>
<td>17/06/2008</td>
<td>09:46</td>
<td>18,1695</td>
<td>-17.3396</td>
<td>122.0520</td>
<td>Sand</td>
<td>No Biohabitat,</td>
<td>Urchin</td>
<td></td>
</tr>
<tr>
<td>17/06/2008</td>
<td>09:46</td>
<td>22,1695</td>
<td>-17.3396</td>
<td>122.0521</td>
<td>Sand</td>
<td>Bioturbated,</td>
<td>Urchin</td>
<td></td>
</tr>
<tr>
<td>17/06/2008</td>
<td>09:46</td>
<td>26,1695</td>
<td>-17.3396</td>
<td>122.0521</td>
<td>Sand</td>
<td>Sponge Garden Sparse,</td>
<td>122.052133,Sand</td>
<td></td>
</tr>
</tbody>
</table>

Prior to the commencement of the habitat survey, AIMS, CSIRO and DECWA field staff established an agreed consistent habitat classification system. This classification system was designed considering video footage DECWA had taken of several of the current survey locations during previous site visits. This also included agreeing on operator consistency on the sparse, medium and dense densities for some of the biohabitat categories available.
Table 4-3: Look up list of substratum, biohabitat and animal events used in the tappity habitat classification system. These events were standardised between the CSIRO and AIMS classification systems.

<table>
<thead>
<tr>
<th>Substratum Type</th>
<th>Biohabitat Type</th>
<th>Animal Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft Mud</td>
<td>Sponge Garden Sparse</td>
<td>Anemone</td>
</tr>
<tr>
<td>Silt (Sandy-Mud)</td>
<td>Sponge Garden Medium</td>
<td>Ascidian</td>
</tr>
<tr>
<td>Sand</td>
<td>Sponge Garden Dense</td>
<td>Bryozoa</td>
</tr>
<tr>
<td>Coarse Sand</td>
<td>Alcyonarian Garden Sparse</td>
<td>Holothurian</td>
</tr>
<tr>
<td>Sand Waves / Dunes</td>
<td>Alcyonarian Garden Medium</td>
<td>Starfish</td>
</tr>
<tr>
<td>Rubble/Stones (&lt;250mm)</td>
<td>Alcyonarian Garden Dense</td>
<td>Crinoid</td>
</tr>
<tr>
<td>Rocks (&gt; 250 mm)</td>
<td>Gorgonian Garden Sparse</td>
<td>Uronin</td>
</tr>
<tr>
<td>Low Relief Reef (&lt; 0.5m)</td>
<td>Gorgonian Garden Medium</td>
<td>Hydroid</td>
</tr>
<tr>
<td>High Relief Reef (0.5-2m)</td>
<td>Gorgonian Garden Dense</td>
<td>Tridacnid Clam</td>
</tr>
<tr>
<td></td>
<td>Whip Garden Sparse</td>
<td>Sepan</td>
</tr>
<tr>
<td></td>
<td>Whip Garden Medium</td>
<td>Gastropod</td>
</tr>
<tr>
<td></td>
<td>Whip Garden Dense</td>
<td>Solitary Coral</td>
</tr>
<tr>
<td></td>
<td>Hard Coral Garden Sparse</td>
<td>Porites Coral</td>
</tr>
<tr>
<td></td>
<td>Hard Coral Garden Medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hard Coral Garden Dense</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seagrass Sparse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seagrass Dense</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Live Reef Corals</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bioturbated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bivalve Shell Beds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Algae Halimeda</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Algae turf / microphytobenthos</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Algae red / green mix</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Algae Sargassum</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Algae other brown</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No Biohabitat (bare substrate)</td>
<td></td>
</tr>
</tbody>
</table>

At the end of each video transect, or at regular intervals during the day, the tappity databases were backed up onto a secondary hard drive. At the end of each day’s activities, a third copy was saved to an external hard drive.

Once the seabed substratum, biohabitat and animal datasets (in csv format) were completed for a location, they were imported into MS Excel and Access databases for data collation and summarising to calculate the proportion of each habitat type at each transect. The details of this procedure are described below.

Each habitat classification file for a transect was loaded into an Excel worksheet and manually error checked. This included making any necessary corrections detailed in a log book during the video transect tow, backfilling the biohabitat type into the first record and adding a termination record as the final record. Each record was then given a unique sequential number and the datasets for each transect were then collated into a single file. The dataset imported into a MS Access database and compressed.
by removing similar sequential records of the substratum and biohabitat types. The ground coverage of each individual substratum and biohabitat habitat event was calculated by using the GPS data entry (start latitude and longitude) for that record and the GPS data (end latitude and longitude) from the following record where the event had changed. This gave a distance in meters which was summed for each unique substratum and biohabitat type in the transect. The percent coverage for each substratum and biohabitat type was then calculated by dividing their summed measurement by the total distance of the video tow, calculated from the addition of each of the individual summed measurements within the transect. This information was then mapped as pie diagrams and bubble plots to generate distribution maps of the relative abundances of substratum and biohabitat type. The animal event data (Event 3) was used to calculated the number of animals seen along the transect and was expressed in animals per km, and mapped as bubble plots.

4.6 Benthic sample collection

During the survey, CSIRO deployed the benthic dredge on a number of transects to collect biological samples for habitat classification validation and later species level identification. The dredge had a galvanised steel frame with the opening mouth measuring 1.5 m wide by 0.4 m high and steel meshed sides of a depth of 1.0 m. A nylon codend (25 mm stretched mesh) was attached to the posterior of the dredge. The dredge was towed from a chain attached to the front of each side of the frame and coupled to the winch wire via a 2 tonne shearing link. A camera housing was side mounted inside the dredge mouth for video recording.

The dredge was targeted at different benthic community types at each site with three to four dredges carried out at each location. When a suitable habitat was observed during a video transect, the vessel would turn around once the video transect was completed and tow the dredge at 1 – 1.5 knots for about 250 m (5 minutes) along the same tow path to sample the benthic communities. However, the length of the dredge tow was varied depending on the density of the biohabitat targeted. If dense seabed structure was observed on the echosounder, the tow length was restricted to 150 – 200 m.

Once the dredge sample was brought on deck, it was sorted to taxonomic groups, similar to the habitat classification categories used in the video analysis. Within each of these broad groups, the dominant genera or species were separated, bar-coded, photographed and weighed. The remaining biota in each group was bar-coded, photographed and weighed as a mixed taxonomic group. These data and images were then entered into a MS Access database. A representative sample of each of the different species was retained, placed in labelled plastic bags and frozen.

4.7 Depth Data Analysis

Depth soundings were recorded with four standard singlebeam echosounders from three vessels. The four data sets are subsequently referred to as CSIRO, WALCOTT, AIMS and DEC. CSIRO and WALCOTT were recorded with the respective vessel’s echosounder in C-plot format set at a 5 second frequency, and AIMS and DEC were recorded with the AIMS tow video system in csv format. WALCOTT and AIMS were recorded from the same vessel but with different echosounders; the WALCOTT and CSIRO data set includes data collected during AIMS camera tows and during steaming, whereas the AIMS csv data set only includes data collected during camera tows. Therefore, the AIMS csv data is not reported here. Data was not corrected for vessel movements (pitch / roll). To enable correction for the local tide, an AIMS tide gauge (Branker XR420TG) was deployed from PV Walcott while surveys were underway at each location.
The following procedure was applied to each data set / location:

1. CSIRO and WALCOTT data were corrected for sounder immersion; DEC data were corrected for sounder immersion in the tow video acquisition software.
2. The raw soundings were cleaned manually and corrected for tidal water level variations.
3. For each of the four bounded locations, the height datum of the cleaned and corrected xyz files was compared to a reference surface based on the WALCOTT data set. The offset between each line and the reference surface was calculated. An IHO order 2 survey test was performed in order to ensure consistency between data sets. The results of the tests are summarized in Table 4-9. Generally, the WALCOTT and DEC data are consistent with each other. The CSIRO dataset is systematically offset by -0.2 m (but not at Gourdon Bay, see Table 4-4 to Table 4-6). WALCOTT and DEC are assumed to be recorded at the correct height datum, and the CSIRO data set has been adjusted to this datum.
4. Data is reported in csv format

```
lat,lon,DepthRaw,DepthTideCorr,timeWST
-18.403467,121.842932,-15.70,-13.66,10-Jun-2008 10:26:02
-18.403567,121.842617,-15.50,-13.46,10-Jun-2008 10:26:08
-18.403683,121.842250,-15.30,-13.26,10-Jun-2008 10:26:14
...
```

where

<table>
<thead>
<tr>
<th>lat</th>
<th>latitude in WGS84 unprojected</th>
</tr>
</thead>
<tbody>
<tr>
<td>lon</td>
<td>longitude in WGS84 unprojected</td>
</tr>
<tr>
<td>DepthRaw</td>
<td>raw sounding</td>
</tr>
<tr>
<td>DepthTideCorr</td>
<td>depth corrected for tidal variation, sounder immersion (where applicable) and cleaned</td>
</tr>
<tr>
<td>timeWST</td>
<td>time in Western Standard time</td>
</tr>
</tbody>
</table>

5. For each of the bounded locations, the bathymetry used for gridding is compiled into one file. In addition, each supplementary transect line is reported separately.

Table 4-4 through to Table 4-6 shows a summary of the data processed. The procedure is described in more detail below.
Table 4-4: Summary of depth data for the Gourdon Bay and Quondong Point – Coulomb Point locations.

### Gourdon Bay

<table>
<thead>
<tr>
<th>filename</th>
<th>tidal correction</th>
<th>SOL WST</th>
<th>EOL WST</th>
<th>offset</th>
<th>IHO offset</th>
<th># points</th>
<th>IHO median</th>
<th>IHO std</th>
<th>order2</th>
</tr>
</thead>
<tbody>
<tr>
<td>bathyWALCOTT_GB.csv</td>
<td>GB observed</td>
<td>10/06/08</td>
<td>13/06/08</td>
<td>1.1</td>
<td>0</td>
<td>19537</td>
<td>0.005</td>
<td>0.127</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyCSIRO_GB.csv</td>
<td>GB observed</td>
<td>10/06/08</td>
<td>13/06/08</td>
<td>3.1</td>
<td>0</td>
<td>2279</td>
<td>-0.071</td>
<td>0.256</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyDEC_GB.csv</td>
<td>GB observed</td>
<td>11/06/08</td>
<td>13/06/08</td>
<td>0.2</td>
<td>0</td>
<td>840</td>
<td>-0.049</td>
<td>0.068</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyWALCOTT_SOLtoGB.csv</td>
<td>GB approx</td>
<td>10/06/08</td>
<td>18/06/08</td>
<td>1.1</td>
<td>0</td>
<td>147</td>
<td>-0.118</td>
<td>0.228</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyWALCOTT_GBtoQU_1.csv</td>
<td>GB approx</td>
<td>13/06/08</td>
<td>13/06/08</td>
<td>0.2</td>
<td>0</td>
<td>58</td>
<td>0.163</td>
<td>0.225</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyCSIRO_SOLtoGB.csv</td>
<td>GB approx</td>
<td>14/06/08</td>
<td>17/06/08</td>
<td>3.1</td>
<td>-0.2</td>
<td>521</td>
<td>0.180</td>
<td>0.242</td>
<td>accepted</td>
</tr>
</tbody>
</table>

### Quondong

<table>
<thead>
<tr>
<th>filename</th>
<th>tidal correction</th>
<th>SOL WST</th>
<th>EOL WST</th>
<th>offset</th>
<th>IHO offset</th>
<th># points</th>
<th>IHO median</th>
<th>IHO std</th>
<th>order2</th>
</tr>
</thead>
<tbody>
<tr>
<td>bathyWALCOTT_QU.csv</td>
<td>QU observed</td>
<td>14/06/08</td>
<td>18/06/08</td>
<td>1.1</td>
<td>0</td>
<td>19284</td>
<td>-0.001</td>
<td>0.285</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyCSIRO_QU.csv</td>
<td>QU observed</td>
<td>10/06/08</td>
<td>14/06/08</td>
<td>1.1</td>
<td>-0.2</td>
<td>397</td>
<td>-0.045</td>
<td>0.273</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyDEC_QU.csv</td>
<td>QU observed</td>
<td>11/06/08</td>
<td>17/06/08</td>
<td>0.2</td>
<td>0</td>
<td>1454</td>
<td>-0.173</td>
<td>0.246</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyDEC_CP.csv</td>
<td>QU approx</td>
<td>15/06/08</td>
<td>16/06/08</td>
<td>0.2</td>
<td>no overlap</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bathyWALCOTT_GBtoQU_2.csv</td>
<td>QU approx</td>
<td>14/06/08</td>
<td>14/06/08</td>
<td>1.1</td>
<td>0</td>
<td>81</td>
<td>-0.151</td>
<td>0.465</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyWALCOTT_QUtoPH_1.csv</td>
<td>QU approx</td>
<td>14/06/08</td>
<td>14/06/08</td>
<td>1.1</td>
<td>0</td>
<td>21</td>
<td>0.154</td>
<td>0.269</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyCSIRO_QUtoPH.csv</td>
<td>QU approx</td>
<td>14/06/08</td>
<td>14/06/08</td>
<td>3.1</td>
<td>-0.2</td>
<td>362</td>
<td>0.120</td>
<td>0.501</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyCSIRO_PH_1.csv</td>
<td>QU approx</td>
<td>08/15/06</td>
<td>15/11/51</td>
<td>3.1</td>
<td>same as bathyCSIRO_QUtoPH.csv</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>filename</td>
<td>file source</td>
<td>tidal correction</td>
<td>SOL WST</td>
<td>EOL WST</td>
<td>offset</td>
<td># points</td>
<td>IHO median</td>
<td>IHO std</td>
<td>order 2</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
<td>------------------</td>
<td>---------</td>
<td>---------</td>
<td>--------</td>
<td>----------</td>
<td>------------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>bathyWALCOTT_PH.csv</td>
<td>PH observed</td>
<td>19/06/08 08:15:00</td>
<td>23/06/08 15:24:58</td>
<td>1.1</td>
<td>0</td>
<td>24449</td>
<td>0.003</td>
<td>0.175</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyCSIRO_PH_2.csv</td>
<td>PH observed</td>
<td>19/06/08 15:11:57</td>
<td>23/06/08 15:24:53</td>
<td>3.1</td>
<td>-0.2</td>
<td>1650</td>
<td>0.033</td>
<td>0.277</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyDEC_PH_1.csv</td>
<td>PH observed</td>
<td>19/06/08 08:42:42</td>
<td>22/06/08 16:05:58</td>
<td>0.2</td>
<td>0</td>
<td>2229</td>
<td>-0.244</td>
<td>0.586</td>
<td>rejected</td>
</tr>
<tr>
<td>bathyDEC_PH_2.csv</td>
<td>PH observed</td>
<td>19/06/08 08:40:45</td>
<td>24/06/08 16:34:03</td>
<td>0.2</td>
<td>0</td>
<td>288</td>
<td>-0.098</td>
<td>0.140</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyWALCOTT_QUtoPH_2.csv</td>
<td>PH approx</td>
<td>18/06/08 18:03:22</td>
<td>19/06/08 08:14:52</td>
<td>1.1</td>
<td>0</td>
<td>334</td>
<td>0.091</td>
<td>0.290</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyWALCOTT_PHtoPI.csv</td>
<td>PH approx</td>
<td>15/06/08 08:42:42</td>
<td>24/06/08 16:05:58</td>
<td>0.2</td>
<td>0</td>
<td>2229</td>
<td>-0.244</td>
<td>0.586</td>
<td>rejected</td>
</tr>
<tr>
<td>bathyWALCOTT_PItoEOL_1.csv</td>
<td>RedBluffPred</td>
<td>16/06/08 16:40:04</td>
<td>26/06/08 17:54:32</td>
<td>1.1</td>
<td>0</td>
<td>31</td>
<td>-0.008</td>
<td>0.222</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyCSIRO_PItoEOL.csv</td>
<td>RedBluffPred</td>
<td>16/06/08 16:40:01</td>
<td>26/06/08 17:54:32</td>
<td>1.1</td>
<td>0</td>
<td>31</td>
<td>-0.008</td>
<td>0.222</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyWALCOTT_PI_2.csv</td>
<td>PI observed</td>
<td>16/06/08 16:41:12</td>
<td>26/06/08 07:37:10</td>
<td>1.1</td>
<td>0</td>
<td>92</td>
<td>-0.008</td>
<td>0.205</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyCSIRO_PI_2.csv</td>
<td>PI observed</td>
<td>15/06/08 16:46:10</td>
<td>26/06/08 16:39:55</td>
<td>3.1</td>
<td>-0.2</td>
<td>4</td>
<td>0.208</td>
<td>0.130</td>
<td>accepted</td>
</tr>
</tbody>
</table>

### Perpendicular Head

<table>
<thead>
<tr>
<th>filename</th>
<th>file source</th>
<th>tidal correction</th>
<th>SOL WST</th>
<th>EOL WST</th>
<th>offset</th>
<th># points</th>
<th>IHO median</th>
<th>IHO std</th>
<th>order 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>bathyWALCOTT_PH.csv</td>
<td>PH observed</td>
<td>19/06/08 08:15:00</td>
<td>23/06/08 15:24:58</td>
<td>1.1</td>
<td>0</td>
<td>24449</td>
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<td>0.175</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyCSIRO_PH_2.csv</td>
<td>PH observed</td>
<td>19/06/08 15:11:57</td>
<td>23/06/08 15:24:53</td>
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<td>-0.2</td>
<td>1650</td>
<td>0.033</td>
<td>0.277</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyDEC_PH_1.csv</td>
<td>PH observed</td>
<td>19/06/08 08:42:42</td>
<td>22/06/08 16:05:58</td>
<td>0.2</td>
<td>0</td>
<td>2229</td>
<td>-0.244</td>
<td>0.586</td>
<td>rejected</td>
</tr>
<tr>
<td>bathyDEC_PH_2.csv</td>
<td>PH observed</td>
<td>19/06/08 08:40:45</td>
<td>24/06/08 16:34:03</td>
<td>0.2</td>
<td>0</td>
<td>288</td>
<td>-0.098</td>
<td>0.140</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyWALCOTT_QUtoPH_2.csv</td>
<td>PH approx</td>
<td>18/06/08 18:03:22</td>
<td>19/06/08 08:14:52</td>
<td>1.1</td>
<td>0</td>
<td>334</td>
<td>0.091</td>
<td>0.290</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyWALCOTT_PHtoPI.csv</td>
<td>PH approx</td>
<td>15/06/08 15:25:04</td>
<td>26/06/08 08:24:56</td>
<td>1.1</td>
<td>0</td>
<td>532</td>
<td>-0.070</td>
<td>0.281</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyWALCOTT_PItoEOL_1.csv</td>
<td>RedBluffPred</td>
<td>16/06/08 16:40:04</td>
<td>26/06/08 17:54:32</td>
<td>1.1</td>
<td>0</td>
<td>31</td>
<td>-0.008</td>
<td>0.222</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyCSIRO_PItoEOL.csv</td>
<td>RedBluffPred</td>
<td>16/06/08 16:40:01</td>
<td>26/06/08 17:54:32</td>
<td>1.1</td>
<td>0</td>
<td>31</td>
<td>-0.008</td>
<td>0.222</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyWALCOTT_PI_2.csv</td>
<td>PI observed</td>
<td>16/06/08 16:41:12</td>
<td>26/06/08 07:37:10</td>
<td>1.1</td>
<td>0</td>
<td>92</td>
<td>-0.008</td>
<td>0.205</td>
<td>accepted</td>
</tr>
<tr>
<td>bathyCSIRO_PI_2.csv</td>
<td>PI observed</td>
<td>15/06/08 16:46:10</td>
<td>26/06/08 16:39:55</td>
<td>3.1</td>
<td>-0.2</td>
<td>4</td>
<td>0.208</td>
<td>0.130</td>
<td>accepted</td>
</tr>
</tbody>
</table>

### Packer Island
## Supplementary Transect Lines

<table>
<thead>
<tr>
<th>filename</th>
<th>tidal correction</th>
<th>SOL WST</th>
<th>EOL WST</th>
<th>offset</th>
<th>IHO offset</th>
<th># points</th>
<th>IHO median</th>
<th>IHO std</th>
<th>order2</th>
</tr>
</thead>
<tbody>
<tr>
<td>bathyDEC_line1.csv</td>
<td>GB approx</td>
<td>28/06/08 10:58:53</td>
<td>28/06/08 13:09:09</td>
<td>0.2</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bathyCSIRO_GB.csv</td>
<td>GB observed</td>
<td>13/06/08 15:24:31</td>
<td>13/06/08 16:00:44</td>
<td>3.1</td>
<td>-0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bathyWALCOTT_PItoEOL_3.csv</td>
<td>GB approx</td>
<td>28/06/08 10:23:24</td>
<td>28/06/08 12:53:00</td>
<td>1.1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Line2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bathyDEC_line2.csv</td>
<td>QU approx</td>
<td>28/06/08 08:36:15</td>
<td>28/06/08 08:51:03</td>
<td>0.2</td>
<td>-0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bathyCSIRO_GBtoQU.csv</td>
<td>QU approx</td>
<td>14/06/08 09:25:48</td>
<td>14/06/08 10:04:54</td>
<td>3.1</td>
<td>-0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bathyCSIRO_QU.csv</td>
<td>QU observed</td>
<td>14/06/08 10:05:00</td>
<td>14/06/08 11:34:38</td>
<td>3.1</td>
<td>-0.2</td>
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<td><strong>Line3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bathyDEC_line3.csv</td>
<td>QU approx</td>
<td>27/06/08 12:32:49</td>
<td>27/06/08 13:52:36</td>
<td>0.2</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bathyWALCOTT_PItoEOL_2.csv</td>
<td>QU approx</td>
<td>27/06/08 11:56:58</td>
<td>27/06/08 13:44:04</td>
<td>1.1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filename</td>
<td>Tidal Correction</td>
<td>SOL WST</td>
<td>EOL WST</td>
<td>Offset</td>
<td>IHO Offset</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------------------</td>
<td>---------------</td>
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</tr>
<tr>
<td>bathyDEC_line4.csv</td>
<td>RedBluffPred</td>
<td>27/06/08 10:54:24</td>
<td>27/06/08 11:31:30</td>
<td>0.2</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bathyCSIRO_PH.csv</td>
<td>PH observed</td>
<td>23/06/08 09:39:55</td>
<td>23/06/08 10:40:00</td>
<td>3.1</td>
<td>-0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bathyWALCOTT_PttoEOL_1.csv</td>
<td>RedBluffPred</td>
<td>27/06/08 10:04:40</td>
<td>27/06/08 11:02:02</td>
<td>1.1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bathyDEC_line5.csv</td>
<td>RedBluffPred</td>
<td>27/06/08 09:39:15</td>
<td>27/06/08 10:15:56</td>
<td>0.2</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bathyCSIRO_PH.csv</td>
<td>PH observed</td>
<td>22/06/08 15:26:17</td>
<td>23/06/08 08:59:26</td>
<td>3.1</td>
<td>-0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bathyWALCOTT_PttoEOL_1.csv</td>
<td>RedBluffPred</td>
<td>27/06/08 09:06:58</td>
<td>27/06/08 09:29:28</td>
<td>1.1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Filename: filename (includes source and location)
Tidal correction: tidal correction applied (observed or approximated predicted tide)
SOL WST / EOL WST: start of line / end of line in Western Standard Time
Offset: sounder immersion (m)
IHO offset: offset from reference surface as calculated from IHO order 2 test (m) as calculated at adjacent bounded survey locations.
4.7.1 Conversion of measured water level to survey datum

The observed tidal water level as measured by the AIMS tide gauge was adjusted to Broome Prediction Datum (4.55 m below MSL; see AHO tide tables, SEAFARER electronic edition) by:

1. converting raw pressure to depth following AIMS standard procedures (based on UNESCO 1983 standards and Matlab conversion script by CSIRO).
2. calculating average depth of tide gauge (MSL) by averaging depth over full tidal cycles (e.g. for Gourdon Bay deployment from 10/06/08 14:55 to 13/06/08 12:10).
3. correcting height datum to Broome datum.

Table 4-7: Summary of the observed tide data at each location.

<table>
<thead>
<tr>
<th>location</th>
<th>filename</th>
<th>from WST</th>
<th>to WST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gourdon Bay</td>
<td>GourdonBayTidesCorrected.CSV</td>
<td>10/06/08</td>
<td>13/06/08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10:25:00</td>
<td>16:55:00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14/06/08</td>
<td>18/06/08</td>
</tr>
<tr>
<td>Quondong</td>
<td>QuondongTidesCorrected.csv</td>
<td>10:05:00</td>
<td>14:30:00</td>
</tr>
<tr>
<td>Perp Head</td>
<td>PerpendicularHeadTidesCorrected.CSV</td>
<td>08:15:00</td>
<td>15:25:00</td>
</tr>
<tr>
<td>Packer Island</td>
<td>PackerIslandTidesCorrected.CSV</td>
<td>08:25:00</td>
<td>16:40:00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24/06/08</td>
<td>26/06/08</td>
</tr>
</tbody>
</table>

Tidal water levels are provided in csv format. For observed tide, columns are:

- timeWST: time in Western Standard time
- PresRaw: measured pressure
- DepthBroomeDatum: water depth in AHO Broome Prediction Datum (4.55 m above MSL)

4.7.2 Approximation of predicted tide

A significant portion of the survey was carried out during time periods when no tide gauge was deployed, e.g. during transits between locations and for supplementary transect lines. Some of this data contributes to the bounded locations or supplementary transect lines. For these periods, the AHO predicted tide was extrapolated using parameters obtained by linear interpolation with the nearest observed tide. This was carried out separately for each study location. For the southern locations (Gourdon Bay and Quondong), the predicted tide at Broome (18° 0’ S; 122° 13’ E: AHO port number 62650) was used in corrections and for the northern locations (Perpendicular Head and Packer Island), the predicted tide at the closer Red Bluff (17° 2’ S; 122° 19’ E: AHO port number 62680) was used. Time offset from the respective tidal station to the survey location was assumed negligible. Subsequent to the tidal correction, each file underwent an IHO order 2 test to verify correct tidal correction (Table 4-7).
Table 4-8: Summary of approximated tide data for the four sampling locations.

<table>
<thead>
<tr>
<th>location</th>
<th>filename</th>
<th>AHO station approximated</th>
<th>A</th>
<th>B</th>
<th>R²</th>
<th>std</th>
<th>max diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gourdon Bay</td>
<td>PredTideBroomeCorrected</td>
<td>Broome</td>
<td>0.212</td>
<td>0.949</td>
<td>0.996</td>
<td>0.061</td>
<td>0.17</td>
</tr>
<tr>
<td>Quondong</td>
<td>PredTideBroomeCorrected</td>
<td>Broome</td>
<td>0.781</td>
<td>0.830</td>
<td>0.992</td>
<td>0.108</td>
<td>0.26</td>
</tr>
<tr>
<td>Perpendicular Head</td>
<td>PredTideRedBluffCorrected</td>
<td>Red Bluff</td>
<td>0.420</td>
<td>0.915</td>
<td>0.997</td>
<td>0.091</td>
<td>0.22</td>
</tr>
<tr>
<td>Packer Island</td>
<td>PredTideRedBluffCorrected</td>
<td>Red Bluff</td>
<td>0.015</td>
<td>1.001</td>
<td>0.996</td>
<td>0.082</td>
<td>0.18</td>
</tr>
</tbody>
</table>

A / B interpolation parameters (tide_approximate = A + B * tide_observed)

R² / std R² and standard deviation of interpolation

max diff maximum difference between approximated and observed tide (m)

Tidal water levels are provided in csv format. For corrected predicted tide, columns are:

timeWST
PredBroomeDatum (PredRedBluffDatum) AHO prediction at datum of respective tidal station
PredCorrXXX corrected predicted tide for a location

Figure 4-7: Comparison of tidal data from the four locations surveyed.
4.7.3 Bathymetry processing

The three different data sets were processed following the procedures detailed below.

**CSIRO C-Plot soundings**

1) Break up continuous C-plot record into sections corresponding with and without deployment of tide gauges (see Table 4-7).
2) Convert time base from UTC to WST.
3) Correct for tidal variation using the tidal record closest to each sounding (5min temporal resolution). Correct for sounder immersion depth (3.1m) and IHO offset as determined from IHO order 2 test (-0.2 m for Quondong, Perpendicular Head and Packer Island; 0.0 m for Gourdon Bay – see Table 4-7 and below).
4) Manually remove bad soundings and bad GPS time records by visual inspection of sounding time series.

**WALCOTT C-Plot soundings**

1) Break up continuous C-plot record into sections corresponding with and without deployment of tide gauges (see Table 4-7).
2) Convert time base from UTC to WST.
3) Correct for tidal variation using the tidal record closest to each sounding (5min temporal resolution). Correct for sounder immersion depth (1.1m).
4) Manually remove bad soundings and bad GPS time records by visual inspection of sounding time series.

**DEC tow cam soundings**

1) Merge all tow cam recording sites for each bounded location.
2) Correct for tidal variation using the tidal record closest to each sounding (5min temporal resolution). No additional correction for sounder immersion depth. Time base in csv file is WST.
3) Manually remove bad soundings by visual inspection of sounding time series.

4.7.4 Cross calibration of bathymetric data sets

In order to ensure a consistent height datum, the tidally corrected bathymetry of each line was compared to a reference surface, and a standard test following IHO protocol was performed (see Table 4-8). Data was tested to IHO order 2 survey standards. For each bounded location, the reference surface was constructed by inverse distance weighted (IDW) interpolation of the WALCOTT data with the ARC GIS toolbox (0.00045° grid spacing (ca 50m), fixed radius of 0.0009°). Soundings of other data sets that overlapped with this grid were used in the hydrographic test.

The median depth in Table 4-7 indicates the systematic depth offset between the reference surface and the respective data set. In the absence of calibration data, the data set WALCOTT is taken as the correct datum. This data set is consistent with the DEC data. The CSIRO data has a -0.2 m offset which has been corrected for.

Note that IHO order 2 survey tests are applicable in areas up to 200 m depth, outside areas where special order or order 1 surveys are required. The later include harbours, berthing areas and critical channels (special order), and approach channels, tracks (shipping lanes etc) and some coastal areas up to 100 m depth (order 1). Order 2 surveys have the following specifications:
horizontal accuracy: 5m+5% depth  
depth accuracy: 0.5 m + a depth dependant error  
100% bottom search: not normally required  
detection capability: cubic features > 2 m in depth up to 40 m, 10% of depth beyond 40 m  
line spacing: 3x average depth or 200 m whichever is greater  

With exception of two DEC lines, all lines passed the IHO order 2 test (Table 4-4 to Table 4-6). For these two lines, the order 2 test narrowly failed because of the relatively large standard deviation of the offset. Considering that the IHO order 2 test is a stricter test than required for the purpose of this report, the data was included. This is not considered a source for a large error. Note that most lines also passed IHO order 1 tests (not reported here).

4.7.5 Interpolation & contouring of corrected bathymetry

For each bounded location, the line data was merged into a single csv file and edited to include data contributing to a gridded surface within the specified bounds or to the supplementary transect lines respectively. These merged bathymetry surveys are shown on the provided mapsheets. The bathymetry was gridded by inverse distance-weighted interpolation using the ARC GIS Spatial Analyst toolbox. The following settings were used: power 2; search radius variable; max search distance 0.009° (ca. 1000m); min number of points 4; output cell size 0.0018° (ca 200m). A brief summary of the relevant features of this algorithm is included below (extract from ARC GIS help files). Subsequently, the interpolated grid was cropped to the location bounds. Bathymetry contours at depths 5, 10, 15, 17 and 20 m were calculated from the interpolated grid using the ARC GIS spatial analyst toolbox.

A grid spacing of ca. 200 m with a search radius of 1000 m is considered an adequate treatment to both conserve measured bathymetry and to provide near-full coverage of the bounded locations by interpolation. Note that the resulting contour lines would not be significantly different if other interpolation settings or grid spacing was used.

Table 4-9: Summary of the compiled bathymetry and grid data for the four locations.

<table>
<thead>
<tr>
<th>Location</th>
<th>bathymetry filename (.csv)</th>
<th>grid filename (.aux)</th>
<th>contour filename (.shp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gourdon Bay</td>
<td>GourdonBayBathymetryComplete</td>
<td>GB_IDW_200m</td>
<td>GB_IDW_200m_contours</td>
</tr>
<tr>
<td>Coulomb/Quondong</td>
<td>QuondongBathymetryComplete</td>
<td>QU_IDW_200m</td>
<td>QU_IDW_200m_contours</td>
</tr>
<tr>
<td>Perp Head</td>
<td>PerpendicularHeadBathymetryComplete</td>
<td>PH_IDW_200m</td>
<td>PH_IDW_200m_contours</td>
</tr>
<tr>
<td>Packer Island</td>
<td>PackerIslandBathymetryComplete</td>
<td>PI_IDW_200m</td>
<td>PI_IDW_200m_contours</td>
</tr>
</tbody>
</table>

For each location, three mapsheets are provided separately to this report in pdf format showing the ungridded bathymetry, the 200 m grid (including contour lines) and contour lines respectively.
4.7.6 Inverse distance-weighted interpolation – ARC GIS help files

Inverse distance weighted (IDW) interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. The surface being interpolated should be that of a locationally dependent variable. IDW lets the user control the significance of known points on the interpolated values, based on their distance from the output point. By defining the higher {power} option, even more emphasis can be put on the nearest points. Thus, nearby data will have the most influence, and the surface will have more detail (be less smooth). Specifying a lower value for power will provide a bit more influence to surrounding points a little farther away. The power is a positive, real number. A common value is 2. The characteristics of the interpolated surface can also be controlled by limiting the input points for calculating each interpolated point. The input can be limited by the number of sample points to be used or by a radius within which there are all points to be used in the calculation of the interpolated points.

**Power**

With IDW, you can control the significance of known points on the interpolated values based on their distance from the output point. By defining a higher power, more emphasis is placed on the nearest points, and the resulting surface will have more detail (be less smooth). Specifying a lower power will give more influence to the points that are farther away, resulting in a smoother surface. A power of 2 is most commonly used with IDW and is the default.

**Search radius**

The characteristics of the interpolated surface can also be controlled by applying a search radius (fixed or variable), which limits the number of input points that can be used for calculating each interpolated cell. You limit the number of points for each cell's calculation to improve processing speeds. You can also limit the number of points, because points far from the cell location where the prediction is being made may have no spatial correlation.

**Variable search radius**

With a variable search radius, the number of points used in calculating the value of the interpolated cell is specified, which makes the radius distance vary for each interpolated cell, depending on how far it has to search around each interpolated cell to reach the specified number of input points. Thus, some neighbourhoods can be small and others can be large, depending on the density of the measured points near the interpolated cell. You can also specify a maximum distance (in map units) that the search radius cannot exceed. If the radius for a particular neighbourhood reaches the maximum distance before obtaining the specified number of points, the prediction for that location will be performed on the number of measured points within the maximum distance. Generally you will use smaller neighbourhoods or a minimum number of points when the phenomenon has a great amount of variation.
Kimberley Bathymetry Survey
June 2008
Site Overview

For survey areas, gridded bathymetry is shown; for lines, ungridded bathymetry is shown.

Figure 4-8: Kimberley bathymetry survey overview. Detailed maps of each bounded location are provided separately in pdf format.
5. DESCRIPTION OF SEABED TYPES

The habitat classification system captured all of the substratum and biohabitat types encountered during the survey work. However, some categories were very sparsely represented such as soft mud and rocky for the substratum types; live reef corals, Porites coral and bivalve shell beds for the biohabitat categories; and gastropods and tridacnid clams for the solitary animals. A representative selection of each of these different substratum and biohabitat types, including the animal events, were captured as still images and shown below.

5.1 Substratum

The images presented below are an example only of the substratum we have observed, there are many variations and these examples are a selection from the video analysis to date.

Figure 5-1: Silt (Sandy-Mud) rippled with a fine layer of filamentous algae on the sand shown in the top left corner.
Figure 5-2: Sand Waves (~0.5 m amplitude) with small ripples less than 100 mm in amplitude. Coarse sand in the troughs between the crests of the waves.

Figure 5-3: Rubble and stones (<250 mm) overlying sand.
Figure 5-4: Coarse Sand substratum with shell, coral, echinoderm and rubble fragments.

Figure 5-5: Low relief reef (< 0.5m) comprising sponges, whips, gorgonians, hard corals and algae. There is a thin layer of sand over a firmer substrate of rock.
Figure 5-6: High relief reef (> 0.5m) comprising sponges, whips, gorgonians and hard corals on a rock ridge.

Figure 5-7: Rock substratum with a hard coral (*Turbinaria* sp) attached at the middle left hand side. The foreground is sand. Classified as rocks.
Figure 5-8: Sand with protruding rock substratum. Gorgonian garden medium and sparse sponges attached to the rock. This is classified as low relief reef (< 0.5m).

5.2 Bioturbated substratum

The images presented below are an example only of the substratum we have observed, there are many variations and these examples are a selection from the video analysis to date.

Figure 5-9: Bioturbated sand with many burrows evident, the dark patches are algae turf / microphyte mats.
5.3 Biohabitat Description

The images presented below are an example only of the biohabitats we have observed, there are many variations and these examples are a selection from the video analysis to date.

5.3.1 Sponges

Figure 5-11: Sponge garden sparse showing individual scattered sponges. May be represented by a single sponge.
Figure 5-12: Sponge garden medium showing a denser community of sponges.

Figure 5-13: Sponge garden dense has many sponges of various species adjacent to each other.
5.3.2 Alcyonaria

Figure 5-14: Alcyonarian garden sparse with smaller sparse sponges. The Alcyonarian is the multi-branched organism in the fore-ground.

Figure 5-15: Alcyonarian garden medium with smaller sparse barrel sponge in the middle.
Figure 5-16: Alcyonarian garden dense on sand.

Figure 5-17: Pennatulacea garden dense consisting of possibly two species of sea pen. Very common at Packer Island deep transects.
5.3.3 Gorgonians

Figure 5-18: Gorgonian garden sparse on a rock substratum, several species of sponge can be seen in background.

Figure 5-19: Gorgonians garden medium, species of Solenocaulon on a sand substratum.
5.3.4 Whips (*Junceella* species)

Figure 5-20: Whip garden sparse mixed with sponge garden sparse.

Figure 5-21: Whip garden medium on sand.
Figure 5-22: Whip garden dense on a sand and rock substratum.

5.3.5 Hard corals

Figure 5-23: Hard coral garden sparse – a solitary flowerpot coral with white rim (*Turbinaria* sp) interspersed with gorgonians and sponges.
Figure 5-24: Hard coral garden medium with numerous flowerpot corals (*Turbinaria* sp) interspersed with sponges.

5.3.6 Marine plants (algae/seagrass)

Figure 5-25: Algae turf / microphyte showing tufts of algae on the crests of rippled sand.
Figure 5-26: Seagrass sparse (Halophila sp) centre of picture on sand with algae turf / microphyte.

Figure 5-27: Algae Sargassum sp on sand
Figure 5-28: Algae mix. *Sargassum* sp and runners of *Caulerpa* sp on sand.

Figure 5-29: Algae red/green mix on a rocky substratum.
Figure 5-30: Live reef coral on a rocky outcrop with encrusting algae and bryozoans.
6. DESCRIPTION OF SAMPLING LOCATIONS

During the survey work, 606 transects were completed with video footage captured and analysed in real time for habitat classification data. The habitat descriptions provided in this report refer to these completed transects and should be viewed as a preliminary description only.

A further 169 transects were completed with video footage recorded only. Post-survey analysis of these video files will be required to obtain habitat classification, which is proposed to be completed for the final report submission due in August 2008.

6.1 Gourdon Bay

A total of 144 transects were completed at Gourdon Bay. However, the transects in the secondary and tertiary priority areas of the Gourdon Bay sampling location were rationalised due to time constraints. All of the tertiary sites (44 sites) were dropped and 20 of the 51 secondary priority sites were dropped from the sampling schedule. Several of the sites that fell within the pearl lease areas were also not completed.

6.1.1 Substratum Type

The substratum composition at Gourdon Bay was mostly fine sand, about 56% coverage of the seabed area surveyed. There were patches of coarse sand, predominantly in the shallower areas of the bay and fine sand substrate in deeper waters. There were also isolated patches of sand waves or dunes around the shoal area offshore where currents are likely to be more pronounced. There was no mud or silty substrates found at this location.

There were a few transects that showed rubble/stones or rock habitat, mainly in the very shallow intertidal zone and along the 10 m contour line. Some low relief reef was also present along the edge of this depth contour, around the edges of the offshore shoals and in shallow waters out from the southern headland of Gourdon Bay.

6.1.2 Biohabitat Type

Sponges were the dominant filter feeding group along most of the transect sites within Gourdon Bay. The abundances of these sponges varied from sparse to medium density, with only a few sites showing dense sponge patches. These sponge patches were generally associated with low relief reef substratum in the mid to offshore depths surveyed. Whip and gorgonian gardens were also relatively widespread, but not generally in high abundances. These groups tended to occur in areas of similar substratum characteristics to the sponge gardens. Very few soft coral or hard coral gardens were observed in the transects from Gourdon Bay.

Where the seabed was mostly characterised by coarse sand and sand dunes and waves, there was generally little biohabitat observed; mostly along the nearshore transect sites and at the deep water sites between the offshore shoals. In the very nearshore transects including the intertidal zone, there was a relatively high percentage coverage of the seagrass, *Halophila* sp. There was also a significant
coverage of bioturbated ground in these shallow areas, with some patches along the 10 m depth contour.

6.1.3 Animal Abundance

Heart urchins and crinoids were the most abundant benthic animal encountered within the Gourdon Bay location, however their distributions were patchy. They generally occurred in large groups, often in the thousands, on flat sandy substrates that had a thin green mat algae cover. Ascidians and bryozoans were also relatively common among sponge and whip gardens, with the bryozoans generally attached to dead whips.

6.2 Quondong Point – Coulomb Point

All of the 172 accessible sites were completed at this location including several additional sites in the inshore area north of James Price Point. The transect sites within the pearl leases at location 2 (Quondong Point to Coulomb Point) were not attempted, except for several sites within the southern pearl lease off Quondong Point where permission was given by the lease owners to enter these areas.

6.2.1 Substratum Type

The majority of the area around Coulomb Point consisted of fine sand substratum (70% sand coverage), from the shallow water out to the extent of the survey boundary, with patches of sand waves and dunes seen in the shallower water transects. The deeper water transects at the southern end were predominately flat sandy substrate and some silty-sand seaward of the southern pearl farm off Quondong Point to James Price Point. The seabed in the northern section within this location, from James Price Point, was also comprised of mostly sand (55% coverage) but there were extensive areas of sand dunes and waves from inshore to the outer depth extent of the survey boundary.

This northern area was also characterised by relatively large areas of low relief reef structure. Only one transect site in this area showed a significant coverage of high relief reef structure and rocky substratum. There were also areas of low relief reef in the surveyed areas along the coast from Quondong Point to James Price Point but these were restricted to the shallow waters.

6.2.2 Biohabitat Type

The offshore flat sandy areas from Quondong Point to Coulomb Point were found to have almost exclusively bioturbation habitat. Where areas were dominated by sand dunes and waves, such as further inshore, there was little biohabitat seen, except for some seagrass and turf or mat green algae coverage on the flat sandy patches between these dunes and waves.

Along the patches of low relief reef, there were sparse to medium densities of sponges, gorgonians and whips. Sparse to medium density gardens of soft corals were also relatively common on this substratum type. At the northern end off Coulomb Point, there was a large patch of Sargassum algae, corresponding to a low and high relief reef and rocky substratum habitat. Other brown algae were major contributors to the percentage biohabitat coverage along the shallow coastal area off Coulomb Point, also where low relief reef structure was present.
6.2.3 Animal Abundance

The most abundant benthic animals seen within the survey location between Quondong Point to Coulomb Point was heart urchins, crinoids and ascidians. Heart urchins and crinoids were found mostly on the sandy flats in the offshore areas, with densities of up to 30 000 and 33 000 animals per linear km, respectively. There were few other animals observed in any numbers along the transects, except for seapens that occurred in the hundreds at a few sites off James Price Point.

6.3 Perpendicular Head

At the Perpendicular Head location, all of the 145 transect sites proposed in the survey design were completed, including those that fell within the pearl lease boundaries.

6.3.1 Substratum Type

The seabed of the deeper water sites were predominantly made up of fine sand (70% coverage) with only small patches of sand waves and dunes interspersed through many of the transects. Along the shallower water transects around the rocky headland, the fine sand was replaced with coarse sand. There were very few transects within this location that showed any mud or silt characteristics.

Some patches of rubble/stones at the northern end of the survey location were observed northwards of the headland in the mid-depth range of water surveyed. Inshore of these rubble areas and along the shallow coastal area, the seabed characteristics consisted of some high and low relief reef, especially off the headland with coarse sand substrate between these reef habitat patches.

6.3.2 Biohabitat Type

The inshore areas of Perpendicular Head were dominated by green turf or mat algae and patches of red algae. Seagrass was also present in small isolated patches throughout this area where flat sandy substrates dominated.

Few soft coral gardens were observed at this survey location. The majority of filter feeding communities were comprised of sponges, gorgonians and whips, but were restricted to the inshore areas around the headland where low relief reef was present and offshore in the northern extent of the location, where some rocky substrate and flat sandy patches were present.

At the southern extent of the survey area, where flat sand and sand dunes and waves predominated, there was little biohabitat recorded, apart from a few small patches of bioturbated sand.

6.3.3 Animal Abundance

The diversity of benthic animals at Perpendicular Head was quite high, with crinoids, seapens and ascidians the most widespread groups. There were also many hydroids, holothurians and starfish observed along the transects. Although heart urchins were relatively uncommon at most transect sites, their density at one site (56 000 per transect km) was the highest seen at any transect throughout any of the sites surveyed. This site was around the extensive areas where green mat algae coverage was dominant.
6.4  Packer Island

Video habitat classifications for all of the 116 transect sites were completed at the Packer Island location.

6.4.1  Substratum Type

The transect video tows within the Packer Island location showed that about a third of the shallow water transects had a significant coverage of low and high relief reef structure separated by patches of coarse sand and sand waves and dunes. This reef habitat tended to be more prominent close to the 10 m depth contour. The seabed at the deeper water sites were however predominately sand with some patches of dunes and waves and only a small area of low and high relief reef and rocky habitat at the southern end of this location. There was also no mud or silty substratum observed along any of the transect sites at this location.

6.4.2  Biohabitat Type

The shallow high and low relief patches of reef were dominated by medium to dense whip and sponge gardens. These generally occurred around the rocky and low relief reef substrates in the shallow nearshore areas in the northern part of Packer Island and from the shallow to deep water of the southern Packer Island survey area. Patches of soft corals and gorgonians were relatively abundant along the northern transects. There were also some patches of sparse to medium density hard corals occurring on the high relief reef structure at the northern extent of this location.

Green algae (turf and mat) were common in the shallow and intertidal areas along the coastal extent of Packer Island. Seagrass was found in relatively high coverage along several transects within the small bays in the northern part of this location. Around the offshore areas where the substrate was mostly fine sand and some coarse sand patches, there was little biohabitat observed.

6.4.3  Animal Abundance

The most common animals encountered at the northern survey location were ascidians, crinoids, seapens and hydroids. The crinoids and seapens generally inhabited the flat sandy patches in the deeper water transects. There was relatively few heart urchins in these sandy offshore areas where most of these transects showed no biohabitat cover, such as green turf or mat algae.

6.5  Supplementary Transect Lines (1-5)

All of the proposed sampling sites at the five supplementary transect lines between the locations were completed during the survey trip.

6.5.1  Substratum Type

The seabed along the supplementary transects south of Broome were predominantly low relief reef and rubble/stones in the offshore, changing to fine and coarse sand in the shallower nearshore waters.
The characteristics of the seafloor at the line north of Broome was relatively uniform with mostly flat sand and small patches of low relief reef.

The two supplementary transect lines north of Coulomb Point showed a significant amount of low relief reef structure along the shallow water transects, shoreward of the 15 m contour. In these areas, a large component of the substratum coverage was also made up of fine sand and sand dunes and waves. At the most northerly supplementary transect line, just south of Perpendicular Head, virtually the entire seabed was found to be the sand dunes and waves.

### 6.5.2 Biohabitat Type

At the two southern supplementary transect lines, the biohabitat was dominated by sponge and gorgonian communities in the deeper offshore rocky and low relief reef habitats. The shallower transects where the seabed habitats where the major component of the seabed was fine and coarse sand patches, the most abundant benthic communities was green or red algae, with a large percent coverage of bioturbated sand.

The two supplementary transect lines north of Coulomb Point were quite diverse in biohabitat, with sponges, whips, several algae types and some hard coral gardens along the deeper transects where high and low relief reef was present. Along the transects of the most northern line (Line 5), where the substrate was almost entirely sand dunes and waves, there was little biohabitat recorded, except for the outer transect, where this site showed the greatest coverage of dense hard coral of any transect in the four locations.

### 6.5.3 Animal Abundance

There were relatively few benthic species observed along the supplementary transect lines. The most abundant animals were the crinoids, especially in the two southern supplementary transect lines and the most northern line. Ascidians were also common in about half of the transect sites surveyed from the five supplementary transect lines.

### 6.6 Comparison of Locations

There was very little mud or silty substrate throughout any of the locations surveyed, indicating a relatively high energy marine environment with considerable currents and seafloor stress. The most common seabed type was sand; between 50 and 70% coverage, across the locations.

The three locations that were located off prominent headlands; Gourdon Bay, Perpendicular Head and Packer Island, were generally similar in substratum characteristics and biohabitat composition. These were quite different from the Quondong Point to Coulomb Point survey location that had extensive areas of either sand dunes and waves or flat sands.

All of the four locations showed some low and high relief reef structure. At the three northern locations, low and high relief reef patches were predominantly in the very nearshore or off shore areas with the patches extending along contours lines for some distance. Whereas, at Gourdon Bay the low and high relief reefs were found in a more patchy distribution, most commonly around the isolated shoals and in shallow waters off the headland. This also influenced the distribution patterns of the key
filter feeding communities; sponges, whips and gorgonians. There was relatively few hard coral
gardens observed in any of the surveyed locations.

Although algae and seagrass were relatively common in all of the four locations, they were restricted
to the shallow areas in Gourdon Bay, Perpendicular Head and Packer Island. Along the coast from
Quondong Point to Coulomb Point, these algae and seagrass habitats extended further offshore,
almost to the seaward extent of the survey boundary.

There was a more diverse range of benthic animal species at the Perpendicular and Packer Island
locations compared to Quondong – Coulomb Point and Gourdon Bay locations. However, the two
southern survey locations did generally show greater numbers of the heart urchins and crinoids than
the other two locations.

### 6.7 Benthic Dredge Sampling

There were 15 sites in the four locations that were dredged to collect biological material from the
range of different biohabitats seen and validate the habitat classification. Two of the dredges caught a
large number of urchins, while the remaining tows landed a mixture of mainly sponges, ascidians and
soft corals, which was similar to what was seen during the transect video tows at these sites. There
were few hard corals caught with the most dominant species being *Turbinaria* sp. A more detailed
description and comparison of the dredge catches with images will be provided in the final report.
7. REFERENCES


### APPENDIX A – TABLE SHOWING THE DATA TYPES USED FOR THE SURVEY STRATIFICATION

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